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Status of Poplar and Willow Culture in Himachal Pradesh

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Abstract: Poplars and willows are ecologically and economically important arboreal species for Himachal Himalayas. These are among a few tree species, which have been grown by the farmers especially in the cold arid region since ages for the tree based needs and by the foresters in their normal forestry programmes. Willow culture is restricted to upper hills especially inner Himalayas and that of poplar to outer Himalayas especially south of the Himalayan foot hills. Of late, poplars have attained a status of cash crop, which are grown in parts of some districts for sale to the wood based industry located within and outside the state. Back-end and front-end synergies in nursery-plantation-wood usage chain are now well established for poplar culture, whereas, similar synergies are lacking for willow culture. Willow has a specific use for making cricket bats for which there is no local wood processing industry. The paper gives an account of the existing practices in nursery and plantation management and marketing of wood for these species.

Key Words*:* Poplar, willow, status, culture, plantations, management

Himachal Pradesh, a Himalayan state, is natural home for some indigenous poplar and willow species which are closely associated with the socio-economical well being of locals who have been growing them since long for firewood, fodder and small timber especially in the cold arid region of the inner Himalayas and as a cash crop for sale to the wood based industry elsewhere. These trees have also been planted by the state forest department for ecological and forestry considerations. Besides some indigenous species, numerous other species and their clones were introduced from many other countries for their testing in the state. Many indigenously developed clones from the local tree improvement programmes have also been made available to the growers. Willows are the life line for tree based needs in cold desert region especially near timber line where other arboreal vegetation does not exist. *Salix fragilis* an arboreal bush or small tree, occurs near the timber line and has been reported to provide 69.5%, 29%, and 42% of the total fuelwood requirements of wood in Jahlma, Khoksar, and Hinsa villages of Lahaul valley, respectively (Rawat *et al.,* 2006). The species is a life line for tree based needs in many other similarly situated villages in the cold arid region. Poplar also has a long history of its culture in high hills but is now considered as a cash crop in locations where its growth and productivity is good and returns from its sale are more remunerative than those from the traditional agricultural crops. Growing poplar for this purpose is an extension of the activity from the Region of Intensive Poplar Culture (RIPC) comprising parts of adjoining states, viz., Punjab, Haryana, Uttrakhand and Uttar Pradesh states where the tree has been commercially grown for the last over three decades. This paper presents an account of the status of poplar and willow culture in the Himachal state and draws information from various reports, personal contacts and self experience having served almost all poplar and willow growing districts in the state including cold desert region of Kinnaur and Lahaul & Spiti districts during the peak of Dessert Development Project (DDP) implementation during 1980's when poplar and willows were planted in large number and also in the University of Horticulture and Forestry (UHF), Nauni, Solan.

Poplar and Willow Species

Populus ciliata (Himalayan poplar), is the only poplar species indigenous to the state. It is one of the associated species of deodar, fir/spruce, kail, and oak forests and is found in parts of Lahaul & Spiti, Kinnaur, Kullu, Mandi, Chamba, Kangra, Shimla, Solan and Sirmour districts in the state. Some monumental trees of *P. ciliata* are reported from cold desert region (Singh, 2000) and these appear to be planted long back. The species is not able to tolerate warm and hot weather conditions of plain areas and foothills, where if planted, maintains shrubby form for a couple of years and finally dies. Some authors consider *P. alba, P. balsamifera* and *P. suveolense* as indigenous poplars (Tewari, 1992; Khurana, 2007), while, others claim them as introduced ones (Naithani *et al.,* 2001). The fact that the natural stands of these species do not exist in the forests and their occurrence in isolated form around villages and gompas (Budhist temples) indicates that these were planted in this region long back. Historical accounts describe overlapping dynasties and rulers in Ladakh, Lahaul, Spiti, Kullu and Chamba princely states at different periods with frequent invasions from one territory to other (Negi, 1995). Introduction and occurrence of species like *P. alba,* and *P. balsamifera* and some others

over these areas appear to have moved with migration of people with change in dynasties or otherwise. *P. alba* is adapted to cold arid conditions and exits in Lahaul & Spiti and Kinnaur districts. *P. balsamifera* has been reported to have affinity with Budhism as it is mostly located in the compounds of gompas. Encircling and flagging of these trees with sacred cloths by Budhists indicate their sacred value for this religion (Dhiman, 2010). *P. nigra* an introduced poplar from Afganistan has been regularly planted in some locations in Lahaul & Spiti and Kinnaur districts, and some trees could also be seen in some other districts especially in botanical gardens and research institutes. *P. nigra* was reported as the main dominant tree species among 142 plant species belonging to 49 families and 105 genera at 3000-5000 m elevation in Namgia village of Kinnaur District, H.P. (HFRIa). *P. deltoides* now occurs in all the districts of the state where it has been planted during the last three decades. UHF and state forest department have introduced many other species and cultivars for research and field trials which have been planted in the state and they along with some indigenously developed clones are also maintained in some germplasm plantations.

Willows are dominant tree genera in cold desert of Lahaul & Spiti and Kinnaur districts. The most important willow species found in the cold desert are *S. alba, S angustifolia, S. caesia, S. daphnoides, S. elegans, S. flabellaris, S. fragilis, S. hastate, S. oxyaxaropa, S. sclerophylla* and *S. tetrasperma* (Nautiyal, 1991). Natural stands of *S. fragilis* are found at number of locations near water courses and glacier sites in Lahaul and Spiti valleys. *S. alba* and *S. babylonica* are also seen in many other locations, the latter species is especially located in parks and botanical gardens in many parts of the state. *S. fragilis* is the only arboreal species which occurs in the upper Sipti valley beyond Hul village and in many locations of Lahaul valley especially those adjoining Spiti valley.

Plantations

Occurrence of some monumental trees of poplar and willow species viz., *P. balsamifera, P. ciliata, S. fragilis, S. viminalis, S. elegans,* etc. in and around gompas (Budhist temples) and habitations (Chauhan and Lakhanpal, 2000) indicates that plantation of these species have traditionally been invogue in this region since long. According to Singh (2000) planting of poplars and willows in this region has been taken up by the farmers since the advent of Moravian during mid 19th century. Agriculture crop production in this specific geo-ecological landscape is totally irrigation dependent for which water is drawn from natural streams. Most landowning families have been planting a few trees along the water channels feeding their fields or collectively on village common land, and their product and value are shared among the village families. Spiti valley in Lahaul & Spiti district represents complete arid conditions with absence of monsoon rains. Planting poplar is rare beyond Kaza, where *S. fragilis* along with *S. alba* are planted. In Spiti valley, below Kaza with its boundaries touching to Kinnaur district, *P. alba, P. deltoides, P. ciliata* along with *S. alba* and *S. tetrasperma* are main planted species. Lahaul valley represents slightly better conditions with rainfall ranging from 300-700 mm where *S. fragilis* is the most common tree planted but *S. vimanalis* and *S. insignis* are also grown (Singh, 1950). Among poplars, *P. nigra* and *P. alba* have been planted since long. Pooh division of Kinnaur district also represents semi-dried conditions where planting of poplars mainly *P. alba, P. ciliata, P. nigra* and *P. deltoides* is more common than willows.

P. ciliata is largely planted on forest land by the state forest department and to some extent by the research organizations in their research trials. The interest in poplar as a plantation species dates back to 1950's when planting of *P. ciliata* along with some introduced species were explored as a nurse crop for regeneration of fir and spruce forests in the state (Agarwal and Patil, 1956). *P. ciliata* with introduced *P. monilifera,* and *P. generosa* were tried and proved useful in regenerating fir and spruce in Kullu district but could not be replicated on a large scale. *P. deltoides,* is the main preferred species in poplar culture in the state. It finds favour among all growers viz., farmers, state forest department and research organizations for growing in locations from cold desert to Himalayan foot hills and valley areas. It is mainly planted in Balh valley of Sundar Nagar, Mandi district, Mand belt (Indora division) of Kangra district, lower areas of Una district, Nalagarh division of Solan district and Ponta valley of Sirmour district. The species was also introduced in the Spiti cold arid region during early 1980's and some of its plantations are better grown than many other plantations of other species. The main cultivars of poplar commercially grown in the state are the same, which are grown in the RIPC. These include G48, Udai, WSL 22, WSL 39, etc. with some last year released clones specifically WIMCO 81, WIMCO 83 and WIMCO 110 also now finding favour among the growers in the plains. University of Horticulture and Forestry (UHF) has developed and recommended some clones of poplars and willows for growing in the state (Table 1).

HFRI has established field trials with number of species viz., *Salix fragilis*, *S. vitellina, S. matsudhana, S. babylonica, S. alba* and *S. corrulea* introduced from Jammu & Kashmir and also with UHF clones, viz. UWA-1, UWA-2, UWE-1;

Table 1. University of Horticulture and Forestry (UHF) recommended clones of poplars and willows for the Himachal state

S. No.	Species	Clone	Zone (m. amsl)
1	*Populus ciliata* and hybrids	UFC-1000, UFC-1900, UFC-2200, UFC-010, UFC-6403, IL-3B	>1500
		UCM-3287, UCM-3220, UCM-3296, UCM-2801, UCM-113	1000-1500
2	*P. deltoides* and hybrids	UD-5503, UD-6502, UD-10007, UD-3210, UD-3296, UD-8800 and Hybrids Solan-1, Hyb-U	1000-1500
		UD-0102, UD-0700, UD-6500, UD-4400, UD-7007, UD-8800, IC, 200/86, 52/86 and P1/92	300-1000
		UD-5501, UD-5512, UD-6501, UD-6502, UD-1007, UD-63N, G-3, D-121 and S7C16	<300
3	*Salix alba* cv. *coreulea*	006/05, 006/06 and KW	
	S. alba	SI-63-007, SI-64-017 and SI-62-096	
	S. matsudana	SE-63-016	
	S. matsudana x S. alba	799, NZ 1002, PN 733, NZ 795	
	S. matsudana X S. arbutifoillia	NZ 795	

(Source: www.yspuniversity.as.in; Singh *et al*., 2014)

UWM-1, UWM-2, UWM-3, UWU-1, UWU-2, UWK, UWHY-1, UWHY-2, and WO2-4 to screen suitable productive and resistance clones (HFRIb). Five clones i.e., J-799, NZ-1140, 131/25, SI-63-007 and PN-731 out of 200 introduced ones have been shortlisted after five years trial based on tree height, dbh growth and clear bole for lower and mid-hills of Himachal Pradesh (Sharma *et al.,* 2011). Individual tree growers and state forest departments are the main stack-holders in poplar plantation programmes. Some poplar is also planted by the research organisations like state agricultural universities especially UHF, Krishi Vishva Vidhyalaya Palampur, Kangra and Himalayan Forest Research Institute (ICFRE), Shimla on their campuses including research centres. State Forest Department has been planting poplars and willows on forest land since long and the data on species-wise planting is available from 1950's (http://himachal.gov.in). Out of a total planted area of 10,26,776 ha under different schemes till date (w.e.f. 1950 to 2009-10), poplar and willow plantations cover 14,958 ha and 10,407 ha, respectively. Poplar therefore represents 1.46% and willow 1.01% of the total plantations made in the state so far. Many of the species planted in the state are slow growing conifers and broadleaved species, the share of poplar and willow planted area is therefore likely to be very low as most of the earlier planted poplars and willows could have lived their physical age. Both species are also highly sensitive to moisture status of planted sites, the initial and final survivals of planted poplars and willows likely to be lower than the hardy conifers and some broad leaved trees.

The state plants around 2 crore plants per year, out of which, poplar and willow constitute 0.58% and 0.57%, respectively. During the last two years i.e., 2008-9 and 2009-10, an average of 1,97,04,735 plants were planted annually. There were 21 plantation schemes, out of which poplars and willows were planted in 14 schemes. Some species specific or programme specific schemes like bamboo mission, regeneration of chilgoza forests, TFC, SWAN, CAT, etc. did not have poplar and willow plantations (Table 2). Poplar plantations under CAT plan has maximum plantation of poplars (28.40%) followed by Backward area sub plan (19.37%), Improvement of tree cover (12.93%), Plantation under MHWD project (9.08%), Soil conservation (7.61%), Enrichment planting (5.83%), Compensatory plantations (5.31%) and others indicate that poplar is planted for multiple purposes. Similarly for willows, maximum plantation was in improvement of tree cover (25.64%) followed by soil conservation (22.70 %), pasture development (14.76%) and scrub development (11.14%) schemes and this species has also been planted for multiple purposes.

Circle-wise data of poplar and willow planting during these two years (Table 3) further confirms that both poplar and willow have almost average equal planting figures. However, poplar is planted over greater area than willow and the latter is mainly planted on high altitude locations. Lahaul Forest Division is attached to Kullu Circle and Spiti and Kinnaur forest divisions to Rampur Circle where planting of both poplars and willows is collectively more than many other circles. Bilaspur and Hamirpur forest circles located in the lower Himachal have some poplar plantations by the private growers though government figures do not show any planting in those areas. The plantation figures further confirm planting of both species under wildlife and watershed programmes.

Poplars and willows were the main tree species planted

Table 2. Average annual planting of poplar and willow under different schemes during 2008-09 and 2009-10.

S. No.	Plantation scheme	Poplars		Willows	
		Total planted (No.)	Share of scheme (%)	Total planted (No.)	Share of scheme (%)
1.	Pasture development	5060	4.57	16625	14.76
2.	Improvement of tree cover	14312	12.93	28888	25.64
3.	Enrichment planting	6450	5.83	6075	5.39
4.	Reforestation of scrub areas	3267	2.95	12547.5	11.14
5.	Sanjhi van yojna	1925	1.74	5674.5	5.04
6.	Soil conservation	8425	7.61	25572.5	22.70
7.	Backward area sub plan	21441	19.37	5037	4.47
8.	FDA samridhi yojna	620	0.56		
9.	Compensatory plantations	5883	5.31	3025	2.68
10.	Macro management (RVP)	1835	1.66	530	0.47
11.	Plantation under CAT plan	31427	28.40	4965	4.41
12.	TFC			400	0.36
13.	Improvement of WL areas			1375	1.22
14.	Plantation under MHWD project	10050	9.08	1950	1.73
	Total	110703	100.00	112664	100.00

(Source: http://himachal.gov.in)

in a centrally sponsored programme -Desert Development Project (DDP), which was launched for Spiti division of Lahaul and Spiti district in 1978 and for Pooh division of Kinnaur district in 1982 with special emphasis on rehabilitation of cold desert. Under this programme, 16,36,735 plants were planted over 830 ha (Negi *et al.,* 1996). *S. fragilis* is the main species planted in Spiti DDP especially over the greater part beyond Kaza. The plantations of *S. fragilis* in lower elevations sustain but is not very productive in comparison to other willow and poplar species regularly planted there. Similarly, planting of many other willow and poplar species in higher elevation locations could not survive due to extreme cold conditions.

Two regional centers of UHF viz., RHRS Jachh and HRRS, Dhaulakuan and its main campus at Solan have been producing poplar saplings for own use and to supply them to tree growers of the locality since mid 1990's. According to Chauhan (2012), Jachh and Dhaulakuan centers have produced and supplied 89,207 and 1,63,305 saplings respectively till 2012. The annual supply is worked out to be 8,600 saplings from Dhaulakuan and 5,500 saplings per year from Jachh. The university had a saleable stock of around 800 fully grown poplar trees that was put to auction during 2011. Himalayan Forest Research Institute is also raising poplar and willow nurseries which have been established in different locations including cold desert region. Some poplar has also been planted by the Public Welfare Department

Table 3. Average annual planting of poplars and willows in different forest circles during 2008-09 and 2009-10.

S. No.	Forest circle	Poplar planting during (No.)			Willow planting during (No.)		
		2008-9	2009-10	Average	2008	2009	Average
1.	Kullu	63391	27775	45583	68667	15058	41863
2.	Shimla	5912	15555	10734	36908	12900	24904
3.	Rampur	22058	23306	22382	5575	3428	4502
4.	Chamba	300	8969	4635	13460	32400	22930
5.	Dharamsala	1050	640	845			
6.	Nahan	12900	300	6600			
7.	Wildlife Shimla	12650	5600	9125	15125	9082	10729
8.	Wildlife Dharamsala		300	150		500	250
9.	Wildlife Shamshi		600	300	6450	1875	4162
10.	MHWD Solan	20100		10050	1250	2650	1950
	Total	138361	83045	110703	147435	77893	112664

(Source: http://himachal.gov.in)

(PWD) along road side especially along national highway around Solan town.

A major share of the planting stock planted by the growers in the plain and in some valley areas is supplied by the private nursery growers from the adjoining poplar growing locations like Hoshiarpur, Ropar (Rupnagar), and Pathankot districts in Punjab and Yamunanagar and Panchkula districts in Haryana. Poplar and willow wood does not find better market within the state. There are only 3-4 plywood factories in the lower Himachal, which use poplar wood for making panel products. The major part of poplar wood harvested in the state is traded at Yamunanagr wood market in Haryana and Hoshiarpur in Punjab. Both these locations are leading centers for poplar sapling production as well. Wood traders who transport wood from different locations of the state also carry saplings from these locations and supply them to the growers during the planting season. Many of good growers especially near the RIPC also directly procure planting stock from the branded nurseries located in the RIPC. Some private nurseries have also come up in Indora belt of Kangra, Plain areas of Una district, Nalagarh area of Solan district, Paonta valley of Sirmour district and Balh valley in Mandi district to meet the increasing demand of the growers. It is inferred that around 6 lakhs poplar saplings were planted in the state during 2012 planting season and the major share of the planting stock was supplied from the adjoining RIPC.

Plantation Management

Willows and poplars have been planted since long back by the local inhabitants of Lahaul and Spiti using their traditional knowledge (Singh, 1950). Planting is carried out in March-April on melting of snow with a piece of branch with the last year growth-commonly called as a set. Sets of 15-20 feet length with fresh bark are made from the actively growing coppice shoots. Set made from side branches have poor apical dominance and are reported not to perform good. The practice has been to plant a bunch of 4-5 sets together to ensure that at-least a couple of them survive and also to avoid animal damage to at-least some inner sets. Sets are planted 2-3 feet deep in crow bar made holes and carefully firmed up during planting. Sets near villages are normally covered with some old clothes, jute ropes, prickly shrubs like *Caragana* and *Hippophae* to avoid stripping of the stem bark by animals. Much has not changed in the planting technique of willows and poplars in the cold arid region except for the length of the planting set has now been reduced to around three feet on increasing their demand under various plantation programmes. Government institutions taking up large scale plantations especially under DDP created market for sale of sets and as a source of earning for the locals from own trees or from village common tree groves. Further the plantation areas was extended to the newly developed command areas of irrigation network and the success of plantations was closely associated with the success of irrigation system developed for this purpose. The plantation areas are protected by stone wall fencing, which is more effective than barbed wire fencing but very costly. The scope of growing nursery saplings in the upper parts of cold desert is limited due to extreme cold conditions, limited growing period, poor soil-site conditions, poor water availability, etc. It generally takes two growing season to attain a plantable size of around one meter length of the nursery plant and therefore the practice of planting sets is common in upper part of Spiti and Lahaul valleys. Polybag raised plants of poplars and willows were also used for making field plantations during offseason, yet the method proved costly and difficult in transportation and planting operations. In other areas, nursery grown saplings commonly called as ETP (Entire Trans-plants) are used for field planting. Poplar nurseries in the lower region are established with stem cuttings made from last year ETPs and plants grow to 3-4 m in one year period. ETPs on uprooting are conditioned in fresh water from 1-2 days before planting in augor made holes. Fields are immediately irrigated on field planting for better survival and early growth.

Both poplars and willows coppice well and these are worked under pollarding system for yielding firewood, fodder and small timber in the cold arid region. The tree trunk is cut at a height and managed for regular harvest of coppice shoots after every 2-3 years. Poplar is generally harvested for poles and timber, though some examples of pollarding are also available. Some examples of coppicing trees are also available (Sharma *et al.,* 2006). In lower Himachal, poplar is harvested and replanted as per the practice followed in the RIPC. *P. alba* is heavily lopped for firewood and fodder and also to meet the domestic needs for construction and agriculture implements. Major part of poplar and some part of willow are grown in agroforestry. Both traditional and commercial forms of poplar based agroforestry are available in the state. The trees have been integrated with agriculture crops under rainfed (Chauhan and Dhiman, 2003), and irrigated crop production systems (Singh and Negi, 1996), pastures (Chauhan and Dey, 1999), medicinal plants (Thakur and Dutt, 2007) and horticultural orchards (Pathak and Singh, 2000). Kumari *et al.* (2008) reported traditional agri-silviculture systems in Kinnaur district where agricultural crops are integrated with poplar are kidney beans (rajmash), peas, capsicum (bell pepper), ogla, fafra, potato, cauliflower and barley in the villages of Sangla, Kupa, Pooh, Nako, Rakcham with a total of 11.65 bighas under this system in

comparison to 42.2 bighas of agri-horticulture system, which is the dominant form of traditional form of agroforestry in this part. Poplar is integrated with normal agriculture crops like wheat, sugarcane, maize, potatoes and others in the lower parts of the state.

Many villages maintain and manage their groves of willows and poplars for firewood, fodder and timber. There is an age old practice of participatory management of village common wood lots including that of willows and poplars in the Inner Himalayas (Dhiman, 2002; Gupta and Singh, 2003). This practice is an extension of the overall management of common property resources (including natural resources like forests and water) in which villagers collectively take decision on management, protection, harvest and sharing of their produce. One such case, among many in the region, is quoted from the Lossar village situated at 13,500 feet altitude is 68 km away from Kaza on Kaza-Kullu state highway and is the last village on this route near the timber line. Coppice shoots of willows (mainly that of *S. fragilis*) are harvested for small timber, firewood, fodder and for sale as sets for making new plantations. The management of the willow forests and harvest of coppice shoots is decided by a 3 member committee headed by Nambardar (village chief) and 2 other members of the villager who are selected from each house by rotation. The area is divided for harvesting and each year a different area is selected and the remaining is allowed to grow. All willow shoots are harvested from stumps during April by employing one or two members from each family. The harvested shoots are made into 1m long sets, which are sold to different agencies for field planting. The lops and tops of these branches are equally distributed among the villagers for use as firewood. During the DDP activities in 1980's around 10,000 sets were annually supplied to the project for planting activity. Every amount of sale of willow shoots and from other collective work is received through Nambardar and is equally distributed among the village families. Besides willow sets, villagers also work collectively in making plantations, their irrigating, watch and ward and in soil conservation works to protect these plantations and other land resources. The committee decides the number of persons to be engaged from each family for planting, irrigation, making stone wall fencing, etc. Persons for watch and ward work are selected by drawing the lots. Each family gets a job for 3-4 months in already made plantations. If any village member violates the instructions of the committee, he is fined with money and other locally available articles. Offenders are asked to undertake an oath in front of the committee for not violating the instructions of the committee. It is believed in the area that taking wrong oath results in some bad omen and therefore people not try to engage in breaking the verbal instructions, which are duly followed. Some poplar is also being planted for shade in tea gardens in Kangra district.

Growth and Productivity

The growth and yield studies of poplars and willows are available from some locations within the state. Poplars are planted under varied soil-site conditions viz., forest land, farmland integrated with crops, pastures and around orchards. Available figures indicate that poplar growth on many locations is subnormal when compared with that grown in the RIPC. Establishment, growth and productivity of poplars and willows is severely affected by the limited growth period, low temperature, inadequate cultural inputs, poor soil and site conditions, unfavourable weather conditions (especially prolonged dry spells), and type of species and cultivars used in plantations. Planting success is also reported to be affected by the quality of planting stock including sets, moisture availability during planting and thereafter, and depth of planting etc (Joshi and Nayital, 2006). The entire poplar and willow plantations in the cold desert region are carried out with assured irrigation, any disruption in the irrigation system results in their failure. *P. deltoides* is reported to be more sensitive to prolonged droughts than indigenous broadleaved species like *Grewia optiva, Morus alba* and *Dalbergia sissoo* studied under mid Himalayan conditions (Thakur and Sood, 2005). *P. deltoides* is faster grown than other available species. Thakur and Chauhan (2008) reported better growth of *P. deltoides* among the six species tried *(Alnus nitida, Salix tetrasperma, Eucalyptus tereticornis, Robinia pseudoacacia, Pinus roxburghii* and *Dalbergia sissoo)* on the riverian tract of Kullu, Himachal Pradesh. Irregular increase and decrease in current annual increment in *P. deltoides* is mainly attributed to the flooding of area (Chauhan *et al.,* 2007). Chauhan and Dey (1999) reported diameter growth of 12 years old *P. deltoides* between the range of 5-25 cm diameter with average biomass of 34.2 t/ha. In Bajaura Kullu, Clone I-C with a maximum ring width of 12.210 mm showed superiority over rest of the clones. The clones like I-C, G-48, D-121 and C-181 showed high growth rate and are adaptable to different environmental conditions.

The rotation of poplar is longer in hills than in plains in the state. The average productivity of poplar plantations in the lower parts of the state is around 15-20 cum ha^{-1} $year^{-1}$ which is better than that in upper regions of the state but slightly lower than the one recorded in the RIPC. In the middle and upper hills, the yield is much below this. An inventory of the trees grown in the UHF campus, Nauni, Solan and placed for auction during 2011-12 (Table 4) is an indicator of the poplar productivity in mid hills. Most of these plantations

were reportedly of over 20 years age. Poplar grows good in some specific nitches near natural nallahs (seasonal rivulets) and the large portion of the university campus is not very suitable for poplar culture because of rainfed conditions and poor soil site conditions. Planting of poplar on this land is part of research trials that university conducts with poplars. The inventory of harvestable trees indicate a large number of 34 dead and dried trees. The visibly healthy trees are also expected to have high degree of internal damage like heartwood rot or termite attack, which is common in poplar grown for such a long rotation. A plantation of 520 number of six years old trees harvested in Bilaspur district a few years back out of which around 80 per cent were hollow inside as these were grown on rainfed conditions having high degree of termite attacked.

In DDP, plantation costs are stated to be very high particularly if they are calculated on the final survival of plants. According to evaluation of the DDP programme, Negi *et al.* (1996) reported the cost incurred on each plant was Rs. 38.7, which did not consider the indirect cost spent on developing irrigation facilities for these plantations. It was calculated on surviving plants during the evaluation of the project in 1993 when it was discovered that out of 16,36,735 only 54% plants (8,84,307 number) survived.

Willows are lopped for firewood and fodder at intervals of 2-3 years in cold desert region. The trees attain a height of around 5 m in around 10 years (Singh, 1950). Tree size and their location (nearness to water course) affect shoot production in pollarded trees. Higher girth trees produce more shoots compared to low girth trees and the figure may vary from around 218 shoots in >90 cm to just 28 shoots in 1-30 cm girth trees (Rawat *et al.,* 2009). It is also reported that shoot number per tree and their thickness is also similarly influenced by tree girth. Mortality of shoots due to self pruning is more in small trees than that in old trees. Maximum height of 19.33m was claimed for clone J-799, 16.5cm diameter for NZ-1140 and 131/25 and bole straightness for J-795 (Sharma *et al.,* 2011).

Marketing of Produce

Himachal was the first north Indian state to issue notification for taking willows and poplars out of transit and felling regulations during 1970's. Despite high demand for its wood for cricket bats, willows have yet to be picked up for commercial farming in the state. Poplar wood is now used in a couple of plywood factories, which came up in Kangra, Solan and Sirmur Districts. Major market for trading poplar wood harvested from the state still remains in the adjoining states of Punjab and Haryana. The main wood trading centers for poplar wood grown are Pathankot and Hoshiarpur in the state of Punjab and Yamunanagar in Haryana. Poplar wood is directly sold to contractors at negotiated price who then supply it to the main contractors, commission agents or directly to the factories. A few good poplar growers near to these markets also directly supply wood to the factories.

Major research on both indigenous and introduced poplars and willows in the state has been carried out by UHF and Himalayan Forest Research Institute of ICFRE (including its erstwhile Conifer Research Centre, Shimla). Some research support on poplars has also been from the State Forest department, Agriculture University Palampur, Kangra and private sector company-WIMCO. The major focus of research on poplars and willows has been on tree improvement, nursery and plantation techniques, plant protection, growth and yield studies and tree-crop interaction involving *P. ciliata, P. deltoides, P. alba, S. fargilis, S. alba* and with some other introduced species and cultivars. New developed cultivars by the private sector WIMCO, which are widely grown in the RIPC have also been procured by the state forest department, universities and farmers for research and field plantations. There was a proposal of initiating refinance scheme for poplar culture in the state on the same line that was implemented in the RIPC. A large number of planting stock was procured from the company and planted in Balh valley in Sundarnagar, Mandi at that stage.

Poplar is planted in the state for three main purposes viz., domestic tree based needs environmental and forestry purposes and as a cash crop. With expanding willow and

Table 4. Inventory of saleable poplar trees in the UHF main campus

S. No.	Tree diameter (cm)		Visibly healthy trees (No.)	Damaged and dried trees (No.)	Total trees (No.)
	Class	Mid value			
1	10-20	15	24	2	26
2	20-30	25	567	27	594
3	30-40	35	145	3	148
4	40-50	45	28	-	28
5	50-60	55	4	-	4
6	60-70	65	2	2	4
	Total	765	34	799	

poplar culture and possibly with climate change, challenges for their sustenance are also increasing. Willows in Lahaul & Spiti district are now highly threatened by pests and diseases infestation, which has fast invaded new plantations and locations. It is reported to be infected with *Cytospora chrysosperma* and giant willow aphid (pest). Reports indicate mortality upto 70% in some villages (Rawat *et al.,* 2009). Poplar is now routinely grown as a cash crop in number of locations in the state. Alike RIPC, poplar has now well established backward and forward linkages for planting stock procurement and wood disposal within and outside state. Willow is now being recommended for field plantations but has yet to pick up the momentum. There is good demand for its wood in cricket bat industry. This tree also needs support of backward and forward linkages to make its culture self sustaining similar to poplar culture.

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The Ecological Aspects of the Production of Electricity in Power Generator Systems

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Abstract. This paper presents problems related to the use of municipal landfill gas as a fuel for engines powering electric generators. The authors focus mainly on the energy-related and ecological aspects. In the first part of the paper the authors briefly analyzed the legal regulations related to the use of alternative sources of energy, municipal landfill gas in particular. In addition, analysis shows that due to a large amount of accumulated waste we should expect a bigger global production of municipal landfill gas in the nearest future. The paper also presents the authors' own results of emission tests performed on a power generator fuelled with landfill gas and these results were compared with the emissions generated during the production of electricity from coal and lignite and from a diesel engine operating in the power generating system. The ecological evaluation of the use of municipal landfill gas in combustion engines has been complemented with the evaluation of the ecological benefits of the tested power-generating unit. This evaluation has been carried out based on the calculation scheme by the United States Environmental Protection Agency (EPA).

Key Words: Biogas, combustion engine, renewable energy, emission measurement

The last century was characterized by rapid technological advancement accompanied by a rapid development of the industry. The spur for this development was the improvement of quality of life. Due to pollution there are more human and animal diseases, forests are dying, the soil is becoming barren and the climate is getting warmer.

Today the priority is a sustainable development seen as a process that unconditionally joins the present needs with the needs of the future generations. Sustainable development could also be interpreted as a supra generational agreement that will secure fair condition of the environment for future generations. In light of this peculiarly defined objective comes a question of how to live up to this expectation. For many years we have seen actions aiming at environment protection in industry and transport. More and more stringent ecological requirements have been implemented. In this aspect energy production is one of the main areas of interest where on the one hand alternative sources of energy are being sought and on the other hand work continues on the improvement and perfection of conventional energy production. Unfortunately, the development of industry is equivalent with a higher demand for fossil fuels – coal, lignite, crude oil and natural gas. An extensive exploitation of the fossil fuels and the accompanying environmental pollution have forced humanity to seek new sources of energy that constitute a lower environmental nuisance. In these sources need is to include energy from municipal landfill gas i.e. generated as a result of the fermentation of municipal waste. Aside from municipal waste a source of this gas is also animal and plant generated biomass. Yet another source is biogas generated in sewage farms. It is commonly accepted that biogas (including landfill gas) can play an important role in reaching the target, Europe's 202020 i.e., obtaining 20% of energy from alternative sources by the year 2020.

The act that has the greatest impact on the future use of electricity as generated from renewable sources is the Directive of the European Parliament and European Council 2009/28/WE dated April 23rd, 2009 on promoting the use of renewable energy. Based on this directive, objectives have been set that Poland must achieve with regards to renewable energy use in the future years. This directive forces the implementation of a policy requiring the use of renewable energy in electricity production, transport, heating and refrigeration. The strategy developed for Poland was adopted by the Cabinet of Ministers on 7 December 2009. It provides for a gradual increase in the share of renewable energy use for the three main energy-consuming sectors: heat engineering, refrigeration, energy production and transport (Fig. 1). It is characteristic that in the analyzed period (until 2019) the highest increase in the energy share from renewable sources falls in the electricity production sector- this share is to grow by 6.59%, while for heat engineering and refrigeration by 3.72% and transport by 2.83% (Anonymous, 2009, 2011a).

All actions of the Polish Energy Policy aimed at fulfilling the Directive 2009/28/WE are positive. Development based on renewable sources is necessary even though in many cases the costs of production of such energy are higher than

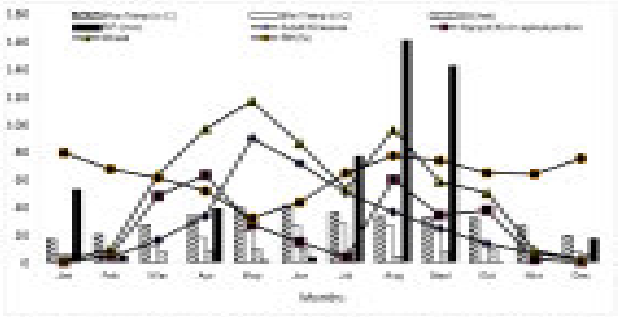

Fig.1. The assumed level of usage of renewable energy sources in Poland (Anonymous, 2011a)

production based on traditional fuels. A national policy in this matter should contribute to a rapid development and use of renewable energy.

The experts' general opinion is that the greatest potential for development in Poland are sources utilizing biomass, biogas and wind energy. Sources utilizing solar energy can play important roles chiefly in heat production, which is reasonable from an economic point of view. In recent years in Poland there has been a development of power stations generating energy from landfill gas. The efficiency of these power stations is growing systematically (Fig. 2).

Furthermore, the European Commission and international scientific centers pin their hopes to this source of energy (ECF, 2010, Evans, 2011, O'Connor, 2010, Shukla, Murty, 2011). According to the data of the EPA (Environmental Protection Agency) the amount of acquired methane from waste disposal sites will be growing until 2020 (Fig. 3). From these forecasts it results that within the next decade the production of methane from the disposal sites in Poland will remain on a constant level and will amount to approximately 2% (which constitutes an equivalent of approximately 17 $MtCO_2eq$) of the world methane yield from this source (EPA, 2011).

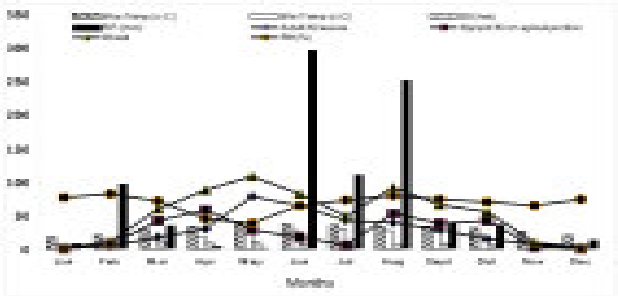

Fig.2. Efficiency of power stations generating electricity from landfill gas in Poland (Anonymous, 2011b)

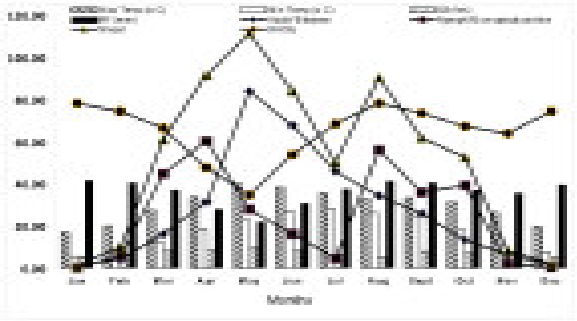

Fig.3. Forecasts of methane emission from municipal solid waste by country in 2005–2020 (EPA, 2011)

in waste disposal sites is the United States. Waste disposal sites are the third anthropogenic source of methane emission in the United States and in 2009 methane generated in these disposal sites constituted 17% (6 840 000 tons) of the total methane emission in the United States. It is estimated that from one million tons of waste, 12 233 m^3 (8 685 tons) of methane can be obtained daily (EPA, 2011). What is significant is that the most frequently used method of electricity production from landfill gas utilizes a piston combustion engine (Fig. 4). The above example confirms the potential of waste disposal sites as a source of cheap alternative energy. Assuming that all the waste disposal sites generate methane, it is worth our while to use this gas for energy generation rather than letting it escape into the atmosphere. It is thus one of the best and cheapest ways to reduce the human environmental impact.

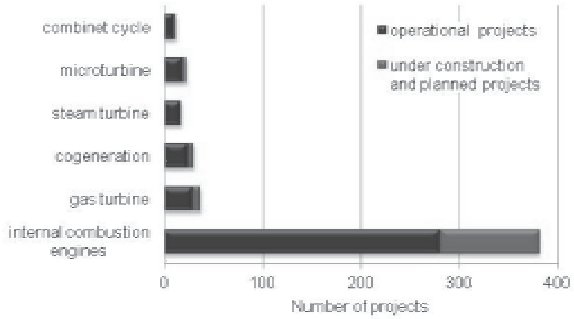

Fig. 4. Technologies used for production of electricity from landfill gas (Diemant, 2011)

The object of the investigations was a landfill gas fueled combustion engine power generator with the power output of 0.2 kW. The exhaust emission tests were performed on this engine. The emission of carbon dioxide, carbon monoxide, hydrocarbons, nitric oxides and sulfur dioxide were determined. In the particular case of the tested generator,

the gas is acquired directly from the disposal site through drilled wells and then transported through pipelines to the collecting stations. From the stations the gas flows to the blower. The gas blower generates vacuum and sucks the gas from the well then compresses it to the pressure of approximately 100 mbar and sends it to the generator (combustion engine) or a torch. At the methane content of less than 30% and oxygen more than 3% the gas cannot be used for energy conversion and that is why it is neutralized through the torch. The gas acquisition and preparation has a system that monitors the following parameters: gas chemical composition, gas mass flow (towards the engine), combustion engine and electric generator operating parameters and the parameters of the generated electric current. The view of the landfill gas-feeding pipeline and the tested engine with the generator have been presented in figure 5. Table 1 shows the landfill gas composition during the tests and table 2 the engine technical specifications.

Fig.5. View of the gas feeding pipeline and the engine with a generator

Table 1. Gas composition during the tests

Compound	Per cent
Methane (CH_4)	45.5
Carbon dioxide (CO_2)	47
Hydrogen sulfide (H_2S)	0.043

Table 2. Engine technical specifications

Number of cylinder/ cylinder arrangement	6/in-line
Cycle/combustion system	4-stroke/spark ignition
Displacement	22.9 dm^3, water-cooled
Power	200 kW (depends on gas content)
Compression ratio	9.5
Gas/ignition system	Air/fuel mixer with zero pressure regulator and mixture adjustment screw/individual cylinder ignition coils
Induction system	Turbocharger

During the tests methods based on on-line measurement of the concentrations of the exhaust components under real operating conditions were used. It is a state-of-the-art methodology in engine exhaust emissions. In order to measure the concentration of the exhaust emissions a portable exhaust emissions analyzer (SEMTECH DS by SENSORS) was used (Fig. 6, Table 3). The analyzer measures the concentration of the exhaust components and simultaneously measures the flow rate of the exhaust gases. The exhaust gases are introduced into the analyzer through a probe maintaining the temperature of 191°C. Then the particulate matter is filtered out (compression ignition engines) and the exhaust is directed to the flame-ionizing detector (FID) where hydrocarbons (HC) concentration is measured. The exhaust gases are then cooled down to the temperature of 4°C and the measurement of the concentration of nitric oxides (NO_x, NDUV – non-dispersive ultraviolet analyzer), carbon oxide and carbon dioxide (CO, CO_2, NDIR – non-dispersive infrared analyzer) and O_2 follows in the listed order. It is possible to add data sent directly from the vehicle diagnostic system to the central unit of the analyzer and to use the GPS signal. The GPS signal is mainly used in road vehicle tests.

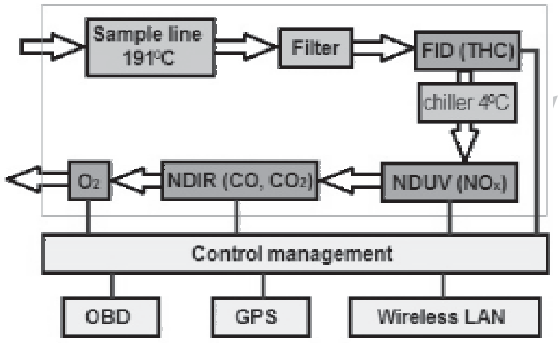

Fig.6. Diagram of a portable exhaust emissions analyzer SEMTECH DS; exhaust gas flow channels (arrow) and electrical connections circled (blue line)

RESULTS AND DISCUSSION

The exhaust emissions of the generator engine were determined based on the performed measurements. The measurements were carried out so that the emission was also recorded during the engine start as seen in figures 7, 8 and 9 showing the emission changes in time. The generator engine typically operates under stationary conditions i.e. at a steady speed and load (0,17 MW, 1500 min^{-1}). The stationary mode of operation of this engine is reflected in the exhaust emissions (Fig. 7, 8, 9). The emission remains approximately on a constant level and only slight deviations from this level are visible (the largest for hydrocarbons). The

Table 3. Characteristics of a portable exhaust emissions analyzer SEMTECH DS

Parameter	Measurement method	Accuracy
Emissions		
CO	NDIR, range 0–8%	±3%
HC	FID, range 0–10.000 ppm	±2%
NO_x=NO+NO_2	NDUV, range 0–2500 ppm	±3%
CO_2	NDIR, range 0–20%	±3%
O_2	Electrochemical, range 0–25%	±1%
SO_2	Electrochemical, range 0–1000 ppm	±3%
Data storage capacity	Over 10 hours at 1 Hz data acquisition rate	
Vehicle interface capacity	SAE J1850 (PWM), SAE J1979 (VPW)	
	ISO 14230 (KWP-2000)ISO 15765 (CAN),	
	ISO 11898 (CAN)SAE J1587, SAE J1939 (CAN)	

stationary conditions of the generator engine operation is one of the main advantages of this system as it is commonly known that dynamic states (changes in engine speed and load) have the greatest negative impact on the exhaust emissions. This is an argument supporting the use of landfill gas for the fueling of generator engines rather than road vehicles that operate under dynamic conditions.

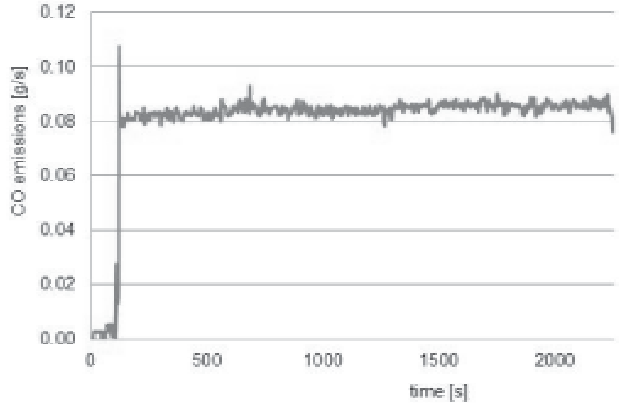

Fig.7. The emission of carbon monoxide from a landfill gas fueled engine during the tests

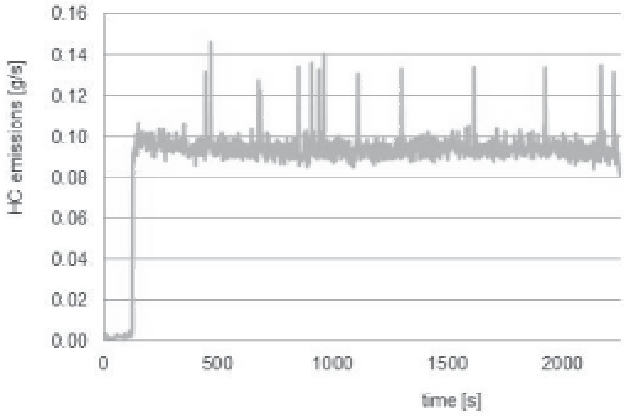

Fig.8. The emission of hydrocarbons from a landfill gas fueled engine during the tests

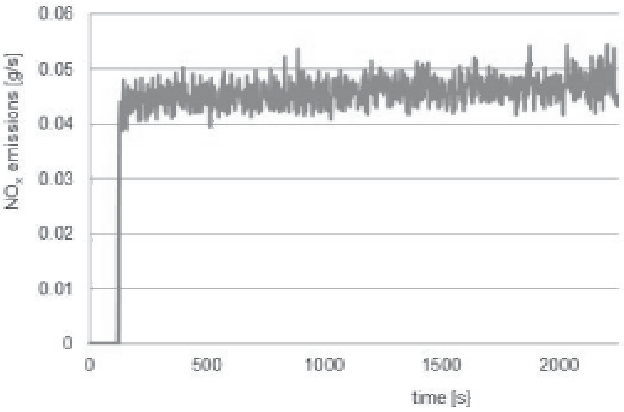

Fig.9. The emission of nitric oxides from a landfill gas fueled engine during the tests

The emissions from the generator engine fueled with landfill gas were compared with the emissions generated in the production of electricity from other sources (Fig. 10). In Poland the greatest share of the production of electricity is held by power stations utilizing coal or lignite as the main fuel which is why it is purposeful to compare these sources in the ecological aspect. For this purpose, the data published by the electricity manufacturers was used (Anonymous, 2011b). Moreover, a comparison was made with the emissions from a diesel engine of a power generator with 10kW power output. The emission of carbon dioxide, nitric oxides, sulfur dioxide and dust were compared in the production of electricity from coal and lignite. The emitted dust was compared with the particulate matter (PM) emission from diesel engines. The particulate matter emission from spark ignition engines is negligible and hence, it was not included for the engine fueled with landfill gas. Based on the presented results we can observe that the production of electricity with the use of engine power generators fueled with landfill gas is more advantageous in terms of the emission of sulfur dioxide and particulate matter/dust when

Table 4. The results of the calculations of ecological and energy related benefits that result from the production of electricity from municipal landfill gas

1.	Direct equivalent emissions reduced (reduction of methane emitted directly from landfills):
	• 0.0065 $MMTCO_2eq/yr$ (million tons of carbon dioxide equivalent per year
	• 339 tons CH_4/yr (tons of methane per year)
	• Equivalent to any one of the following annual benefits:
	  • Annual greenhouse gas emissions from 1234 passenger vehicles
	  • Carbon sequestered annually by 557 ha acres pine or fir forests
	  • CO2 emissions from burning 34 railcars' worth of coal
	  • CO2 emissions from 2747164 dm3 of gasoline consumed

2.	Avoided equivalent emissions reduced (offset of carbon dioxide from avoiding the use of fossil fuels):
	• 0.0008 $MMTCO_2eq/yr$ (million tons of carbon dioxide equivalent per year)
	• 835 tons CO_2/yr (tons of carbon dioxide per year)
	• Equivalent to any one of the following annual benefits:
	  • Annual greenhouse gas emissions from 145 passenger vehicles
	  • Carbon sequestered annually by 66 ha pine or fir forests
	  • CO_2 emissions from burning 4 railcars' worth of coal
	  • CO_2 emissions from 322721 dm^3 of gasoline consumed

3.	Energy benefits: powering about 100 homes Factors used in the calculations: 0.0423 pounds methane/standard cubic foot methane 0.5 standard cubic feet methane/standard cubic foot landfill gas 1 012 Btu/standard cubic foot methane 11 700 Btu/kilowatt-hour (weighted average for engines, gas turbines and boilers/steam turbines) 1.32 pounds carbon dioxide/kilowatt-hour (estimated average electric power plant emissions rate for 2011) 0.12 pounds carbon dioxide/standard cubic foot natural gas 0.93 gross capacity factor for generation units of electricity projects (to account for availability and operating load) 0.85 net capacity factor for generation units of electricity projects (to account for availability, operating load and parasitic losses) 0.91 factor for power delivered to households for electricity projects (to account for transmissions and distribution losses) 21 Global Warming Potentials (GWP) 5.23 metric tons carbon dioxide equivalent per vehicle per year 4.69 metric tons carbon dioxide per acre of pine or fir forest per year 191.5 metric tons carbon dioxide per railcar of coal 0.43 metric tons dioxide per barrel of oil 0.00889 metric tons carbon dioxide per gallon of gasoline 11 476 kilowatt-hours per household (average annual electricity usage) Direct equivalent emissions reduced calculations for electricity generation projects: $MMTCO_2E/yr$=megawatts (MW) of generating capacity*0.93 [gross capacity factor]*(8.760 hours/year)*(1000 kilowatts/megawatt)*11 700 Btu/kilowatt-hour)/(1 012 Btu/standard cubic foot methane) *(0.0423 pounds methane/standard cubic foot methane)/(2 000 pounds/short ton)*(0.9072 metric tons/short ton)/(1E+06 metric tons/million metric tons)*21 GWP of methane Tons CH_4/yr=$MMTCO_2eq/yr$ *(1E+06 metric tons/million metric tons)/(0.9072 metric tons/short ton)/21 GWP of methane Avoided Equivalent emissions reduced calculations for electricity generation: MMTCO2eq/yr=MW of generating capacity*0.85 [net capacity factor] *(8 760 hours/year)*(1 000 kilowatt/megawatt)*(1.32 pounds carbon dioxide/kilowatt-hour)/(2 000 pounds/short ton)*(0.9072 metric tons/short ton)/(1E+06 metric tons/million metrics tons)*21 GWP of methane Tons CO_2/yr=$MMTCO_2eq/yr$*(1E+06metric tons/million metric tons)/(0.9072 metric tons/short ton)

compared to production based on coal and lignite. The emission of carbon dioxide from the tested engine is lower compared to the emission generated in the electricity production from lignite (Table 4). Unfortunately, it is quite the contrary when comparing these technologies with regards to nitric oxides, as it is higher in electricity production from landfill gas. From the comparison of the emissions from engines fueled with landfill gas and diesel oil we may conclude that the landfill gas fuel engine generates a lower amount of nitric oxides, sulfur dioxide but more carbon dioxide, carbon monoxide and hydrocarbons. The landfill gas fueled engine is much more favorable in terms of particulate matter emissions.

The use of landfill methane generated as a result of waste disposal brings a plethora of ecological benefits. One of them is the reduction of fossil fuel exploitation (crude oil, coal and natural gas). Methane is a greenhouse gas whose greenhouse potential is much greater than that of carbon dioxide. Hence, the use of this gas for the production of energy is contributed to the reduction of climatic changes and local smog.

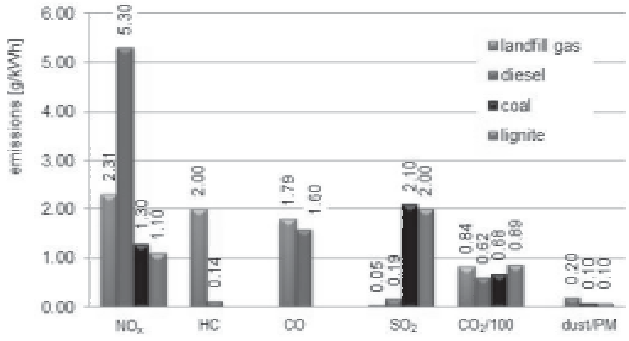

Fig.10. The emissions during the production of electricity from different fuels

The use of landfill gas improves the quality of air on a local scale. It is noteworthy too that burning of the landfill gas reduces the emission of non-methane organic compounds that occur in low concentrations in the gases emitted from the disposal sites, thus reducing the potential perils for human health and the ecosystem. Yet another benefit is the improvement of safety through a reduction of the risk of explosion of the accumulated gas.

Aside from the above mentioned direct results of the emission tests, ecological and energy related benefits from the operation of the tested power generator were assessed using a spreadsheet developed by the EPA (LFGG Benefits Calculator, 2011). The results of these calculations are presented in table 4.

CONCLUSIONS

The use of the municipal landfill gas in the power generator system has a variety of advantages. One of the most important is its relatively high efficiency and good ecological parameters. From the comparison to other methods of electricity production it is evident that a combustion engine fueled with municipal landfill gas has a lower or at least comparable emission of some of the components, which results from the combustion of fuels and its key advantage is the reduction of methane (a greenhouse gas of great greenhouse potential). The presented ecological and energy related benefits promote this type of solution and an additional motivation is the need to reach the 2020 target by Poland and other EU member states. It is noteworthy that obtaining electricity from renewable sources, including municipal landfill gas, is becoming a priority for the legislative authorities of the EU member states, which is also visible in the legal acts in Poland. To sum up, we should state that the application of landfill gas is a huge opportunity for the development of alternative energy engineering and an improvement for the condition of the natural environment.

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Physiological Response of Tropical Tree Species to Elevated CO_2 Levels at Seedling Stage

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Abstract: The increasing CO_2 concentration in the atmosphere levels often stimulates the photosynthesis and biomass. However, the duration and magnitude of this stimulation on physiological processes of tropical tree species is unknown. The objective of this experiment was to examine the physiological response of four commercially important tropical tree species to elevated CO_2 levels. *Tectona grandis* (teak), *Azadirachta indica* (neem), *Ailanthus excelsa* (maharukh) and *Bambusa bambos* (bamboo) seedlings were exposed to ambience (380 ppm) or elevated CO_2 (600 and 900 ppm) levels using an automated open top chamber (AOTC). The seedlings were exposed to elevated CO_2 levels for 180 days. Leaf gas exchange characters were measured in the second or third fully expanded leaves of the seedlings with a portable infra-red gas analyser (Li-Cor 6400XT) at the end of the study period. The elevated CO_2 levels significantly affected the physiological processes and did not show identical response in the studied tree species. Maharukh and bamboo plants were recorded optimistic response in terms of photosynthesis under elevated CO_2 even up to 900 ppm. Teak also registered a high photosynthesis up to 600 ppm level of CO_2, but it showed a decreased photosynthetic rate under 900 ppm of CO_2. Contrary to these three species, neem showed a negative response to the elevated CO_2 at both 600 and 900 ppm levels. The response of the species on transpiration (E) mmol $m^{-2}s^{-1}$ was similar to that of the photosynthetic rate (Pn). This study recommend that we should not generalise the response of tropical tree species to elevated CO_2. However, the commercially important tropical tree species should be assessed individually for the physiological functions to elevated CO_2.

Key Words: Automated open top chamber, Li-Cor, photosynthesis, CO_2, transpiration, tree physiology, neem, maharukh, teak, bamboo

Atmospheric CO_2 concentration has risen from a pre-industrial concentration of ~280 to 384ppm in 2008. It is predicted to reach ~550 ppm by 2050 and ~730 to 1020 ppm by 2100 (Solomon *et al.,* 2007). The predicted increasing CO_2 concentration in the atmosphere will affect both the current and future ecosystem processes at many stages of the organisation. It is very important to study the effects of increasing CO_2 levels ranging from molecular to global scale. It is a major challenge to realise the complex relationship between photosynthesis and yield (Gifford and Evans, 1981; Fichtner *et al.,* 1993), besides the interactions between plant growth and environment. Tropical forests play an important role in the global carbon cycle, accounting for about one-third of global primary productivity (Beer *et al.,* 2010; Lucas *et al.,* 2011). Compared to temperate tree species, little is known about the physiological responses of tropical tree species to elevated CO_2 (Korner, 2009). There is a debate on how the tropical tree species, particularly seedling, will respond to continuously increasing level of atmospheric CO_2 (Holtum and Winter, 2010; Lewis *et al.,* 2009; Wurth *et al.,* 1998).

Short-term experiments in tree species exposed to elevated CO_2 levels have shown that increased photosynthetic rate up to 40-80% in *Pinus ponderosa, P. radiata, Quercus coccinea* and *Populus deltoides* seedlings (Green and Wright, 1977) have increased net production by 20% (Couteaux and Bottner, 1996). Wang *et al.* (1998) reported 110% increased annual total net photosynthesis in elevated CO_2 than in an ambient CO_2 level. Short-term exposure of C_3 plants to elevated CO_2 concentrations often stimulates photosynthesis. It increases in biomass as a result of the improved competitiveness of CO_2 over O_2 as a substrate for the enzyme ribulose-1,5-bisphosphate carboxylase/oxygenase (Woodward *et al.,* 1991).

Researchers have recorded up-and-down-regulations of photosynthesis to elevated CO_2. Prasad *et al.* (2004) reported that the up-regulation of the carbohydrate metabolism resulted in greater accumulation and export of carbohydrates associated with photosynthesis, despite a decline in rubisco activity and protein content. Photosynthetic down-regulation in response to elevated CO_2 is also common in nutrient-poor soils, as it can affect photosynthesis. Progress has been made in determining the biochemical and molecular process by which photosynthesis is down-regulated in response to elevated CO_2. The photosynthetic down-regulation of leaf biochemicals was characterised by reduced chlorophyll and rubisco activity, limitations in RuBP and *Pi* regeneration, higher leaf mass/leaf area ratio and

decreased leaf nitrogen concentration on a leaf mass basis (Sage, 1994; Tissue *et al.,* 1995). The studies on response of commercially important tree species at seedling stage to elevated CO_2, particularly in peninsular India are limited. Hence, an experiment was initiated to understand the physiological response of tropical seedlings using AOTC.

MATERIALS AND METHODS

Research was conducted using AOTC facility at Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, India, located on 11°59'0.69" N, 76°57'2.32" E and 437 m MSL. Mean yearly temperature and rainfall at the site were maximum 35 °C, minimum 18.5°C and 503 mm, respectively. The chambers were cubical type structures of 3 x 3 x 3 m dimension, fabricated with galvanised iron pipe frames. The structures were covered with UV protected polyvinyl chloride sheet to have a transmittance of more than 95% of ambient photosynthetic active radiation. The upper portion of the chamber was kept open to maintain near-natural conditions. Elevated CO_2 conditions were achieved by injecting CO_2 gas (Food grade; Sakthi Gas Service, Coimbatore, India) at the bottom of the chamber from pressurised cylinders through valves. Ambient air was mixed with CO_2 and the gas mixture was dehumidified by passing through a passage filled with silica gel followed by soda lime. Temperature and humidity of the AOTC were measured with the inbuilt thermistor and capacitance sensors. In order to record, display and control the actual and desired CO_2 levels, relative humidity and temperature in each AOTC, data logger software called supervisory control and data acquisition (SCADA) was used. These conditions were monitored inside and outside the chambers during the study period on real-time basis by feedback control loop, which passed through programmable logical controllers (PLC).

The seedlings were grown on the mother bed according to the standard recommendations. Seedlings of ~3-4 weeks old with almost uniform size (10 to 25 cm) were transferred into polybags (30 x 20 cm). Treatments were imposed ~30-60 days after established seedlings of teak, neem, maharukh and bamboo tree in a completely randomised design. Seedlings were kept in a circle, 60 cm apart from each other and from the chamber walls. To reduce the boundary effect, the seedlings of the same seed lot surrounded by each AOTC. Seedlings were rotated within a chamber every week to minimise the effects of within the chamber variation in temperature, light and CO_2. Plants were watered daily with tap water (without any nutrients) or according to the need, throughout the experimental period and grown with day/night temperature regimes of prevailing weather conditions of Coimbatore. No artificial light was provided in the chamber.

The treatments included one ambient CO_2 concentration (approximately 382 ppm) outside the chamber which served as a control and four in AOTC. AOTCs were maintained as i) chamber control (ambient CO_2, temperature and relative humidity), ii) 600 ppm CO_2 + ambient temperature + ambient relative humidity, iii) 900 ppm CO_2 + ambient temperature + ambient relative humidity, and iv) 600 ppm CO_2 + temperature regulated through controlling of relative humidity. When CO_2 concentration of the AOTC was increased to 600 and 900 ppm, the temperature of the chamber also increased 2-4°C more than the ambient environment. To maintain the chamber's temperature as equal to ambient level, a custom-built humidifier unit was used. Level and uniformity of CO_2 distribution of each chamber were continuously checked using infra-red gas analyser (IRGA: Fuji Electric Systems Co. Ltd., Japan), which was calibrated regularly with reference CO_2 cylinders (400 and 800 ppm) throughout the experimental period.

Net photosynthetic rate (Pn), stomatal conductance (g_s), intercellular CO_2 concentration (Ci) and transpiration rate (E) were measured in the second or third fully expanded leaves. All these measurements were recorded in twelve plants per species and three replications per leaf using Li-COR 6400XT Portable Photosynthesis System (Li-Cor Instruments, USA) 180 days after the seedlings (totalling 210-240 days old) were exposed to elevated CO_2 concentrations. The measurements were performed at midday, between 1000 and 1300 eastern daytime, when the solar photosynthetic photon irradiance was saturated at 1000-1200 µmol m^{-2} s^{-1} under cloud free conditions. The photosynthetic chamber was calibrated at regular intervals using two reference CO_2 cylinders before taking the measurements. After the reference CO_2 concentration become stabilised (~5 min), the chamber CO_2 was matched to the reference CO_2 so that the chamber and reference CO_2 concentrations were equilibrated prior to a leaf being inserted into the chamber. The leaf was allowed to equilibrate for 5 min before measurements were taken and the duration of each measurement was usually 30-45 seconds. Air temperature was around 35°C during the measurement, and leaf temperature inside the cuvette ranged between 30 and 35°C. To minimise the heat load within the cuvette, a small external fan was used. The relative humidity at the inlet of the cuvette was kept between 60 and 80%. Water use efficiency (WUE) was calculated using net photosynthetic rate and transpiration (Pn/E) (Li *et al.,* 2004). Intrinsic water use efficiency (IWUE) was calculated as the ratio of the net photosynthetic rate to the stomatal conductance (Pn/gs). Intrinsic carboxylation efficiency (ICE) was derived as the ratio of the net photosynthetic rate of intercellular CO_2 concentration (Pn/Ci). The direct or short-

term effect (STE) of increasing CO_2 concentration was quantified as the ratio of stomatal conductance (g_s) measured at elevated CO_2 concentration to the plant grown at the ambient growth conditions (Del Pozo *et al.,* 2005). A similar ratio was calculated for the net CO_2 assimilation rate (NAR), which was adopted from (Zhang *et al.,* 2008).

The data on 12 seedlings per treatment in three replications were subjected to analysis of variance (ANOVA) for completely randomised design in which $P<0.05$ was considered as significant. The software utilised for statistical analysis was IBM SPSS® version 20 for Windows™.

RESULTS AND DISCUSSION

The response of tropical species to elevated atmospheric CO_2 is impeded by the absence of experimental studies for intact tropical ecosystems. The present study was conducted to understand the physiological response of tropical seedlings to elevated CO_2 concentrations that are predicted to affect the tropical ecosystems in the year 2050 onwards. The effect of gas exchange parameters, which are measured in the seedlings grown in both ambient and elevated CO_2 conditions was highly significant in overall responses (Table 1).

The physiological response of teak seedlings were significantly influenced by elevated CO_2 levels as compared to counterparts in the ambient environment. The seedlings imposed to 600 ppm of CO_2, Pn (39.7 and 20.2%) and Ci (13.4 and 11.1%) significantly increased respectively with or without relative humidity. However, neem seedlings registered significantly higher Pn (17.6%) under chamber environments. Elevated levels of CO_2 (600 and 900 ppm CO_2) reduced Pn by 10.20 and 4.40% when compared to ambient ~382 ppm of CO_2. Maharukh seedlings showed less pronounced Pn than the ambient environment when they were treated with 600 and 900 ppm CO_2. But, within the chamber environment, the species responded positively to CO_2 enrichment in terms of increase in Pn, except the chamber treated with 600 ppm CO2 + RH, where the temperature was controlled by a humidifier. Bamboo seedlings showed a significantly positive response to elevated CO_2 levels. Highest Pn was recorded in 600 (3.40 µmol CO_2 m^{-2} s^{-1}), and 900 ppm of CO_2 (3.20 µmol CO_2 m^{-2} s^{-1}). Pn remained low in chamber environment and 600 ppm CO_2 + RH.

The range of Pn in tropical seedlings varied between 2.09 and 6.71 µmol CO_2 m^{-2} s^{-1}. There was an increased Pn in teak, maharukh and bamboo seedlings to 600 ppm CO_2 (over the chamber control/ambient), that resulted from improved competitiveness of CO_2 over O_2 in the carboxylation. Ci influences the Pn either by up-and-down-regulation, as obvious when an increased Pn (6.71 µmol CO_2 m^{-2} s^{-1}) was observed in teak by maintaining higher Ci (318.53 µmol CO_2 mol air^{-1}), whereas, increased Pn (4.41 and 4.82 µmol CO_2 m^{-2} s^{-1}) with lower Ci (254.94 and 211.85 µmol CO_2 mol air^{-1}) was observed in maharukh, followed by bamboo Pn 3.40 and 3.20 µmol CO_2 m^{-2} s^{-1} with Ci 234.80 and 224.35 µmol CO_2 mol air^{-1}, respectively at 600 and 900 ppm CO_2. This trend indicated that higher Pn in neem and maharukh seedlings is directly correlated with elevated CO_2 concentrations *viz.,* 600 and 900 ppm, which was attained by upholding lower Ci concentrations. Whereas, in bamboo, Pn declined from 3.40 to 3.20 µmol CO_2 m^{-2} s^{-1} at 600 and 900 ppm CO_2 concentrations because of inadequate Ci to meet maximum photosynthesis. This up-and-down-regulation in Pn at varied levels of Ci have been previously demonstrated by Ceulemans *et al.* (1999), Hsiao and Jackson (1999), Rogers and Ellsworth (2002). When additional carbohydrate support increased growth, there is a tendency for up-regulation, whereas when carbon is assimilated over a plant's ability to cause sinks, there is a tendency for down-regulation. The physiological response of tropical species to elevated CO_2 will depend, in part, on opportunities to start new sinks (Stitt, 1991; Amthor, 1995; Ceulemans *et al.,* 1999). This sink regulation of photosynthesis may be important in tropical species with a high capacity for carbon assimilation but low carbon use efficiency (Herold, 1980; Ng and Hew, 1999).

One of the most consistent responses of a plant to elevated CO_2 is an increase in WUE and involves the inherent ability of the plant to assimilate CO_2. Generally, the amount of carbon assimilated per unit water loss increase because g_s and E reduces under-elevated CO_2, whereas, Ci remains relatively constant (Marshall and Monserud, 1996). Therefore, more carbon is assimilated at a given E rate (Hsiao and Jackson, 1999). Thus, an increase in WUE is similar to some extent with a decrease in water stress (Amthor, 1999). Higher the ratio of WUE, better the ability for carbon assimilation. WUE is ranged between 21.36 and 73.01 µmol $mmol^{-1}$ in teak and maharukh seedlings, respectively, at 600 ppm CO_2 + RH and 900 ppm CO_2. Almost higher WUE registered by 900 ppm CO_2 in all the species studied except neem, increased in proportion with CO_2 levels and transpiration (E). Higher g_s often decreased WUE in the case of neem and maharukh trees due to increased elevated CO_2. A notable difference found in g_s but not stomatal aperture is the cause of increased transpiration. However, in teak, higher g_s increased WUE when compared within treatments because of lack of stomatal sensitivity in bamboo. Morison (1993) confirmed the trend where WUE increased invariably in elevated CO_2 which will lead to reduced gs and therefore transpiration. In the present study, g_s and g_r were directly correlated with transpiration and its influence on WUE and

Pn. On transpiration, the displayed differences among treatments were significant P>0.01 for all the studied tree species. The differences in treatment with respect to g_s were statistically significant as well. The extent of this effect, however, is dependent on the experimental conditions. Field *et al.* (1995) found that g_s was reduced by 31% for plants in growth chambers, 17% for plants in open top chambers and 4% for plants grown in the soil. Decreases in g_s or E in elevated CO_2 were small or absent in mature trees (Dufrne *et al.,* 1993), seedlings (Heath and Kerstiens, 1997), and *Pinus taeda* (Ellsworth *et al.,* 1995). In *Picea sitchensis*, an increase in g_s was observed in elevated CO_2 (Barton *et al.,* 1993). It is obvious that, the g_s of many woody species were rather unresponsive to elevated CO_2. In such a case, the increase in WUE might be because of increased carbon assimilation rates (Eamus, 1996). An increase in WUE is probably the most common leaf level response to elevated CO_2, although changes in WUE are not necessarily linked with proportional changes in plant growth and Pn (Beerling *et al.,* 1996).

Higher the value of intrinsic water use efficiency (IWUE), better the efficiency of the plant to divert water for photosynthesis (Pn) than transpiration (E). The efficient control of water loss has been indicated by higher IWUE (Tuomela, 1997). IWUE of the present study ranged between 0.56 and 1.20 µmol mol^{-1}, respectively, in 600 ppm CO_2 + RH and ambient conditions of maharukh seedlings. However, observed higher IWUE 1.14 µmol mol^{-1} in neem at 900 ppm CO_2, which is notably 12.30% greater than the ambient condition. Results suggested that neem seedlings efficiently regulated water that was used for Pn than E even at higher CO_2 concentrations. RH significantly influenced the IWUE, when the species subjected to 600 ppm CO_2 + RH, consumed higher amounts of water for E rather Pn. Maharukh (112%) seedlings were found to be vulnerable to water loss followed by teak (95%), bamboo (87%) and neem (64%). The IWUE decreased when CO_2 concentrations increased because of lower Ci, and thus limiting the Pn through E.

Positive correlation existed between WUE, IWUE and Ci/Ca with Pn and Ci. This relationship indicated that the Ci and Pn of the seedlings were influenced by stomatal density, stomatal index and transpiration against given environmental conditions. Woodward (2000) found out the correlation between stomata density found on the leaf surface and atmospheric CO_2 concentration. Stomatal density declined in response to increasing CO_2 concentration. The differences observed in the species response were because of the differences in CO_2 concentrations at different temperatures and RH maintained in AOTCs. This is primarily due to competitive carboxylation and oxygenation reactions catalysed by Rubisco and limitation of stomatal functioning at cellular levels of CO_2 and O_2 concentration. The rate of the oxygenation reaction (photorespiration) increases more rapidly than the carboxylation reaction as temperature rises and CO_2 is also less soluble than O_2 at higher temperatures (Lambers *et al*., 1998). Thus, under elevated CO_2, higher temperatures are less inhibitory because the substrate concentration in the carboxylation reaction is proportionally increased.

The plants having a higher intrinsic carboxylation efficiency (ICE) showed better efficiency for carboxylation. In the present study, higher ICE was recorded by *Ailanthus* 0.023 µmol m^{-2} s^{-1} at 900 ppm CO_2 followed by teak 0.021 µmol m^{-2} s^{-1} at 600 ppm CO_2 and this ratio ranged between 0.007 and 0.023 µmol m^{-2} s^{-1}. The ICE was increased over ambient with *Ailanthus* (5.93 to 27.94 %) when 600 and 900 ppm CO_2 were imposed to seedlings. In contrast, teak seedlings responded reversely, where it declined from 29.00 to -39.91% when the CO_2 concentration was increased. There was no change in ICE of neem (0.007 µmol m^{-2} s^{-1}) at both 600 and 900 ppm CO_2 and was at par in the case of bamboo (0.015 µmol m^{-2} s^{-1}). RH (600 ppm CO_2 + RH) significantly influences the ICE of all the tree species when compared to chamber control, 600 ppm CO_2 or ambient conditions.

Short-term responses of tropical seedlings to elevated CO_2 was also observed. The short-term or direct response to elevated CO_2 caused a smaller reduction of g_s in bamboo 10.66-15.82% but a greater in Pn (17.70 and 12.54%), showing that the decrease in g_s in response to increased CO_2 is more than compensated by the larger substrate for carboxylation (Del Pozo *et al.,* 2005). Acclimation can be detected as a growth CO_2 concentration effect on values of g_s measured under similar environmental conditions (Bunce, 2001). The limited CO_2 enrichment experiments have reported g_s acclamatory effects to elevated CO_2. The degree of acclimation of g_s in the present study are similar with Zhou *et al.* (2005), who found that g_s of *Pinus sylvestriformis* was 22% lower in plants grown under elevated CO_2 compared with ambient CO_2 grown plants. By contrast, Li *et al.* (2003) have reported that growth in elevated CO_2 had no effect on g_s of *Quercus myrtifolia*. Such variable patterns of g_s acclamatory may indicate that the length of the exposure to elevated CO_2 or different environmental conditions or differences between species can account for the contrasting results. Following a decrease in g_s with a continuing rise in the atmospheric CO_2, many C_3 plants will use less water and become more efficient in water use. The reduced g_s recorded in plants grown in elevated CO_2 is presumably caused by a developmental (indirect) effect of CO_2 rather than by a direct CO_2 enrichment effect on the stomatal aperture, resulting in

Table 1. Effect of elevated CO_2 on physiological responses of fully expanded leaves in tropical species for 180 days under ambient or elevated CO_2 concentrations.

Species/Treatments	Pn	Ci	E	g_s	Ci/Ca	WUE	IWUE	ICE	g_r	STE	NAR
Teak											
Ambient	4.04	275.83	3.87	0.09	0.72	48.08	1.03	0.015	0.91	-	-
Chamber control	2.40	268.27	4.13	0.06	0.71	42.54	0.59	0.009	0.94	0.66	0.59
600 ppm CO2	6.71*	318.53*	6.89*	0.27*	0.84*	26.56	1.00	0.021*	0.73	3.05	1.66
600 ppm CO2+ RH	5.07*	310.27*	10.29*	0.30*	0.82*	21.36	0.53	0.016	0.70	3.37	1.25
900 ppm CO2	2.66	243.39	3.86	0.05	0.65	54.81	0.69	0.011	0.95	0.55	0.66
SE	0.22	8.13	0.64	0.03	0.02	4.51	0.07	0.001	0.03	-	-
CD (0.01)	0.58	21.62	1.69	0.07	0.06	12.00	0.18	0.002	0.07	-	-
Neem											
Ambient	2.46	272.49	2.46	0.05	0.71	51.85	1.00	0.009	0.95	-	-
Chamber control	2.98*	288.44*	3.41*	0.07*	0.74*	43.60	0.88	0.010*	0.93	1.06	1.21
600 ppm CO2	2.23	316.49*	2.21	0.07*	0.81*	32.36	1.00	0.007	0.93	1.16	0.91
600 ppm CO2+ RH	2.19	272.17	3.50*	0.06*	0.74*	38.27	0.61	0.008	0.94	1.00	0.89
900 ppm CO2	2.35	326.03*	2.02	0.08*	0.84*	28.66	1.14	0.007	0.92	1.20	0.96
SE	0.08	4.01	0.14	0.00	0.01	2.16	0.08	0.000	0.00	-	-
CD (0.01)	0.20	10.65	0.37	0.01	0.03	5.75	0.22	0.001	0.01	-	-
Maharukh											
Ambient	4.71	287.48	3.95	0.11	0.76	43.57	1.20	0.016	0.89	-	-
Chamber control	3.10	272.78	5.01*	0.08	0.72	41.43	0.62	0.012	0.92*	0.67	0.66
600 ppm CO2	4.41	254.94	4.54*	0.08	0.69	53.48*	0.97	0.017	0.92*	0.72	0.94
600 ppm CO2+ RH	2.73	271.75	4.82*	0.07	0.74	36.71	0.56	0.010	0.93*	0.65	0.58
900 ppm CO2	4.82	211.85	5.25*	0.07	0.57	73.01*	0.92	0.023*	0.93*	0.58	1.02
SE	0.18	6.01	0.19	0.01	0.02	3.50	0.04	0.001	0.01	-	-
CD (0.01)	0.47	15.99	0.51	0.02	0.04	9.32	0.11	0.002	0.02	-	-
Bamboo											
Ambient	2.80	259.84	2.57	0.05	0.67	59.96	1.16	0.011	0.95	-	-
Chamber control	2.58	244.50	3.48*	0.05	0.65	55.57	0.75	0.011	0.95	0.94	0.92
600 ppm CO2	3.40*	234.80	3.43*	0.05	0.64	63.34	1.00	0.015*	0.95	0.90	1.22
600 ppm CO2+ RH	2.09	254.47	3.46*	0.05	0.69	45.82	0.62	0.008	0.95	0.98	0.75
900 ppm CO2	3.20*	224.35	3.73*	0.05	0.61	63.53	0.87	0.014*	0.95	0.86	1.14
SE	0.12	7.85	0.28	0.00	0.02	5.23	0.08	0.001	0.00	-	-
CD	0.33	20.89	0.75	0.01	0.06	13.91	0.21	0.002	0.01	-	-

*The photosynthesis (Pn) µmol CO_2 m^{-2} s^{-1}, intercellular CO2 concentration (Ci) µmol mol^{-1}, transpiration (E) mmol m^{-2} s^{-1}, Stomatal conductance (g_s) mmol m^{-2} s^{-1}, ratio of intercellular CO_2 concentration and ambient CO_2 concentration (Ci/Ca), water using efficiency (WUE) µmol mol^{-1}, intrinsic water use efficiency (IWUE) µmol mol^{-1}, intrinsic carboxylation efficiency (ICE) µmol m^{-2} s^{-1} (µL L^{-1})$^{-1}$, stomatal resistance (g_r) mmol m^{-2} s^{-1}, direct or short-term effect (STE) and net CO_2 assimilation rate (NAR).

a reduction in the leaf E and, thus, an improvement in WUE and in the tissue water status (Darke *et al.,* 1997; Jarvis *et al.,* 1999; Vu, 2005).

Observations on physiological parameters were recorded in one set of climatic conditions. In other words, the observations were made during the summer. Similar studies need to be conducted at different seasons and the changes in physiological processes have to be observed in order to conclude on the species level response to elevated CO_2, as the various climatic features like sunshine, rainfall, humidity, temperature, wind, etc. also greatly change the physiological processes in the plant systems.

CONCLUSION

The present study outlined the physiological response of tropical species to the elevated CO_2 levels under simulated temperature and moisture regimes, primarily at seedling stage. Statistical analysis showed substantial variation in photosynthesis (P>0.01) when seedlings of the tree species were exposed to various CO_2 levels. *Ailanthus* seedlings have registered greater Pn in ambient environment than in chamber environments. Teak and bamboo seedlings registered a higher photosynthetic rate in a chamber with

elevated CO_2 concentration at 600 ppm. High temperature in a chamber environment favoured greater photosynthesis in neem. The physiological response of commercially important tropical tree species need to be evaluated individually to understand the physiological and biochemical metabolisms, since the species included in the study that showed up-and-down regulated activities to the elevated levels of CO_2. In this context, the 'Automated Open Top Chambers' can be used for evaluation of selected tree genotypes for enhanced CO_2 sequestration under elevated levels of CO_2 as well as temperature.

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Land Resources Appraisal Using Satellite Remote Sensing and GIS: A Case Study of Rajni Devi Sub-watershed (District Hoshiarpur)

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Abstract: In the present study of Rajni Devi sub-watershed, focus was on the drainage parameters and their impact on the land use of the basin. Satellite remote sensing and GIS have been used to map the various land use classes along with drainage parameters. Ten land use/land cover classes have been identified at level III and the stream is of sixth order. The 0.63 value of elongation ratio in the study area showed it to be slightly elongated basin and the concentration time of flow is high, resulting deposition of the solids along the choes.

Key Words: Drainage parameters, land use, remote sensing, GIS

A watershed is a natural hydrological unit and is considered more rational for land and water recourses development because its resources have optimum and synergetic interaction. Remote sensing and GIS jointly provide geo-informatics support in terms of relevant, reliable and timely information needed for economic development and environmental planning (Ashenafi *et al*., 2013; Iqbal *et al*., 2013). The qualitative analysis of drainage network enables relationship between different aspects of the drainage pattern of the basin in numerical terms (Nageswara *et al*., 2010). The Punjab sizeable area is covered by Shiwalik foot hills and these shiwalik watersheds have three distinct problematic areas. The up landed area mostly non-arable, middle reach having undulating topography with combination of arable and non-arable land and lower areas which are arable with better soils.

The repeated deposition of coarse sediments in the piedmont plains renders these areas comparatively low in agricultural productivity. These degraded lands not only represent a locked up production potential but also pose serious-economic problems. In order to restore such degraded lands for productive purposes and control their spread, a comprehensive strategy for survey, monitoring and planning is warranted. Before planning soil conservation strategies and a forestation in the Shiwalik hills, it is essential to collect detailed information about the land and water management problems, land use; nature of soils and extent of erosion, etc. Land and water management on watershed management basis with adequate database has no substitute. Spatial distribution of resources in the form of maps will help to understand the interrelationship of various resources. In the present investigation, Rajni Devi Sub-watershed of Hoshiarpur district has been selected for detailed land use mapping and drainage characteristics.

MATERIALS AND METHODS

The Rajni Devi sub-watershed lies between Latitudes of 31°24'25" to 31°30' 43" North and Longitudes of 75°59'50" to 76°7'30" East. It covers a total geographical area of 5698 hectares falling in villages Bachhohi, Rajni Devi, Badhan, Tajewal, Sarangwal, Bajwara, Jandoli, Ghokhar, Lehli Khurd, Parsowal, Bhulewal, Rathan, Chak Mallan, Chanthu Brahamna, Singhpur and Handowal. The sub-watershed comprises of gentle sloping Shiwalik hills, gentle to moderately sloping piedmont plain and seasonal 'rivulets' or 'choes'. The hills are located in the northeastern and eastern part and the plains occur in the north, south and western part of the study area. The altitude of the region varies from 310 meters, in the plains to 580 meters, above mean sea level in the hills. The hilly terrain covers nearly 42% of the total geographical area and is covered with moderately dense to dense forest. The climate of area is semi-arid to sub-humid, with annual rainfall between 64 and 117 cm annum^{-1}. Most of the rain occurs in monsoon season and hilly areas receive higher rainfall as compared to the plain areas. A great amount of rainfall goes waste as run off causing floods and severe soil erosion due to lack of infiltration and vegetation cover. The highest temperature (38.1°C) occurs in the month of June and lowest (6.1°C) in January.

Administrative boundaries viz. district, village boundaries were taken from the revenue maps published by Director, Land Records, Punjab. The High resolution (Cartosat-1 Pan & LISS- IV MX merged) digital satellite data of 2010 was on screen interpreted using ARC GIS software. Various photo-elements like shape, size, association, pattern, tone, texture, colour etc. were used to identify the various land use categories and drainage network. Well defined boundaries of agricultural land, bright cyan coloured settlements, dark colored water bodies and bright red coloured forests were

clearly observed in the image. Adequate ground truth was collected to substantiate the result and the map was finalized after making necessary modifications. The area for different land use classes, drainage length, watershed area and other drainage parameters were calculated.

RESULTS AND DISCUSSION

Land use/land cover of the study area: The land use/land cover in the study area to a large extent is controlled by parent material, physiography and climate. There are ten land use/land cover classes identified at level III in the study area as rural settlements, hemlets, cropland, orchards, plantations, forest land and wastelands with or without scrub, choes, brick kilns and ponds (Fig.1).

Built-up land: Rural settlements and the hamlets are built categories present in the region. The rural built-up cover an area of 149.92 ha, which is 2.66 per cent of the TGA (total geographical area) of the sub-watershed while small hamlets scattered over the watershed cover an area of 38.06 ha collectively and contribute 0.67 per cent to the total area of watershed. The region has a well developed road network of main road, secondary roads and cart tracks.

Agricultural land: The agricultural land consists of cropland, orchards and plantations. It covers an area of 2746.47 ha, which is 48.64 per cent of TGA.Wheat, paddy, maize and fodder are the main crops of the region. The area is both tubewell irrigated and rainfed. Kinoo and mango are the main fruit species and poplar is the main plantation species present in the study area.

Forest land: The study area has got a very good forest cover, which is located in the hilly region and is of deciduous type and cover an area of 2403.77 ha. This is 42.57 per cent of the total geographical area. The main species of forest vegetation include *Acacia catechu* (khair), *Acacia nilotica* (kikar), *Dalbergia sissoo* (tahli), scrub and grasses.

Wasteland: The area especially adjoining the choes is covered by wasteland, which at some places is covered by scrub. This is due to the erosion and deposition of choes by fluvial action. The sub-watersheds wasteland covers an area of 234.07 ha, which is 4.14 per cent of the total geographical area. The mining area of brick kilns was the other category mapped and covered an area of 25.57 ha (0.45% of total area).

Water bodies: Seasonal choes and village ponds were the water bodies mapped in the entire sub-watershed. A part of original course of the Rajni Devi choe is presently non-existent because of the expansion of cropland and settlements. Choes cover total area of 48.49 ha, which is 0.86 per cent of the total geographical area. The drainage of maximum order of 6 is present in the study area. The area covered by village ponds was very small and only 0.81 ha.

Drainage Pattern and Characteristics of Study Area

The shape of basins affects stream flow hydrographs and peak flows. The important parameters describing the shape of the basin are form factor (Rf), circulatory ratio (Rc) and elongation ratio (Re). The various characteristics of the Drainage basin which were calculated are:-

a. Size of the basin (Area) = 56.50 km^2

b. Shape of the watershed: - It governs the rate at which water enters the stream. It is expressed in the form factor and compactness ratio.

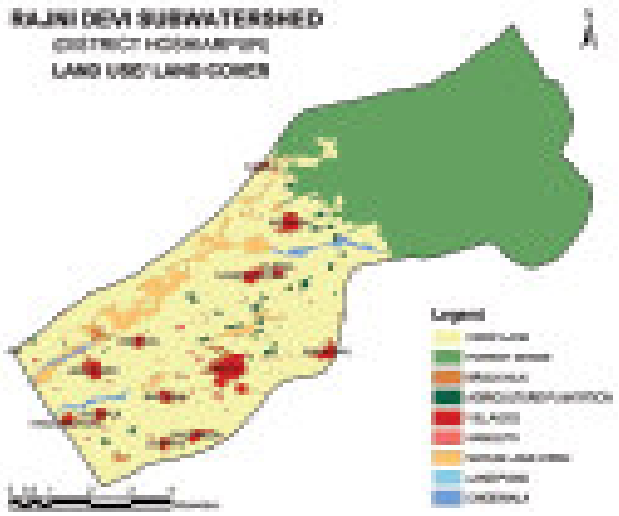

Fig. 1. Land use and land cover of Rajni Devi Sub-Watershed of 2010 year

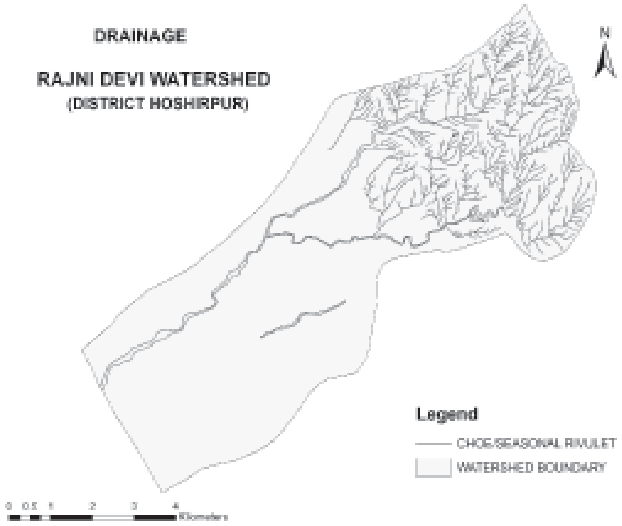

Fig. 2. Drainage map of Rajni Devi Sub-Watershed of 2010 year

b.1 Form factor (R_f):Form factor is defined as the ratio of the watershed area (A) to square of watershed length.

= B/L = Area / Length^2

= 56.50 km^2 / (13.4)^2 km^2 = 0.32.

b.2 Compactness coefficient (C_c): Compactness coefficient is computed as ratio of watershed perimeter to perimeter of circle of watershed area.

= Perimeter/Circumference = P/2*A

=37558.945/2$\sqrt{\Lambda}$ *5650565

c. Elongation ratio (Re): Elongation ratio (Re) is the ratio between the diameter of the circle having the same area (as that of the basin) and the maximum length of the basin (Schumm 1956).

Elongation ratio (Re) is

Re = √56.50/3.14 * 2/13.4

= 0.63

Drainage pattern: The watershed is of fern type shape (Fig.2). The drainage network of the catchment's is gentle and the concentration time of the flow is high, resulting deposition of the solids along the bed sides in the watershed resulting increase in the wasteland area.

The factors describing the characteristics of the drainage are:-

i) Order of the streams = 6th

ii) Length of the streams (L) = 128.748

iii) Stream density (D_s) = No. of streams/total area km^2= 803/56.5 = 14.21 km^{-2}

iv) Drainage density (D_d) = L/A= Total length of the streams/ total area of the watershed km^2 = 128.7/56.5=2.27 km^{-1}

v) Circularity ratio (R_c): Circularity ratio was computed as the ratio between the basin area (A) to the area of the circle (A_c) having the same perimeter of the basin (L_p). = 56.50km^2/224.5 km^2 = 14.3

vi) Bifurcation ratio: The term bifurcation ratio (Rb) is used to express the ratio of the number of streams of any given order to the number of streams in the next higher order. The first order streams are those which have no tributaries. The second order streams are those which have only first order streams as tributaries. Similarly, the third order streams receive first and second order streams as tributaries and so on.

When the logarithm of number of streams is plotted against order, the drainage network shows a linear relationship and the plot on a semi logarithm paper (number of streams on the logarithm scale and the order on the linear scale) is nearly a straight line. The average value of the bifurcation ratio can be calculated by determining the slope of the regression line of logarithm of stream number (ordinate) and stream order.

The regression coefficient is identical with the logarithm of the bifurcation ratio (Fig.3). The slope of the fitted regression line give the average value of bifurcation ratio (Rb) and for Rajni Devi sub-watershed this comes out to be 8.3 (regression coefficient R^2 = 0.902).The lower bifurcation ratio values are characteristics of the watersheds that have suffered less structural disturbance and the drainage pattern has not been distorted because of the structural disturbances. The Rb values range varies from 3 to 5 in such areas. The Rb values computed in Rajni Devi sub-watershed indicate that the drainage has been affected by the structural disturbances suffered by the area.

Stream length: The cumulative length of stream of a particular order is measured and the mean length (Lu) of that order stream (u) is obtained by dividing cumulative stream length by numbers of segments of that order (Nu). The mean lengths computed for Rajni Devi is given in Table 1. In the present study, it is observed that the points lie in a straight line except the points corresponding to the third order streams. This is not necessarily due to the failure of Horton's law of streams length but may be due to the measurement errors. If larger scale photographs are used a better relation will emerge. In the present study, an attempt has been made to establish the relation between the stream order (u) and the cumulative stream length ($\Sigma_1^u \Sigma_1^{nu}$ Lu). The plot of logarithm of cumulative stream length along ordinate and stream order along abscissa for Rajni Devi gives a straight line fit. The straight line fit indicates that the ratio between Lu and u is constant throughout the successive order of a basin and suggest that geometrical similarity is preserved in basins of increasing order.

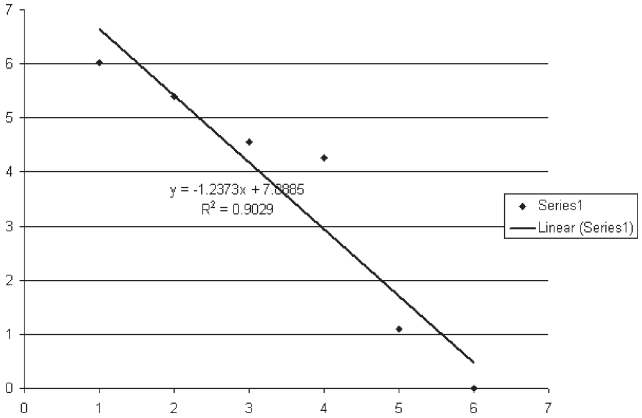

Fig. 3. Regression coefficient of bifurcation ratio of Rajni Devi sub-watershed

Table 1. Mean length of Rajni Devi sub-watershed

Rajni Devi sub-watershed		1st	2nd	3rd	4th	5th	6th
a)	Stream length (km)	80.77	27.563	13.343	7.06	0.09	0
b)	Number of streams	411	222	96	71	3	1

The factors controlling streams length are resistance to weathering and permeability of rock formation apart from the climate and other factors like vegetation. In general, low drainage density is observed in regions of highly resistant or permeable soil material under dense vegetative cover and low relief. High drainage density observed the regions of weak and impermeable subsurface material and sparse vegetation and mountainous relief. In the present study area, the low values in spite of mountainous relief indicate that the area is covered by resistant permeable rocks with a dense vegetative cover. Constant of channel maintenance are inverse of drainage density. The calculated values of morphometric parameters of Rajni Devi sub-watersheds are given in Table 2.

Table 2. Morphometric parameters of Rajni Devi sub-watershed

	Description	Rajni Devi sub-watershed
1	Rb (4th/5th order)	23.67
2	Constant of maintenance (1/Dd)	0.44

The morphometric parameters evaluated using remote sensing and GIS is found to be of immense use in better understanding the landforms, their processes and drainage pattern. The bifurcation ratios computed in the study indicated that the drainage has been affected by the tectonic disturbances and due to high concentration time of flow, solids deposit along the bed sides resulting excess of wastelands along the choes. A part of the original natural drains have eloped due to agricultural practices. The project has demonstrated that visual interpretation and mapping of satellite imagery in conjunction with information obtained from field checking can be advantageously used to prepare detailed drainage and land use/ land cover maps with acceptable accuracy and is essential for integrated and everlasting development of a sub-watershed.

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Exploration of Plant Based Ethno-Botanical Knowledge of Rural Community: Basis for Biodiversity Conservation

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Abstract: Human beings derive their food and many of their medicines and industrial products from both domesticated and wild forms of biodiversity. Medicinal and aromatic plants are subject to over exploitation due to increasing global demand and therefore require urgent conservation efforts. This study highlights the traditional use of' medicinal and aromatic plants for health care by the rural communities of the Ramban Forest Division of Jammu and Kashmir, India. Extensive field surveys were carried out in various locations of the study area, starting from the lower elevation of 740m up to 3600 m, above mean sea level in both Ramban and Banihal ranges of the division. A large number of shepherds, desi-hakims, pansaris and traders were interviewed accompanied by the field observations and voucher specimen collection. Altogether, 73 species of medicinal and aromatic plants belonging to 62 genera and 43 families were collected and documented. 67 species of 57 genera under 40 families were angiosperms while 6 species belonging to 5 genera of 3 families were gymnosperms implying that angiosperms dominate the vegetation of the area. The information gathered reveals that a number of ailments ranging from mild fever, stomach ache, cough and asthma and critical diseases like kidney trouble and cancer could be cured using these medicinal plants. These findings could contribute in pharmaceutical sector by directing further investigation of bioactive compounds in these medicinal plants. The information will give clues for conservation strategies of forest resources in the region including traditional kmowledge.

Key Words: Medicinal and aromatic plants, ethno-botany, diversity, survey, Ramban forest division

Forests have been playing key roles in the lives of people by moderating, climate, maintaining soil mantle, improving the soil fertility, minimizing soil erosion, purifying the air, preservation of wild life and regulating the flow of in rivers and streams (Kala, 2004). Forests also provide us timber, fuel wood, fodder and other non- timber minor products. Besides this forests provide numerous products for food and medicine. Amongst these resources medicinal and aromatic plants play very important role in the life support system and well being of the mankind.

The ethnic races and tribal people of the study area include Gujjars, Bakerwals and Gaddies, which have their own cultures, customs, religions, rites, taboos, myths, folk tales, songs, food and medicinal practices. Numerous wild and cultivated plants play an important and vital role among these cultures and this inter-relationship has evolved over generations of experience and practice (Maheswari, 1983). The accomplishment of forest dwellers in understanding plants and properties of their roots, stems, leaves, flowers and fruits is simply a result of long and intimate association with the flora and their dependence on them. Since their knowledge is based on experimentation on human beings though highly empirical, it warrants careful consideration of behove us to take advantage of their knowledge that still exists in many parts of the world for scientific scrutiny and adoption for posterity and should not be forgotten under the debris of modernism (Khan and Khanum, 2005).

Revival of the traditional medicine system in India and abroad has put extra assurance on the forests especially the medicinal plants. Out of 17,500 flowering plants species found in India, over 1600 are used in traditional medicine systems (MOEF, 1993). Over exploitation, unscientific harvesting and habitat degradation have led to extinction of more than 150 plant species in the wild. Some of the species which are in great demand from various pharmaceutical companies include *Saussurea costus, Aconitum heterophyllum, Picrorhiza Kurroa, Podophyllum hexandrum,* etc. (Uniyal *et al*., 2002).

Forest vegetation of the study area mainly extends between altitudes of 950 meters to 4000 meters above mean sea level. The dense cover of the forests increases with altitude which helps in checking the landslides. Forests constitute a major portion of total land area. The area is rich in various kinds of medicinal herbs like patis, kuth, bankakari, karu, chairta, dhoop, mushki-bala, prambchalan etc. Deodar trees are in higher concentration in middle range while at higher covers fir and kail are in abundance along with broad leaved trees like kikar, kakarshing, dhaman, kharak, olive, etc. whereas, in middle and upper regions, oaks, horse chestnut and walnut are broad leaved species are found in abundance. Being the rich resource area, study was planned to document the available resources for their appropriate conservation and judicious utilization.

MATERIAL AND METHODS

The problem of biodiversity loss is quite severe in the western Himalayas states due to the large scale trans humane activity of migratory cattle and local biotic pressures for fuel wood, fodder, and medicinal plants and overgrazing. Despite ongoing, socio-cultural transformation in the Himalayan region, local communities still have invaluable knowledge of plants and their uses. Therefore, there is need to documentation and rehabilitation of these degraded forests for understanding ecosystem function and biodiversity (Kaur and Joshi, 2010). Owing to enormous size and elevation, the Himalayas represent a complete transition from sub-tropical to temperate conditions. The state of Jammu and Kashmir in the lap of North-Western Himalayas, which is known to be a reservoir of about medicinal plants species. Western Himalayas of J&K including the study area of Ramban forest division has great plant diversity. The region represents ethno-botanical wealth, which has not been systematically surveyed for their judicious use and conservation. A lot of genetic diversity has already been eroded due to unscientific exploitation, the construction of various hydroelectric projects and other developmental activities. Keeping above in view, the study has been carried in Ramban forest division, which falls mainly under the geographical jurisdiction of district Ramban of Jammu Province of Jammu & Kashmir State. It has a total area of 77 hectare. The study area lies within 33°9'5" to 33° 32'26" North latitude and 75°0'39" to 75°25'8" East Longitude. The tract has highly mountainous and rugged topography comprising high ranges and deep valleys, flat or gently sloping meadows, steep slopes with great variation from 640 meters above mean sea level at the point where divisional boundary lies with Mahore forest division, which merges into Chenab to about 4553 meters above mean sea level at Monimal highest peak of the division on Pir Panchal Range (Working Plan, 1985, J&K State Forest Department)

The methodology adopted for the field surveys, data collection and analysis of the information was collected as per the requirement of the study. Extensive field surveys were carried out in various parts of the study area, starting from the lower elevation of about 740 m to 3600 m above mean sea level in both Ramban and Banihal ranges of the division. The altitudes of the different locations of the study area were measured by using Global Positioning System (GPS). The collections of voucher specimens were carried out during flowering/fruiting period to facilitate the process of identification. Only angiosperms and woody gymnosperms species of the medicinal and ethno-botanical importance have been collected. Identification of the collected specimens was done according to the Bentham and Hooker's system of classification. The specimens thus collected were processed i.e. pressed, dried by keeping in filter paper and changed periodically. The specimens were poisoned with naphthalene powder to provide protection against insect and fungal attack before mounting on the Herbarium sheets and deposited for future records, collected specimens of medicinal and aromatic plants were given the scientific names and local or common names and placed in respective families. Locality and description have also been documented along with their therapeutic uses.

The information regarding the traditional knowledge, local names and uses of the plants of the study area, parts used, purpose for which used, mode of administration and curative properties have been obtained through interviews and discussions with gujjars, bakarwals, shephards, elderly people, local hakims, traders/their helpers and have been appropriately documented in this study. Economy of the study area is basically agrarian and over 90 per cent of people are engaged in agriculture and horticulture. As only about 5% area of district Ramban is under irrigation, therefore, agriculture crop production depends on rainfall, if there is no rainfall in the months of April, May and June i.e. before monsoon arrival, the crop fails, particularly in the lower Kandi belt.

RESULTS AND DISCUSSION

The local communities in both the forest and non-forested areas of the division were found to use plants for curing various diseases of man and animals. Altogether a total of 73 plants species belonging to 43 families distributed over 62 genera were recorded in the study area. Out of the 43 families recorded with medicinal properties, the dominating families include: Rosaceae (5 genera and 7 species), Lamiaceae (5 genera and 6 species), Polygonaceae (3 genera and 5 species), Asteraceae (3 genera and 3 species), Scrophulariaceae (3 genera and 3 species), Ructaceae and Urticaceae (2 genera and species each), Geraniaceae and Maxaceae (1 genera and 3 species each), Lerberidaceae and Malvaceae (1 genus and 2 species each) and all remaining 31 families have one genus and one species each. For curing disease, use of both the above and below ground plant parts was reported in the study areas. Various plant parts utilized include leaf, fruit, bark, dot and others. Leaves were found to be mostly used for causing ailments in the study area. The other category includes flower, seed, stem, twig, latex and whole plant. The ample use of leaves is due to its continuous temporal availability, which has been reported by workers. The plentiful use of leaves can ensure sustainable harvesting of medicinal plants that provides an incentive protect and maintain domestic and wild

Table 1. Medicinal plants and their relative importance in the study area

S. No.	Species	Local name	Habit	Family	Parts used	Ethno-botanical uses (Ailments)
1.	*Abies pindrow* Royle	Raile	Tree	Pinaceae	Leaf, barks, cones	Tea, cough, phthisis
2.	*Aconitum heterophyllum* Wall.	Patish	Herb	Ranunculaceae	Root	Fever, abdominal pains
3.	*Achyranthers aspera* L.	Puthkanta	Herb	Amaranthaceae	Leaf, stem	Killing ticks and mites
4.	*Adhadota vasica* Nees	Basuti	Shrub	Acanthaceae	Leaf, flower, bark roots	Expectorant, antispasmodic
5.	*Ajuga bracteosa* Wall. ex. Benth	Chethor	Herb	Lamiaceae	Leaf	Fever pneumonia and excess bile
6.	*Anisomeles indica* L.	Dard jadi	Herb	Lamiaceae	Whole plant	Toothache
7.	*Arnebia benthamii* (Wall ex D. Don) Johnston	Johnston/ Toathvan	Herb	Asplemiaceae	Leaves, stem	Breast and teats infection
8.	*Berberis aristata* DC.	Paharishamal	Shrub	Berberidaceae	Root, bark, fruit	Laxative, eye and skin diseases
9.	*Berberis lycium* Royle	Shamal	Shrub	Berberidaceae	Stem, roots and fruit	Laxative and eye tonic
10.	*Bergenia liqulata* (Wall) Engl L.	Arali	Herb	saxifragaceae	Root	Quick healing of wounds
11.	*Betula utilis* D. Don	Burge	Tree	Betulaceae	Bark	Roofing material, antiseptic
12.	*Bistorta amplexicaulis* Greene (Basionym)	Zarathie	Herb	Polygonaceae	Root	Tea, joint pain
13.	*Buddleja paniculata* wall	Shungria	Shrub	Scrophulariaceae	Root	Making children healty
14.	*Calotropis rocera* L.	Aak	Shrub	Asclepiadaceae	Wholeplant	Toothache, anthelmintic
15.	*Cannabis sativa* Unn.	Bhang	Herb	Cannabinaceae	Whole plant	Sedative analgesic
16.	*Cedrus deodara* (roxb. Ex D. Don) G. Don	Dayar	Tree	Pinaceaeeae	Wood	Killing ticks remits
17.	*Colebrookia oppositifolia* Smith	Sloli	Shrub	Lamiaceae	Leaf	Blood clothing
18.	*Corydalis govaniana* Wall.	Gadi booti	Herb	Fumariaceae	Root	Diuretic, muscular and gastric pains
19.	*Cuscuta reflexa* Roxb.	Amalu	Creeper	Convolvulaceae	Stem	Increasing milk production
20.	*Debregeasia salicifolia* (D.Don) Findle	Sainsaru	Shrub	Urticaceae	Leaf	Dysentery and diarrhea of animals
21.	*Ficus carica* L.	Fagvoda	Tree	Moraceae	Leaf, stem, fruit	Spine removal laxative
22.	*Ficus roxburghii* Wall.	Trimal	Tree	Moraceae	Fruit	Laxative, appetizer
23.	*Ficus palmate* Forsk.	Fagorie	Tree	Moraceae	Fruit, leaf, stem	Spineremoval, laxative emollient
24.	*Fragaria nubicola* Lindey exlacaita	hinglechu	herb	Rosaceae	Root, fruit	Joints pain, appetizer
25.	*Geranium nepalense* sweet	Gurda gadi	Herb	Gerniaceare	Whole plant	Kidney diseases, dying medicinal preparations
26.	*Geranium pratense* L.	Ratnal	Herb	Geaniaceare	Root	Blood purification healing wounds
27.	*Geranium wallichianum* D. Donar Sweet	Sapjadi	Herb	Geaniaceare	Root	Snake bite
28.	*Geum elatum* Wall.	Jungle hinglechu	Herb	Rosaceae	Whole plant	Quick healing of wounds and cuts
29.	*Grewia optiva* J. R. Bruman	Dhraman	Tree	Tiliaceae	Fruit, bark, leaves	Appetizer, increase milk production, fibres
30.	*Hypericum perforatum* L.	Suganjadi	Herb	Hypericaceae	Whole plant	Chronic inflammation of internal organs and gynaecological disorders
31.	*Juglans regia* L.	Achud	Tree	Juglandaceae	Bark, fruit, leaf	Cleaning teeth
32.	*Jurinea dolomiala* Boiss	Doop	Herb	Asteraceae	Root	Incense gout and rheumatism
33.	*Juniperus communis* L.	Bethar	Shrub	Cupressaceae	Fruit, root, needles	Joint pains flavouring gins liqueurs and cordials
34.	*Mallotus philippinensis* (Lam) Muell-Arg.	Dadu	Tree	Euphorbiaceae	Fruit	Red dye constipation, wounds, ulcers
35.	*Malva neglecta* Wall.	Laffa	Herb	Malvaceae	Whole plant	Astringent, laxative, inflammation
36.	*Meconopsis aculeata* Royle	Charuke gadi	Herb	Papaveraceae	Root	To make children healthy

37.	*Melia azedarach* L.	Dhrankh	Tree	Meliaceae	Bark	Ascariasis, vaginal infection
38.	*Mentha Arvensis* L.	Puthnu	Herb	Lamiaceae	All ground above parts	Vomiting and increasing digestibility
39.	*Mentha lognifolia* (L.) Handson	Pufaklie	Herb	Lamiaceae	Leaf, stem	Killing lice and other insects, carminative
40.	*Olea ferruginea* Royle	Kau	Tree	Oleaceae	Whole plant	Cure pimples, anti periodic in fever and debility
41.	*Pinus roxburghii* Sargent	Chir	Tree	Pinaceae	Wood	Resin, perfumery industry insecticide
42.	*Pinus wallichiana* A. B. Jackson	Kail	Tree	Pinaceae	Wood	Resin which forms oleoresin and herpentine oil
43.	*Pistacia integerrima* Stewart Ex Brandis	Kankrya	Tree	Anarcadiaceae	Pod	Cough bronschitis asthma
44.	*Plantago lanceolata* L.	Musal	Herb	Plantaginaceae	Leaf, seed husk	cough diuretic antimicrobial, constipation
45.	*Plumbago zeylamica* L.	Pachas jadi	Herb	Plumbaginaceae	Root	Diarrhea/dysentery
46.	*Primula denticulate* Sm.	Chonk	Herb	Primulaceae	Leaf	Reappearance of hairs
47.	*Prunus armeniaca* L.	Cher	Tree	Rosaceae	Fruit	Excellent dresser
48.	*Punica granatum* L.	Daru	Small tree/ Shrub	Punicaceae	Fruit	Cure cough
49.	*Pyrus communids* L.	Bhagosha	Tree	Rosaceae	Fruit	Constipation appetizer
50.	*Pyrus malus* L.	Sau	Tree	Rosaceae	Fruit	Sour apple given to diabetic patients
51.	*Pyrus pashia* Buch Ham. ex D. Don	Kainth	Tree	Rosaceae	Fruit	Eye conductivities and diarrhea
52.	*Rheus austral* D. Don	Prambachalan	Herb	Polygonaceae	Root	Quick healing of wounds
53.	Rheum morcro fianum Royle	Prambachalan	Herb	Polygonaceae	Root	Purgative, dying woolen clothes
54.	*Rhododendron companulatum* D. Don.	Englu	Tree	Ericaceae	Leaf	Chromic rheumatism syphilis and scratica
55.	*Rubus ellipticus* Smith	Kanchu	Shrub	Rosaceae	Fruit	Increase digestibility
56.	*Rumex hastatus* D. Don.	Khatyami	Shrub	Polygonaceae	Leaf	Appetizer swelling of belly of animals
57.	*Rumex nepalensis* Spreng.	Hablu	Herb	Polygonaceae	Leaf	Excreting poison left inside body of animals after delivering offspring fever pneumonia of animals
58.	*Saussurea costus* (Fale)	Kuth	Herb	Asteraceae	Root	Joint pains
59.	*Skimmia laureola seib* et. Zucc ex Walp	Shangli	Shrub	Rutaceae	Leaf	incense at the time of worship kuldevas and devtas
60.	*Solanum surattense* Burn. F	Kantari	Shrub	Solanaceae	Whole plant	Seed are given to dogs to cure all diseases
61.	*Solena amplexiculis* Lam.	Bankakri	Creeper	Cucurbitaceae	Root, leaf and seed	Appetizer, carminative, purgative fevers of animals
62.	*Swertia petiolata* D. Don	Chirata	Herb	Gentianaceae	Wholeplant	Stomachache, laxative
63.	*Taxus baccata* L.	Patulu	Tree	Taxaceae	Leaf, bark	Asthma, bronchitis and cough
64.	*Thymus serphyllum* Linn.	Marchi	Herb	Lamiaceae	Whole plant	Common cold, stomach ailments, to correct eyesight
65.	*Urtica dioica* L.	Shader	Herb	Urticaceae	Root	Dysentery and diarrhea of animals
66.	*Valeriana jatamansi* Jones	Murmou	Herb	Valerianaceae	Whole plant	Hypertension and excess anger
67.	*Verbascum Thapsus* L.	Lavashlather	Herb	Surophulariaceae	Whole plant	Relieve respiratory tract irritation
68.	*Viola canescens* Wallich.	Bunafsha	Herb	Violaceae	Whole plant	expulsion of phlegm, cure sore throat

populations, their habitats and genetic diversify (Schippmann *et al.,* 2002).

During the course of study a number of myths and traditional beliefs were explored in the study area of Ramban forest division. Traditional knowledge of use of medicinal plants are passed-on from one generation to next as a family secret. Most of the shepherds and other people living on or near forests have belief that if they share their traditional knowledge regarding herbs they may lose their curative properties some people have belief that if a specific medicinal herb is uprooted on a specific day only then it's effect property is at its peak. Some people believe in myth that some specific medicinal herbs are uprooted after reciting of mantras only then they are effective in controlling the diseases.

During the course of survey, it has been found that tribes viz., gujjars and bakarwals, shepherds and few old people living in the upper reaches of the study area have a vast knowledge of usage of medicinal and aromatic plants. The information regarding traditional knowledge local name and parts used, purpose for which used and curative properties of the collected plant species have great significance. Traditional knowledge of the local communities in the study area may provide the scientific communities with the clues for screening medicinal plants as potential source for bioactive compounds that could result in the discovery of novel anti-microbial agents. The important endangered medicinal and aromatic plants in the study area are *Saussurea costus*, *Dioscorea deltioidea*, *Jurinea dolomiaea, Podophylum hexandrum, Rheum emodi* and *Skimmia laureola*. The unscientific extraction, overgrazing and unorganized trade are responsible for sharp decline of the herbal wealth of the area. It is therefore suggested that some immediate measures like banning of unscientific extraction and promotion of medicinal plants in their natural zones should be encourages saving the important species from extinction.

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Performance of Multipurpose Tree Species and Grasses under Different Soil Working Techniques on Degraded Lands of Himachal Pradesh

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***Abstract*:** The present investigation on performance of MPT's and grasses under different soil working techniques revealed that continuous contour was the most suitable soil working technique for establishment of MPT's and grasses among three soil working techniques used i.e., continuous contour, small ridge ditch and pit planting. The survival percentage, plant height, collar diameter, above ground biomass, total biomass, and root weight, was found better in continuous contour in *Grewia optiva* and *Morus alba*. Continuous contour also proved to be most effective in relation to performance of grasses and resulted into higher survival (%), maximum number of tillers and maximum tiller length plant^{-1} for *Setaria sphacelata* and *Panicum maximum*.

Key Words: Multipurpose tree species, MPT's, soil working techniques, degraded lands

In the foothills of Western Himalaya, large areas are categorized as bouldery wastelands, which have been formed due to the deposition of huge amounts of coarse soil-forming material brought down by seasonal torrents originating in the higher reaches. Deforestation, inappropriate land use practices and road construction in the upper reaches lead to the displacement of soil, which moves down the slopes and is deposited in the foothills in the form of gravel bars, with coarser fractions spreading out over the original soil layers (Singh *et al.,* 2008). Increasing human population, livestock and improper landuse has been attributed to be a major causative factor of serious land degradation in India.

In the state of Himachal Pradesh, 17.6% of the geographical area is under permanent pasture or grazing lands. The livestock population of the state is three times the carrying capacity of grazing lands and this has resulted in the deterioration of the grass cover as well as valuable forest species. Due to population explosion and land hunger, even marginal land area have been increasingly brought under cultivation, leaving only highly degraded or poor areas for raising social forestry species (Anonymous, 2010). The biomass based economy of rural population calls for restoration of tree vegetation on degraded and poor areas in order to fulfill the fodder, fuelwood, small wood, minor forest produce needs of rural masses, besides providing benefits of protective/regulative functions and amelioration of the environment. The main constraints in the establishment of plant seedlings on degraded stress sites are poor soil depth, lack of moisture availability and rapid runoff rate. High intensity of soil working coupled with moisture conservation practices likely provide an answer to overcome these constraints towards successful establishment and subsequent performance of tree/crops aimed at greening sites/soil with useful broad leaved tree species. The basic aim of planting MPTS is to rehabilitate highly eroded areas, check soil and water losses and to improve the degraded lands as also to provide fuel wood, fodder and small timber to the farmers. It was, therefore, proposed to investigate the performance of two useful; tree species *Grewia optiva* Drummond and *Morus alba* Linn. along with two grass species under different intensities of soil working coupled with soil conservation techniques.

Grewia optiva Drummond belongs to family Tiliaceae is one of the most important fodder trees of North-western Himalayas. It is distributed throughout the sub-Himalayan tract, upto an altitude of 1800 m (Brandis, 1972). *Grewia optiva* Drummond excels all the other fodder in overall nutritive value and very well compares with cultivated leguminous fodders (Negi, 1986). It is sparingly found in forest area but mostly raised along agriculture fields (Singh, 1982) and heavily lopped for fodder. Similarly *Morus alba* Linn. is also important species of the region and belongs to the family Moraceae commonly known as shahtoot has been found promising because of its multiple uses. It provides a highly palatable nutritious leaf fodder and also used for rearing silk worms. The grass species viz. *Setaria sphacelata* var. *kazangula* and *Panicum maximum* (guinea grass) belonging to Poaceae family are considered good for intensively grazed permanent pastures in the humid subtropics as well as for hay production. These grasses possesses qualities like

palatability, establishes easily from seed, persists under moderate grazing and are adapted to a wide range of soils.

MATERIAL AND METHODS

The experiment was laid out in the month of April 2013. The plantation of MPT's was done in the month of May-June and the grass tufts were planted in between the rows of trees in the month of July and data on various growth parameters of MPT's and grasses were recorded from June – October, 2013. The experiment was laid out in the field near University's Farmer Hostel, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan at an elevation of 1200 m above mean sea level facing south west aspect and lies at 30°51' N latitude and 76°11'E longitude. The climate of the site is sub-temperate to sub-tropical and semi-arid. Summer is moderately hot during May and June, winters severe during December and January. Frost occurrence is almost a daily feature during December and January. The average annual rainfall ranges from 1000-1100 mm, most of which is received during monsoon (July and August). Winter showers although common but usually mild.

Experimental details: Experimental field was prepared by worked out trenches for establishing continuous contour and small ridge-ditch treatments. Pit was dug directly without preparing the land. The plot was prepared to accommodate all the treatments for the MPT's. Uniform and healthy seedlings of *Grewia optiva* Drummond and *Morus alba* Linn (approx. same height) were transplanted in experimental field. Similarly, grass tufts were shifted from the grass nursery in the month of July and transplanted in the field between rows of MPT's. In all, three soil working techniques were applied as treatments for both MPT's and grasses, replicated sevenfold and worked out under Randomized Block Design for MPT's and RBD factorial for grasses.

Observations on growth parameters of MPT's were recorded throughout the experiment. Survival per cent of seedlings were recorded at the end of experiment. Plant height and collar diameter were recorded in the month of October. Three plants of each treatment were randomly taken for total above ground biomass measurement. The length of tap root of three plants per treatment was measured with the help of tape at the end of experiment. The length of primary and secondary roots (up to 2 mm in diameter) was determined with the help of measuring tape at the end of experiment. The samples of the roots were first air dried and then oven dried at 60 °C till constant weight. Numbers of leaves were recorded at the end of the experiment by manual counting. Numbers of branches were recorded by random selection of plants per treatment at the end of the experiment by manual counting. Observations on grass species were also recorded during October, 2013.

Statistical analysis: Data generated from present investigations were statistically analyzed as per the methods outlined by Gomez and Gomez (1984). Critical difference (CD) at 5% level of significance was used for testing the significant difference among the treatment means.

RESULTS AND DISCUSSION

Effect of different soil working techniques on survival and growth of *Grewia optiva* and *Morus alba:* The results obtained from experiment show that different soil working techniques had a non-significant influence on the survival per cent of *Grewia optiva* and *Morus alba* (Table 1). The survival per cent varies from 80.95- 100 per cent in *Grewia optiva* and 95.24-100 per cent in *Morus alba* under different soil working techniques. The survival percentage of *Grewia optiva* and *Morus alba* was recorded hundred per cent in continuous contour as compared to other two soil working techniques. This might be due to high moisture

Table 1. Effect of different soil working techniques on survival (%), plant height (cm) and collar diameter (cm) of *Grewia optiva* and *Morus alba*

Soil working techniques	Survival (%)		Plant height (cm)		Collar diameter (cm)	
	Grewia optiva	*Morus alba*	*Grewia optiva*	*Morus alba*	*Grewia optiva*	*Morus alba*
Continuous trench	100.00 (10.00)	100.00 (10.00)	122.00	143	1.43	1.46
Ridge ditch trench	90.47 (9.50)	100.00 (10.00)	120.71	104	1.21	0.93
Pit	80.95 (8.90)	95.24 (9.47)	39.57	74	0.82	0.85
Mean	90.47 (9.50)	98.41 (9.91)	94.10	107	1.15	1.08
CD (0.05)	NS	NS	15.55	11	1.23	0.15

*Figure in parentheses are square root transformation values

Table 2. Effect of different soil working techniques on no. of leaves, branches/plant and root length (cm) of *Grewia optiva* and *Morus alba*

Soil working techniques	*Grewia optiva*		*Morus alba*		*Grewia optiva*		*Morus alba*	
	No. of branches plant^{-1}	No. of leaves plant^{-1}	No. of branches plant^{-1}	No. of leaves plant^{-1}	Root length (cm)	Tap root length (cm)	Root length (cm)	Tap root length (cm)
Continuous trench	10.86	40.86	13.14	76.95	78.57	20.57	55.14	42.43
Ridge ditch trench	11.29	46.67	14.00	75.86	62.71	41.14	63.14	35.14
Pit	5.00	26.33	5.57	37.76	33.57	19.43	44.43	23.86
Mean	9.05	37.95	10.90	63.52	58.29	27.05	54.24	33.81
CD (0.05)	2.04	19.93	1.51	10.35	5.03	3.06	4.30	3.77

conservation, less nutrients loss, etc. in continuous contour as compared to other soil working techniques. Various growth parameters viz., plant height, collar diameter, number of leaves, number of branches, root length, tap root length, above ground biomass, total plant biomass and root weight were recorded and presented in Tables 1-3.

The results obtained from experiments show that different soil working techniques had a significant effect on plant height in both the species (Table 1). Maximum plant height and collar diameter was recorded under continuous contour, whereas minimum plant height was recorded under pit planting technique in both the species. Numbers of branches per plant and number of leaves were significantly affected by different soil working techniques in both the species. In *Grewia optiva,* small ridgeditch recorded maximum number of branches per plant followed by continuous contour whereas, it was recorded minimum in pit planting. A similar trend was obtained in *Morus alba*. All the soil working techniques noticed to exert a significant influence on the root length and tap root length of *Grewia optiva* and *Morus alba* (Table 2). In case of *Grewia optiva*, continuous contour recorded maximum root length followed by small ridgeditch whereas, it was recorded minimum in pit planting. On the other hand, in *Morus alba* maximum root length was recorded in small ridge-ditch followed by continuous contour, whereas, it was recorded minimum in pit planting.

Similarly, different soil working techniques exercised significant influence on above ground (fresh and dry) biomass of both the species (Table 3). The above ground biomass of *Grewia optiva* and *Morus alba* was recorded maximum in continuous contour, whereas, it was recorded minimum in pit planting. The root weight (fresh) of *Grewia optiva* and *Morus alba* was recorded maximum in continuous contour followed by small ridge-ditch, whereas, it was recorded minimum in pit planting technique (Table 3). Similarly different soil working techniques were noticed to exert a significant influence on dry root weight of both the species. The root weight (dry) of *Grewia optiva* and *Morus alba* was recorded maximum in continuous contour followed by small ridge-ditch, whereas, it was recorded minimum in pit planting.

The reason for this may be the higher conservation of moisture and nutrients, less soil loss through runoff in continuous contour as compared to other soil working techniques. These observations were in accordance with the findings of Firdaus (1944), Chang (1960), and Bacvarov (1965).

Performance of grasses: The survival and growth parameters of *Panicum maximum* (Table 4) and *Setaria sphacelata* (Table 5) was recorded highest under continuous contour with *Grewia optiva* and *Morus alba* based silvipasture system. This might be due to less nutrient loss and high moisture conservation in gradoni. These results are also in conformity with the findings of Samra *et al*. (2000), while working on biomass production of trees and grasses in silvipasture system on marginal lands of Doon Valley of north-

Table 3. Effect of different soil working techniques on above and below ground biomass of *Grewia optiva* and *Morus alba*

Soil working techniques	Above ground biomass of *Grewia optiva* (gm)		Above ground biomass of *Morus alba* (gm)		Root weight of *Grewia optiva* (gm)		Root weight of *Morus alba* (gm)	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Continuous trench	91.51	44.35	151.73	80.57	51.68	21.49	118.24	57.41
Ridge ditch trench	40.01	15.39	56.09	26.20	43.81	15.69	36.65	19.70
Pit	12.15	5.90	27.16	14.47	11.18	5.34	19.76	11.79
Mean	47.89	21.88	78.33	40.41	35.56	14.17	58.22	29.64
CD (0.05)	4.10	2.99	8.67	4.94	3.19	2.61	10.22	4.05

Table 4. Effect of different soil working techniques on survival, tiller length and tiller number of *Panicum maximum* under *Grewia optiva* and *Morus alba* based silvi-pasture system

Soil working techniques	Survival (%)			Tiller length plant^{-1} (cm)			No. of tillers plant^{-1}		
	Grewia optiva	*Morus alba*	Mean	*Grewia optiva*	*Morus alba*	Mean	*Grewia optiva*	*Morus alba*	Mean
Continuous trench	73.92	60.84	67.38	57.89	43.39	50.64	8.16	5.41	6.79
	(59.97)	(51.45)	(55.71)						
Ridge ditch trench	58.57	54.61	56.59	45.04	40.32	42.68	6.67	4.38	5.52
	(50.06)	(47.65)	(48.85)						
Pit	59.41	43.31	51.36	37.14	47.03	42.08	6.29	3.48	4.88
	(50.95)	(41.00)	(45.80)						
Mean	63.97	52.92		46.69	43.58		7.04	4.42	
	(53.54)	(46.70)							

*Figures in parentheses are arc sign transformation

CD (0.05)

Techniques	5.97	6.28	1.00
Species	4.88	NS	0.82
Tech. x sp.	NS	8.89	1.42

Table 5. Effect of different soil working techniques on survival (%), tiller length and tiller number of *Setaria sphacelata* under *Grewia optiva* and *Morus alba* based silvi-pasture system

Soil working techniques	Survival (%)			Tiller length plant^{-1} (cm)			No. of tillers plant^{-1}		
	Grewia optiva	*Morus alba*	Mean	*Grewia optiva*	*Morus alba*	Mean	*Grewia optiva*	*Morus alba*	Mean
Continuous trench	83.52	86.31	84.92	66.38	56.3	61.34	9.63	9.11	9.37
	(8.69)	(8.86)	(8.77)						
Ridge ditch trench	78.38	79.21	78.79	67.34	55.86	61.6	7.67	7.06	7.36
	(9.10)	(9.28)	(9.19)						
Pit	81.02	85.18	83.1	76.27	48.17	62.22	5.27	5.73	5.5
	(8.96)	(9.21)	(9.08)						
Mean	80.97	83.57		70.00	53.44		7.52	7.30	
	(8.92)	(9.12)							

*Figures in parentheses are square root transformation

CD (0.05)

Techniques	NS	NS	0.99
Species	NS	8.79	NS
Tech. x sp.	NS	NS	NS

west India. Similar findings were reported by Butt *et al*. (1992), Mustaque *et al*. (2009) and Sah *et al*. (2005).

From the results, it can be concluded that the different soil working techniques directly influenced the growth parameters of both trees and grass species. Continuous contour are better soil working technique for establishment of trees and grasses in slopy area for the establishment of silvipasture system.

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Sustaining Water Yield from Forest Catchment Through Vegetation Manipulation in Shivalik Himalayas

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Abstract: Vegetation manipulation was done in forest micro-watersheds in lower Shivalik region having dry mixed deciduous vegetation. The slope of watersheds varied from 32 % to 50 %. The watersheds were calibrated for two years followed by removal of 50 % crown of trees. Latter shrubs were removed in form of strips at different intensities viz. 30 %, 40 %, 50 % and complete removal. The average per cent runoff for two calibration years varied from 1.24 in MWS 31 to 10.74 in MWS 33. The runoff reduced over a period of time and in 2010 in varied from 0.21 per cent in MWS 31 to 1.66 per cent in MWS 30 of total rainfall. The removal of shrubs, in year 2011 in form of strips, induced the runoff and it varied from 1.3 to 8.39 per cent of the rainfall received. Before thinning the runoff received would not have been sufficient enough to provide one supplementary irrigation in all watersheds. However, the number of irrigation, after thinning, which can be provided, is about one in MWS 31 to about five irrigation in MWS 34 from three hectare forest watershed depending upon the intensity of thinning.

Key Words: Thinning, runoff, soil loss, vegetation, watershed

Himalayas are water towers of many important and perennial rivers of India. Over decades the upper catchment areas of the Himalayas had faced degradation and hence the water yield of many rivers and rivulets has decreased and many of them are now seasonal and ferocious during rainy season. Efforts are made from time to time through different schemes and agencies to afforest these catchments with the aim to conserve soil and water and to get water yield throughout the year. However, it had been observed in many studies that efforts of mechanical and vegetative measures reduced the runoff drastically. Dogra (2000) reported that imposing treatment of soil and water conservation reduced the runoff from 40.3 - 50.4 per cent to 0.4 - 5.8 per cent of the rainfall, within a span of four years in four different watersheds. Such efforts, though important from soil conservation point of view, have negative impact on the water flow in the rivers and rivulets in terms of quantity. The reduction in water yield was reported 14 to 29 % of rainfall in the watershed treated with mechanical and vegetative measures in Shivaliks (Hadda *et al*., 2001). The major factor contributing this variation in runoff is the vegetation stratification, diversity and quantity. Samra *et al.* (1999) reported that replacement of 59 per cent of grassland by eucalyptus resulted in 16 % and 25.4 % reduction in water yield in first and second rotation of eucalyptus. The vegetation in lower strata of the forest particularly shrubs and grasses has a dominant role in variation in runoff and soil loss. Lower vegetation strata needs manipulation in such a way that we can augment the runoff but still keep the soil loss within the limits. Therefore, this study was initiated to develop technology for vegetation manipulation in micro-catchments through which sustained water yield is received from catchment and simultaneously soil loss is kept within tolerance limits.

MATERIALS AND METHODS

The study area lies in lower Shivalik Himalayan region of India with $30^0$45' N latitude and 70^0 45' E longitude with an average altitude of 370 m above mean sea level. Five natural micro-hilly watersheds (MWS 30 to MWS 34) located within the research farm of CSWCRTI, Research Centre-Chandigarh were selected for the study. The area of micro-watersheds ranged from 0.8 ha to 4.7 ha (Table 1). Watershed number MWS – 33 was maintained as control under grass. The vegetation of the region falls under northern dry mixed deciduous types (Type 53/C2) typical natural mixed deciduous forest. The soil texture varies from sandy loam to loamy sand. Available carbon content ranged from 1.06 to 2.39 %. Steady state infiltration rates gradually decreases from upper to lower reaches. Mean steady state infiltration rate varied from 2.37cm hr^{-1} to 8.79 cm hr^{-1} in different watersheds in different reaches (Table 1).

The watersheds were under different treatments since 1970's and later on were maintained as natural forests. In the year 2005, all the five watersheds were calibrated for two years (2005 and 2006) with an objective of manipulating the vegetation of the watersheds for hydrological studies. In post calibration years (2007-2009), fifty per cent crown of each tree was removed from lower, middle and upper part of each watershed in 2007, 2008 and 2009, respectively, which

Table 1. Characteristics of different watersheds

Watershed characteristics	MWS30	MWS31	MWS32	MWS33	MWS34
Area (ha)	4.5	2.0	4.7	0.8	1.7
Perimeter (m)	980	600	940	430	580
Length of main channel (m)	450	255	420	190	240
Relief (m)	105.9	69.8	102.2	57.9	64.9
Overland slope (%)	44.9	32.1	48.9	50.4	50.6
Form factor	0.22	0.31	0.27	0.22	0.29
Drainage density (mm^{-2})	0.032	0.022	0.036	0.05	0.048
Compactness coefficient	1.29	1.19	1.21	1.35	1.24
Time of concentration (min)	3.76	2.29	3.51	1.75	2.20

allowed the light to penetrate to the ground floor and this encouraged the lower strata vegetation. Simultaneously *Lantana camara,* which had invaded the watershed was also removed every year in all the micro-watersheds. Vegetation survey was also done regularly in the watersheds. In the year 2011, shrubs were removed with the objective of inducing the runoff while simultaneously keeping the soil loss below the tolerance limits. The shrubs were removed in strips at different intensities ranging from about 30 per cent to complete removal of shrubs (Table 2). To achieve these thinning intensity, each watershed was divided into lower, middle and upper reaches (Fig. 1). The removal of shrubs in strips as per the thinning intensity was done on upper side of the lower reach as well as middle reach and lower side of the upper reach (as shown by shaded areas). Runoff and soil loss were measured every year by gauging watersheds through 0.6 m deep 2:1 broad crested triangular weirs. The runoff was measured by water level recorders.

RESULTS AND DISCUSSION

Runoff observed during calibration period and thereafter is given in table 3. It was found that during calibration years 2005 and 2006, the rainfall was low (490 and 543 mm), respectively as compared to post calibration period. The runoff in the watersheds varied from 5 mm in MWS 31 to 63.3 mm in MWS 30 in the year 2005 and from 7.7 mm in MWS 31 to 47.7 mm in MWS 33. The average per cent runoff for two years during calibration period varied from 1.24 in MWS 31 to 10.74 in MWS 33.

In the vegetation survey in all the watersheds after removal of vegetation, it was found that the understorey vegetation has increased. Indigenous species like *Justicia adhatoda*, *Murraya koenigii*, *Carissa opaque,* etc., which are light demanders got encouraged over a period of time (Panwar *et al*., 2011 and Sharma *et al*., 2012). As a result of good diversity of the lower vegetation strata, the runoff in all the watersheds reduced. In 2007, the minimum runoff was 0.3 per cent in MWS 31 followed by 1.20 per cent in MWS 30, 1.23 per cent in MWS 33, 1.62 per cent in MWS 34 and highest 3.06 per cent in MWS 32. In 2010, the runoff further decreased in all the watersheds except MWS 30, where it slightly increased. The runoff varied from 0.21 per cent in MWS 31 to 1.66 per cent in MWS 30 (Table 3).

In 2012, it was found that after removal of the shrubs, the runoff increased. Runoff varied from 1.3 to 8.39 per cent of the rainfall received. It was highest in MWS 30 followed by MWS 33, MWS 34, MWS 31 and least in MWS 31 (Table 3). The per cent increase in the runoff after removal of shrubs was 2.7 per cent in MWS 30, followed by MWS -32 (4.4 %), MWS – 33 (6 .0 %), MWS – 31 (5.2 %) and maximum runoff was in MWS – 34 (8.02 %). The mean runoff per cent received between 2007 to 2011 was compared with the post vegetation manipulation (Fig. 2). It was found that the runoff was higher in all the watersheds post treatment compared to pre-treatment period. In pre-treatment period, the runoff varied from about 1 per cent to just less than 4 per cent, whereas, in post-treatment, the runoff increased and varied from just above 1.5 per cent to more than 8.0 per cent.

Soil loss was compared between pre and post treatment. It was found that soil loss in 2007 ranged from 50 kg ha^{-1} in MWS 31 to 5520 kg ha^{-1} in MWS 34, whereas, it ranged from 30 kg ha^{-1} in MWS 31 to 2770 kg ha^{-1} in MWS 30 in 2012 (Table 4). Mean soil loss between 2007 to 2011 in different watersheds were compared with the soil loss in 2012 (Fig. 3). It was found that mean soil loss was much higher or equal to in pre-treatment period except for MWS 33 where soil loss was higher in post treatment phase.

The amount of runoff (mm) obtained before and after thinning (Table 3) was converted to cubic meter to find out the benefits, which can be reaped by a user/ manager/forester for supplemental irrigation. Since area of each watershed was different, therefore, the runoff obtained in each watershed was converted to runoff (cu m) per hectare (Table 5). It was found that thinning intensity had direct relation with the amount of runoff, which can be induced per hectare.

Table 2. Thinning intensity in different watershed

Watersheds	MWS 30	MWS 31	MWS 32	MWS 33 (Control)	MWS 34
Upper reach	30	40	50	No intervention (grass watershed)	Complete removal of under storey from all reaches
Middle reach	50	50	50		
Lower reach	20	30	50		
% removal	33	40	50		100 %

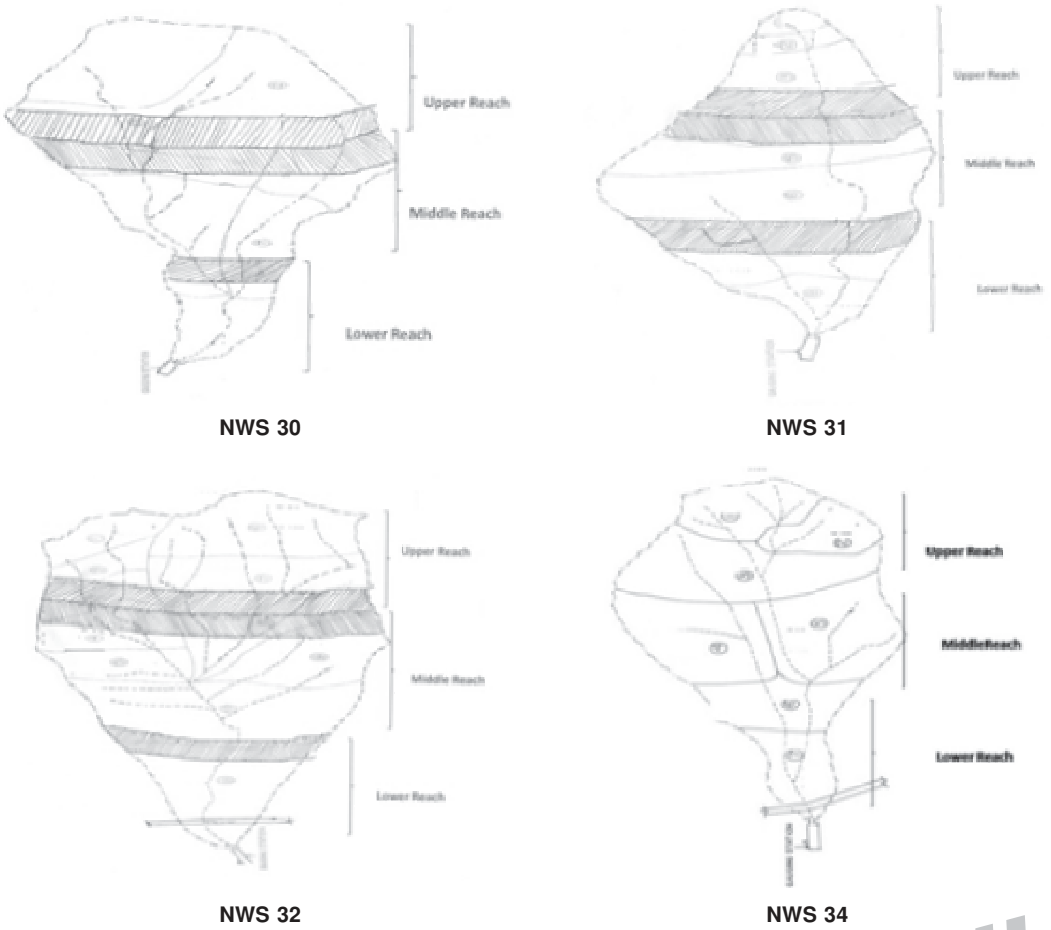

Fig. 1. Location of vegetation removal in strips (Maps not to the scale)

Generally one supplemental/life saving irrigation to wheat crop in one hectare require 500 cu m (if 5 cm depth) water. If all the watersheds were of three hectare, the water which can be harvested/received before thinning was 57 to 444 m^3, whereas, it would be 369 to 2382 m^3 after thinning. Before thinning, the runoff received would not have been sufficient enough to provide one supplementary irrigation of 5 cm depth in one hectare of wheat crop in all watersheds. However, the area which can be irrigated, after thinning, ranged from 0.738 hectare in MWS 31 to about four and a half hectare in MWS 34 (Table 5). Thus, availability of sufficient water will certainly improve the production of the crop.

It was found in the study that after removal of 50 % of tree canopy, the runoff decreased during 2007 and 2010. This is because of the fact that removal of tree canopy resulted in penetration of sun light to the ground surface as a result of which many shrubs started growing profusely leading to dense vegetation which led to decrease in the runoff. In addition to 50 per cent removal of tree canopy, *Lantana camara* was also removed in all the watersheds throughout the experimental years. This activity also had a positive effect on growth of the other vegetation, as *Lantana*

Table 3. Rainfall and per cent runoff in different watersheds

Watershed characteristics	Rainfall (mm)	MWS30	MWS31	MWS32	MWS33	MWS34
2005	490.3	36.8	5.1	18.7	63.3	26.2
2006	543.1	10.5	7.7	13.8	47.7	16.4
Total (mm)	1033.4	47.3	12.8	32.5	111	42.6
Runoff (%)		4.58	1.24	3.14	10.74	4.12
2007	708.6	8.50	2.10	21.70	8.70	11.50
Runoff (%)		1.20	0.30	3.06	1.23	1.62
2010	893	14.80	1.90	8.00	8.80	8.30
Runoff (%)		1.66	0.21	0.90	0.99	0.93
			Post thinning			
2012	945.8	59.6	12.3	46.1	65.6	79.4
Runoff (%)		6.3	1.3	4.87	6.93	8.39

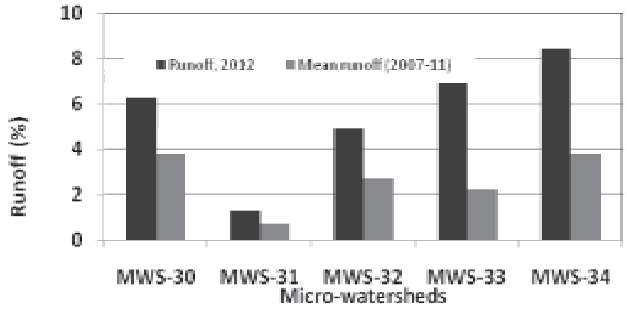

Fig. 2. Runoff per cent in different watersheds

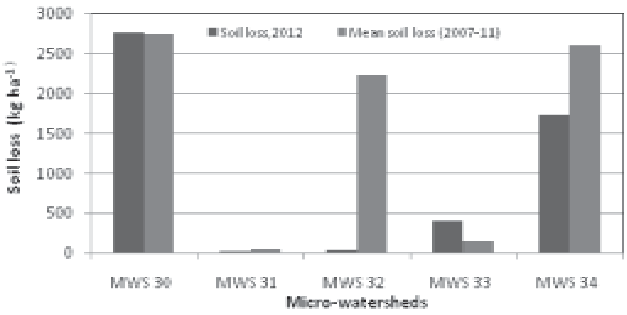

Fig. 3. Soil loss in different watersheds

camara is a vigorous growing species which suppresses the growth of other species (Sharma *et al*., 2009). Kyongha (1998) while studying the hydrological variation in forest catchments in Korea also found that afforestation resulted in reduction in runoff. Samra *et al*. (1999) reported that replacement of 59 per cent of grassland by eucalyptus resulted in 16 % and 25.4 % reduction in water yield as compared to natural forest during first and second rotation of eucalyptus, respectively. Long term study on effect of vegetative and mechanical measures in Shivalik had also revealed that the runoff can be harvested to a range of only 10 – 20 per cent of the total rainfall (Tiwari *et al*., 2012).

Reduction in soil loss with increase in vegetation had been reported by many authors. Panwar *et al*. (2012) reported the effect of conservation measure on reduction of runoff and reported that the watershed in which afforestation was done kept the soil loss much less than the untreated watershed in all range of rainfall. Madhu *et al*. (2011) reported that the growth and development of tea bush canopy have indirect effect on soil erosion by way of interception of rainfall. The exponential relationship was observed between tea canopy and runoff.

Inducing water yield from the forest watersheds is important for providing drinking and irrigation water and for other uses for downstream population. Since shrubs had more biomass and hence intercept more water therefore, removal of shrubs increased the water yield. Though removal of shrubs increased the runoff as well, but soil loss reduced. It was because of the fact that the shrubs were not removed from the lower part of the watershed which acted as a buffer and hence did not allowed the soil particle to move away from the area.

The study reveals an effective technique for optimizing runoff and reducing soil loss by just removal of the canopy by pruning of the trees so that the natural vegetation of the region grows profusely due to availability of light to ground flora. Removal of *Lantana camara* also have positive effect

Table 4. Soil loss during pre and post treatment

Watershed (Landuse)	Soil loss (kg ha^{-1})	
	2007	2012
MWS 30	360	2770*
MWS 31	50	30
MWS 32	140	40
MWS 33	440	420
MWS 34	5520	1740

*During 2012 landslide occurred in MWS 30, which resulted in more soil loss

Table 5. Amount of water harvested and its utilization

Water Shed	Area (m^2)	Water received through runoff (cum)	Water received through runoff per ha (cum)	Water received from 3 hectare (cum)	Area of wheat which can be given one supplemental irrigation (ha)*
Before thinning (2010)					
MWS -30	45000	666.0	148	444	0.88
MWS -31	20000	38.0	19	57	0.11
MWS -32	47000	376.0	80	240	0.48
MWS -33	8000	70.4	88	264	0.53
MWS -34	17000	141.1	83	249	0.49
After thinning (2012)					
MWS -30	45000	2682.0	596	1788	3.58
MWS -31	20000	246.0	123	369	0.74
MWS -32	47000	2166.7	461	1383	2.77
MWS -33	8000	524.8	656	1968	3.94
MWS -34	17000	1349.8	794	2382	4.76

*assuming 5 cm depth of water for one supplementary irrigation

on runoff reduction. It was also found that the removal of shrubs in form of strips at appropriate places helps in inducing the runoff without increasing the soil loss. The increased water quantity, after thinning, if harvested (from 3 hectare land) will be able to provide supplementary irrigation to about five hectare lands without compromising the soil loss.

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Biotechnological Interventions for Improvement of Forest Trees

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Abstract: Biotechnology provides important tools for the sustainable development of agriculture, fisheries and forestry and can be of significant help in meeting the food needs of a growing urbanized population. Potential applications of biotechnology in tree improvement fall into three main areas viz., genetic markers that help researchers identify trees with desirable genes, new vegetative reproduction methods that aid in the production of improved planting stock and genetic engineering that can provide useful information about cell biology and function and in the long term help researchers produce trees with novel traits. Molecular markers specially RAPD are being applied to a greater extent in forest trees to study genetic diversity and contribute about 25 per cent of the total molecular markers used in forest biotech activities (FAO, 2004b). Micro-propagation by rooted cutting is commonly used in more than 20 species of commercial importance, the majority of which the angiosperms. In broad-leaved species, vegetative propagation of GM material is likely to use a combination of micro-propagation and rooted stem cuttings, at least in the beginning. The current trend in MAS is towards the selection of superior alleles in candidate genes directly controlling phenotypic variation in traits of interest. Introducing targeted genes into the genome of a forest tree is a way to obtain GM plants. It is also a basic research tool for better understanding of gene functioning in woody plants. The impact of biotechnology on genetic studies has allowed the use of cutting-edge methodologies in forest tree species in spite of their poor domestication compared with food crop.

Key Words: Genetic markers, GM trees, micro-propagation, genome mapping

Biotechnology research and application in forestry is truly global in scope with activities identified in 76 countries. Significant activities occurred in developed countries (68%), with United States (14%), France (9%) and Canada (8%) the most active participants represented in the data set (percentages are of total citations of main biotechnology activities). India (9%) and China (6%) were far away from the developing countries and countries in transition. Regionally, forest biotechnology activities were numerous in Europe (39%), Asia (24%) and North America (23%), and least numerous in Oceania (6%), South America (5%), Africa (3%) and the Near East (less than one per cent) (White *et al*., 2007). While forest biotechnology research and application has spread to at least 140 genera, majority of which (62%) has been focused on only six genera (*Pinus, Eucalyptus, Picea, Populus, Quercus* and *Acacia,* in descending order of activity) and are represented in Fig. 1.

Fig. 1. Proportion of biotechnology activities in forestry sector

Potential applications of biotechnology in tree improvement fall into three main areas (Yanchuk, 2001) viz., (i) genetic markers that help researchers identify trees with desirable genes, (ii) new vegetative reproduction methods that aid in the production of improved planting stock and (iii) genetic engineering (MMG's) that can provide useful information about cell biology and function and finally may help researchers produce trees with novel traits. The forestry sector appears to have rapidly adopted markers developed for agricultural crops. Isozymes and random amplified polymorphic DNA's (RAPD's) have been widely used for genetic diversity description although the present trend seems to favour microsatellites (nuclear and chloroplast) and amplified fragment length polymorphisms (AFLP's). Driven by research on genomics, expressed genome banks (EST's [expressed sequence tags]) are being widely developed. The majority of the work reported is still mainly at the experimental stage in the laboratory however, field trials are mainly geared to support laboratory research (Srinidhi and Chauhan, 2007). Commercial applications of micro-propagation are, however, generating increasing interest. The potential is huge although, up to now, only several thousand hectares seem to have been established globally using micro-propagated material.

Molecular Markers

Recent approach to forest genetics is to develop appropriate molecular markers or system of markers to examine the diversity, genetic differentiation and gene flow in fragmented populations. Information emerging from such studies is useful in formulating proper conservation

strategies. Molecular markers have significant value in breeding programmes to characterize and evaluate genetic diversity in germplasm, population etc. Strauss *et al.* (1992) distinguished between two classes of molecular marker viz. molecular genetic markers (those derived from direct analysis of polymorphism in DNA sequences), and biochemical markers (those derived from study of the chemical products of gene expression). Molecular markers can be either dominant (only the dominant allele is expressed if both parents are genetically different at a given locus) or codominant (the genotypes of both parents are quantifiable at a locus). Dominant markers (amplified fragment length polymorphisms [AFLP's], randomly amplified polymorphic DNA's [RAPD's]) require larger sample sizes for statistical analysis than codominant markers (isoenzymes, microsatellites/simple sequence repeats [SSR's], restricted fragment length polymorphisms [RFLP's], sequence-tagged sites [STSs], expressed sequence tags [EST's], single nucleotide polymorphisms [SNP's] (White *et al.*, 2007).

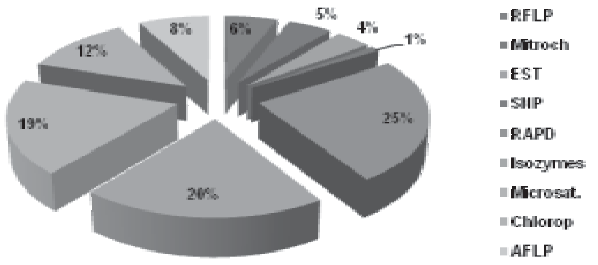

Fig. 2. Distribution of molecular markers used in forest biotechnology

Molecular markers especially RAPD are being applied to a greater extent in forest trees to study genetic diversity and contributes about 25% of the total molecular markers used in forest biotechnology (FAO, 2004a). Molecular tools have been widely used to measure gene flow and genetic diversity of natural and artificial populations of forest trees and associated species, and the impacts of anthropogenic disturbance on their evolutionary potential (Ritland and Ritland, 2000; Yanchuk, 2001). Use of molecular markers provides an objective assessment of genetic diversity in a plant species and enables unequivocal identification of elite genotypes.

Genetic Markers

A genetic marker is a measurable character that can detect variation in either a protein or DNA sequence. A difference, whether phenotypic or genotypic, may act as a genetic marker if it identifies characteristics of an individual's genotype and/or phenotype, and if its inheritance can be followed through different generations. A genetic trait may not have necessarily observable consequences on an individual's performance. Sometimes, however, this trait may be linked to, or correlated with, other traits that are more difficult to measure and do affect the individual's performance. In such cases, these unobservable genetic traits may be used as genetic markers for the linked traits because they indirectly indicate the presence of the characteristics of interest.

Traditionally, diversity within and between populations was determined by assessing differences in morphology known as morphological markers. These measures have the advantage of being readily available, do not require sophisticated equipment and are the direct measure of phenotype, thus they are available for immediate use, an important attribute. However, morphological determinations need to be taken by an expert in the species, which are subject to changes due to environmental factors and may vary at different developmental stages and their number is limited. Albino needles, dwarfing and many other aberrations, resultant mutations were observed as morphological markers but due to rare occurrence, highly detrimental and often lethal have limited application to trees (Mandal and Gibson, 1998; White *et al.*, 2007).

To overcome the limitations of morphological traits, other markers have been developed both at the protein level (phenotype) and the DNA level (genotype). Protein markers are usually named 'biochemical markers' but, more and more; they are mistakenly considered as a common class under the so-called 'molecular markers'. Most of the work under forestry was earlier focused on biochemistry (e.g. terpenoids especially mono-terpenes in pines), progressed to biosynthetic constitutive or induced protein expression (isoenzymes) and is now utilizing DNA-based tools (e.g. microsatellites, quantitative trait loci [QTLs]) since the advent of PCR (polymerase chain reaction) technology. However, protein markers are also limited by being influenced by the environment and changes at different developmental stages. Even so, isozymes are a robust complement to the simple morphometric analysis of variation. Another type of protein based genetic markers utilizes 2-D PAGE technology mostly utilized for extensive linkage mapping in *Pinus pinaster* are more difficult than Isozymes and often dominant in expression (Plomion *et al.*, 1997).

For forest tree species, isozymes have been widely used for the assessment of among and within population variation e.g. for *Abies alba, Larix decidua, Picea abies, Pinus cembra, P. halepensis, P. leucodermis, P. nigra, P. pumila, P. sibirica, P. sylvestris, Castanea sativa, Fagus sylvatica, Ficus carica, Quercus ilex, Quercus petraea, Quercus robur* (Muller-Strack *et al.,* 1992), *Alseis blackiana, Picea glauca, Robinia pseudoacacia, Pinus resinosa, P. torreyana, Populus balsamea, Acer saccharum* (Hamrick *et al.* 1992). *Pinus*

banksiana, P. contorta, P. monticola, Picea mariana, P. glauca, P. sitchensis, Pseudotsuga menziesii and Thuja plicata (Neale and Williams, 1991).

Mapping, Marker-Assisted Selection and Genomics (MMG)

During 1990s significant biotechnology activity centred on the development of molecular markers, test populations, genetic linkage maps, and statistical means of identifying quantitative trait loci (QTLs). QTLs represent statistical associations between markers and genes that control some proportion of the genetic and phenotypic variation of a quantitative trait (generally less than 10% per QTL). QTLs have several potential applications including (i) genetic dissection of complex quantitative traits, (ii) providing the basis for MAS, and (iii) providing guidance for selection and prioritization of candidate genes. Linkage and QTL maps have been created for over two dozen tree species and though more maps are likely to appear, most current efforts appear to focus on increasing the density and type of markers located on these maps. The current trend in MAS is towards the selection of superior alleles in candidate genes directly controlling phenotypic variation in traits of interest. This approach, termed association genetics, differs in application from traditional QTL studies primarily in the form of the test population being studied. The recent completion of a whole-genome sequence for *Populus* has laid the foundation for reaching this goal for a model species, and efforts follow to replicate this deed in *Eucalyptus*, though progress is slower. Public and private EST libraries for conifers now exceed one million entries. The immediate application of genomics includes identification of candidate genes for association studies and targets for genetic modification. Also, comparative studies of EST's from different trees have revealed the tremendous similarity among taxa of conifers, and raise hope that what is learned from one species will benefit many others.

MMG activities are conducted globally, but are concentrated in Europe (43%) and North America (34%). About 40 genera have been studied but only four genera dominate the MMG landscape (*Pinus, Populus, Eucalyptus* and *Picea).* Methodological approaches to MMG studies heavily favour gene discovery, functional genomics and candidate gene identification (65% of total studies), while linkage and QTL mapping account for 31 per cent of activities. Proteomics activities are modest (2%). Where identified, MMG studies have targeted primarily genes controlling wood property traits (57%) and resistance to abiotic (20%) and biotic (4%) stresses. Growth rate (6%), genetic diversity (8%) and flowering (5%) make up the remaining major categories.

Genetic Diversity

Most studies targeting genetic diversity appear to be addressing and validating population genetic models or providing baseline data for the elaboration of conservation strategies. However, the application of these data for conservation purposes at the operational level is generally not obvious in the literature. Marker applications for fingerprinting and paternity analysis have found considerable utility in both basic science and commercial applications. Studies on paternity analysis of commercial willow hybrids (Choudhary *et al.,* 2013), genetic diversity characterization based on RAPD and microsatellite (Singh *et al*., 2013) with gradually increasing use of nuclear and cytoplasmic microsatellites are the scope of studies. Virtually all these markers are considered neutral (not related to selection pressure) and may not be ideal for understanding genetic patterns influenced by evolutionary forces. There is a small but growing trend to use SNP markers located in coding regions of candidate genes controlling phenotypic expression in adaptive traits to study the influence of evolutionary forces on allele frequencies.

In forestry sector range of services being offered like gene cloning, DNA sequencing, molecular mapping and tagging of genes, and DNA fingerprinting besides analysis of genetic diversity. The use of DNA markers that are insensitive to environmental factors helps breeders screen individual plants at the seedling stage. As the cost of molecular marking is dependent on the nature of markers used, the type of material being processed, and the volume of work, the whole protocol prove out to be cost-effective (Lakshmikumaran, 2003). Molecular markers potential applications in forest tree included use of amplified fragment length polymorphism (AFLP) and SCAR (sequence-characterized amplified region) molecular markers to determine the incidence of 2n pollen (unreduced pollen) in *Populus tomentosa* (Zhang *et al*., 2007), cpDNA to detect introgression in populations of *Quercus alba* from other oak species (Whittemore and Schaal, 1991), mtDNA RFLP to study introgression between *Picea sitchensis and P glauca* (Sutton *et al*., 1991), RFLP's for studying the taxonomic relationships in *Eucalyptus* at various levels (Maunders, 1992), determining genotype data for biparentally (ISSR's) and maternally inherited (cpDNA PCR-RFLP's) molecular markers for 26 Swiss populations of *S. torminalis* (Angelone *et al*., 2007), determining natural introgressive hybridization through analysis of nine highly polymorphic microsatellite (nuSSR) loci in three mixed oak populations (Valbuena *et al*., 2007), Identification between *Prosopis juliflora* and *P. pallid*. (Landeras *et al*., 2006), developing molecular databases with STS and EST DNA markers for discrimination

of provenance regions of Norway spruce (Pucko *et al*., 2005), using orthologous expressed sequence tag polymorphism (ESTP) and restriction fragment length polymorphism (RFLP) markers for identifying ten homologous linkage groups in loblolly pine (*Pinus taeda* L.) and Douglas fir (*Pseudotsuga menziesii* [Mirb.] Franco) (Krutovsky *et al.,* 2004), construction of expressed sequence tag (EST) libraries and the resequencing of EST-derived unigenes for a diverse array of forest tree species (http://dendrome.ucdavis.edu/cmap/) (Eckert *et al*., 2009), mapping of genetic markers based upon expressed sequence tag polymorphisms (ESTPs) in loblolly pine (*Pinus taeda* L.) with primers designed from sequenced cDNA's, (Temesgen *et al.,* 2001), AFLP, SSR, and SNP for construction of a highly informative genetic map of *P. nigra* (Gaudet *et al.,* 2007), genetic linkage map of European chestnut (*Castanea sativa* Mill.) based on 311 RAPD's, 65 ISSR's, 5 isozymes markers (Casasoli *et al*., 2001), conservation, sustainable use and genetic enhancement of bio-resources in fragile ecosystems for twenty-four species of mangroves and mangrove associate (Raghavan and Parida, 2006) and RAPD and micro-satellite markers to detect and maximize the genetic variability, identifying crossings favourable to a tree breeding programme in willows (Choudhary *et al*., 2013), aiming at multiple use of markers in forest tree species.

Micro-propagation

Tree species can be micro-propagated by micro-cuttings or by somatic embryogenesis. Micro-propagation is used to create large numbers of individual clones or genotypes. Because vegetative propagation bypasses the genetic mixing associated with sexual reproduction, it represents an ideal way to deliver genetic gain: select individuals are replicated precisely. Micro-propagation by rooted cutting is commonly used in more than 20 species of commercial importance, the majority of which are angiosperms. Conifers are less easily rooted than angiosperms, though modest programmes for several genera exist. Organogenesis, or the creation of plantlets from tissues such as cotyledons, has largely fallen out of favour in forestry operations and is used infrequently. Germplasm and protocols are likely to be available for large-scale deployment for many of forest tree species like *Anogeissus* in India (Saxena and Dhawan, 2001); *Acacia mangium* and *A. mangium* × *A. auriculiformis* in Malaysia (Galiana *et al.,* 2003), *Pinus* in Canada and New Zealand (Lelu and Thompson, 2000) *Eucalyptus* in Australia (Watt *et al*., 2003). It seems that cuttings are likely to dominate propagation in angiosperms in developing countries while somatic embryos will dominate in conifer propagation in developed countries. The majority of GM trees is likely to be used in the form of clonal materials and will need to be vegetatively propagated. In the case of conifers, somatic embryogenesis, especially when derived from a single cell, seems the most suitable regeneration and propagation technique. However, with the increased use of hybrids or triploids, the occurrence of somaclonal variation may increase (Dave *et al*., 2001) true-to-typeness, particularly, may remain a problem for certain genotypes, and efforts are still needed for optimizing this technique to make it more reliable, especially when using mature selected genotypes.

Genetic Modification (GM) in Trees

Populus was the first tree to be genetically modified (1986) and is by far the most commonly studied tree genus for genetic modification purposes today (47% of activities). Since then, the genus has become a model for genetic modification and related tree biotechnology studies. The first attempt to genetically modify a conifer (*Larix*) was reported in 1991. Genetic modification activities in forestry are taking place in at least 35 countries, 16 of which host some form of experimental field trials. These field trials are generally very small and typically of short duration and are destroyed before seed bearing occurs. In the remaining 15 countries, experimentation is restricted to laboratories or greenhouses (Chaix and Monteuuis, 2004). To date, only China has reported the establishment of approved, commercial plantations of GM trees. Nearly two-thirds of the 520 reported genetic modification activities in forestry occur in North America (48%) and Europe (32%). Asia follows with 14 per cent of reported activities, Oceania with 5 per cent, South America with one per cent and Africa with less than one percent (FAO, 2004a).

Introducing targeted genes into the genome of a forest tree is a way to obtain GM plants. It is also a basic research tool for a better understanding of gene functioning in woody plants. This is no doubt a function of ease with which some genotypes of the genus can be transformed and vegetatively propagated for experimental purposes. As per FAO (2001), *Pinus* (19%), *Eucalyptus* (7%), *Liquidambar* (5%) and *Picea* (5%) make up the majority of the remaining experimental studies. Field trials of GM trees are restricted largely to four top genera (*Populus,* 51%; *Pinus*, 25%; *Liquidambar*, 11% and *Eucalyptus*, 7%).

Introduction of a mutated version of the gene encoding the enzyme target for various herbicides: glyphosate for *Populus alba* × *P. grandidentata, P. trichocarpa* × *P. deltoides, Eucalyptus grandis, Larix decidua* and *Pinus radiata* (the herbicide blocks the synthesis of tryptophan, tyrosine and

phenylalanine), or chlorosulfuron for *Populus tremula* and *Pinus radiata* (the herbicide blocks the synthesis of leucine, isoleucine and valine) was achieved. Moreover, introducing a microbial gene encoding an enzyme for the detoxification of the herbicide, and has been applied to *Populus alba*, *P. alba* × *P. tremula*, *P. tremula* × *P. alba, P. trichocarpa* × *P. deltoides* and *Eucalyptus camaldulensis* and *Pinus radiata* and *Picea abies* (Bishop-Hurley *et al.,* 2001). Use of microprojectiles to insert a gene encoding an endotoxin which binds to the receptors in the intestine of Lepidoptera, Coleoptera and Diptera, lysing the organ and killing the insect was done in *Populus alba* × *P. grandidentata, P. tremula* × *P. tremuloides* and *Picea glauca*. GM *Populus* trees and *Pinus radiata* expressing the *Bacillus thuringiensis* endotoxin '*Bt*' have been obtained. Potato gene *pin*2, a protease inhibitor was introduced into *P. alba* × *P. grandidentata* through *A. tumefaciens* (Klopfenstein *et al*., 1991), and the gene of a rice protease inhibitor introduced into *P. tremula* × *P. tremuloides* (Heuchelin *et al.,* 1997). Simultaneous modification of two genes for enhanced resistance to insects was achieved in *Liquidambar styraciflua*, combining a peroxidase anionic enzyme gene involved in cell growth and wall development with a '*Bt*' gene (Sullivan and Lagrimini, 1993).

Genetic transformation to modify lignin characteristics is a key research feature on species used in the paper industry. The aim is to regulate the activity of key enzymes involved in the lignin biosynthesis pathway (Li *et al.,* 2003). Active on-going research targets the effects of lignin biosynthesis in *Populus* on soil carbon transformation and its storage. Researchers have developed techniques of tissue culture and genetic transformation for many tree species such as Poplar, Birch, Eucalypts, Larch, Wallnut, Apple and Citrus etc (Chaix and Monteuuis, 2004). Also for production of sterile trees and to prevent possible dispersal of transgenic pollen in the environment, an approach based on genetic ablation has been tested on poplar (Skinner *et al*., 2000). Other approaches, based on the suppression of key flowering genes, are being tested.

Constraints to Genetic Modification in Trees

Environmentalists are concerned about potential negative impacts of genetic engineering of trees. Among major concerns includes escaping of novel genetic material into wild relatives, impacts of inserted pesticidal properties on forest food webs and ecosystem processes, repercussions of EST's developing resistance to pesticidal properties, enhanced weediness of the transgenic organism or its relatives in natural systems, impacts of altered lignin content on forest food webs and ecosystems and negative environmental impacts from application of technologies intended to manage the GE organism including induced sterility and increased use of herbicides (Faith and Rachel, 2001).

Future Perspective

Unlike work carried out on crop or farm animal species, the domestication of forest trees is, with few exceptions. However, within a few decades, knowledge transfer from agriculture to forestry has been so fast that genetic information of a few tree genera, such as poplar (*Populus*), pine (*Pinus*) and *Eucalyptus*, is important, in terms of complexity and quality. Expected gains for tree breeders include new genetic pools and significant reduction in tree selection. The impact of biotechnology on genetic studies has allowed the use of cutting-edge methodologies with forest tree species in spite of the late domestication process compared with crop species. The sequencing of the *Populus* genome has significant implications for forestry (Campbell *et al*., 2003). *Eucalyptus* gene sequencing pursued by the Eucalypt Genome Initiative, The Eucalyptus Genome Sequencing Project Consortium and the Brazilian project Genolyptus. The Dendrome Project (http://dendrome.ucdavis.edu/cmap/) is a collection of forest tree genome databases and other forest genetic information resources, with a special emphasis on conifers (*Pinus).* It is in genome sequencing that research is currently most active.

Since genes regulating secondary tissue and lignin formation in the annual plant *Arabidopsis thaliana* were identified (Goujon and Jouanin, 2003), research on the genetic basis of wood quality in forest trees has significantly increased (mainly in *Eucalyptus, Pinus* and *Populus*). With the exception of micro-propagation, for which some applications are reported, most public domain information relates to research activities. Field applications appear extremely limited, according to the literature. Nevertheless, and in spite of unclear economic rationale, the use of biotechnology in forestry research has increased and provided new knowledge on tree biology and functioning. Commercial deployment of new biotechnology-based forest tree varieties of a limited number of taxa (*Eucalyptus*, *Pinus taeda*, *P. radiata*, *P. pinaster*, *Populus,* etc.) can be expected in the near future. The impact of biotechnology applications on global wood supply may, however, take longer to materialize at least not before 2020 (Seppala, 2003). In this context, genetic modification appears to be the most significant sector of forest biotechnology. DNA fingerprinting, through its high precision in identifying plant genotypes, holds considerable promise as a reliable tool of intellectual property protection of tree species. Genomics and proteomics

outcomes are expected to boost conventional tree breeding and improve the efficiency of existing programmes.

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Wheat Yield Performance in Relation to Poplar Tree Density and Age (*Populus deltoides*) in Bet Area of Punjab

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Abstract: Wheat yield performance data was collected from farmers field at different tree densities (i.e. 225, 250 and 300 plants acre^{-1}) at different ages (1, 2, 3 and 4 years old) of poplar. The perusal of data revealed that there was non-significant difference in number of tillers and ear length under 225 and 250 trees per acre density, but these parameter reduced significantly at higher poplar density (300 plants acre^{-1}). Poplar density of 225 plants per acre produced significantly higher grain yield by 8.0 and 25.6 per cent as compared to 250 and 300 plants acre^{-1}, respectively. Ear length, test weight and grain yield were negatively correlated with increase in age of poplar. Test weight reduced significantly with age of poplar trees, which led significant decrease in wheat grain yield. Wheat yield under 2, 3 and 4 years old poplar reduced by the margin of 9.9, 26.9 and 49.8 per cent as compared to one year old poplar. Diameter at stump height and at breast height of poplar decreased with increase in poplar plantation density, but differences were not significant during initial two years.

Key Words: Agroforestry, poplar density, tree age, wheat

Poplar is a very prominent taxonomic group of tree species in plantation forestry as well as in natural forests in northwestern states in India. Its natural population is small and found only in the mountains with six indigenous species. As an exotic species (*Populus deltoides*), it acquire great role in afforestation/reforestation programmes, agro-forestry and conservation activities. According to India country report on poplars and willow (Anonymous 2012), area under poplar outside the forest in India is estimated 312,000 ha. The annual returns from poplar at current market rates are estimated to be around one Rs.60-80,000 rupees acre^{-1} year^{-1}, which is much higher than any other on-farm intervention (Dhiman, 2012a).

Poplar is an integral part of farming system and an important enterprise for farmers of bet areas of Punjab (Chauhan and Mangat, 2006). It has straight bole, small crown and winter deciduous nature that allows winter cropping with only marginal negative effect on crop yields. In the first 2 years of poplar, any crop can be grown as intercrop without much reduction (10–15%) in the yield during summer and winter seasons. Dhiman (2012b) identified that around 98% of the poplar block plantation have intercrops. However, during summer season, rice is not recommended for planting with poplar as flooding of rice often results in uprooting of trees (Dhanda *et al.,* 2008). Third year onwards, crops like wheat, oats, berseem, etc. can be grown successfully throughout its rotation. This is due to the ability of poplar to adapt to the wheat competition by distorting its root architecture that improves complementarity between trees and crops (Cannel *et al.,* 1996) as well as leaf fall starts in October and become totally leaf less in January and February. In a study by Sharma and Dadhwal (2011), wheat plant population was greatly affected during the leaf shedding stage of poplar. During dormant period of poplar, significantly lower values of plant height, leaf area index and dry matter yield of wheat were recorded. Gradual decrease in yield (10–46%) of intercropped wheat, with the increase in age of trees (first–sixth year) have been reported earlier by Gill *et al.* (2007). However, such yield loss is often compensated by the sale of poplar wood at the end of rotation (Chauhan *et al.,* 2009)). Competition for below and above ground resources often changes with the increase in tree age. The main objective of the study was to find out optimum poplar plant density for successful intercropping with winter crop i.e., wheat.

MATERIALS AND METHODS

Poplar is an important enterprise for farmers of bet areas of Punjab in district Ropar. Its falls between north latitude 30º -32´ and 31º-24´ and east longitude 76º-18´ and 76º-55´. Annual rainfall in the district Ropar was recorded 103.5cm during 2013-14. Farmers of bet area are growing poplar at different plant densities and intercrop with wheat during winter season. Data of poplar growth and wheat performance was collected from farmers field during the year 2013-14. The diameter at breast height (DBH) and diameter at stump height (DSH) of the trees were also measured. The various growth and yield attributes of wheat viz., number of tillers, ear length and 100-grain weight were recorded on harvesting of one square meter representative area from each field and grain yield, straw yield and harvest index were recorded from whole field.

RESULTS AND DISCUSSION

Effect of poplar density: The perusal of data (Table 1) revealed that differences in number of tillers and ear length were non-significant under 225 and 250 trees per acre poplar plantation density, however, these parameter were significantly less under higher poplar plantation density (300 plants acre^{-1}) due to competition between poplar and wheat for space, light and nutrients in addition to this higher leaf litter fall under higher poplar density might be responsible for inhibits wheat germination/growth. Test weight decreased significantly with each increase in poplar population density led to significant decrease in wheat yield with each increase in poplar population density. Wheat crop under poplar density of 225 plants per acre produced significantly higher grain yield by the margin of 8.0 and 25.6 per cent as compared to 250 and 300 plants per acre, respectively. Grain yield recorded under 250 poplar plants per acre was significantly higher by 16.3 per cent than 300 poplar plant density. This reduction in test weight and grain yield might be due to lower production of photosynthates under low light conditions as the light intensity decreased under higher poplar plantation. Chauhan and Dhiman (2002); Chauhan *et al.* (2010) recorded influence of light reduction under poplar on wheat yield. Kaur *et al.* (2010) reported that all growth parameters showed inverse relationship with the age of plantation as number of tillers and 100-grain weight decreased under higher aged plantation. Similarly data presented in Fig. 1 showed that ear length, test weight and grain yield were negatively correlated with increase in age of poplar with R^2 values 0.189, 0.107 and 0.130, respectively. Straw yield and harvest index followed similar trend as number of tillers. Straw yield was significantly higher under 225 and 250 poplar plants per acre by the margin of 10.7 and 7.3 per cent, respectively as compared to 300 poplar plants per acre. Similarly harvest index was superior under 225 and 250 poplar plant per acre by 9.4 and 6.1 per cent, respectively than higher poplar plant density (300 plants acre^{-1}). Proportionally higher affect on grain yield than vegetative growth led to decrease in harvest index. Chauhan and Dhiman (2002) also recorded inverse relationship of wheat yield to row spacing.

Effect of age of poplar: An appraisal of the data presented in the Table 1 indicated that number of tillers and ear length of wheat were not affected up to two years growth of poplar plantation. The decrease in values thereafter with each year increase in age of poplar plantation was due to increased competitive interactions for light and soil resources. Chauhan *et al.* (2011) also reported that poplar at its earlier stage caused less harmful effect on crops but older trees reduced the plant stand due to more exploitation of resources by poplar trees. Kumar *et al.* (2001) reported significant impact of leaf fall on wheat seed germination, which could be reduced by removing the leaf litter. Sharma and Dadhwal (2011) confirmed that wheat plant population was greatly affected during the leaf shedding stage of poplar. Test weight recorded maximum under one year old poplar plantation and reduced significantly with the age of poplar plantation. Reduction in ear length and hundred grain weight with increase in the age of poplar was also reported by Gill *et al.* (2009). Reduction in these yield attributes led to significant decrease in wheat grain yield with each increase in the age of poplar. Grain yield under 2, 3 and 4 years old poplar reduced by the margin of 9.9, 26.9 and 49.8 per cent as compared to under one year old poplar. Chauhan *et al.* (2009) also recorded 11, 39, 50 and 54 per cent decrease in grain yield at one, two, three and four year old poplar plantation, respectively than the control. They also reported decrease in light intensity by 23, 35, 46 and 47 per cent (one to four year old poplar, respectively) than the open condition, indicating that light becomes a limiting factor for reduction in crop yield. Similarly, trend followed in straw yield, decreased

Table 1. Wheat yield and yield attributes as affected by density and age of poplar

Treatment	Tiller m^{-1} row length	Ear length (cm)	100-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Poplar density acre^{-1}						
225	95.75	9.13	4.31	3.92	5.91	39.7
250	91.26	8.83	4.09	3.63	5.73	38.5
300	83.13	8.10	3.79	3.12	5.34	36.3
CD (0.05)	6.37	0.60	0.21	0.28	0.33	1.3
Age of poplar						
1 yr	100.86	9.76	4.71	4.54	6.85	39.8
2 yr	96.67	9.17	4.41	4.09	6.34	39.2
3 yr	88.17	8.41	4.03	3.32	5.42	37.9
4 yr	74.47	7.40	3.10	2.28	4.03	35.8
CD (0.05)	7.35	0.69	0.24	0.32	0.38	1.5

Table 2. Diameter growth of poplar at different densities

Poplar density	Diameter at stump height (cm)				Diameter at breast height (cm)			
acre^{-1}	1 yr	2 yr	3 yr	4 yr	1 yr	2 yr	3 yr	4 yr
225	8.1	14.8	20.3	24.0	5.9	10.6	16.0	20.8
250	7.7	14.5	18.6	21.3	5.4	10.2	15.4	17.6
300	7.3	13.3	16.6	18.7	4.6	9.5	12.9	14.6

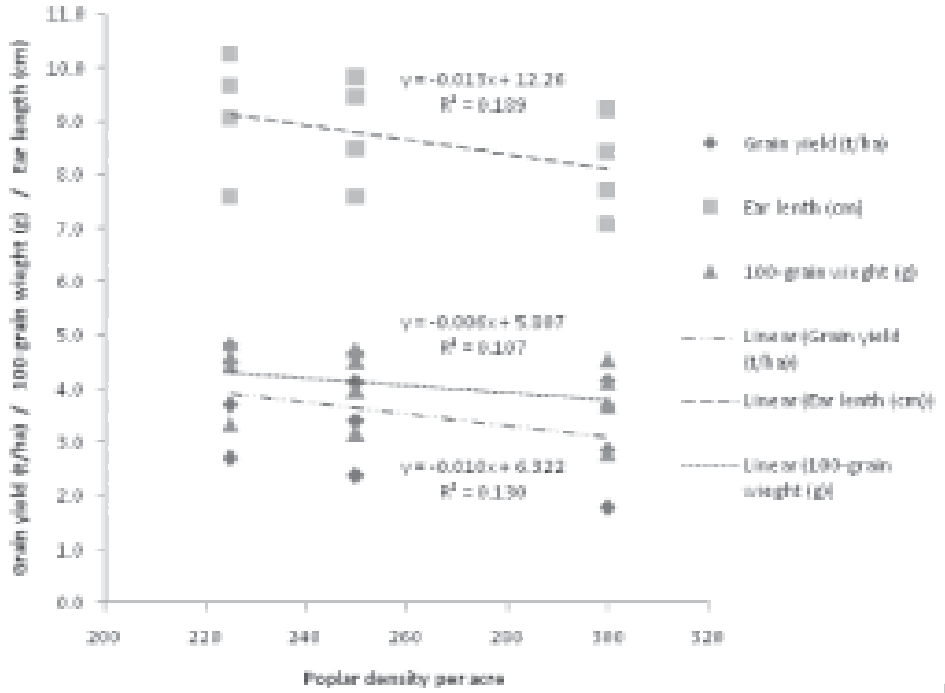

Fig. 1. Relationship between poplar plantation densities and; yield and yield attributes of wheat

significantly with the age of poplar plantation. Significant reduction in yield may be due to lower production of photosynthates under low light conditions.

Poplar growth: Data presented in Table 2, revealed that poplar growth was not much affect by its densities up to two years, while during 3rd and 4th years poplar growth in terms of diameter at stump height (DSH) and diameter at breast height (DBH) was more in poplar density 225 plants acre^{-1} as compared to higher poplar plant densities and decreased with each increase in poplar plantation density. This indicates that the competition among threes induce during third year onwards, thus suitable measures are essentially required including fertilization, pruning, etc. Khan and Chaudhry (2007) also recorded positive relationship of tree growth with increasing tree spacng. Durai *et al.* (2009), however, recorded reduced diameter increment after fourth year at a low density of 400 trees ha^{-1}, therefore, with increase in density, the competition advanced to third year.

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Utilization of Salt Tolerant Species for Rehabilitation of Coastal Saline Soil in Petchaburi Province Thailand

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***Abstract*:** The growth of various halophytes in coastal saline soils was compared and the effect of halophytes on changes in chemical properties of saline soils and rehabilitation of coastal saline soils was investigated at the Sirindhorn International Environmental Park, Cha-am district, Petchaburi province between April 2010 and September 2011. The experimental design was a randomized complete block design with 4 replications. The halophyte species were: i) Dixie grass (*Sporobolus virginicus* coarse type), ii) Smyrna grass (*Sporobolus virginicus* smooth type), iii) Seabrook grass (*Distichlis spicata*), iv) Georgia grass (*Spartina patens*), and 5) natural grasses. It was found that Dixie grass showed the highest survival rate, followed by Smyrna grass, Georgia grass and Seabrook grass. Seabrook grass had the highest fresh and dry weights of 19,796.25 and 12,178.75 kg ha^{-1}, respectively, followed by Georgia grass, Dixie grass and Smyrna grass. Seabrook grass accumulated larger amounts of sodium (Na) than Georgia grass, Dixie grass and Smyrna grass. The study of the effect of halophytes on soil chemical changes found that in general, soil organic matter, as well as phosphorus and potassium levels, increased, while soil electrical conductivity decreased.

***Key Words*:** Coastal saline soil, Dixie grass, Smyrna grass, Seabrook grass, Georgia grass

In Thailand, coastal saline soils cover an area of 0.425 million ha, most of which is not suitable for agriculture (Office of Soil Survey and Land Use Planning, 2006). One way to rehabilitate saline soils is to utilize salt-tolerant plant species. In areas of high salinity, which are unsuitable for economic crops, many other plants can still be grown. Yuvaniyama and Arunin (1996a) found that Dixie grass (*Sporobolus virginicus* coarse type), Smyrna grass (*Sporobolus virginicus* smooth type), *Spartina patens*, *Distichlis spicata*, Kallar (*Leptochloa fusca*), and *Atriplex spp.* are well adapted to the highly saline soils of northeastern Thailand. On the other hand, Im-Erb *et al*. (1994) reported that *Spartina patens* had a higher survival rate than *Panicum repens*, Dixie grass, and Smyrna grass in coastal saline soils. The objectives of our research were to compare the growth of different halophytes in saline soils in coastal areas and to investigate the effect of halophytes on changes in the chemical properties of saline soils and their suitability for the rehabilitation of coastal saline soils.

MATERIALS AND METHODS

The research was carried out using a randomized completed block design with four replications. The tested halophytes that consisted of exotic halophytes were imported from the United States of America i.e., Dixie grass (*Sporobolus virginicus*, coarse type); Smyrna grass (*Sporobolus virginicus*, smooth type); Seabrook grass (*Distichlis spicata*); Georgia grass (*Spartina patens*) and Naturally-grown grasses (non-halophyte block).

Each experimental block measured 3x3 m. Farmyard manure at the rate of 12.5 t ha^{-1} was applied at soil preparation. On August 20th 2010, the 4 halophyte species were planted at plant spacing of 30x30 cm. Weed and pest controls were also employed. Soil samples were taken at a depth of 0-30 cm to determine the soil pH according to Peech (1965), soil electrical conductivity (EC_e) according to Rhoades (1982), soil organic matter according to Walkley and Black (1934), available P according to Bray and Kurtz (1945), available K and soluble Na according to Rhoades (1982).

Data on survival rates and biomass were collected thrice (December 2010, June 2011, and September 2011). The concentration of total N was determined according to AOAC (1990), total P according to Barton (1948), total K and total Na according to Jackson (1958). Data were suitably analyzed.

RESULTS AND DISCUSSION

Among the four halophyte species planted on August 20th, 2010, Dixie grass showed the highest survival rate, though it was only slightly higher than Smyrna grass and Georgia grass, while Seabrook grass had the lowest survival rate (Table 1). This result differed from that of Im-Erb *et al*. (1994) who reported that Georgia grass had a higher survival rate than Dixie grass and Smyrna grass. Furthermore, Yuvaniyama and Arunin (1992) reported that Dixie grass and

Table 1. Survival rate in 2010, fresh and dry weight of salt tolerant species on coastal saline soil

Salt tolerant species	Survival (%)			Weight (kg ha^{-1})	
	8 September	5 November	28 December	Fresh weight	Dry weight
Dixie grass	100.00	99.31	99.31	6,855.63	2,972.25
Smyrna grass	99.31	97.22	97.22	4,916.69	2,148.31
Seabrook grass	90.97	83.33	83.33	19,796.25	12,178.75
Georgia grass	94.44	94.44	93.05	8,827.81	3,929.06
LSD	9.53	8.80	9.06	6,586.00	4,323.20
C.V. (%)	6.43	6.10	6.31	42.33	52.87

Smyrna grass can show survival rates of up to 100% at a salinity of 40 ppt NaCl. While Gallagher (1979) reported that *Sporobolus virginicus* is a highly salt-tolerant plant that can survive in media with salinity of 30%. These four species could survive because of their superb ability to excrete excess salt through their leaves.

Data on biomass were collected three times in December 2010, June 2011, and September 2011. Throughout the research period, Seabrook grass produced the highest fresh and dry weights of 19,796.25 and 12,178.75 kg ha^{-1}, respectively, which were significantly higher than for Georgia grass, Dixie grass and Smyrna grass (Table 1). However, the difference in fresh and dry weight also depends on the phenotype of the species.

The results suggested that the N, P, K, and Na concentrations varied with species, while the accumulation or uptake of N, P, K, and Na varied with the biomass of the specific species. N, P. K and Na accumulation of seabrook grass at both six and fourteen months were higher than in other grasses (Table 2).

Changes in Soil Chemical Properties

The average initial pH of the experimental plots was 7.15. However, all experimental plots showed an increases in pH by the end of the experiment, especially the Dixie grass plot, which had a pH value increase from 7.40 to 7.92 (Table 3). The EC_e values of all experimental plots were initially between 6.85 and 12.46 dS m^{-1}, which could be classified as moderately to severely saline. After the experiment was completed, all plots showed a decreases in EC_e, especially the plot with Seabrook grass whose EC_e decreased from 12.46 to 6.02 dS m^{-1}. The characteristics of specific species may affect the EC_e value. Seabrook grass has a creeper form that helps preserve soil moisture and reduce the accumulation of salt on the soil surface. These characteristics of Seabrook grass may affect its EC_e so that it decreased more than in the other species, which is consistent with the observations of Yuvaniyama and Arunin (1996b). In contrast, Sakai *et al.* (2012) reported that the levels of Na, Cl and EC_e in all test plots decreased after the growth of halophytes.

The organic matter of the soil and available P before the experiment was low; however, it had increased when measured at the end of the experiment, especially in the Seabrook grass plot where organic matter increased from 0.52 to 1.32% and P from 40.25 to 225.75Mg ha^{-1}. There was a general decrease in the amount of available K after the experiment, with an exception of the non-halophyte control plot with natural-grown grasses where the available K increased slightly. The soil in the Dixie grass, Smyrna grass, and Seabrook grass plots showed decrease in soluble sodium. This may have been a result of the species growth characteristics that helped to cover the soil surface and their mechanism to absorb salt from the soil and excrete excess salt through the stomatal leaves, thus reducing soluble sodium in the soil. This observation is consistent with

Table 2. Nutrient content (%) and nutrient uptake (kg ha^{-1}) of salt tolerant species at 6 and 14 months

Salt tolerant species	Age (month)	N		P		K		Na	
		Content	Uptake	Content	Uptake	Content	Uptake	Content	Uptake
Dixie grass	6	0.95	6.69	0.24	1.69	0.53	4.75	0.67	4.69
	14	0.97	13.44	0.16	2.19	0.68	9.44	0.65	9.00
Smyrna grass	6	1.12	5.06	0.39	1.75	0.80	2.75	0.80	3.63
	14	0.93	11.63	0.24	3.00	0.60	7.50	0.60	7.50
Seabrook grass	6	1.02	38.44	0.18	6.81	1.90	24.50	0.98	36.94
	14	0.97	57.81	0.18	10.75	0.65	38.75	0.62	36.94
Georgia grass	6	0.81	11.69	0.30	4.31	0.73	8.38	0.68	9.81
	14	1.00	7.63	0.15	1.13	0.58	4.44	0.68	5.19

Dixie grass Smyrna grass Seabrook grass

Georgia grass Natural grass

Table 3. Effect of salt tolerant species on change of soil properties

Salt tolerant species	pH		EC_e (dS m^{-1})		Organic matter (%)		Available P (mg kg^{-1})		Available K (mg kg^{-1})		Soluble Na^+ (m mol l^{-1})	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Dixie grass	7.15	7.92	6.85	2.75	0.46	0.85	11.25	33.65	240.00	188.25	60.05	28.74
Smyrna grass	7.30	7.85	8.95	3.31	0.48	0.98	16.75	86.55	215.00	200.00	81.00	38.24
Seabrook grass	7.13	7.52	12.46	6.02	0.52	1.32	40.25	225.75	228.75	170.00	109.82	63.45
Georgia grass	7.10	7.88	5.58	5.12	0.45	0.88	25.50	125.00	198.75	177.50	49.57	61.62
Natural Grass	7.08	7.78	7.35	5.70	0.60	0.95	28.25	135.25	208.75	212.5	64.85	68.17

Yuvaniyama and Arunin (1996b). On the other hand, the amount of soluble sodium in the Georgia grass and the non-halophyte blocks increased.

CONCLUSIONS

Dixie grass showed the highest survival rate while Seabrook grass had the highest growth, fresh and dry weights, and the best nutrient accumulation especially of nitrogen and sodium. Growing Seabrook grass resulted in a greater reduction in electrical conductivity and sodium in the soil than from planting the other grasses or allowing grasses to grow naturally. Seabrook grass also seemed to improve the soil fertility more than the other grasses.

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Litterfall, Carbon and Nutrient Returns in Stands of *Ceiba pentandra* (L.) Gaertn. Subhumid Tropics of Eastern India

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Abstract: The study was conducted in a nine-year old *Ceiba pentandra* (L) Gaertn. stands planted in a three tree spacing 4 x 4 m, 4 x 6 m and 4 x 8 m and two pruning regimes. Litterfall samples were collected from the field of *C. pentandra* for 12 months. The litterfall occurred throughout the year showing significant differences between tree spacing, pruning regimes and months. Total litterfall includes tree components (leaf litter + wood litter + flower litter + pod litter) ranged from 0.451 to 1.153 Mg ha^{-1} throughout the year. Total litterfall followed unimodal pattern with highest peak in April and lowest in August. In different tree spacings, total monthly litterfall, leaf litter contributed from 59 to 60 %, wood litter from 30 to 31.6 %, flower litter from 2.4 to 3.0 % and pod litter from 6.2 to 6.8 %. Litterfall was significantly higher in 4 x 4 m and lower in 4 x 8 m tree spacing. The study showed that litterfall was strongly and positively correlated with temperature and negatively correlated with relative humidity. The *C. pentandra* stands with high density returned highest amount of C and nutrients to soil.

Key Words: Litterfall, pruning, carbon, nutrient returns, *Ceiba pentantra*

India is one among the important tropical countries, which have renewed its interest as part of global and national policies to rehabilitate 175 m ha of the degraded lands. Over exploitation, shifting cultivation, uncontrolled wind and water erosion, soil salinity, alkalinity and poor land management in the last few decades virtually transformed 100 m ha into wasteland (Ravindranath and Hall, 1994). This large tract of degraded land mass of India has vast potential and could become crucial in national and global efforts to enhance carbon sequestration. National agriculture policy (2000) also envisaged restoring degraded lands by tree farming or through agroforestry practices. Both agroforestry and tree plantations have strong potential for sequestering carbon as they could sequester 0.8 to 2.2 pg of carbon per year globally over a period of 50 years time frame (Dixon *et al.,* 1994). Carbon management has tremendous potential to increase productivity of degraded lands since it improves fertility/ nutrient use efficiency and also contribute positively to soil quality by improving porosity, available water holding capacity and cation exchange capacity (CEC), improve pH, help in increasing yields and economical returns per unit of land (Delgado and Follett, 2002). Land management practices *viz.* agroforestry and monoculture tree plantations have different impacts on development of soil organic matter and nutrient pools. Plants get their nutrients from the soil in which they grow. As the plants develop, they shed their leaves and branches as litter which decays to enhance the nutrients of the soil that are again used up by plants a process known as nutrient cycling (Wood *et al.,* 2006). The most important concern of litterfall studies is the quantification of this process as a principal way in nutrient cycling, and the analysis of the efficiency of this cycle (Proctor, 1983). The data on litterfall is useful for predicting the productivity of an ecosystem. Litter production depends on tree species, environmental conditions and management practices followed in plantations. Different species have distinct growth and phenological stages and thus show variation in their litterfall pattern, which is correlated to weather conditions. The amount of litterfall could be modified through pruning management quantity as well as quality of litter could be affected by land management practices. There have been efforts to find the relationship between climatic variables and litter production at regional levels. Williams and Tolome (1996) reported that some tropical tree species showed a positive correlation of litterfall with maximum temperature. Williams *et al.* (1997) observed that leaf fall coincide with the attainment of the seasonal minimal level in leaf water potential. There is a need for a narrower, location-specific investigation of the interaction of climatic variables and litter production if the processes involved are to be well understood.

Choice of tree species plays a key role and influences both trajectories of growth rate, biomass production, carbon sequestration and nutrient cycling in agroforestry systems. *Ceiba pentandra* (L), commonly known as silk cotton tree is a fast growing multipurpose tree and proved as one among the promising species for agroforestry practices (Rajendran *et al.,* 2002). Because of the straight bole, acute branching and deciduous nature and potential to produce high quality floss and seeds at early age made the species as an ideal choice of farmers to practice in agroforestry. Gawali (2003)

evaluated that the total biomass production in nine year old *Ceiba pentandra* stands contributed highest in stem 45.3 to 47.7 % fallowed by root 22.8 to 22.9 %, branch 16.75 to 17.84 %, pod 6.36 to 9.11 % and leaf 5.82 to 5.92 % tree component.

This study aimed to quantify the litterfall production in nine-year old *Ceiba pentandra* stands; find out correlation between climatic variable, litterfall and quantify the carbon and NPK nutrient elements returns to soil.

MATERIALS AND METHODS

The study site, agriculture field of Department of forestry, IGAU, Raipur, Chattisgarh state is situated in eastern India. It lies at 21.76 ^{0}N latitude and 81.36 ^{0}E longitude having an altitude of 295 m above mean sea level. The climate is sub-humid tropical with an average rainfall of 1250 mm. Most of the rainfall (90%) is received during monsoon season from second week of June to third week of September. Average number of rainy days from 60 to 79. Mean monthly maximum temperature in study site ranges from 30.9 ^{0}C in December to 43.3 ^{0}C in May, while the minimum temperature varies from 11.9 ^{0}C in December to 28.3 ^{0}C in May. Maximum temperature occasionally goes beyond 45 ^{0}C for few days in May and minimum even falls below 10 ^{0}C in December. Relative humidity is generally highest in July and August, while it is lowest during April and May. The mean relative humidity varies from 82 % in Augest to 32 % in May. The measurement of different climatic variables were carried out in the open at the central weather station of Agrometeorology Department, I.G.A.U. Raipur, India.

Experimental design and sample collection: The litterfall study was conducted in a split-split-plot design with four replicates (Gomez and Gomez, 1984). Litter was collected at monthly intervals from September to August by randomly placing litter traps 0.5 x 0.5 m beneath tree in different treatments. Twenty-four (3 tree spacing x 2 pruning x 4 replicates) traps were placed for collection of litter production. The litter collected from the traps in various treatments were sorted and separated into different components *viz.,* leaf, wood, flower and pods. These samples placed in a paper bag, and dried in an electric oven at 70 ^{0}C temperature until they reach constant weight. The different components of litter were summed to obtain total litterfall. The litterfall recorded in traps was extrapolated to hectare basis and later converted in to Mg ha^{-1}. The oven dry litter collected for twelve months was summed to derive annual litter production.

Laboratory analyses of samples: The different components (12 months) of litter were bulked and composite sample was prepared. Four sub samples of litter were randomly drawn from composite sample and oven dried at 70^0 C temperatures for 72 hrs. The oven dried samples were ground in a Wiley mill and pass through 2 mm sieve before chemical analysis. The litter was analysed for total carbon on solid sample module using automatic carbon analyzer (SSM-5000A). Total nitrogen was analysed in concentrated H_2SO_4 -using a catalyst mixture (Potassium sulphate and Copper Sulphate in ratio 9:1) with KEL PLUS digestion unit. The total nitrogen was estimated following micro-kjeldhal method. Phosphorus and Potassium were estimated after digesting sample in diacid mixture (HNO_3 and $HClO_4$ in 9:4 ratio). Phosphorus was determined by Vanado-molybdo phosphoric yellow colour procedure and potassium by Flame Photometer method (Jackson, 1967). Carbon and nutrient status Kg ha^{-1} were obtained from the product of litter biomass and average C and nutrient concentration.

Data collected was analyzed in laboratory and the result was subjected to descriptive and inferential statistical analyses using the MSTATC 1.41 Version.

RESULTS AND DISCUSSION

Litterfall pattern in *Cieba:* Tree spacing, pruning and monthly litter collection had significantly influenced leaf litter production In different tree spacings, monthly leaf litter production ranged from 0.436 to 0.449 Mg ha^{-1}. Leaf litter was significantly higher in 4 x 4 m and lower in 4 x 8 m tree spacing. Significantly higher leaf litter was produced in unpruned compared to pruned trees (Table 1). Wide variation was observed in leaf litter production in different months. Peak leaf litter was observed in January and lowest in August. Litterfall showed distinct monthly variations. Through out the year leaf litter ranged from 0.267 Mg ha^{-1} to 0.614 Mg ha^{-1}. The cumulative leaf fall indicated unimodal pattern with a peak in April (Fig. 1). Jamaludheen and Kumar (1999) also observed unimodal distribution of litterfall in *Acacia*, *Ailanthus*, *Pterocarpus* and *Casuarina* plantations. Higher litter fall values were observed in dry compared to wet season. The peak of litterfall in the tropics coincides with the dry season (Jhon, 1973).

Wood litter varied significantly due to differences in tree spacing, pruning regimes and months. A maximum wood litter amounting 0.241 Mg ha^{-1} month^{-1} was produced in 4 x 4 m followed by 0.221 Mg ha^{-1} month^{-1} in 4 x 6 m and 0.217 Mg ha^{-1} month^{-1} in 4 x 8 m tree spacing. The maximum wood litter of 0.227 Mg ha^{-1} month^{-1} was produced under unpruned compared to pruned treatment 0.225 Mg ha^{-1}. The maximum wood litter was produced in March and lowest in September. Wood litter ranged from 0.124 to 0.335 Mg ha^{-1}. Interactions

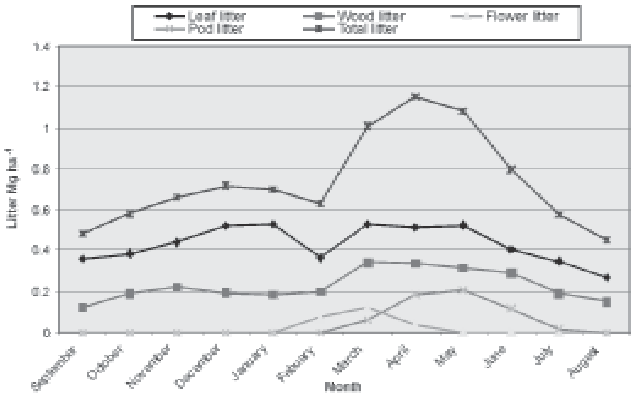

Fig. 1. Montly litterfall pattern in *Ceiba pentandra*

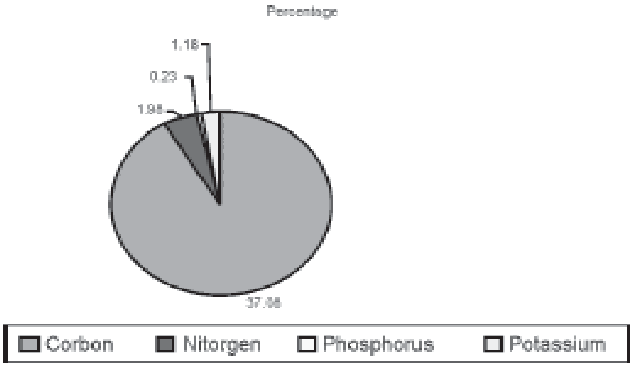

Fig. 2. Carbon and nutrient returned to soil through litterfall

between tree spacing x pruning, pruning x month, spacing x month and spacing x pruning x month were statistically significant for wood litter (Table 1). This may be related to the phenology of the *Ceiba* tree associated with the edaphic factors, where due to high water stress conditions in summer (high temperature and low humidity), trees will rapidly defoliate. Leaf fall of the most dominant speices was asynchronous. Besides, the higher pod and twig litter added to other litter components, thus cumulatively more litterfall was observed during this period. The rapid loss of foliage is mechanism of combating drought during summer by the species. This phenomenon was also observed by Nwoboshi (1981) where rapid shedding of litter by teak in south western Nigeria in dry season was occurred to withstand drought. Litterfall is not only affected by water scarcity, more likely it is the result of the interaction of different factors i.e, resource availability, heavy winds, soil characteristics, mineral deficiency and the rain mechanical effects (Jhon, 1973).

Litter from floral component also significantly affected by both tree spacing and pruning treatments. Monthly variation was also significant for this component. It ranged from 0.023 Mg ha^{-1} to 0.018 Mg ha^{-1} in different tree spacing. It was significantly higher in 4 x 4 m tree spacing, which gradually reduced with an increase in tree spacing. The maximum litter from floral components was found in unpruned than pruned stands. It was highest in March (0.122 Mg ha^{-1}). Pod litter ranged from 0.052 to 0.045 Mg ha^{-1} in different tree spacings, which was highest in 4 x 4 m and lowest in 4 x 8 m tree spacing. The unpruned stands produced significantly higher pod litter compared to pruned trees. Pod litter was produced from March to July. The highest amount of pod litter was produced in May. Total litterfall (leaf litter + wood litter + flower litter + pod litter) significantly ranged between 0.721 to 0.761 Mg ha^{-1} month^{-1}. It was highest in 4 x 4 m, while lowest in 4 x 8 m 0.721 Mg ha^{-1} tree spacing. The total litter was statistically at par in 4x6 m and 4 x 8 m tree spacings. Significantly highest litter of 0.766 Mg ha^{-1} was produced in unpruned than pruned condition. Total litterfall followed unimodal pattern with highest peak in April and lowest in August. In different tree spacings, for total monthly litterfall, leaf litter contributed from 59 to 60 %, wood litter from 30 to 31.6 %, flower litter from 2.4 to 3.0 % and pod litter from 6.2 to 6.8 % (Table 1).

Correlation between climatic variable and monthly litterfall: The litterfall is strongly correlated to the climatic variables. It was established that the maximum temperature and minimum humidity influenced litterfall. This study showed that the change in litterfall on seasonal basis was not gradual

Table 1. Monthly litterfall pattern in different components of *Ceiba pentandra* (Mg ha^{-1})

Treatment	Leaf litter	Wood litter	Flower litter	Pod litter	Total litter
Tree spacing (S)					
4 x 4 m	0.449	0.241	0.023	0.052	0.761
4 x 6 m	0.438	0.221	0.017	0.048	0.725
4 x 8 m	0.436	0.217	0.018	0.045	0.721
CD (0.05)	0.414	0.013	0.007	0.011	0.242
Pruning (P)					
Unpruned	0.456	0.227	0.021	0.056	0.766
Pruned	0.425	0.225	0.017	0.041	0.705
CD (0.05)	0.0147	0.013	0.006	0.011	0.036
S x P	0.0202	0.0182	NS	0.015	0.0504

Table 2. Correlation between climatic variable and monthly litterfall

	Max. temp. (^{0}C)	Rainfall (mm)	RH %	Wind velocity (kms hr^{-1})	Sun shine hour
Rainfall (mm)	-0.1479				
RH %	-0.9384	0.2772			
Wind velocity (kms hr^{-1})	0.5186	0.6677	-0.3996		
Sun shine hour	0.0567	-0.8285	-0.1538	0.6636	
Litter	0.7520	-0.527	-0.8332	0.02982	0.5144

but an erratic process with the dominating climatic variables asserting their role more in the dry season than in the rainy season. It was not the shift from one season to the other that made the difference in quantity of litter produced, but the interactions of relevant climatic variables within seasons, which also had differing effects depending on the phenological characteristics of species. Lugo *et al.* (1978) reported positive correlation between litterfall and temperature and rainfall. Agbim (1987) found a significant negative correlation between *Chromolaena odorata* litterfall and atmospheric relative humidity in a study conducted in the dry season in Southern-Eastern Nigeria. Regression analysis showed that only 58.88 % variation in litterfall was explained by temperature, whereas, relative humidity explained 74.48 % variation in total litterfall. Earlier studies also showed that only a fraction of total litterfall will be well explained during particular season. Vogt *et al.* (1986) reported that climatic variables (latitude, temperature and precipitation) could explain 50 % of the variation in above ground litterfall for broadleaved forest of the world, but they were poorly related to data analyzed for needle leaved forests. Vitousek (1984) also reported that the interaction of temperature and precipitation was significant for litter production in the tropics.

Annual litter production: Perusal of data on results indicated that tree spacing had significantly influenced component wise and total annual litterfall (Table 3). In different tree spacings, total annual litter varied from 8.65 to 9.09 Mg ha^{-1} yr^{-1} under different tree spacing.

The production of litter depends primarily on the site productivity but environment and other factor such as temperature, water and nutrient availalblity limit production. Litterfall data for the *Ceiba* species in similar age groups in their natural forest environment and plantation are not available for comparison with present study. Litterfall production is within the range and comparable with litterfall reported by Rajgopal *et al*. (2001). Jamaludheen and Kumar (1999) reported that annual litter production in 8-9 year old stands was highest (12.69 Mg ha^{-1} yr^{-1}) in *Acacia* followed by *Paraserinthes* (9.17 Mg ha^{-1} yr^{-1}) and lowest in *Peterocarpus* (3.42 Mg ha^{-1} yr^{-1}). The present study also showed significant effect of tree density and pruning on annual litter production. It was higher under 4 x 4 m tree spacing and gradually decreased with increase in tree spacing.

The greater number of trees and prolonged shade conditions contributed for higher litter production in 4 x 4 m spacing. Pruning of trees had reduced total litter production by 7.8 %. It is proven fact that pruned trees contain lower foliage biomass and thus they contribute lower litterfall. George and Kumar (1998) and Jamaludheen and Kumar (1999) showed lower annual litter production under pruned stands of *Acacia auriculiformis*, *Paraserianthes falcataria*, *Pterocarpus marsupium* and *Artocarpus herterophyllus* in silivipastoral and wood lots system. Age, stand density and/or stage of stand development are also major determinants of litterfall. Litterfall increases with stand age and/or unite canopy closer (George and Kumar, 1998). Similar trend in litter contribution by different component in other species

Table 3. Annual litter production (Mg ha^{-1})

Treatment	Leaf litter	Wood litter	Flower litter	Pod litter	Total litter
Tree spacing (S)					
4 x 4 m	5.42	2.98	0.76	0.62	9.09
4 x 6 m	5.25	2.65	0.18	0.57	8.69
4 x 8 m	5.23	2.59	0.25	0.54	8.65
CD at 5%	NS	NS	0.04	0.003	NS
Pruning (P)					
Unpruned	5.47	2.72	0.20	0.66	9.18
Pruned	5.10	2.61	0.19	0.46	8.46
CD at 5%	NS	NS	NS	NS	NS

Table 4. Annual carbon and nutrient addition (kg $ha^{-1}yr^{-1}$) to soil through litterfall

Treatment	Carbon	Nitrogen	Phosphorus	Potassium
Tree spacing (S)				
4 x 4 m	385.1	239.1	23.7	142.81
4 x 6 m	372.0	233.9	22.3	128.8
4 x 8 m	345.4	228.5	21.7	119.45
CD (0.05)	0.032	NS	NS	0.145
Pruning (P)				
Unpruned	367.4	242.0	23.7	134.25
Pruned	359.0	282.0	20.8	127.29
CD (0.05)	0.04	NS	NS	0.04

Table 5: Comparative account of nutrient via litterfall in plantation and agroforestry system in India

System	Tree species	Age (yr)	Nutrient (kg ha^{-1} yr^{-1})			Source
			N	P	K	
Woodlots	*Acacia auriculiformis*	9	203.0	15.7	12.6	Jamaludheen and Kumar (1997)
Plantation	*Populus deltoides*	4	91-148	8-15	70-99	Lodhiyal and Lodhiyal (1997)
Plantation	*Dalbergia sissoo*	7	74.8-108.4	5.6-8.4	8.7-46.9	Lodhiyal *et al.* (2002)
Plantation	*Ceiba pentandra*	9	228.5-239.1	21.7	119.4-142.8	Present study

was observed by Rajgopal *et al*. (2001), Jamaludheen and Kumar (1999).

Concentration of Carbon and Nutrients in Littermass

The study showed that nutrient concentrations varied as 1.98% N, 0.23% P, 1.18% K and 37.08% C. Concentration of nutrients in litter in *Ceiba* was comparable to litter nutrient concentrations in other species (Rajagopal *et al*., 2001; Jamaludheen and Kumar, 1999; Salako and Tian, 2002).

Carbon addition in soil through annual litter fall in *C. pentandra* stands ranged from 345.4 to 385.16 kg ha^{-1} yr^{-1}. Annual C addition to soil through litter was highest in 4 x 4 m and lowest in 4 x 8 m tree spacing (Table 4). The higher C return to soil in 4 x 4 m was due to comparatively higher amount of litterfall in these stands. Similarly, the unpruned stands had produced greater amount of litter compared to pruned trees resulted in higher C content in former and lower C in later stands. George and Kumar (1998) also emphasised the higher age and high density, where the canopy closure became full will produce highest amount litterfall, which return highest amount of C and nutrients to soil**.** Quantity of nutrients returned to soil via annual litterfall ranged from 228.55 to 239.10 kg N ha^{-1} yr^{-1}, 21.79 to 23.74 kg P ha^{-1} yr^{-1} and 119.45 to 142.81 kg K ha^{-1} yr^{-1} (Table 4). Significantly higher amount of all these nutrients returned in soils under 4 x 4 m tree spacing compared to other tree spacings. A similar trend in nutrient return from poplar plantations was observed by Lodhiyal *et al.* (1995) and multipurpose trees by George and Kumar (1998).

The comparative accounts of nutrient via litterfall in plantations and agroforestry system of multipurpose tree in India are depicted in Table 5. As compared to the tree species, *Ceiba* showed the higher N ,P and K nutrient release to soil through litter fall.

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Estimation of Genetic Parameters for Growth and Wood Characteristics in Commercially Important Clones of Willow

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***Abstract*:** Introduction work on willows in India is directed towards the development and screening of wide range of species and clones of diverse genetic origin. Twenty-five clones from five countries were evaluated for various growth and wood characteristics. Maximum values for plant height (290.35cm) and collar diameter (17.38mm) were recorded for clone 799 (U.K.). The highest value for shoot fresh weight (243.25gm), shoot dry weight (138.94gm), root fresh weight (184.05gm) and root dry weight (102.87gm) were recorded for Kashmir willow (U.K.). Clone SE-75-001 (Italy) and Kashmir willow (India) showed the highest values in wood density (0.58) and fibre length (0.81), respectively. Heritability (broad-sense) was recorded maximum (99.78%) for leaf area followed by wood density (56.10%), and fibre length (55.29) depicting stronger genetic control of these characteristics. Maximum genetic gain (61.58%) was recorded for leaf area that was closely followed by number of branches (60.39%). Growth characteristics were found to have positive and significant correlation with most of the characters, only wood density was recorded to have negative correlation with other traits. Total dry weight was recorded maximum loading value and can be recommended for selection on the basis of principle component analysis.

Key Words: Willows, heritability, genetic gain, correlation, wood density, fibre length, PCA

The willows (genus *Salix)* consists of about 350-500 species world wide occurring mostly in the arctic region and north temperate zone but some in the southern hemisphere covering tropical and subtropical area (Argus, 1997). In India few introduced species have been sporadically cultivated in the foot hills and inner valleys of Jammu & Kashmir, Himachal Pradesh, Uttarakhand and the northeastern regions of India for many years. Among them, the most popular clone is cricket bat willow, *S. alba* var. *coerulea* (Desch and Dinwoodie, 1996) which is a female cultivar of hybrid origin between *S. alba* and *S. fragilis* (Stott, 1984) and was introduced by the Britishers in Jammu and Kashmir state in the beginning of the 20th century.

The inherent benefits associated with willow have been recognized and recorded for millennia, with references to willow for medicinal uses and basket production by both the Egyptians and Romans. The ability of many species of willow to coppice vigorously and develop from unrooted cuttings was recognized and used by native Americans as part of their management and use of the species for medicinal purposes and as construction material for a wide array of items including sweat lodges, furniture, baskets, rope, whistles, arrows and nets (Masoodi *et al.,* 2008). In some regions, willow cuttings were actively used to stabilize stream banks that were prone to erosion (Gregory and Timothy, 2006). They are a source of cheapwood, indispensable for stabilization of soil on slopes river banks, nutrient filters, biomass energy plantations and phytoremediations (Christersson, 1986). In terms of productivity, 44m^3 ha^{-1} year^{-1} has been reported in 4 x 4 m spacing at 6 year rotation in Argentina. Similarly 10 m height at 2 years age was also obtained in outstanding willow hybrids (Arreghini and Cerrillo, 1996). 19m plant height and 106cm girth has been observed in *Salix alba* under agroforestry system in six year rotation and this can be compared with any clone of Poplar in India. Both tree and shrub willow can be grown on short-rotation coppicing system where animals can browse to supplement pasture feed supply. Several willows have aesthetic features associated with growth habit, foliage, catkins or shoot colour that makes them particularly suitable for ornamental purpose on farms, parks or large gardens.

Salix tree improvement projects are in progress around the world because willows are used in many different ways. Research mission include the study of willow taxonomy, morphology, physiology, cultivation practices, advanced breeding molecular fingerprinting and genome mapping (Kuzovkina *et al*., 2008). Efforts to improve biomass willows by breeding are currently hampered by the limited information available on genetic diversity, differences in flowering phenologies and on genetic relationships within and among species, clones, and hybrids in the gene pool. Differing flowering phenologies have been observed among willow species, which may have been evolved to restrict natural hybridization, and must be considered for controlled breeding (Choudhary *et al*., 2011).

Tree willows have direct bearing in order to diversify short rotation forestry under different agroforestry systems in India. The genetic base for willow improvement has been significantly broadened by assembling large collection of exotic species and their hybrids. The genetic variation at field level through multilocation testing is underway. Very significant clonal differences were observed in many qualities of wood, bark and foliage.

MATERIAL AND METHODS

The experiment was conducted in the Department of Tree Improvement and Genetic Resources, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The present study included total 25 clones of genus *Salix* from five different countries namely UK, Italy, New Zealand, Croatia and Turkey (Table 1). The 25 clones were selected based on their performance from initial screening experiment done on the basis of plant height and collar diameter at Departmental Naganji Nursery, Solan (HP). Twelve cuttings of each clone of standard size in complete randomized block design were planted at 40 cm X 30 cm. spacing in four replications. The uniform irrigation, weeding and other cultural practices were applied and observations on growth (plant height, collar diameter, number of branches, leaf area), biomass and wood characteristics (specific gravity and fibre length) were recorded in the month of December.

The data obtained for natural variation were subjected to statistical analysis using RBD design. The statistical analysis for each parameter was carried out on mean values and the analysis of variance (ANOVA) and covariance was worked out using standard procedure given by Panse and Sukhatme (1967) and Singh and Chaudhary (1985). Coefficient of variability was calculated as given by Burton and De-Vane (1953). The expected genetic advance at 5 per cent selection intensity was calculated by the formula suggested by Lush (1937), and genetic gain was worked out following the method suggested by Johnson *et al.* (1955).

RESULT AND DISCUSSION

The growth, biomass and wood characters viz., plant height, collar diameter, number of branches, leaf area, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, total green biomass, total dry biomass, wood density and fibre length depicted highly significant differences among all the clones (Table 2). Analysis of variance revealed highly significant differences among different genotypes of *Salix,* thereby indicating existence of variability for different characters undertaken for study. The results are in conformity with findings of Huse *et al.* (2008) on willow where significant variance in clones with respect to different growth characteristics were reported.

In consonance with the present study, Vihera-Aarnio (1988) had also noticed large variation for willow clones with respect to shoot length, collar diameter, above ground biomass (shoot biomass) and length of growing season. Similar findings were obtained on *Salix* and *Populus deltoides (*Tharakan *et al*., 2005) and on Salix (Tunctaner, 2002). Wood samples of various clones showed a wide variation in wood density (0.39-0.58gcm^{-3}). Significant differences existed among the clones for fibre length, ranged between 0.59-0.81mm. Clone SE-75-001(Italy) and Kashmir Willow (U.K.) exhibited maximum wood density (0.58 gm cm^{-3}) and fibre length (0.81 mm). The results are in conformity with the findings on *Salix* species (Deka *et al*., 1992; 1994 and Pan *et al*., 1998).

Estimate of genetic parameters: The observed variation in a character is partly composed of genetic (heritable) variation and partly of non-heritable. Heritability and genetic advance provide the information of total variation present in the population and simultaneously gives an indication of the influence of environment on the character under study. Broad sense heritability is a measure of the gain, one can expect from clonal selection.

The growth, biomass and wood characters showed wide range of values (Table 3), indicating the extent of variation existing in the clones. Coefficient of variation was found maximum in shoot fresh weight (36.59%) and minimum in leaf area (1.37%). GCV was recorded maximum (39.85) for number of branches, while minimum (6.54) was exhibited by fibre length. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the characters. High heritability (99.78) was recorded for leaf area, whereas number of branches, wood density and fibre length registered moderate heritability with wide range (10.02-61.58) of genetic gain. This shows scope for further improvement through clonal selection. Similar findings were observed during study on clonal variation, heritabilities, genetic gain, genotypic and phenotypic correlations and efficiency of indirect selections in clonal test of *Salix* clones (Vihera-Aarnio, 1988; Zsuffa *et al*., 1993) and *Populus deltoides* (Rawat *et al*., 2001).

Since the leaf area, wood density, root fresh weight, total green biomass, root dry weight and total dry biomass showed higher heritability percentage, the selection for these traits would be quite effective and expected improvement would be achieved through mass selection. High heritability indicates the effectiveness of selection based on good phenotypic performance but does not necessarily mean a high genetic gain for a particular trait. Heritability estimates

Table 1. Description of the willow clones selected for study

S. No.	Clones	Scientific name	Source country (procured from)
1.	PN-733	*Salix nigra*	New Zealand
2.	17-93-A	*S.alba*	New Zealand
3.	SE-63-016	*S.jessoensis*	Italy
4.	PN-722	*S.matsudana*	New Zealand
5.	212/03	*S.matsudana* X *S. caprea*	U.K.
6.	84/11	*S.alba*	Turkey
7.	MB-368	*S.alba*	Croatia
8.	PN-227	*S.matsudana*	New Zealand
9.	SI-64-017	*S.alba*	Italy
10.	NZ-1002	*S.matsudana X S.alba*	New Zealand
11.	795	*S.matsudana X S.alba*	U.K.
12.	SI-63-007	*S.alba*	Italy
13.	V-99	*Salix X rubens*	Croatia
14.	NZ-1179	*S.matsudana X S.alba*	U.K.
15.	PN-721	*S.matsudana X S.alba*	New Zealand.
16.	131/25	*S. alba X S. babylonica*	U.K.
17.	799	*S.matsudana X S.alba*	U.K.
18.	PN-731	*S.nigra*	New Zealand
19.	NZ-1040	*S.matsudana X S.alba*	New Zealand
20.	NZ-1140	*S.matsudana X S.alba*	U.K.
21.	SE-75-001	*S.matsudana*	Italy
22.	NZ-1130	*S.matsudanaa X S.alba*	New Zealand
23.	V-311	*S.matsudana*	Italy
24.	SE-69-002	*S.matsudana*	Italy
25.	Kashmir willow	*S.alba cv coerulea*	U.K.

in broad sense will be reliable if accompanied by high genetic gain. Heritability estimates along with expected gain is more useful and realistic than the heritability alone predicting the resultant effect for selecting the best genotype in poplars and willows (Singh *et al*., 2001; Lin and Zsuffa, 1993).

High estimates of genetic advance expressed in percentage of mean (genetic gain) was observed for root fresh weight, root dry weight, total green biomass, total dry biomass, number of branches and leaf area for all the genotypes. In present investigations, high estimates of heritability along with high genetic gain was observed in root fresh weight, root dry weight, total green biomass, total dry biomass and leaf area. This indicates the higher proportion of additive gene effects for expression of these traits. Hence individual clone selection for these traits would be attempted for the effective improvement of these characters.

Jha (2002) recommended that at age one year, selections should be based on height and at the age two selection is to be practiced based on volume index, however, the dry weight biomass which is the key character for the selection of productive genotypes in fast growing tree species for screening of genotypes in nursery was not studied. On the other hand, both wood density and fibre length exhibited moderate heritability coupled with low genetic gain which indicated that these characters are more under control of non-additive genes. Hence, to make effective improvement in these characters, one has to go for heterosis breeding followed by clonal propagation in order to capture additive and non-additive genetic variances (Li *et al*., 1993; Li and Wu, 1996)

Moderate heritability values for wood density (56.10) and fibre length (55.29) were obtained in the present study. The findings revealed strong genetic control for wood density and fibre length among *Salix* clones.

Principal component analysis: Principal component analysis is a multivariate statistical technique, which helps to reduce the data with large number of correlated variable into a substantially smaller set of new variables, through linear combination of variables that account most of the variation present in the original variables. Here in principal component analysis some information contained in original variables has to be sacrificed, but has an advantage that this lost information is kept to minimum. In the present study, three out of twelve components had given eigen value greater than

Table 2. Mean values of growth, biomass and wood characteristics of 25 clones of willow

Clones	Height (cm)	Collar diameter (mm)	Number of branches	Leaf area (cm^2)	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight(g)	Total greenbiomass (g)	Total dry biomass (g)	Wood density (g cc^{-1})	Fibre length (mm)
PN-733	202.63	17.17	19.87	20.38	218.75	131.25	131.00	69.90	349.75	201.15	0.42	0.70
17-93-A	200.30	13.01	10.75	22.59	171.00	104.20	94.00	52.15	265.00	156.35	0.51	0.63
SE-63-016	282.23	15.13	12.07	15.06	156.25	88.48	66.25	36.41	222.50	124.88	0.51	0.68
PN-722	248.80	14.62	21.46	15.57	128.00	72.87	88.25	43.28	216.25	116.15	0.48	0.70
212/03	262.95	14.93	28.95	16.57	135.25	93.45	98.83	60.18	234.08	153.63	0.49	0.61
84/11	150.03	8.66	4.57	19.72	93.75	60.52	69.75	41.09	163.50	101.60	0.54	0.67
MB-368	246.95	14.35	17.51	13.50	185.75	89.48	138.00	73.75	323.75	163.22	0.40	0.63
PN-227	237.48	12.50	16.25	18.57	184.75	100.34	146.00	70.65	330.75	170.99	0.43	0.70
SI-64-017	273.65	17.15	16.10	19.41	233.25	136.66	161.64	85.53	394.89	222.19	0.43	0.68
NZ-1002	252.13	13.87	21.47	8.07	144.75	83.00	105.65	59.18	250.40	142.18	0.50	0.71
795	210.68	10.65	6.49	18.83	158.75	97.33	116.40	66.21	275.15	163.54	0.47	0.76
SI-63-007	252.05	12.90	12.15	12.62	143.75	95.48	102.06	58.13	245.81	153.61	0.49	0.59
V-99	219.90	9.97	9.24	10.30	149.00	79.21	111.13	61.04	260.13	140.24	0.50	0.67
NZ-1179	265.75	14.95	23.48	11.30	170.00	93.82	133.55	78.78	303.55	172.60	0.48	0.73
PN-721	221.63	12.44	11.15	15.66	123.00	79.93	127.63	77.46	250.63	157.38	0.46	0.75
131/25	216.43	12.86	14.23	17.44	183.25	108.20	142.14	81.18	325.39	189.38	0.45	0.68
799	290.35	17.39	27.90	14.59	197.00	122.72	150.49	81.45	347.49	204.17	0.42	0.77
PN-731	203.13	15.89	11.91	20.88	139.00	86.53	108.83	62.10	247.83	148.63	0.42	0.79
NZ-1040	257.55	13.74	16.98	11.53	135.00	73.12	105.01	62.28	240.01	135.40	0.46	0.77
NZ-1140	224.03	13.41	19.28	17.46	215.50	119.28	163.19	95.23	378.69	214.50	0.42	0.77
SE-75-001	164.53	8.33	6.97	6.80	136.25	66.95	106.92	59.73	243.17	126.68	0.58	0.65
NZ-1130	212.80	11.08	19.04	8.07	178.75	86.97	136.08	78.60	314.83	165.56	0.56	0.75
V-311	237.23	13.36	12.65	11.17	144.25	71.68	113.59	60.15	257.84	131.83	0.41	0.68
SE-69-002	178.30	9.42	10.95	9.16	95.50	56.78	76.50	39.87	172.00	96.64	0.57	0.72
Kashmir willow	261.65	15.92	29.81	16.72	243.25	138.94	184.05	102.87	427.30	241.81	0.46	0.81
Mean	228.55	13.21	15.92	14.87	162.55	93.48	119.10	66.28	281.62	159.77	0.48	0.71
CD (1%)	79.82	4.92	10.93	0.38	111.28	56.75	79.16	42.86	185.02	95.75	0.08	0.08
C.V(%)	18.67	19.91	36.70	1.37	36.59	32.44	35.54	34.56	35.12	32.03	8.54	5.88

Table 3. Mean, Range, C.V. (%), GCV, PCV, heritability, genetic advance and genetic gain (%) of growth, biomass and wood characteristics

Characters	Mean	Range	C.V. (%)	Coefficient of variance			Heritability	Genetic advance (K=2.06)	Genetic gain (%)
				Genotypic	Phenotypic	Environmental			
Height (cm)	228.55	150.02- 290.35	18.67	13.42	23.00	18.66	34.07	36.87	16.13
Collar diameter (mm)	13.21	8.32-17.38	19.19	17.43	92.55	52.37	43.40	3.13	23.66
Number of branches	15.92	4.57-29.80	36.7	39.85	54.17	36.69	54.11	9.61	60.39
Shoot fresh weight (g)	162.55	93.75-243.25	36.59	15.51	39.74	36.59	15.23	20.26	12.46
Shoot dry weight (g)	93.48	56.78-138.94	32.44	18.05	37.13	32.44	23.64	16.9	18.08
Root fresh weight (g)	119.07	66.0- 184.0	35.54	17.65	39.7	35.55	19.78	19.25	16.17
Root dry weight (g)	66.28	36.40-102.90	34.56	18.52	39.21	34.56	22.31	11.94	18.02
Total green biomass (g)	281.62	163.50-427.29	35.12	15.61	38.43	35.11	19.75	44.03	15.64
Total dry biomass (g)	159.77	96.64-241.81	32.03	16.5	36.03	32.03	20.96	24.86	15.55
Wood density (g cc^{-1})	0.47	0.39-0.58	8.54	9.65	12.88	8.53	56.10	0.070	14.89
Fibre length (mm)	0.705	0.59-0.81	5.88	6.54	8.79	5.88	55.29	0.070	10.02
Leaf area (cm^2)	14.87	6.80-22.58	1.37	29.93	29.96	1.37	99.78	9.16	61.58

unity (Table 4). These three characters are retained in further analysis as they contributed 83.49 per cent of total variation. The decision was made according to the Kaiser (1958) suggested the dropping of those principal components of the correlation matrix with eigen roots less than one.

The first component explaining 59.55 per cent including ten characters namely root fresh weight, root dry weight, shoot fresh weight, total fresh weight, total dry weight, collar diameter, shoot dry weight, number of branches, fibre length and wood density. The second component accounted for 12.60 per cent of total variation, defined by height. 11.33 per cent of the third component was defined by leaf area. Trunctaner (2002) reported five principal components on the basis of 14 traits studied in willow clones. Cumulative variability of 56 per cent from three principal components were recorded while studying on *Populus deltoides* clones (Singh, 2006). Root fresh weight, root dry weight, shoot fresh weight, total fresh weight, total dry weight, collar diameter, shoot dry weight, number of branches, fibre length and wood density are the important morphometric traits, which indicate the growth and development of plant. These may be attributed to the growth characteristics to distinct genetic constitution of the clones and their performance in given set of climatic and edaphic conditions (Sharma *et al*., 2011).

The maximum weightage should be given to total dry

Table 4. Three principal components of growth, biomass and wood characteristics of 25 clones of willow

Characters	Principal components		
	I	II	III
Height (cm)	0.562	-0.688	0.284
Collar diameter (mm)	0.737	-0.595	-0.117
Number of branches	0.662	-0.428	0.417
Shoot fresh weight (g)	0.928	0.135	-0.062
Shoot dry weight (g)	0.921	0.030	-0.224
Root fresh weight(g)	0.901	0.334	0.164
Root dry weight (g)	0.870	0.366	0.208
Total green biomass (g)	0.953	0.230	0.037
Total dry biomass (g)	0.966	0.186	-0.043
Wood density (g cc^{-1})	-0.682	0.251	0.335
Fibre length (mm)	0.379	0.297	0.322
Leaf area (cm^2)	0.350	-0.010	-0.865
Eigen value	7.147	1.513	1.360
Per cent variability	59.55	12.60	11.331
Cumulative per cent variability	59.55	72.16	83.49

weight (having maximum variable loading) for the selection along with other characters in first component, whereas, maximum variable loading for the shoot fresh weight and recommended the same for the selection along with other components.

CONCLUSION

Clonal forestry is meaningful only if clones used in planting are reliable. It depends on the way selection criteria used and the effectiveness of nursery testing followed by field evaluation. The situation of willow planting world over with regard to the registered clones is very bleak. A single clone *S. alba* var *coerulea* has been planted largely in U. K. for the production of cricket bats. Almost similar situation is well realized in India too with regard to genetic base of willow clones. Multiclonal plantations are desirable in willows. The concept of multiclonal varieties in individual tree mixture is very much desirable particularly in various agroforestry systems prevailing in northern part of the country. Selection of clones at juvenile age on plant height and diameter is very well in practice especially in short rotation tree species. Based on plant height, five clones were found to be promising viz., 799 (*S. matsudana X S. alba*.) followed by SE-63-016 (*S. jessoensis*), NZ-1179 (*S. matsudana X S. alba*.), 212/03 (*S. matsudana X S. caprea*) and Kashmir willow (*Salix alba*). Clone 799 and Kashmir willow registered as most promising clones on the basis of principal component analysis. Total dry weight followed by total fresh weight, shoot fresh weight and shoot dry weight are to be given maximum weightage on the basis of principal component analysis.

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Current Status of Vulture Conservation in Haryana

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***Abstract*:** Vultures are nature's ambassador for ensuring ecological security and as quick disposal squad, they are must for the hygiene of the ecosystem. Till 1960's, vultures were found in abundance but in late 1980s, it was noticed in Keoladeo National Park of Rajasthan that there had been a considerable decline in vulture nests and by the advent of year 2000, 90% of vulture population had vanished. Sudden crash in vulture population created an emergency situation to know the cause of their death, breed them and release back into the nature. Bombay Natural History Society (BNHS) and the then Chief Wildlife Warden of Haryana took up the lead to save vultures from extinction and decided to set up a centre for vulture research. This led to the birth of world's first vulture conservation breeding centre (VCBC) at Pinjore in 2000. The scientists at this centre remained clueless for the mysterious death of vultures till 2002 but ultimately discovered that common painkiller drug diclofenac administered in domestic animals, which ultimately reached vultures via dead carcass is causing havoc by causing visceral gout and renal failure followed by their death. BNHS and Haryana Govt's efforts have led to ban on the use of diclofenac as a veterinary drug. At VCBC, three *Gyps* vulture species namely *Gyps bengalensis, G. indicus and G. tenuirostris* have been kept for research and during 13 years of the centre's existence, lot of nature's secrets related to life of vultures have been studied in captivity. The centre has succeeded in captive breeding of all vulture species. The centre plans to release first stock of birds in 2016, and the birds are being trained accordingly.

***Key Words*:** *Gyps*, diclofenac, king vulture, BNHS, Pinjore, breeding

Vulture crisis is one of the critical ecological issues the world is facing today. From 40 billion in 1960s to just 1,20,000 in 2010. Yes, that is the estimated population of vultures left in nature. Once very common, vultures are today on the verge of extinction. This is the biggest population crash and ecological disaster after the Passenger Pigeon (*Ectopristis migratorius)*. About two and half decades ago, the vultures were seen in plenty near cities, towns, villages, open areas, scrubby jungles and scattered tall trees. However in 80's, the gradual decline in vulture population was observed by the environmentalists, which assumed alarming proportion in late 80s. Today these scavenging birds are hardly seen at the places where they were seen in large numbers. The scientists world over have focused their attention to protect and preserve this important bird playing a vital role for the maintaining environment in proper health. In agrarian states like Haryana where rearing of cattle is a traditional profession and matter of pride, the vultures have more important role in the ecosystem as more number of carcasses are produced in the state.

Nature's Quick Disposal Squad

The moment the vultures come to know of the dead animal, they will come out in a group of hundreds, will do their job within minutes and fly back for a sun bath. This way they keep the nature neat and clean. They are able to reach at places where other human beings can not reach. They dispose of the carcasses of the dead wild animals in the jungle and the domestic animals outside the forests. Nature has gifted them the iron clad digestive system. They can happily eat meat in any stage of putrefaction and no toxin even putricine cannot make them sick. While they are on their job of cleaning the nature, they continuously urinate to kill the pathogens, which get on to their legs. In their absence, the carcasses are eaten by the feral dogs. Since the dead animals are generally infected with deadly pathogens, the dogs also get the disease. Thus, vultures prevent the spread of diseases like anthrax and rabies, which could play havoc to the wildlife, domestic animals and human beings. According to a recent report, as a result of vulture decline, an additional 5.5 million feral dogs have been added between 1992 and 2006. This has resulted into additional 38.5 million dog bites resulting into 47,300 deaths.

Vultures in Culture

Vultures have deep roots in Indian culture. They are the part and parcel of Indian culture. They have historical, mythological, cultural, and ecological importance.

Jatayu has great respect among Hindus. Jatayu is nothing but a vulture that lived during Ramayana period. It is said that during Ramayana period Jatayu had helped Lord Rama, Lakshmana and Sita during their exile. The story goes that when mother Sita was being forcefully taken away by Ravana, Jatayu, had spotted mother Sita in trouble from the sky top. He immediately blocked the way for Ravana. It is further said that he fought fiercely with Ravana and forced him to come down from his chariot. He fought bravely for a long time but finally Ravana succeeded to cut one of his

wings. Jatayu fell injured and Ravana moved away. However, he did not give up and guided Rama in locating Sita in Srilanka. Thereafter, Jatayu succumbed to his injuries and died. Afterwords his brother Sampati also helped Rama in fight against evil. Having come to know of the help Jatayu had extended to Rama, which was revealed by Lord Rama himself, local people built a temple at the place of death of Jatayu. The place at present is called Jatayu Para. It is 30 km. away from Kollam in Kerala.

Gidhraj Parvat also called Gridha Kuta Parvat meaning Vulture Peak is located in village Devrajnagar of tehsil Ramnagar in Satna district of M.P. The vulture peak is located at an altitude of 2354 feet. It has been vultures preferred place for breeding and roosting. An annual fair is also organized here every year in the month of Magha on the occasion of Vasant Panchami.

Vultures and Parsi cultures are inseparable. Parsis follow Zoroastrianism. According to Zoroastrian faith, the dead bodies cannot be buried or burnt because corpses could pollute Panchabhootam (earth, water, air, space and fire). Hence, Parses leave their bodies in a high-rise 'Tower of Silence' to be consumed by the vultures.

Species, Their Distribution and Classification

The vultures are found everywhere on the earth except Australia and Antarctica. They move with thermals. Antarctica has inhospitable climate and Australia does not have thermals. The vultures have been broadly divided into two categories viz., Old World and New World Vultures. The New World Vultures belong to America and they are represented by Californian & Andean Condors. The vultures belonging to Asia, Europe, & Africa have been classified as Old World vultures. Out of 20 species nine are found in Old World. The new world vultures have olfactory canals and are able to smell, the moment they come to know of the carrion. The new world vultures lack olfactory canals and cannot smell.

India has nine species of vultures i.e., White backed vulture (*Gyps bengalensis);* Slender billed vulture (*Gyps tenuirostris);* Long billed vulture (*Gyps indicus);* Red headed vulture or King vulture or Pondicherry vulture (*Sarcogyps calvus);* Indian Griffon Vulture or Eurasian vulture (*Gyps fulvus);* Himalayan Griffon (*Gyps himalayensis);* Cinereous Vulture or Monk Vulture *(Aegypius monachus);* Bearded vulture or Lammergier vulture (*Gypaetus barbatus) and* Egyptian vulture *(Neophron percnopterus).* Except the Bearded/Lammergier vulture, all other vultures are seen in Haryana. The King vulture has wide distribution and is found throughout India. As regards *Gyps* species, *G. tenuirostris* is distributed mostly in north eastern region; *G. benghasis* has fairly wide distribution and is found in southern and central India. *G. indicus* has narrow distribution and is found in southern India. While Himalayan Griffon and Lammergier restrict their distribution in cool Himalayas, the Monk vulture too lives in Himalayas but descends to sub Himalayan region during winters. Eurasian vulture is a winter visitor and seen in Gujarat, Rajasthan and in drier parts of Haryana and Punjab adjoining Rajasthan.

Decline in vulture population: Till late eighties nobody knew that the vultures were declining. Infact in India still vultures are considered as bad omen waiting for somebody to die. So, neither anybody bothered nor anybody reported the vanishing population of vultures in the nature. It was only in late nineties, Dr. Vibhu Prakash of Bombay Natural History Society (BNHS) while studying the raptors in Keoladeo National Park of Rajasthan observed that the vultures were no longer nesting and no eggs are being laid.

Neck drooping was first observed in Keoladeo National Park by Dr. Vibhu Prakash, where birds exhibit this behaviour for over several weeks before finally collapsing and falling to death. This is behavioural indication that birds are ill.

Meanwhile an injured vulture landed up in Pinjore near Chandigarh in 2000. Local took it as Jatayu. They worshipped it and offered prayers and money. A team of scientists headed by Dr. Vibhu Prakash visited Pinjore to identify the bird on the request of chief wildlife warden Haryana, Sh. Ram Dhirendra Jakati. The bird was identified as Cinereous vulture. It was kept in Pinjore zoo and was treated for its injuries. After the bird recovered, it was released at a place called Bir Shikargah about eight kilometres from Pinjore. It is a place where the present Vulture Conservation Breeding Centre exists.

Leave *Gyps* species, at present almost all species of vulture are critically endangered. It is not in India alone, but all over the world the vultures are vanishing. So, it is not that only *Gyps* species are endangered but all vulture species are in danger. Most critical of all is the Slender Billed vulture and experts opine that there are very few Sender Billed left in the wild. Perhaps King vulture is also equally endangered. It was seen throughout Indian sub continent. But now it is rare to see King Vulture. Till two years back, it was nesting in Nepal, but since 2010, the report is not encouraging. Its nests are no longer being seen in Nepal as well.

From Vulture Care Centre to Vulture Conservation Breeding Centre (VCBC)

The Vulture Conservation Breeding Centre (VCBC), earlier known as Vulture Care Centre (VCC), was established in September 2001 to investigate the dramatic declines in

India's *Gyps* species of vultures. It is a collaborative initiative between Bombay Natural History Society and the Haryana Forest Department, to save the three species of vultures (*Gyps bengalensis, Gups indicus* and *Gyps tenuirostris)*. The VCBC is located 8 km east of Pinjore, off the Chandigarh-Shimla highway, aims to establish a founder population of 25 pairs of each of the 3 species of vultures; produce a population of at least 200 birds of each species in 15 years to be reintroduced to the wild and release 100 pairs each of the three species of vultures in the next fifteen years.

VCBC has two quarantine aviaries or holding aviaries and each can hold 20 birds. Any bird brought to the centre is first kept in these aviaries and their health is monitored for 45 days. It has three nursery aviaries to provide a natural nest-like environment for rearing of nestlings. These aviaries can rear up to 24 nestlings at a time. Four hospital aviaries for treating injured bird and eight breeding aviaries for conservation breeding of vultures are also established. Three colony aviaries meant to house sub-adult and adult birds are also available. These aviaries are large enough for the birds to exercise by flying from one end to another and feed socially on carcasses, exactly as they do in the wild. Also two displays for education and generating awareness are also additional components at the centre.

The centre has holding aviaries with capacity to hold 10 pairs in the big aviary and 2 pairs each in the smaller ones. These aviaries house the juveniles after they fledge in nursery aviaries. The centre has a well-equipped laboratory also.

Achievements of VCBC

There are a total of 160 birds at the centre of which 62 are Oriental white-backed vultures, 75 Long-billed vultures, 21 Slender-billed vultures and 2 Himalayan Griffons. The founder stock has been collected from various states of the country viz. Assam, Haryana, Rajasthan, Gujarat, Madhya Pradesh and Maharashtra. All three *Gyps* species, the Oriental white-backed vulture, Long-billed vulture and Slender-billed vulture have been bred at the centre. This has happened the first time ever for all the three species. So far, 61 nestlings have successfully hatched and fledged at the centre. Of these, 25 are of Oriental white-backed vulture, 29 of Long-billed vulture and ten of Slender-billed vulture. This does not include the chicks that have hatched in December, 2013 January, 2014.

The pioneering work done at VCBC during 2005 in identifying a vulture safe drug, Meloxicam, in collaboration with Indian Veterinary Research Institute, Izzatnagar, which could be given to cattle and is absolutely safe for vultures is of great significance and would go a long way in saving the vultures from extinction. Meloxicam as a vulture safe alternative drug to diclofenac was successfully tested at the centre.

The centre has successfully implemented the technique of double clutching by inducing the pairs to lay again by removing the first clutch. The eggs removed are incubated in incubators. The birds lay again in about three week's time. Eggs of Oriental white-backed vulture and of Long-billed vulture have been successfully hatched in incubators.

When the cause of vulture was known, the efforts started for eliminating diclofenac from the system. The Govt. of Haryana took up the matter with Govt. of India and breakthrough came in the year 2006 when Govt. of India put a ban on the use of doclofenac for veterinary use. However, recently a NSAID named Aceclofenac has been introduced for veterinary and human use. When it goes into the system, it is metabolised into diclofenac. The detailed biochemical studies need to be conducted on this drug as it may prove equally fatal to vultures as diclifenac is.

The first batch of vultures bred at VCBC will be released into the wild in 2016. But the place of release has to be carefully chosen depending upon the best suited habitat for particular *Gyps* species. Vulture safe zones have to be identified/established and it has to be ensured that diclofenac is completely out of the system. Initially scientists were reluctant to adot the diclofenac theory but now they agree that diclofenac resulted in decline of *Gyps* and non-*Gyps* species (Green *et al*., 2004, Oaks *et al*., 2004, Shultz *et al*., 2004, Prakash *et al*., 2005; Swan *et al*., 2006). Therefore, we have to be cautious before their release.

There is no doubt that the vultures are nature's most efficient scavangers. They are the ultimate recyclers – able to strip a carcass in just an hour to keep environment clean. Vulture crisis is one of the critical ecological issues the world is facing today. They are the most endangered group of birds globally. IUCN has already placed them in critically endangered category and their removal from the ecosystem will affect the equilibrium between populations of other scavenging species. The Parsi culture is on the verge of disintegration as there are no more vultures left to dispose of a Parsi body. Not only *Gyps* species, all other species are also equally important as each species of vulture has a specific role in disposing of carrion. There is need to be vulturiphils rather than being Gypsiphils. Ban on diclofenac in only preventive. We have to think for the ways and means to reduce uric acid in vultures. There is need to generate mass awareness about the conservation needs of vultures on the lines of tiger. Let us do it now before it is too late. Already some initiatives have started, captive breeding efforts

are ongoing in breeding centres in India (Pain *et al.,* 2008). In 2009, captive birds laid eggs, raising hopes that they will successfully breed in captivity in the near future.

CONCLUSION

There is no doubt that the vultures are the inseparable part of our ecosystem. However, they are not being given the kind of importance they deserve. Very important reason for this is that they are still treated bad, opportunistic, dirty and as if waiting for some one to die. Leave common man, there is lack of awareness about them among all sections of the society. Many learned people, elite class and even media paints bad picture about them. So, we need to sensitize all sections of the society including common man, educate elite class and even print/electronic media about the conservation needs of vultures and myths surroundings these innocent birds. Besides generating awareness, we need to focus on conservation breeding of all vulture species especially the Red headed or King vulture, which is also critically endangered. At present, the vulture conservation programme in India is being run with assistance from organizations like Darwin's Initiatives, Zoological Society of London, and Birds of Prey London etc. There is need to pump more finds for vulture research in India.

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Status of Bird Diversity in Belagavi District, Karnataka State

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***Abstract*:** This study was conducted to determine the urban bird diversity and status in Belagavi city of Karnataka state. The study showed the presence of 37 species of birds spread over 25 families and eight orders. The study area was dominated by non-passerine birds compared to passerine birds. Out of 25 families, 15 families belonged to non-passerines, whereas, the passeriform birds consisted of ten families. The birds with omnivorous, carnivorous and insectivorous food habits were more common compared to those with specialized feeding types such as granivorous and frugivorous. Both passerine and non-passerine birds exhibited differential food choices despite being in the same environment. The per cent occurrence of resident birds was maximum compared to resident migratory and migratory birds. The overall depletion in species richness in the city area could be due to damage caused by human interference including urbanization and pollution, which might significantly affect the bird diversity.

Key Words: Passerine birds, non-passerine birds, bird diversity, feeding habit, urban birds

Bird diversity is helpful in determining the species richness, but the urban biodiversity has received very little attention from conservation biologist compared to natural and protected ecosystem. Since the biological diversity is under tremendous pressure from a variety of human activities (Bawa *et al.,* 2007), there is a need to determine the urban diversity status of birds. As the population of birds is a very sensitive indicator of degree of population in both terrestrial and aquatic ecosystem (Turner, 2003), determination of bird diversity status is a key to understand the impact of changing ecological conditions on fauna. Belagavi city is situated near the foot hills of Sahyadri mountain range of the north-western part of Karnataka and has good avian fauna. However, no information was available on species diversity of the birds in this area. The present study is an attempt to determine the urban bird diversity and status in Belagavi city.

MATERIALS AND METHODS

Belagavi has an average elevation of 2463 ft. above sea level, lying between 15^0 51' N and 74^0 31' E. It exhibits swift and kaleidoscopic changes in topography, vegetation and climate. The fort lake, situated at the entrance of the city, is one of the big lakes in northern part of Karnataka. This lake is not only ecological habitat for a many species of birds, but also significant to the environment of city. The lake is surrounded by area-wise gardens and historical fort. The fort surroundings have variety of plant species namely, *Bambusa bambos, Ficus benghalensis, F. racemosa, Acacia greggii, Tectona grandis, Cocos nucifera, Mangifera indica,* etc. These plants not only provide food and shelter, but also nesting sites for birds in the city. The study area was divided into ten different zones, namely, Fort lake, Gandhi nagar Central bus stop area, Court road, Ambedkar garden, Nehru Nagar, Shree Nagar garden, Mahantesh Nagar, Ashok Nagar and Fort area (Fig. 1).

A regular survey was carried out 3-4 times in a month between 6.00-10.30 and 17.00-18.30 IST from June 2012 to April 2013 encompassing monsoon, winter and summer seasons. The birds were observed using prismatic binoculars (10 × 40) and identified up to lowest possible taxonomic level with the help of field guides (Ali, 2002; Grimmett *et al.,* 1998). Feeding guilds were classified on the basis of direct observations and available literatures. The common names were assigned according to Manakadan and Pittie (2001). The percentage occurrence of birds was calculated.

RESULTS AND DISCUSSION

This study recorded the presence of 37 species of birds spread over 25 families and eight orders (Table 1). Passeriformes is generally known as the largest and most diverse commonly recognized clade of birds. The dominance of passerine birds was reported in the Arki hills region of Himachal Pradesh (Thakur *et al.,* 2010), the Tawa reservoir and its surrounding areas at Hoshangabad district of Madhyapradesh (Joshi and Shrivastav, 2012), and in Katgal region of Western Ghats, Uttara Kannada district (Bhat and Ganesh, 2014). However, the present study documented highest percentage of non-passerines (59.46%) compared to Passeriform (40.54%) birds (Fig. 2). Most populations of non-passerine birds comprised of Ciconiiformes (27.1%), Columbiformes (8.1%), Coraciiformes (8.1%), Charadriiformes (5.4%), Cuculiformes (5.4%), whereas, orders Strigiformes (2.7%) and Anseriformes (2.7%) were infrequent (Fig. 2). Similar dominance of non-passerine birds over passeriform birds was observed in Karnaphuli River delta and adjacent areas of Chittagong, Bangladesh (Ahsan

Table 1. Checklist of birds observed at Belagavi city

	Common name	Scientific name	Status*	
			Habitat	Food
PASSERIFORMES				
Pycnonotidae	Red-vented bulbul	*Pycnonotus cafer*	R	F
	Red-whiskered bulbul	*Pycnonotus jocosus*	R	O
Sturnidae	Common myna	*Acridotheres tristis*	R	O
	Brahminy starling	*Sturnus pagodarum*	R	O
Dicruridae	Black drongo	*Dicrurus macrocercus*	R	I
Corvidae	Jungle crow	*Corvus macrorhynchos*	RM	O
	House crow	*Corvus splendens*	R	O
Motacillidae	Yellow wagtail	*Motacilla flava*	RM	I
	Large pied wagtail	*Motacilla maderaspatensis*	R	O
Muscicapidae				
	Oriental magipie robin	*Copsychus saularis*	R	I
	Jungle babbler	*Turdoides striatus*	M	I
Passeridae	House sparrow	*Passer domesticus*	R	O
Zosteropidae	White eye	*Zosterops palpebrosus*	RM	O
Daniidae	Rufous backed shrike	*Lanius schach*	R	C
Cisticolidae	Ashy prinia	*Prinia socialis*	R	I
CICONIIFORMES				
Laridae	Little tern	*Sterna albifrons*	R	C
Scolopacidae				
	Common sandpiper	*Actitis hypoleucos*	RM	O
	Wood sandpiper	*Tringa glareola*	M	C
Accipitridae	Brahminy kite	*Haliastur indus*	R	C
Threskiornithidae	Oriental white ibis	*Threskiornis melanocephalus*	M	C
Ardeidae	Cattle egret	*Bubulcus ibis*	RM	I
	Little egret	*Egretta garzetta*	R	C
	Median egret	*Mesophoyx intermedia*	RM	C
	Little green heron	*Butorides striatus*	R	C
	Indian pond-heron	*Ardeola grayii*	R	C
COLUMBIFORMES				
Columbidae	Blue rock pigeon	*Columba livia*	R	G
	Little brown-dove	*Streptopelia senegalensis*	RM	G
	Spotted dove	*Streptopelia chinensis*	R	G
CORACIIFORMES				
Meropidae	Small bee-eater	*Merops orientalis*	R	I
Cerylidae	Lesser pied kingfisher	*Ceryle rudis*	R	C
Halcyonidae	White-breasted kingfisher	*Halcyon smyrnensis*	R	C
CUCULIFORMES				
Cuculidae	Asian koel	*Eudynamys scolopacea*	R	O
Centropodidae	Greater coucal	*Centropus sinensis*	R	C
CHARADRIIFORMES				
Recurvirostridae	Black-winged stilt	*Himantopus himantopus*	R	C
Charadridae	Red-wattled lapwing	*Vanellus indicus*	R	C
STRIGIFORMES				
Strigidae	Spotted owlet	*Athene brama*	R	C
ANSERIFORMES				
Anatidae	Spot-billed duck	*Anas poecilorhyncha*	RM	O

*Abbreviations

R-Resident; M-Migratory; RM-Resident migratory; O-Omnivorous; C-Carnivorous; G-Granivorous; I-Insectivorous; F-Frugivorous.

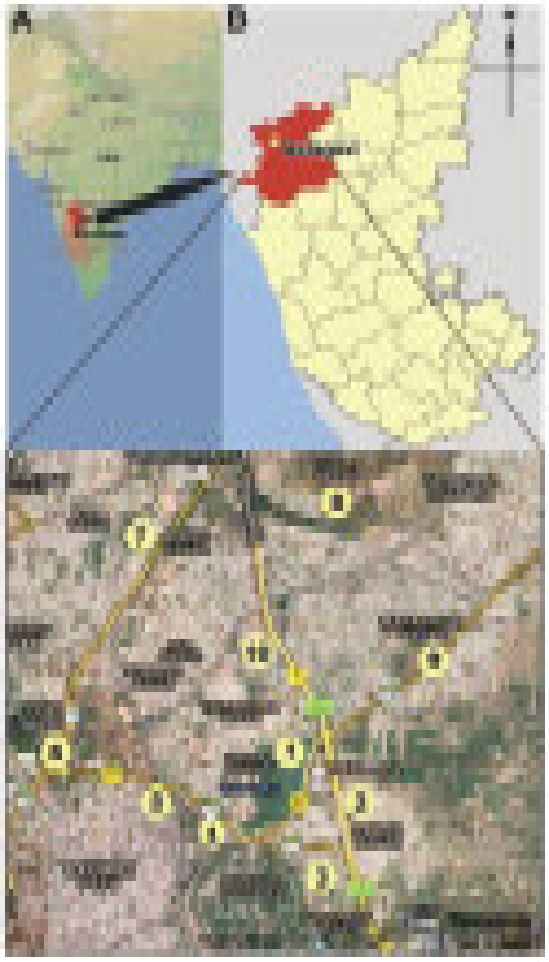

Fig. 1 (A - C). Map showing locating of Karnataka state (A), Belagavi district (B) and different zones of the study area (C).

1. Fort Lake
2. Gandhi Nagar
3. Fort Region
4. Central bus stand region
5. Court Road
6. Ambedkar Garden
7. Nehru Nagar
8. Shree Nagar Garden
9. Mahantesh Nagar
10. Ashok Nagar

and Hannan, 2002) and in Kurugodu, an area, which was close to mining activities at Bellary District, Karnataka (Konkal and Ganesh, 2014). However, Jose and Zacharias (2003) found almost equal distribution of passerine (56 species) and nonpasserine (55 species) birds in Calicut University campus at Kerala. These observations suggest that the species richness of specific families depend on their interactions with the local environment and vary depending on the ecological conditions.

In the present study, highest percentage of birds showed carnivorous (40.54%) followed by omnivorous (29.72%) and insectivorous (18.91%) feeding types (Fig. 3). The birds with feeding habits such as granivorous (8.10%) and frugivorous (2.70%) were less frequent (Fig. 3). These observations suggest that the bird population in the study area mainly rely on carnivorous and omnivorous feeding types as these

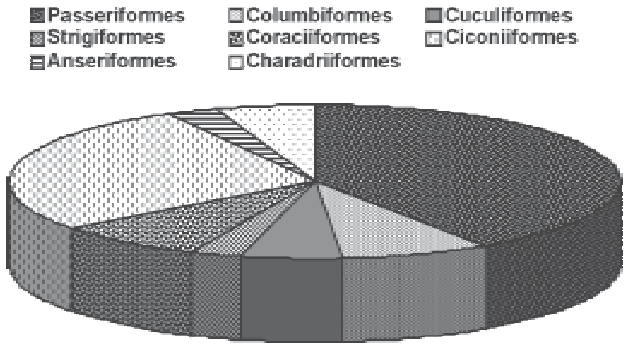

Fig. 2. Per cent occurrence of birds belonging to different orders

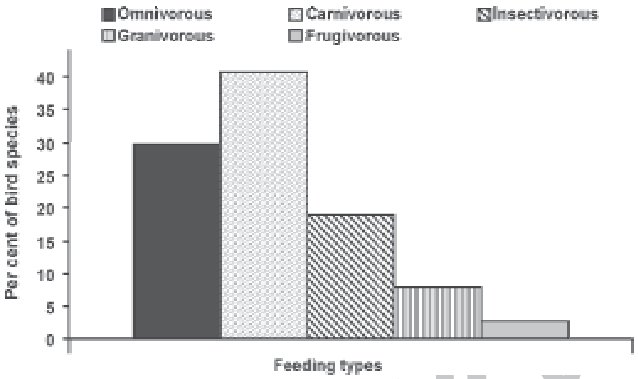

Fig. 3. Distribution of birds according to their feeding types in the study area

adaptations enable them to feed on variety of food types. Jayson and Sivaperuman (2005) reported dominance of birds with omnivorous feeding habit, wherein out of 66 omnivorous birds, 58 species belonged to Charadriiformes followed by five species of Passeriformes at Thrissur District, Kerala. Konkal and Ganesh (2014) found that omnivorous (50%) and insectivorous (43.75%) feeding habits were dominated by the passerine birds, whereas, most of non passerine birds had carnivorous (47.36%) followed by omnivorous (19.4%) feeding habit. In the present study, most of the passerine birds exhibited omnivorous (53.33%) followed by insectivorous (33.33%), carnivorous and frugivorous (each 6.66%) feeding types. On the other hand, majority of the nonpasserine birds showed carnivorous (63.63%), followed by omnivorous and granivorous (each 13.63%) and insectivorous (9.09%) feeding types. None of the passerines and nonpasserines showed granivorous and frugivorous feeding habits respectively. These observations suggest differential feeding choices of passerines and non-passerines despite the same ecological conditions in the study area.

The occurrence of resident birds was maximum (72.97%) compared to resident migratory (21.63%) and migratory birds (5.40%). Among Passeriformes, the Jungle

barblers (Muscicapidae) were exclusive to monsoon, whereas, Ciconiiformes members such as Wood sandpiper (Scolopacidae) and Oriental white ibis (Threskiornithidae) were seen during summer and winter, respectively. Some birds such as Jungle crow, Yellow wagtail, White eye, Common sandpiper, Cattle egret, Median egret, Little brown dove and Spot-billed duck were observed as resident migratory birds within the study area.

The present study suggests a general depletion in the species richness as shown by the presence of only few members in most families, which could be due to damage caused by human interference including urbanization and pollution that might affect the bird diversity of the Belagavi city. In view of this, there is an immediate need to take necessary precautions to prevent the habitat loss. Besides, plantation of more trees in and around the city might help restoring the natural habitats, thereby bird diversity.

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Studies on Genetic Divergence in Karanj (*Pongamia pinnata*) Germplasm Collected from Haryana, Punjab and Rajasthan

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Abstract: Karanj mature pods were collected from the three states viz. Haryana, Punjab and Rajasthan in two consecutive years 2009 and 2010. Intra-cluster average D^2 value of cluster V was minimum (1.238) thus revealed the minimum genetic diversity and cluster IV had maximum (2.471), which indicated the existence of maximum genetic diversity. The average inter cluster D^2 value between cluster IV and V was maximum (7.176), whereas, the minimum inter-cluster average D^2 value was in cluster I and V (2.514). The genotypes which had highest cluster means and showed higher inter-cluster divergence with several other characters would be considered as putative parents for hybridization. Hybridization among genotypes of the same cluster may not provide a good scope for obtaining useful segregates.

Key Words: Genetic divergence, *Pongamia pinnata, Karanj,* inter and intra-clusters, variation

The extent of genetic diversity in a crop forms the basis for its genetic improvement. Therefore, the information on presence of genetic diversity is an essential prerequisite for developing superior progenies through hybridization program by using statistical tools. It is now possible to quantitatively measure the genetic divergence between two or more populations and the relative contribution of individual characters to the total divergence in such comparisons. Such studies have been very useful for hybridization in crop plants. *Pongamia pinnata* (L.) Pierre belongs to family Fabaceae (Papilionoideae) and locally know as karanj, karanja or sukhchain. It is native tree of India and available along coasts and riverbanks throughout the Indian plains. Its lateral roots have dense network which helps in controlling soil erosion and binding the sand dunes. Large seeds of this medium sized tree contain up to 40% non-edible oil (Natanam *et al*., 1989; Nagaraj and Mukta, 2004). This tree species have diverse medicinal values as roots, bark, leaves, sap and flowers have been used in traditional medicine by the tribal practitioner/ vaidya. This tree is also useful in green manuring, as a small timber and fuel wood tree and used as fish poison, in tanning and soap industry. The extracts from various parts are known to have diverse properties viz. medicinal, insecticidal, nematicidal and pesticidal (Baswa *et al*., 2001; Latha *et al*., 2001; Chauhan and Chauhan, 2002; Carcache-Blanco *et al*., 2003; Srinivasan *et al*., 2003; Ahmed *et al.,* 2004; Alam *et al*., 2004; Li *et al*., 2006). The species bearing oily seeds (TBOs) with high seed oil content and ability to grow under harsh and diverse climatic conditions makes this species most suitable to meet the domestic needs of biodiesel as large area in the form of waste lands are available in our country to raise the plantations. *Pongamia pinnata* (L.) Pierre is the most promising tree species capable of producing large quantity of oil seeds for extraction of biodiesel.

Systematic research efforts for the improvement of characters like seed yield and oil content in *P. pinnata* are lacking, information regarding variation in seed yield and its oil content across agro-climatic zones is also scanty. Hence, before going for the plantations of *P. pinnata* on large scale, it is very important to identify its promising seed sources from various agro-climatic zones for ensuring high seed yield, oil content and good storability. Due to its high economic, medicinal and ecological value, systematic research work carried out to find the variation in morphological traits of seeds/ pods in three important states namely Haryana, Punjab and Rajasthan.

MATERIAL AND METHODS

The research material of Karanj was collected from the three states viz. Haryana (Ambala, Bhiwani, Jhajjar, Karnal, Kurukshetra, Panipat, Rewari and Yamuna Nagar districts), Punjab (Fatehgarh Sahib, Ferozpur, Jalandhar, Ludhiana, Patiala, and Sangrur districts) and Rajasthan (Banswara, Dungarpur, Pratapgarh, Rajsamand and Udaipur districts) located under five distinct agro-climatic zones and two agro-ecological regions (Ghosh,1991, Sehgal *et al*., 1992) The experimental material for achieving the objectives of this study comprised of the mature pods collected from the mature trees with an average age of 15 years. Ten mature trees were selected (with average age of 15 years) from each agro-climatic zone, in February, 2009 (Table 1). The mature and

ripened pods from 50 selected trees were collected in the month of April and May for two consecutive years 2009 and 2010.

All the pods of the selected trees were harvested individually to estimate the seed yield from each tree. The sampling method as suggested by Schmidt (2000) was used for recording the seed yield. Observations on seed weight/pod (g), 100-pod weight (g), number of seeds/100 pods, yield/plant (kg), pod length (mm), pod breadth (mm), seed length (mm), seed breadth (mm) and total oil content were recorded. The multivariate diversity (Mahalanobis, 1936) was analysed for appropriate interpretation of results.

RESULTS AND DISCUSSION

The cluster analysis is commonly used for studying the genetic divergence and for forming core subset for grouping accessions with similar characteristics into homogenous categories. Among several methods of multivariate analysis, Mahalanobis D^2 statistic and Euclidean cluster analysis has been found to be very useful in selecting parents for hybridization that will meet the specific objectives of the crop improvement program. One of the important aspects of the present investigation was to classify 50 trees into different clusters based on the genetic distances (Table 2-4). This aspect is important in the sense that in long run it will help to avoid repetition of genetically similar genotypes in hybridization programs and these objectives were achieved by assignment of these genotypes into groups and studying their intra as well as inter-group diversity. The entire population of *P. pinnata* selected for the present study were grouped into eight clusters. The cluster VI was the largest group comprising of 11 trees and second largest groups of trees were cluster I and II comprising of 7 trees each. Cluster VII and VIII had six trees each, whereas, each of the clusters III and IV included five test trees. Cluster V comprising of only three sources was the smallest group. Average intra- and inter-cluster D^2 values in table 3 indicated that intra-cluster average D^2 value of cluster V was minimum (1.238) thus recording the minimum genetic diversity among its constituents. The intra-cluster average D^2 value of cluster IV was maximum (2.471), which indicated the existence of maximum genetic diversity among its constituents. The intra-cluster average D^2 values of cluster II (2.215), cluster VII (2.030), cluster III (1.958), cluster VI (1.883), cluster I (1.723) and cluster VIII (1.461) revealed sizable genetic diversity among the genotypes. The average inter cluster D^2 value between cluster IV and V was maximum (7.176) which revealed maximum genetic divergence between these two clusters followed by cluster III and IV (6.699), cluster I and IV (5.760), cluster II and V (5.342), cluster V and VIII (4.865) and cluster III and VII (4.725). The minimum inter-cluster average D^2 value was found between the cluster I and V (2.514) followed by cluster II and VI (2.668) and cluster VI and VIII (2.680). Cluster III had the lowest cluster mean for seed weight per pod, 100-pod weight, 100-seed weight, breadth of seeds and oil content while cluster IV recorded maximum cluster mean for seed weight per pod, 100-pod weight, 100-seed weight, pod breadth, seed length, seed

Table 1. Agro-climatic zones surveyed for the collection of germplasm

S.No.	Name of agro-climatic zone	Name of agro-ecological region
1	HR-1 (Eastern Zone, Haryana)	Trans Gangetic Plain Region
2	HR-2 (Western Zone, Haryana)	-do-
3	PB-3 (Central Plain Zone, Ludhiana, Punjab)	-do-
4	RJ-7 (Sub Humid Southern Plain and Aravalli Hill Zone, Udaipur, Rajasthan)	Central Plateau and Hill Region
5	RJ-8 (Southern Humid Plain Zone, Banswara,Rajasthan)	-do-

Table 2. Distribution of different test trees of *P. pinnata* in clusters based on D^2 statistics

Clusters	No. of trees/ genotypes	Details of test trees/genotypes
I	7	RJ-7/7,RJ-7/8,RJ-7/10,RJ-8/1,RJ-8/7,HR-1/7,HR-2/2
II	7	HR-1/1,HR-1/2,HR-1/10,HR-2/1,HR-2/9,PB-3/4,PB-3/6
III	5	HR-2/10,PB-3/1,PB-3/2,PB-3/3,PB-3/5
IV	5	RJ-7/2,RJ-7/3,RJ-7/9,RJ-8/6,RJ-8/10
V	3	RJ-7/1,RJ-8/2,RJ-8/9
VI	11	RJ-7/5,RJ-8/3,HR-1/3,HR-1/6,HR-1/9,HR-2/3,HR-2/7,PB-3/7,PB-3/8,PB-3/9,PB-3/10
VII	6	RJ-7/4,RJ-7/6,RJ-8/5,RJ-8/8,HR-2/6,HR-2/8
VIII	6	RJ-8/4,HR-1/4,HR-1/5,HR-1/8,HR-2/4,HR-2/5

Table 3. Average inter- and intra-cluster distance (D^2) among eight clusters of *P. pinnata*

Clusters	I	II	III	IV	V	VI	VII	VIII
I	1.723							
II	3.341	2.215						
III	2.722	3.767	1.958					
IV	5.760	3.849	6.699	2.471				
V	2.514	5.342	4.084	7.176	1.238			
VI	3.119	2.668	3.098	4.690	4.256	1.883		
VII	3.069	2.786	4.725	3.626	4.138	3.214	2.030	
VIII	3.429	2.865	4.288	3.310	4.865	2.680	2.963	1.461

breadth and oil content indicating that these genotypes have poor performance (Table 4). The cluster VI had highest cluster mean for number of seeds per 100 pods and lowest cluster mean for pod length. Cluster VII had highest cluster mean for pod length, while cluster II recorded lowest cluster mean for number of seeds per 100 pods and seed yield per plant. The cluster V had the lowest cluster mean for pod breadth and seed length but highest cluster mean for seed yield per plant. The genotypes, which had highest cluster means and showed higher inter-cluster divergence with several other characters can be considered as putative parents for hybridization. Since the hybridization among genotypes of the same cluster may not provide a good scope for obtaining useful segregates, the putative parents for hybridization program should thus belong to different diverse clusters with high cluster means for the yield components as selection criterion. At the same time, *per se* performance of the constituents of diverse clusters should also be considered for selection as parents. The parentage of 50 trees included in the present study indicated that the genotypes, which belong to different eco-geographical areas were observed to be included in the same cluster and genotypes from different agro-climatic zones/ eco-geographical areas were included in the same cluster, which indicated that there is no association between clustering pattern and eco-geographical distribution of the trees. Bhat (1970) had also reported that eco-geographical diversity is not necessarily related to genetic diversity. Also, the clustering of genotypes from different eco-geographical locations into one cluster could be attributed to the possible free exchange of breeding materials or even species from one place to another. It may also be due to the fact that the unidirectional selection practiced for a particular trait in several places produced similar phenotypes which were aggregated in one cluster irrespective of their distant geographic origin (Somayajulu *et al.,* 1970). On the other hand, many species originating from one place were scattered over different clusters. Such genetic diversity among the genotypes of common geographic origin could be due to the factors like heterogeneity, genetic architecture of the populations, past history of selection, developmental traits and degree of general combining ability (Murty and Arunachalam, 1966). This fact is also supported by wide inter-cluster differences among them. This situation, however, helps the investigator to arrive at a very important conclusion that the grouping based on total D^2 analysis can be relied upon only when the characters of major importance like pod length, 100-seed weight, total seedling length, early vigor and storage behavior are taken into consideration. Similar results for cluster assignment of different genotypes of *P. pinnata* have been reported by Hooda *et al*. (2009) and Divakara *et al*. (2010).

Table 4. Cluster mean values for various pod and seed traits of *P. pinnata*

Clusters	Seed weight pod^{-1} (g)	100 pod weight (g)	No of seeds/ 100 pods	100 seed weight (g)	Yield plant^{-1} (kg)	Pod length (mm)	Pod breadth (mm)	Seed length (mm)	Seed breadth (mm)	Oil content (%)
I	1.17	264.33	117.14	112.46	23.05	50.19	21.95	19.76	14.86	38.80
II	1.53	359.48	114.76	150.06	13.57	52.05	24.72	22.57	16.10	34.97
III	o.99	273.07	124.87	97.80	17.00	49.66	26.73	18.07	14.73	33.12
IV	1.99	420.53	124.07	194.19	25.20	57.93	27.13	23.53	17.60	42.16
V	1.15	244.78	139.00	103.80	26.67	49.89	19.33	17.89	12.89	41.31
VI	1.45	325.76	146.58	129.42	13.61	49.30	25.30	20.15	16.18	37.40
VII	1.57	340.05	127.06	149.20	20.06	58.66	21.67	22.28	15.11	41.31
VIII	1.62	340.11	134.72	145.14	31.17	51.56	25.17	21.61	17.22	37.71

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Congruence of Random Amplification of Polymorphic Deoxyribonucleic Acid and Simple Sequence Repeats Markers in Genetic Characterization of Willow (*Salix* Spp.)

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Abstract: Genetic characterization of 94 genotypes (4 female, 10 male, and 80 half sibs) of *Salix* were analyzed using 10 SSRs and 15 RAPDs PCR-based molecular markers. RAPD analysis yielded 87 polymorphic fragments (98.9%), with an average of 5.8 polymorphic fragments per primer. Similarly, SSR analysis produced 33 bands, out of which 26 were polymorphic (78.8%) with an average of 2.6 polymorphic fragments per primer. The genetic diversity was high among the genotypes (Nei's genetic diversity = 0.354 and Shannon's information index = 0.536) as measured by combination of both RAPD and SSR markers. The mean coefficient of gene differentiation (Gst) was 0.037, indicating 96.6% of the genetic diversity resided within the genotypes. It was found that the genetic diversity among genotypes was broader, suggesting the importance and feasibility of introducing elite genotypes from different hybrids for willows germplasm conservation and breeding programs.

***Key Words*:** *Salix sp.*, half sibs, molecular markers**,** genetic diversity, RAPD, SSR

There are more than 300 *Salix* species, and they are widespread in both the Northern and the Southern hemispheres, excluding Australasia and New Guinea. Willows are dioecious but may reproduce as well sexually as by vegetative propagation. The willows are typical tree-forming pioneer species in alluvial plains and riparian zones. The delimitation between these polyploid taxa relies on relatively few diagnostic features in the morphology. Consequently, large overlaps exist, which make it difficult to identify samples from the field unambiguously. In many cases, the two species coexist in mixed stands. Artificial hybridization is possible, but the taxonomic identity as well as the identification of their metapopulations remains difficult. Different elements such as the lack of qualitative diagnostic characters, the frequent occurrence of intermediate morphological forms and the successful interspecific controlled crosses support the hypothesis that *S. alba* and *S. fragilis* may hybridize frequently in nature (Triest *et al.,* 2000). *S. viminalis L.* and *S. schwerinii* E. Wolf are dioecious willows that are phenotypically very similar. Both are multi-stemmed shrubs with long and slender leaves and are commonly found along streams and rivers and in other wet areas. As other *Salix species*, the sex-ratio is often female biased (Ueno *et al.,* 2007). In *S. sachalinensis*, for example, clonal propagation was less important than expected. *S. viminalis* has a vast natural distribution ranging from Ireland and United Kingdom in the west to Siberia in the east. The exact boundaries of the natural range in Western Europe are uncertain due to extensive cultivation in the past.

A number of problems have been highlighted, including a largely undefined genetic pool of clonal lines, which can be used as progenitors in a breeding programme and limited information on the genetic basis of many agronomically important traits. Within the last twenty years, molecular biology has revolutionized conventional breeding techniques in all areas. Biochemical and molecular techniques have shortened the duration of breeding programs from years to months, weeks, or eliminated the need for them all together. The use of molecular markers in conventional breeding techniques has also improved the accuracy of crosses and allowed breeders to produce strains with combined traits that were impossible before the advent of DNA technology. Many of the willow cultivars exploited for biomass production are closely related genetically and can be difficult to distinguish using traditional morphological criteria. The objective of this study was to compare the effectiveness of both the PCR-based molecular approaches to determine the genetic relationships among several genotypes of willows parents and their hybrids.

MATERIALS AND METHODS

Ninety four genotypes (eighty half sib, four female and ten male) of *Salix sp.* were collected from Naganji nursery farm of the Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) India, (Table 1). Although these plants showed distinctive taxonomic traits of the different willow species, they were chosen for their great variability in terms of morphological traits such as young and mature

leaves, bark colour etc. The detailed methodology including the list of primers used for RADP/SSR, GC content, total number of loci, the level of polymorphism, resolving power and PIC value are same as followed by Singh *et al.* (2013)

RESULTS AND DISCUSSION

A total of 94 plant samples were fingerprinted using 15 RAPD makers. These primers produced multiple band profiles with a number of amplified DNA fragments varying from 4 to 7. All the amplified fragments varied in size from 100-2000 bp. Out of 88 amplified bands, 87 were found polymorphic (98.8%). The observed high proportion of polymorphic loci suggests that there is a high degree of genetic variation in the *Salix spp.* The resolving power of the 15 RAPD primers ranged from 5.471 for primer OPJ-10 to a maximum of 8.471 for primer OPJ-2. Polymorphism information content (PIC) refers to the value of a marker for detecting polymorphism within a population or set of genotypes by taking into account not only the number of alleles that are expressed but also the relative frequencies of alleles per locus. As evident, RAPD marker 'OPJ-2' showed the highest level of polymorphism with PIC value of 0.795, whereas, the PIC values for the rest of the RAPD markers were in the range of 0.713 to 0.791. A dendrogram analysis based on bootstrapping and neighbor joining (NJ) method grouped all the 94 genotypes into 3 main clusters which are further extensively divided into mini clusters (Figure 1a). Similarly, an unbiased clustering of genotypes based on STRUCTURE program without prior knowledge about the populations, clustered all the 94 genotypes into three major clusters. Under the admixed model, STRUCTURE calculated that the estimate of likelihood of the data i.e. ΔK reached its maximum value when K = 3 (Figure 1b [A]), suggesting that all the populations fell into one of the 3 clusters albeit small interference (Figure 1b[B]). This result is almost similar to the splitting in the NJ tree. Overall the cluster analysis strongly suggested that the 94 sampled genotypes can be divided into 3 clusters, however, there is no distinct clustering of genotypes based on their 4 female, 10 male, and 80 half sibs.

The genetic diversity of 94 genotypes was calculated in terms of Na, Ne, H, I, Ht, and PPL with respect to 3 different groups such as 4 female, 10 male, and 80 half sibs revealed higher values, indicating more variability among the genotypes (Table 2). Polymorphic loci of 100% was calculated using POPGENE among 4 females, 10 males, and 80 half sibs genotypes. Three groups containing genotypes with different sexes such as female, half sibs and males showed Nei's genetic diversity (H): 0.390, 0.412 and 0.398, respectively and of Shannon's information index (I): 0.563, 0.601 and 0.583 (Table 2), respectively showed a higher genetic differentiation within each of the three groups. The

Table 1. List of the 94 *Salix* genotypes

Female	Half sibs	Half sibs	Half sibs	Half sibs	Male
Salix tetrasperma	Half sib 1	Half sib 21	Half sib41	Half sib61	*Salix alba*
Salix matsudana x Salix alba (J7990)	Half sib 2	Half sib22	Half sib42	Half sib62	*Salix babylonica*
Salix matsudana (PN227)	Half sib 3	Half sib23	Half sib43	Half sib63	*Salix tetrasperma*
Salix matsudana (SE-69-002)	Half sib 4	Half sib24	Half sib44	Half sib64	*Salix matsudana* (PN722)
-	Half sib 5	Half sib25	Half sib45	Half sib65	*Salix rubence*
-	Half sib 6	Half sib26	Half sib46	Half sib66	*Salix udensis* (SX59)
-	Half sib 7	Half sib27	Half sib47	Half sib67	*Salix alba X Salix babylonica* (131/25)
-	Half sib 8	Half sib28	Half sib48	Half sib68	*Salix matsudana X Salix alba* (NZ1140)
-	Half sib 9	Half sib29	Half sib49	Half sib69	*Salix matsudana X Salix alba* (NZ1179)
-	Half sib 10	Half sib30	Half sib50	Half sib70	*S.matsudana X S.alba* (NZ1002)
-	Half sib11	Half sib31	Half sib51	Half sib71	-
-	Half sib12	Half sib32	Half sib52	Half sib72	-
-	Half sib13	Half sib33	Half sib53	Half sib73	-
-	Half sib14	Half sib34	Half sib54	Half sib74	-
-	Half sib15	Half sib35	Half sib55	Half sib75	-
-	Half sib16	Half sib36	Half sib56	Half sib76	-
-	Half sib17	Half sib37	Half sib57	Half sib77	-
-	Half sib 18	Half sib38	Half sib58	Half sib78	-
-	Half sib 19	Half sib39	Half sib59	Half sib79	-
-	Half sib20	Half sib40	Half sib60	Half sib80	-

Table 2. Summary of genetic variation statistics RAPD, SSR and combination of both RAPD and SSR profiling among the genotypes of *Salix sps* grouped according to sex.

	Sample size	Na	Ne	H	I	Ht	NPL	PPL
RAPD markers								
Male	10	2.00	1.698	0.398	0.583	0.398	61	100
		(0.00)	(0.234)	(0.094)	(0.108)	(0.009)		
Half sibs	80	2.00	1.720	0.412	0.601	0.412	61	100
		(0.00)	(0.178)	(0.065)	(0.071)	(0.004)		
Female	4	1.917	1.697	0.390	0.563	0.390	60	91.67
SSR Marker								
Male	10	2.00	1.561	0.351	0.533	0.351	59	100
		(0.00)	(0.174)	(0.074)	(0.086)	(0.005)		
Half sib	80	2.00	1.389	0.278	0.450	0.278	59	100
		(0.00)	(0.070)	(0.036)	(0.045)	(0.001)		
Female	1.983	1.677	0.396	0.581	0.396		58	98.33
	(0.129)	(0.188)	(0.073)	(0.094)	(0.005)			
Combination of RAPD and SSR markers								
Male	10	2.00	1.629	0.375	0.558	0.375	120	100
		(0.00)	(0.217)	(0.088)	(0.100)	(0.008)		
Half sibs	80	2.00	1.555	0.345	0.526	0.345	120	100
		(0.00)	(0.214)	(0.085)	(0.096)	(0.007)		
Female	4	1.950	1.687	0.393	0.572	0.393	114	95
		(0.219)	(0.240)	(0.107)	(0.144)	(0.011)		

Na, Observed number of alleles; Ne, Effective number of alleles; H, Nei's gene diversity; I, Shannon's Information index; Ht, Heterozygosity; NPL, Number of polymorphic loci; PPL, Percentage of polymorphic loci

respective values for overall genetic variability for Na, Ne, H, I, Ht, Hs, Gst, NPL, PPL and Gene flow (Nm) across all the 94 genotypes were also given in Table 3. The rate of gene flow estimated using Gst value (70.93) was found to be very high. Analysis of molecular variance among genotypes based on three major groups with respect to 4 female, 10 male, and 80 half sibs plant indicated that majority of genetic variation (99.53%) occurred among genotypes, while the variation between the three groups was minimum (0.50%) (Table 4).

SSR analysis: The 10 SSR primers selected in the study generated a total of 33 SSR bands (an average of 3.3 bands per primer), out of which 26 were polymorphic (78.8%). Among the dinucleotide repeat types (AG)n and (GA)n were produced more number of bands followed by (CT)n, and (AC)n. Similarly among the tri-nucleotide repeat types, (CTC)n produced more number of bands. The primers that were based on the (GA)n, (AG)n and (CT)n motif produced more polymorphism than the primers based on any other motifs used in the present investigation. We obtained good amplification products from primers based on (AG)n and (GA)n repeats, despite the fact that (AT)n di-nucleotide repeats are thought to be the most abundant motifs in plant species (Martin and Sanchez-helamo , 2000). A possible explanation of these results is that SSR primers based on AT motifs are self-annealing, due to sequence complementarity, and would form dimers during PCR amplification (Blair *et al*., 1999) or it may be due to its-non annealing with template DNA due to its low Tm. The resolving power (Rp) of the 10 SSR primers ranged from 2.118 to 6.882 (Singh *et al.,* 2013). Similarly the PIC value ranges from 0.105 to 0.777 demonstrating uniform polymorphism rate among all the 10 SSR primers.

The complete data set of 723 bands was used for cluster analysis based on bootstrapping and NJ method. The genotypes were clustered into three major clusters, well supported by bootstrap value of > 20 (Figure 2a). The estimated likelihood of the clustering of data using structure was found to be optimal i.e. ΔK reached its maximum value when K = 3 (Figure 2b[A]), suggesting that all the populations were distributed with high probability into one of the 3 clusters (Figure 2b[B]). The clustering pattern of the genotypes were almost similar to the splitting in the NJ tree, however, there is no distinct clustering of genotypes based on their 4 female, 10 male, and 80 half sibs plants.

A relatively high genetic variation was detected among the genotypes categorized into 3 different groups. Genetic diversity analysis in terms of Na, Ne, H, I, Ht, Hs, and PPL

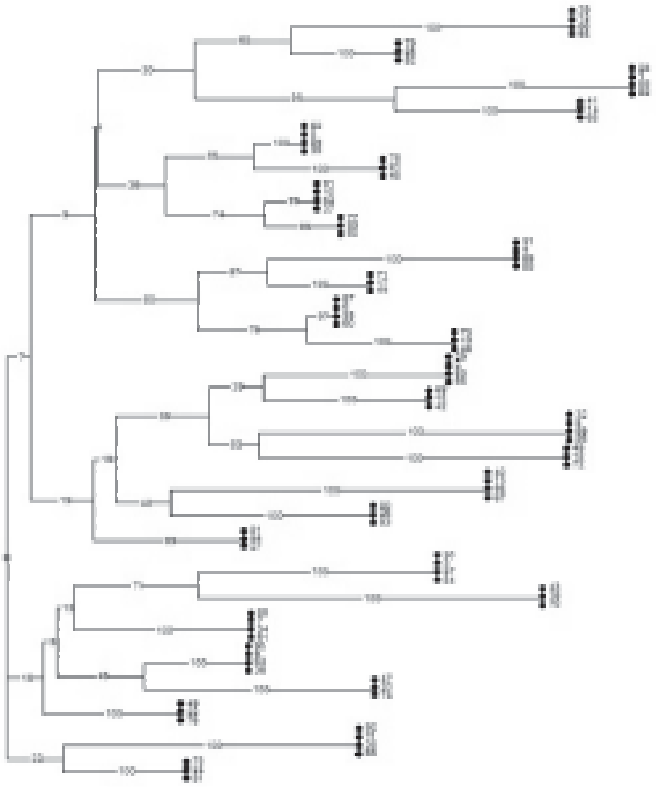

Fig. 1a. Dendrogram generated by Neighbor joining (NJ) clustering technique showing relationships between 94 genotypes of *Salix* based on RAPD profiling. Number indicates bootstrap support values.

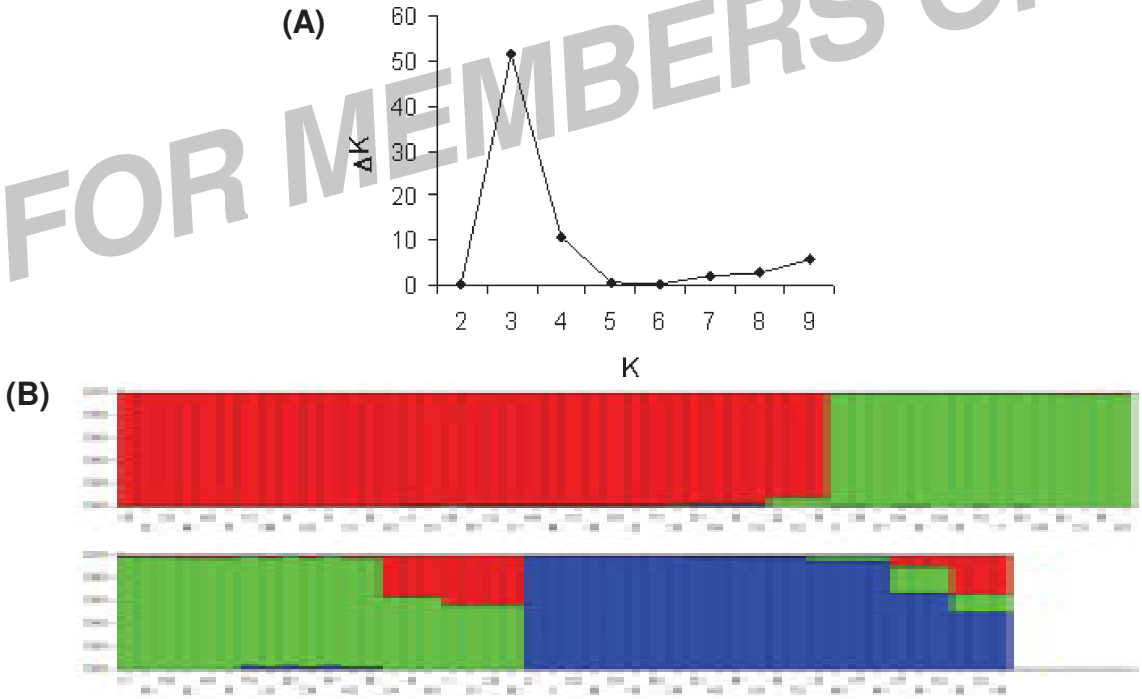

Fig. 1b. A model based clustering of 94 genotypes of *Salix sps* based on RAPD profiling and using STRUCTURE without prior knowledge about the populations and under an admixed model. (A) The relationship between K and ΔK., i.e. ΔK is reaches its maximum when K = 3, suggesting that all genotypes fall into one of the 3 clusters. (B) Grouping of genotypes when K = 3. The genotypes were more likely clustered with respect to one of the 3 clusters. Genotypes from different clusters are represented with different colours.

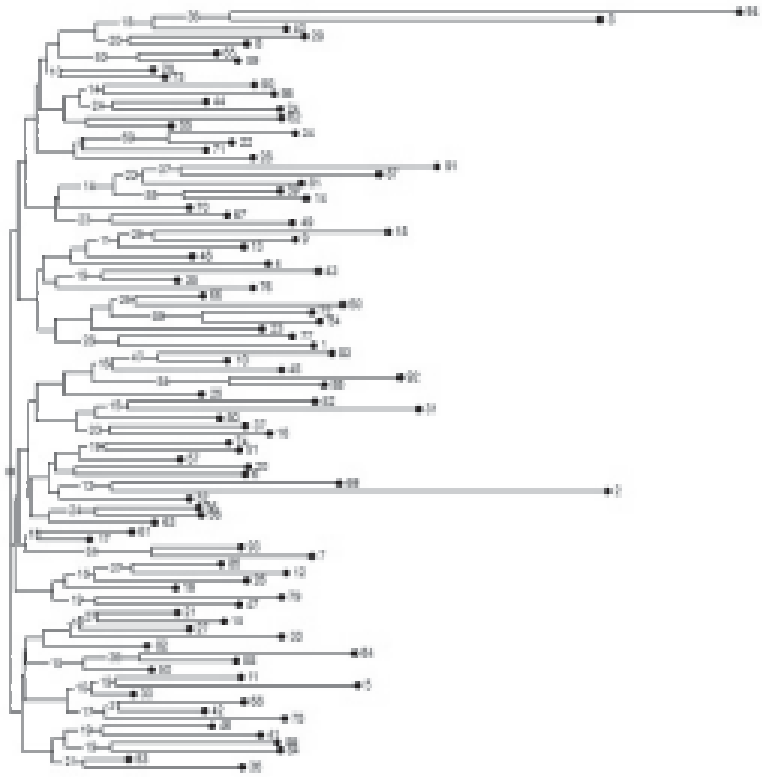

Fig. 2a. Dendrogram generated by Neighbor joining (NJ) clustering technique showing relationships between 94 *Salix* genotypes based on SSR profiling. Number indicates bootstrap support values.

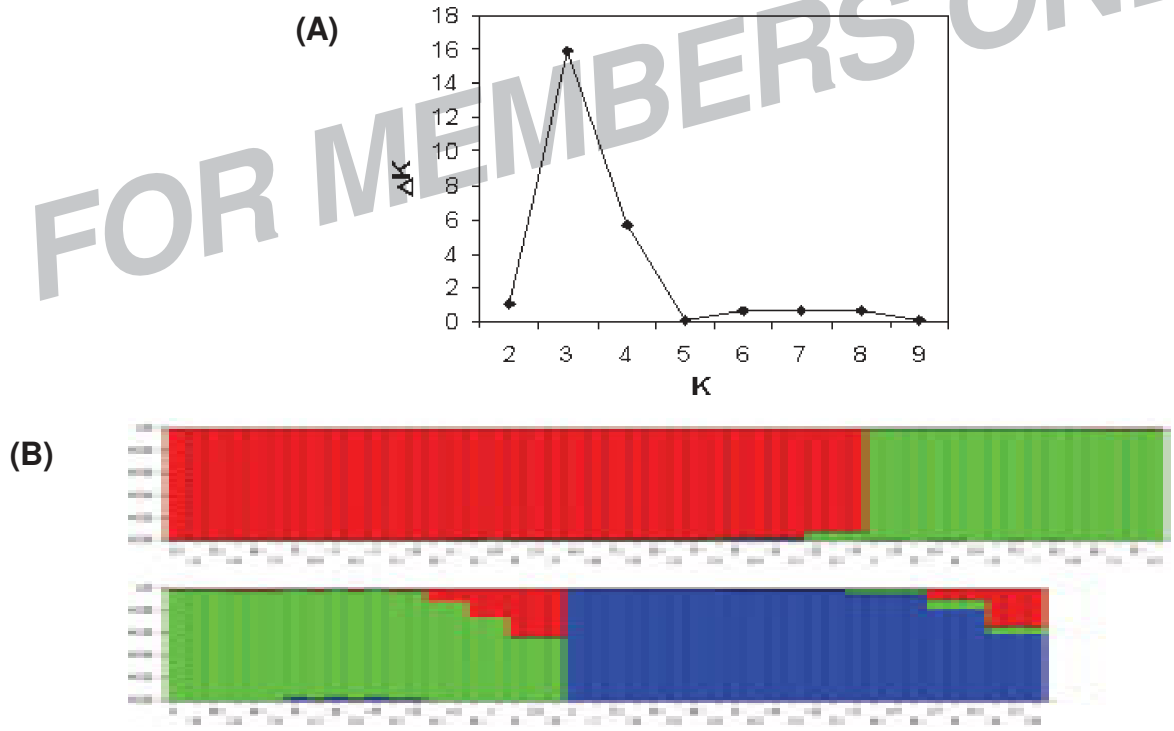

Fig. 2b. A model based clustering of 94 genotypes of *Salix sps* based on SSR profiling and using STRUCTURE without prior knowledge about the populations and under an admixed model. (A) The relationship between K and ΔK., i.e. ΔK is reaches its maximum when K = 3, suggesting that all genotypes fall into one of the 3 clusters. (B) Grouping of genotypes when K = 3. The genotypes were more likely clustered with respect to one of the 3 clusters. Genotypes from different clusters are represented with different colours.

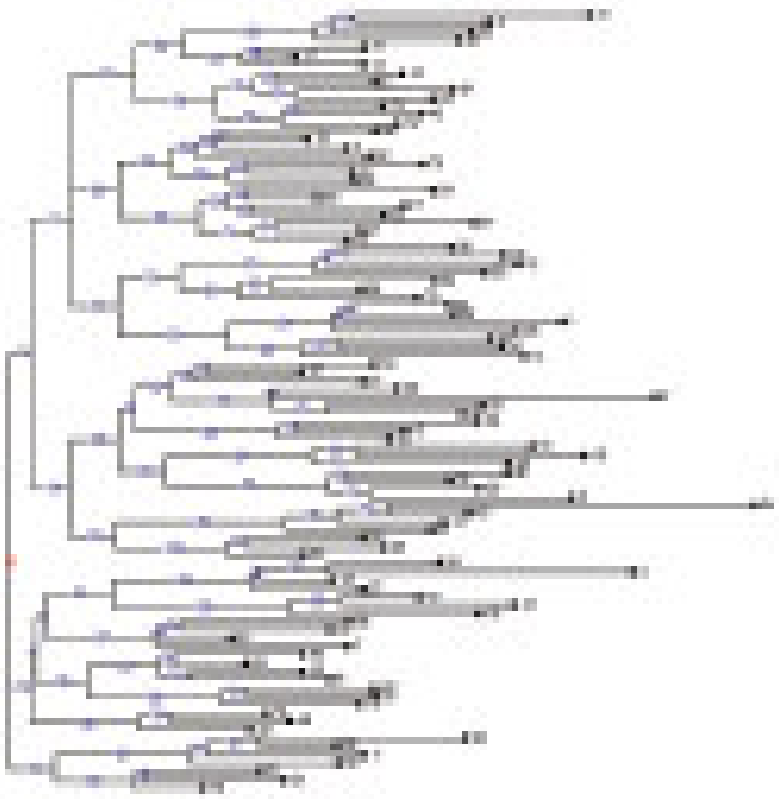

Figure 3a. Dendrogram generated by Neighbor joining (NJ) clustering technique showing relationships between 94 genotypes of *Salix* based on combination of both RAPD and SSR profiling. Number indicates bootstrap support values.

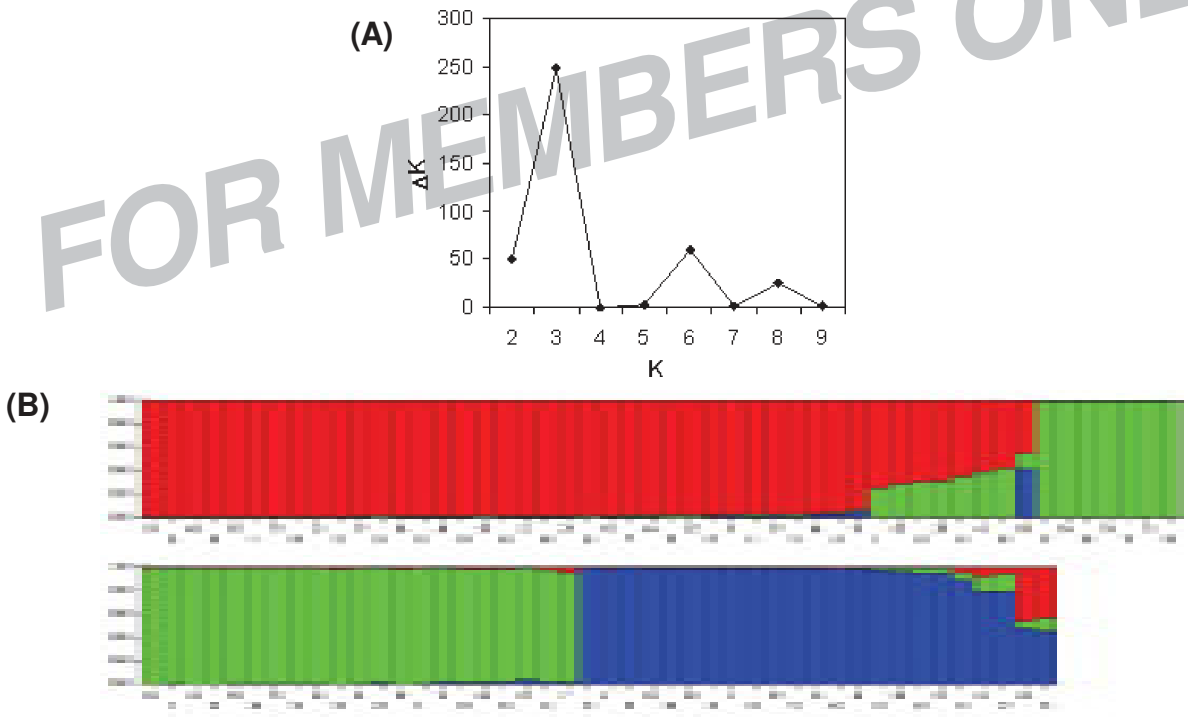

Fig. 3b. A model based clustering of 94 genotypes of *Salix sps* based on combination of RAPD and SSR profiling and using STRUCTURE without prior knowledge about the populations and under an admixed model. (A) The relationship between K and ΔK., i.e. ΔK is reaches its maximum when K = 3, suggesting that all genotypes fall into one of the 3 clusters. (B) Grouping of genotypes when K = 3. The genotypes were more likely clustered with respect to one of the 3 clusters. Genotypes from different clusters are represented with different colours.

Table 3. Overall genetic variability across all the 94 genotypes of *Salix* spp. based on RAPD, SSR and combination of both RAPD and SSR markers

	Na	Ne	H	I	Ht	Hs	NPL	PPL	Gst	Nm
RAPD	2.00	1.721	0.412	0.601	0.412	0.410	61	100	0.042	70.93
	(0.00)	(0.179)	(0.065)	(0.071)	(0.004)	(0.004)				
SSR	2.00	1.422	0.296	0.471	0.296	0.291	59	100	0.025	32.83
	(0.00)	(0.063)	(0.031)	(0.038)	(0.001)	(0.001)				
RAPD+SSR	2.00	1.572	0.354	0.536	0.354	0.350	120	100	0.037	49.5
	(0.00)	(0.201)	(0.078)	(0.086)	(0.006)	(0.006)				

Gst, Genetic differentiation; Nm, Gene flow

Table 4. Summary of analysis of molecular variance (AMOVA) based on RAPD, SSR and combination of both RAPD and SSR markers among the genotypes of *Salix* spp. Levels of significance are based on 1000 iteration steps.

Source of variation		Degree of freedom	Variance component	Percentage of variation	P-value
(a)	Based on RAPD profiling				
	Among groups	2.0	0.042	0.496	-
	Among genotypes	91.0	8.953	99.53	< 0.001
(b)	Based on SSR profiling				
	Among groups	2.0	0.063	0.880	-
	Among genotypes	91.0	7.094	99.16	< 0.001
(c)	Based on combination of both RAPD and SSR profiling				
	Among groups	2.0	0.069	0.944	-
	Among genotypes	91.0	7.242	99.06	< 0.001

reveals higher value for the group with 4 female, 10 male, and 80 half sib plants. This disparity may be because of more number of genotypes included in the group with 4 female, 10 male, and 80 half sibs (Table 2). Overall genetic variability across all the 94 genotypes in terms of Na, Ne, H, I, Ht, Hs, Gst, NPL, PPL and Gene flow (Nm) were also included in Table 3. The Nei's genetic diversity index was 0.296 and Shannon information index was 0.471 demonstrating high rate of genetic variability. AMOVA for among groups (0.88%) and among genotypes (99.16%) indicated that there are more variations across the genotypes and not among the groups (Table 4). The estimated gene flow was 32.83.

RAPD and SSR combined data for cluster analysis: Based on combined data set of RAPD and SSR markers, the dendrogram obtained gave similar clustering pattern like RAPD and SSR (Figure 3a). This result is corroborate with STRUCTURE analysis; the estimated likelihood of distribution for all the 94 genotypes was highest i.e. ΔK was maximum with K = 3 (Figure 3b[A]), reveals that all the genotypes were clustered better (with high likelihood probability) with 3 clusters (Figure 3b[B]). Other genetic variation studies were also performed on RAPD and SSR combined data which are represented in different tables (Tables 3, 4 and 5). The differences found among the dendrograms generated by RAPDs and SSRs could be partially explained by the different number of PCR products analyzed reinforcing again the importance of the number of loci and their coverage of the overall genome, in obtaining reliable estimates of genetic relationships as observed by Loarce *et al.* (1996) in barley. Another explanation could be the low reproducibility of RAPDs (Karp *et al.*, 1997). The genetic similarity of these genotypes is probably associated with their similarity in the genomic and amplified region.

Comparative analysis of RAPD with SSR markers: RAPD markers were found more efficient with respect to number of polymorphism detection (based on average NPL value), as they detected 61 polymorphism loci as compared to 59 polymorphism loci for SSR markers. This is in contrast to the results obtained for several other plant species like wheat (Nagaoka and Ogihara, 1997) and *Vigna* (Ajibade *et al.,* 2000). More polymorphism in case of RAPD than SSR markers might be due to the fact that 10 SSR primers used in the study only amplified 732 number of fragments. While in case of RAPD, all the 15 primers which were used in the investigation amplified 1795 number of fragments (Table 1). This shows that RAPD data is more close to RAPD+SSR combined data. A possible explanation for the difference in resolution of RAPDs and SSRs is that the two-marker techniques target different portions of the genome. The mean effective multiplex ratio is more for RAPD (6.246) than that for SSR (4.588) and similarly marker index is more for RAPD (0.876) than that for SSR (0.751) markers.

Based on polymorphic feature, genetic diversity, genetic similarity, and gene flow among the populations of *Salix* based on molecular markers study, it is recommend that any future conservation plans for this species should be specifically designed to include representative populations with the highest genetic variation for both *in situ* conservation and germplasm collection expeditions.

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Genetic Resources of Bamboo in Orissa (India)

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Abstract: Orissa is traditionally an agrarian state and the rural people including tribals are very much dependent on bamboos since time immemorial. It holds over 134 million tonnes of bamboo, which exists mostly in the forest areas. The annual production of bamboo in the state is approximately 2 lakh tonnes of which 55,000 tonnes is produced from private land. *Dendrocalamus strictus, Bambusa bambos, Bamusa vulgaris* and *Bambusa nutans* are the major bamboo species of Orissa. *Schizostachyum pergracile, Gigamtochloa rostrta, Thyrsostachys oliveri* and *Bambusa tulda* are grown at small scale in specific locations either in forests or in village areas. Besides these more than fifty species of bamboo are grown in bambusetums of different organizations for conservation.

Key Words: Orissa, bamboo, genetic resource, conservation strategies

Orissa, the East Indian State, is unique in geography location, physiographical features, agro-ecological condition, demographic composition, natural resources and socio-cultural heritage. It holds both coastal and continental climate. It has 155707 km^2 geographical area, which constitutes 4.74% area of the country. The state lies between latitude 17^{0}47' and 22^{0}34' N and longitude 81^{0}22' and 87^{0}29' E and experiences both tropical and sub-tropical climate. Physiographically, the state can be divided into four regions, viz. Northern Plateau, Eastern Ghats, Central Tableland and Coastal Plains. It has been divided into 10 agro-climatic zones based on land farm, topography, climate, soil and coastal plains. The average annual rainfall varies from 1200 to 1600 mm and mean annual temperature ranges between 25 to 27.5^{0}C. The state is rich in groundwater, mineral wealth, fertile soil and diverse flora and fauna. The state has more than 480 km coastal line. As per the census 2011, the total population of the state is 41947358. The rural population constitutes 85% of the total population. The scheduled tribe and scheduled caste population constitute 22 % and 16.5% of the population, respectively. The above facts have led the state traditionally an agrarian state and the rural population including tribals have been depending on forests including bamboos since time immemorial.

The state has forest area of 48,855 km^2, which is 31.38% of the state's geographical area (FSI, 2009). The state has 19 different forest types as per Champion and Seth's classification 1968 belonging to 4 type groups viz. Northern Tropical Semi Evergreen, Northern Tropical Moist Deciduous, Littoral and Swamp and Northern Tropical Dry Deciduous Forests. The major species occupying the Orissa forests are sal, teak and bamboo. The approximate area under forests of different major species are : sal forest – 16938. 25 km^2, miscellaneous forest – 21024.34 km^2, teak forest – 2030.64 km^2, pure bamboo forest – 474.77 km^2, mixed bamboo forest – 17794.61 km^2 and mangrove forest – 219 km^2. The agro-ecological and socio-cultural features of Orissa have led bamboo to be associated closely with people of Orissa. This state has potential to accommodate a vast genetic resources of bamboo. An attempt has been made to compile and document information on genetic resources of bamboo in Orissa, which will be useful to common people, researchers, students, foresters, bamboo entrepreneurs and other stake holders of bamboo.

Bamboo Resource in Orissa

Orissa posses the third largest bamboo resource of India after Madhya Pradesh and Maharashtra containing 8.7% of the bamboo area. It accounts 7% of the estimated stock of the country bearing over 134 million tonnes, which exists mostly in the forest areas. In Orissa, bamboo is grown in forest areas as well as non-forest areas. In forest areas *Dendrocalamus strictus* (salia bamboo) and *Bambusa bambos* (daba bamboo) area the dominating bamboo species, whereas, in homesteads and cultivated areas *Bambusa vulgaris* (sunderkani bamboo) and *Bambusa nutans* (badia bamboo) are the dominating bamboo species. All the 30 districts of Orissa have bamboo resources. Concentration of bamboo is high in Mayurbhanj, Keonjhar, Sambalpur, Nayagarh in North Orissa, Kandhamal (Phulbani), Kalahandi, Ganjam, Koraput in South and South-Central Orissa. The annual production of bamboo in the state is approximately 2 lakh tonnes of which 55,000 tonnes is produced from private land.

I. Major Bamboo Species in Orissa

There are four major bamboo species grown in Orissa such as *Dendrocalamus strictus, Bambusa bambos, Bamusa vulgaris* and *Bambusa nutans* (Swain, 2005). The former two species generally occur naturally in forest areas and later two

are cultivated in private lands. The farmer two species are also found outside forest areas in small extent and even grown by people in private lands. The specific characteristic, distribution and uses of these species in Orissa are given here.

A) *Dendrocalamus strictus* Roxb.: This is the most gregarious natural bamboo of Orissa and locally called as salia baunsa. Generally, it is a deciduous and densely clumped species. There are three different variants of this bamboo such as (i) tall culms with moderately thick walls and a small lumen generally found in moist hill slopes of Ganjam and Phulbani districts, (ii) culms of medium height, fully solid or nearly so and 3-4 cm in diameter and (iii) culms with larger lumen and thin walls generally found in depressions and dry areas. Salia bamboo is used for construction of houses, agricultural implements, musical instruments, furniture, mats, baskets and above all paper and pulp. Young shoots are commonly used as food.

B) *Bambusa bambos* Voss. : This is a large thorny bamboo species forming dense clump. Two variants of this are found in Orissa, one being very tall with large diameter and lumen (locally called as Daba baunsa) and the other producing medium sized but think walled culms (locally called as Kanta baunsa). The former is seen in moist valleys in semi-evergreen forests and the latter in the lateritic soil. The most common use of this species is for paper and pulp. It is used for rafters, scaffolding, roof thatching, cart making, basket making, furniture making, etc. The thorny branches are used for fencing. Young shoots are edible. Wild animals particularly elephants and gaur relish the young shoots in forests.

C) *Bambusa vulgaris* Schrad.: This is the commonly cultivated and moderate sized bamboo in Orissa and locally called as Sunderkani baunsa. The cultivation package of this species has been developed at Orissa University of Agriculture and Technology, Bhubaneswar (Bhol and Nayak, 2008). There are three variants of this species found in farmlands of Orissa, (i) one has very tall culms with bigger diameter, much hollow inside and arching above 2/3rd of its height, (ii) second is of medium height, thick walled, comparatively erect and arching towards top and (iii) third variant has culms of 6-8 m high, 4-5 cm diameter and very much arching from the mid height. This species flowers sporadically in very few culms in the state, but does not produce seeds (Bhol, 2006; Bhol and Nayak, 2010).This species is extensively used for construction, implements, manufacturing of household articles and handicrafts. The artisans prefer this bamboo as compared to salia bamboo.

D) *Bambusa nutans* Wall.: This is a big sized, luxuriant, cultivated bamboo and locally called as badia baunsa. This species flowers sporadically in very few culms in Orissa. The flowering occurs either in parts of the clump or in whole clump. This is commonly cultivated in the villages particularly in Mayurbhanj and Baleshwar districts of the state, occasionally planted in other districts. This is the most preferred bamboo species in the state for building purposes and for scaffolding. The culm is good, strong and straight, thus has a variety of uses. It is also used for mat making and incense sticks. Large quantities of culms are supplied to paper pulp industries and bamboo wood chip industries.

II. Bamboo Species Grown on Limited Scale

There are four bamboo species such as *Schizostachyum pergracile, Gigamtochloa rostrta, Thyrsostachys oliveri* and *Bambusa tulda* are grown on small scale in specific locations either in forests or in village areas. The specific characteristics, distribution and uses of such species in Orissa are given here.

A) *Bambusa tulda* Roxb.: It is locally called as tarala or taleda baunsa. It is a densely tufted bamboo forming dense clump. This species is cultivated in different parts of the state in limited scale, but found relatively more in Baleshwar and Mayurbhanj districts. It is preferred in basket making and woven applications. It is very often used in cultivation of betel vine and roof of thatched houses. It is suitable for mechanized processing for bamboo boards and composites and for manufacture of wrapping, writing and printing paper. Young shoots are used for making excellent pickles.

B) *Schizostachyum pergracile* Munro: Its synonym is *Cephalostachyum pesgracile* Munro and locally it is called as dangi baunsa. It is a deciduous, arborescent, tufted bamboo of moderate size. This species is found occasionally in shady valleys and near streams/nalla banks deep inside the forests. The clumps are found on the lower slopes of hills where *Dendrocalamus strictus* is found on higher slopes. The sporadic clumps are found in Dango-West reserve forest of Phulbani Forest Division. The bamboo is soft and the green culm has the property to split and crack on drying. Because of softness even at the nodes, it is extremely popular among the artisans for making fine works such as hats, flower baskets, decorative mats, etc. The single internode culm pieces are used as blow pipes by rural women for fanning fire in the hearth.

C) *Gigantochloa rostrata* Wong.: Its synonyms are *Gigantochloa maxima* var. *minor* Holttum and *Oxytenanthera nigrociliata* Munro. It is locally called as bolangi or pani baunsa. It is a tufted dark green bamboo of small size and forms dense clump. This species is found in moist valleys

along the stream banks in Khurda and Kandhamal district. The bamboo is used for making huts and baskets. Its special use is for stitching leaf plates. It is said that tribal women present bundles of stitching sticks prepared from this bamboo to their relatives as gift while they visit them where this is not available.

D) *Thyrsostachys olivari* Gamble : This is called as nala baunsa locally. It is a moderate sized tufted elegant bamboo. This species is a native of Myanmar (Burma). It is believed that it has been brought from Burma and introduced by some people of Nayagarh and Ganjam district of the state who were working there long years ago. This bamboo is used for construction of thatch houses, basket making and mat making. Farmers prefer it to use as pole or stick required in agricultural works. This species has potential to be included in agroforestry systems because of small crown and straight growing behaviour.

III. Bamboo Species Grown Sparsely

There are some bamboo species grown by people in countable number of clumps primarily for ornamental purpose. However, these can be used for construction works. These are grown in parks, gardens and/or homesteads. This category includes the species given in Table 1.

IV. Bamboo Species Grown in Bambusetums/ Germplasm Banks

In Orissa different organizations like State Forest Department, Orissa University of Agriculture & Technology, Regional Plant Resource Centre, etc. are engaged in research and development of bamboo. These organizations are maintaining few clumps of different bamboo species in their respective bambusetums/germplasm banks (Table 2).

Besides these species, the common bamboo species like *Dendrocalamus strictus, Bambusa bambos* and *Bambusa vulgaris* are grown in small blocks in other silvicultural gardens of the state.

Recent Initiatives to Enhance Bamboo Resources

The Government of Orissa has set up Orissa Bamboo Development Agency (OBDA) during the year 2007 for addressing all aspects of bamboo sector development including enhancing the bamboo resources of the state. Under this, a state plan scheme called Orissa Bamboo Development Programme has been launched since 2008-2009 and over 2574 hectares of bamboo plantations have been established by 2011-2012 (OBDA, 2011). Bamboo plantation is even being encouraged under MGNREG scheme. To encourage easy removal of bamboo from private lands vis-à-vis more bamboo plantation, the species mostly grown and found on such lands viz. *Bambusa vulgaris, Bambusa nutans* and *Bambusa tulda* have been exempted from the purview of transit permit.

National Bamboo Mission (NBM) is also operating in Orissa since 2006. So far 3902 hectares of plantations have been taken up in forest areas over 36 Forest Divisions with major concentration in Bolangir, Ghumsur, Kalahandi, Koraput and Baripada Divisions. Similarly in non-forest areas, 2225 hectares covering 2885 beneficiaries in 25 districts with major concentration in Baleshwar, Mayurbhanj, Kalahandi, Ganjam, Koraput and Kandhamal districts have been developed (OBDA, 2011).

Orissa is a potential state to accommodate vast genetic resources of bamboo and utilize them for wellbeing of people. The rural population which accounts about 85% of the total population is very much dependent on bamboo besides there is wide use of bamboo in urban areas and paper mills. Although 12 species of bamboo have naturalized in the state,

Table 1. Particulars of bamboo species grown in few individuals in Orissa (India)

S. No.	Species	Local name (Oriya name)	Brief characteristics in Orissa condition
1.	*Bambusa striata* Lodd. ex Lindl. / *B. vulgaris* var. *striata* Lodd. ex. Londl.	Champa baunsa	A graceful tufted bamboo. Culms 8-10m high, 4-7cm diameter, yellow with light green stripes or rarely light green with yellow stripes. Internodes 15-25cm long, thick walled.
2.	*Bambusa wamin* Camus / *B. vulgaris* cv. *wamin* McClure	Budhapeta baunsa/ Bottle baunsa	A medium to small size graceful bamboo, culms 3-6m high, loosely tufted usually arching at top, dark green, shinning, glabrous. Internodes 10-15cm long much swollen (pitcher shaped) in the lower half, lower 3 or 4 nodes with root lets.
3.	*Thyrsostachys regia* (Munro) Bennet/ *Thyrsostachys siamensis* Gamble	Lathi baunsa	A grraceful small bamboo. Clump is compact with culms, which curve out at upper height. Culms 5-7m high, 2-4cm diameter, thick walled, usually covered with persistent sheaths, nodes hardly thickened with a white band below. Internodes 25-30cm long, light green.
4.	*Dendrocalamus giganteus* Munro/ *Bambusa gigantea* Wall.	Rakshasha baunsa	It is the longest bamboo with close culms and slender branches. Culms 20-25m tall, 15-25cm diameter, usually 1.5-2.0cm thick walled, dull green covered with white waxy crust when young. Internodes 35-40cm long, lower nodes with root scars.

Table 2. List of bamboo species grown in bambusetums/germplasm banks of different organizations of Orissa (India)

A. Bamboo species at Bambusetum (inside Knowledge Centre of Orissa Forest Department), Bhubaneswar

S. No.	Species	S. No.	Species
1.	*Bambusa glaucascence*	32.	*Dendrocalamus hookeri*
2.	*Bambusa aureostriata*	33.	*Dendrocalamus sikkimensis*
3.	*Bambusa affinis*	34.	*Dendrocalamus stocksii*
4.	*Bambusa assamica*	35.	*Dendrocalamus strictus*
5.	*Bambusa arundinacea*	36.	*Dinochloa compactiflora*
6.	*Bambusa balcooa*	37.	*Gigantochloa albociliata*
7.	*Bambusa burmanica*	38.	*Gigantochloa atroviolacea*
8.	*Bambusa cacharensis*	39.	*Gigantochloa manggong*
9.	*Bambusa giganteus*	40.	*Guadua angustifolia*
10.	*Bambusa goruchakua*	41.	*Melocalamus maclellandi*
11.	*Bambusa longispiculata*	42.	*Melocanna baccifera*
12.	*Bambusa membranaceus*	43.	*Ochlandra ebrecteata*
13.	*Bambusa nangal*	44.	*Ochlandra scriptoria*
14.	*Bambusa nutans*	45.	*Ochlandra travancorica*
15.	*Bambusa pallida*	46.	*Oxytenanthera parvifolia*
16.	*Bambusa polymorpha*	47.	*Oxytenanthera abyssinica*
17.	*Bambusa striata*	48.	*Oxytenanthera nigrociliata (Giantochloa rostrata)*
18.	*Bambusa tapi*	49.	*Oxytenanthera stocksii*
19.	*Bambusa tulda*	50.	*Phyllostachys aurea*
20.	*Bambusa ventricosa*	51.	*Phyllostachys mannii(assamica)*
21.	*Bambusa vulgaris*	52.	*Phyllostachys nigra*
22.	*Bambusa wamini*	53.	*Phyllostachys bambusoides*
23.	*Cephalostachyum pergracile*	54.	*Pseudossasa japonica*
24.	*Dendrocalamus giganteus*	55.	*Pseudoxytenanthera ritcheyi*
25.	*Dendrocalamus hamiltonii*	56.	*Sasa fortunei*
26.	*Dendrocalamus longispathus*	57.	*Schizostachyum dullooa*
27.	*Dendrocalamus membranaceus*	58.	*Schizostachyum glaucifolium*
28.	*Dendrocalamus multiplex*	59.	*Schizostachyum japonica*
29.	*Dendrocalamus asper*	60.	*Schizostachyum polymorphum*
30.	*Dendrocalamus brandisii*	61.	*Thyrsostachys oliveri*
31.	*Dendrocalamus calostachys*	62.	*Thyrsostachys regia*

B. Bamboo species at Kalinga Research Garden (Silviculture Division, Orissa Forest Department), Kalinga

S. No.	Species	S. No.	Species
1.	*Bambusa nutans*	10.	*Dendrocalamus calostachyus*
2.	*Thyrsostachys oliveri*	11.	*Bambusa balcooa*
3.	*Dendrocalamus strictus*	12.	*Bambusa striata*
4.	*Bambusa wamin*	13.	*Bambusa tulda*
5.	*Bambusa vulgaris*	14.	*Thyrsostachys regia*
6.	*Bambusa bambos*	15.	*Bambusa polymorpha*
7.	*Dendrocalmus giganteus*	16.	*Gigantochloa rostrata*
8.	*Dendrocalamus membranaceus*	17.	*Melocana baccifera*
9.	*Dendrocalamus hamiltonii*	18.	*Dendrocalamus asper*

C. Bamboo species at Khandagiri Research Garden (Silviculture Division, Orissa Forest Department), Bhubaneswar

S. No.	Species	S. No.	Species
1.	*Bambusa bambos*	6.	*Dendrocalamus strictus*
2.	*Bambusa vulgaris*	7.	*Dendrocalamus giganteus*
3.	*Bambusa nutans*	8.	*Thyrsostachys oliveri*
4.	*Bambusa tulda*	9.	*Thyrsostachys regia*
5.	*Bambusa striata*	10.	*Bambusa wamin*

D. Bamboo species at College of Forestry, Orissa University of Agriculture and Technology, Bhubaneswar

S. No.	Species	S. No.	Species
1.	*Bambusa vulgaris*	6.	*Bambusa balcooa*
2.	*Bambusa bambos*	7.	*Thyrsostachys oliveri*
3.	*Dendrocalamus strictus*	8.	*Dendrocalamus brandisii*
4.	*Bambusa striata*	9.	*Bambusa wamin*
5.	*Bambusa nutans*	10.	*Ochlandra travancorica*

E. Bamboo species at Regional Plant Resource Centre, Bhubaneswar (RPRC,2009)

S. No.	Species	S. No.	Species
1.	*Bambusa arundinacea*	16.	*Dendrocalamus strictus*
2.	*Bambusa balcooa*	17.	*Dinochloa maclellandii*
3.	*Bambusa multiplex*	18.	*Gigantochloa rostrata*
4.	*Bambusa nutans*	19.	*Melocana baccifera*
5.	*Bambusa polymorpha*	20.	*Oxytenanthera nigrociliata*
6.	*Bambusa ventricosa*	21.	*Phyllostachys aurea*
7.	*Bambusa vulgaris*	22.	*Phyllostachys nigra*
8.	*Bambusa vulgaris "Vittata"*	23.	*Pleioblastus fortunei*
9.	*Bambusa tulda*	24.	*Pleioblastus pygmaeus*
10.	*Bambusa wamin*	25.	*Pseudossasa japonica*
11.	*Bambusa nangal*	26.	*Sinarundinaria longispiculata*
12.	*Bambusa tapi*	27.	*Thyrsostachys oliveri*
13.	*Dendrocalamus giganteus*	28.	*Thyrsostachys regia*
14.	*Dendrocalamus hamiltonii*	29.	*Thysanolaena maxima*
15.	*Dendrocalamus membranaceus*		

another 50 plus species are growing in different bambusetums. The state has potential to explore the genetic resources of bamboo for development of bamboo sector in the state.

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Agroforestry: An Approach for Food Security

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***Abstract*:** Periodic unavailability of farm inputs, degradation of natural resources and population explosion problems are the main causes of food insecurity. Intensive agricultural practices required to meet food requirements of increasing human population, led to large scale resource degradation. The unavailability of natural resources, high costs and periodic limited availability of mineral fertilizers and other farm inputs have reduced the farm production. The past approaches in agriculture production have failed to reduce food insecurity and sustainability in production. Agroforestry science, and its application by smallholders throughout the tropics, have a potential and played an important role in achieving sustainability in farm productivity. The incorporation of a diverse variety of trees into agricultural systems can increase crop productivity and incomes of smallholding farmers through diverse products *viz.,* edible flowers, fruits and fodder. The well managed multipurpose tree species on farm benefits in the case of efficient use of natural resources enhance the overall (biomass) productivity, improvement in soil fertility, soil conservation and nutrient cycling, micro-climate amelioration, carbon sequestration, bio-drainage, bio-energy and bio-fuel production etc. Nowadays farmers, researchers, policy makers are interested in agroforestry for its ability to contribute in meeting deficit of agricultural and tree products with socio-economic and environmental benefits.

Key Words: Farm productivity, sustainability, agroforestry, livelihood security

Rising human population, abrupt climate changes and unsustainable utilization of natural resources, are the main reasons of decreasing farm productivity. Generally assume that food production is the base for food security but it is not so and food security will not be achieved by focusing only on the increasing crop productivity. However, some researcher suggests that the food scarcity is primarily caused by inadequate distribution, a lack of purchasing power and other non-productive causes. Thus, the emphasis on food production alone is not sufficient to insure future food security but involves judicious use of natural resources, changing climate, socio-economics, etc. FAO has defined food security as a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Agroforestry is a wide-spread land-use system. Agricultural crops, vegetables, forest and horticultural trees, shrubs and grasses are the system components, which made it diverse and productive. It may potentially support livelihoods improvement through simultaneous production of food, fodder and firewood as well as mitigate the problems created by abrupt climate change. Through increasing diverse food production, resource conservation, employment generation and enhancing rural income, agroforestry systems may solve food insecurity problems (Pandey, 2007; Singh and Pandey, 2011; Sharma *et al.,* 2007). Current area under agroforestry is 7.45 million ha, has potential to extend up to 25.36 million ha by next two decades and will meet increasing food requirements of the country (Dhyani *et al.,* 2009).

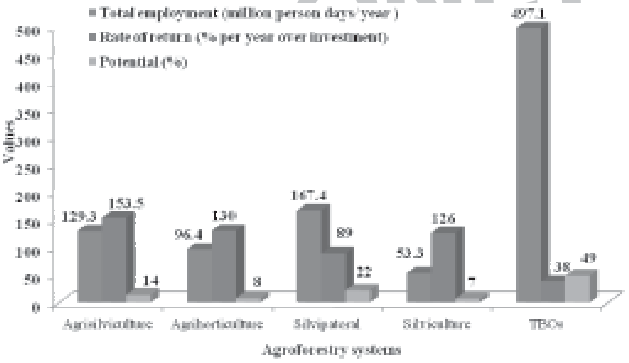

Fig.1. Agroforestry adoption, rate of return and total employment potential (Dhyani *et al.*, 2009)

Resource Conservation and Efficient Utilization

Water and soil nutrients are the most important resources for farm productivity. Continuous resource depletion decreases productivity of the farmlands. Intensive agriculture, climate change and unsustainable use of resources are the main causes of resource degradation. Trees in agro-ecosystems can enhance soil productivity through conservation and efficient use of natural resources (Kumar, 2011). Cardamom based agroforestry system from the North-East India reported best agroforestry system for resource conservation (Sharma *et al.,* 2007). The runoff and soil erosion losses were arrested through *Leucaena* based alley cropping system and improve average soil moisture

(Burman and Gill, 2001). *Prosopis cineraria* and *Tecomella undulata* maintained at optimum tree densities can enhance productivity of associated agricultural crops by improving soil water, organic matter and N availability in degraded lands of Indian desert (Singh, 2009). The coconut-based poly-cultural systems often include diverse kinds of woody perennials, ensures more efficient resource utilization (Kumar, 2006 and 2011). Combining grasses and legumes, such as *Stylosanthes guyanensis*, *Panicum maximum*, *Setaria,* etc. with fodder trees, such as alder (*Alnus nepalensis*) in a silvi-pastoral system stabilizes terrace risers and increases water use efficiency (Fanish and Priya, 2013).

Increase Food Production

The diverse food productions through agroforestry systems are widely contributing to solve food insecurity problems. Applications of agroforestry practices on wasteland are defiantly going to increase country's food production potential. The fig.1 showes the potential of most widely adopted agroforestry systems of India. Woody perennial components may cause competition with annual crops; however, it showed food production potential on degraded lands with appropriate management practices. The yield of some important food crops under different woody species is given in table 1. Ginger rhizome yield in the interspaces of *Ailanthus triphysa* and *Acacia mangium* was increased with increasing thinning intensity exhibited better growth and yield compared to without tree systems (Kumar, 2011). The yield of rice crop was increased due to residual nitrogen effect of *Acacia nilotica* trees in central India (Singh and Pandey, 2011). The wider spacing of kapok trees intercropping with wheat significantly increases crop yield and yield attributing characteristics (Singh *et al.,* 2004). Poplar-wheat based agroforestry system is most popular and widely adopted food production system in northern plains of India (Chauhan *et al*., 2010).

Increase Livestock Production

Silvi-pastoral system from different regions (arid, semi-arid and hill) of India widely provides fodder for grazing animals during lean period. Nutritive fodder from *Albizia amara*, *Leucaena leucocephala* trees and *Chrysopogon fulvus*, *Sehima* spp., *Heteropogon* spp. grasses, *Stylosanthes hamata*, *S. scabra* pasture legume species increases body weight of goat and sheep. *Prosopis cineraria, Grewia optiva, Celtis australis* and *Morus alba* other fodder yielding tree species has potential to provide fodder in fodder deficient period. Forage yield of 13.5 t/ha was obtained from the combination of *Stylosanthes* and *Setaria* from silvi-pastoral system, which improves livestock production (Fanish and Priya, 2013).

Nutrition and Health

Advances in agroforestry have many links with improving the health and nutrition of the rural poor people. Fruit plants are the most valuable component of agri-horticulture systems. The fruit tree cultivation on farms can have a significant effect on the quality of child nutrition. This is particularly important as indigenous fruit tree resources in local forests are overexploited. They yield nutritious fruits and serve rich source of minerals, vitamins and important alkaloids. The nutritional status of important fruit crops is given in table 2. Local peoples are widely using these fruits in their diets and medicine as well.

Increase Wood and Non-wood Forest Products

More than half of the timber requirement is being met from agroforestry systems. *Eucalyptus*, poplar, *Salix*, *Acacia mangium* and *Casuarina* are the most important industrial agroforestry tree species. The 50 % of the demand of fuel wood is being met from farmlands and community land (Dhyani *et al.,* 2009). Home gardens in the state Kerala with a diverse tree and shrub species constitute a principal source of bio-fuels for most (51% to 90%) rural households (Kumar, 2011).

Enhance Rural Income

The TBOs (Tree born oil seeds) based system generates employment to the 497.1 million persons per year, whereas, agri-silviculture gives 153.5% rate of return (Fig. 1). The intensity of profit generation was highest for the smaller home gardens with both adaptive managements and the presence of other intangible benefits. Enhancing rural income through agroforestry systems helps to poverty alleviation (Garrity, 2004). The net present value for the different agroforestry models on six years rotation in Haryana varied from Rs. 26626 to Rs.72705 ha^{-1} yr^{-1}, whereas, the benefit:cost ratio and the internal rate of return varied from 2.35 to 3.73 and 94 to 389%, respectively (Kumar *et al.,* 2004). Average net monetary benefit from guava based agroforestry systems was Rs. 20,610 per hectare and Rs. 13,787.60 per hectare from lemon based agroforestry systems in Assam. Such systems are most useful livelihood improvement strategies in the rainfed systems (Bhatt and Misra, 2003). The combination of *Acacia* and rice traditional agroforestry system has a benefit/cost (B/C) ratio of 1.47 and an internal rate of return (IRR) of 33% at 12% annual discount rate during a ten year period (Viswanath *et al.,* 2000). In case of commercial agroforestry systems, additional income (71.3 %) was the major factor in their adoption (Dwivedi *et al.,* 2007).

Table 1. Productivity of food crops under different agroforestry systems

Agroforestry systems Plant species	Agri-silviculture	Horti-silviculture	Agri-horticulture	Home gardens/ Plantation crop based systems	Sources
Triticum aestivum L.	25.60 q ha^{-1}				Singh *et al*. (2004)
Oryza sativa L.	37.07 q ha^{-1}		30.58 q ha^{-1}		Thaware *et al*. (2004); Tomar and Bhatt (2004)
Sorghum bicolor L. Moench	16.90 q ha^{-1}				Divya *et al*. (2004)
Vigna radiate L.	8.64 q ha^{-1}				Pandey and Tewari (2004)
Glycine max L. Merril	14.2 q ha^{-1}				Mishra *et al*. (2004); Patil *et al*. (2012)
Brassica campestris L.			5.77 q ha^{-1}		Lal *et al*. (2004)
Brassica juncea L.	10.62 q ha^{-1}				Lal *et al*. (2004)
Solanum tuberosum L.		131.1 q ha^{-1}			Kumar and Nandal (2004)
Citrus limon (L.) Burm.F.			27.61 q ha^{-1}		Tomar and Bhatt (2004)
Prunus persica (L.) Stokes			64.44 q ha^{-1}		Tomar and Bhatt (2004)
Psidium guajava L.			58.11 q ha^{-1}		Tomar and Bhatt (2004)
Zizyphus mauritiana			140.55 q ha^{-1}		Zhang *et al*. (2013)
Zingiber officinale Roscoe			127.07 q ha^{-1}		Vanlalhluna and Sahoo (2009)
Curcuma longa L.				115.22 q ha^{-1}	Vanlalhluna and Sahoo (2009)
Theobroma cacao L.				37.28 kg $tree^{-1}$	Isaac *et al*. (2007)

Table 2. Nutritional value of fruit plants used in agroforestry systems

Nutritional value	Aonla	Ber	Jamun	Mahua	Imli	Bael
Carbohydrates (%)	14	17.1	19.7	22.9	67.4	31.8
Protein (%)	0.5	0.8	0.7	1.4	3.1	1.8
Fat (%)	0.1	0.3	0.1	1.6	0.1	0.4
Ca (mg/100g)	50	4.0	20	45	170	-
P(mg/100g)	20	9.0	10	22	110	-
Fe(mg/100g)	1200	1.8	1000	1.1	11	-
Vit-A(mg/100g)	-	0.002	-	512	0.06	55
Vit-B(mg/100g)	30	0.74	-	-	0.14	1.32
Vit-C(mg/100g)	600	76	-	41	3.0	8.0

Agroforestry has potential to increase food production through resource conservation, reclamation of degraded lands and efficient use of natural resources. The diverse and nutritious food production will be the major component of the food security policy statement. It also helps to ensure livelihood security through generating rural income and employment.

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Nursery Evaluation of Selected Tree Willow (*Salix* Spp.) Clones: Estimation of Variability, Heritability, Genetic Gain and Correlation

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Abstract: The promising *Salix* species/clones and hybrids were procured from different countries and introduced at UHF Nauni, Solan, India during the year 2002-04. After nursery screening, the selected clones were planted in the field. These selected clones were repeatedly raised in nursery every year from 2011 to 2013 to find out the most adaptive and superior clones along with check clone (Kashmiri willow). Plant survival, height and basal diameter were recorded and volume index was calculated. The data revealed significant differences among clones. Plant survival was at par among clones except in clones J194, NZ1002 and V-311. Maximum plant height (389.77 cm) was recorded by clone J799 followed by clones J795 (355.36 cm) and NZ 1002 (344.95 cm). Basal diameter was recorded at par in the clones SI-64-017 (17.66 mm), J799 (17.52 mm), NZ1002 (16.49 mm), 131/25 (16.25 mm) and NZ1140 (16.11 mm). The clone J799 recorded maximum (1329 cm^3) volume index, which was at par with clone SI-64-017 (1171 cm^3) followed by clone NZ 1002 (1015 cm^3). Check clone Kashmiri willow remained at 5th, 6th, and 7th position for basal diameter, plant height and volume index, respectively. The selected clones have to be tested in the field conditions to find the genotype x environment interaction.

Key Words: Willow, clones, genotype x environment interaction, heritability, genetic gain, correlation, volume index

The genus *Salix* is popularly known for its fast growth, wide geographic adaptation with a significant economic value. It comprises of about 350–500 species worldwide (Argus, 1997), distributed over wide ecological and climatic zones ranging from North America to China, excluding Australasia (Trybush *et al.,* 2008). These are multipurpose and eco-friendly species having variety of end uses viz., baskets, cricket bats, hurdles, furniture, plywood, paper and pulp, rope making, etc. (Verwijst, 2001; Kuzovkina *et al.,* 2008; Andleeb *et al.,* 2011; Sharma *et al.,* 2011). The arborescent willow species are able to grow on various types of soil and are most suitable for the biological control of soil erosion, siltation, nutrient recycling, phyto-remediation, carbon sequestration and filtering of sewage polluted water (Zalesny and Bauer, 2007).

In India, there are about 31 indigenous and 4 exotic species of willows (Saini and Sharma, 2001) but majority of them are not suitable for industrial use (Sharma *et al.,* 2011 and Singh *et al.,* 2012a). Under short rotation forestry, they are better adopted in monoculture as well as in agroforestry system. Sinha and Sharma (2002) have emphasized the suitability and growth pattern of *Salix* species in Himalayan foot hills. Most of the arborescent species of *Salix* are confined to hilly region of the country except *S. tetrasperma* and *S. babylonica,* which occur right from tropical to temperate regions of India (Sharma *et al.,* 2011).

Stability of clones for growth and yield traits helps in enriching the tree improvement programme by assessing the profitability of a plantation because grower can choose the most stable material to the specific site (Sixto *et al.,* 2011). Stability analysis is done from the data of replicated trials conducted over many locations or for many years on same location or both (Gupta *et al.,* 1997). Different environmental conditions created at one location are a common practice in agriculture crops to find the stable genotypes for various climates (Sharma, 2006). Keeping in view the ever increasing demand of willow wood for multifarious uses particularly for sports good manufacturing entrepreneurs, household timber, constituted wood, etc., selected promising clones from by various research organizations through out the world (Table 1), were procured and introduced at university of Horticulture and Forestry campus, Solan (HP) followed nursery screening for three years (Singh *et al.,* 2012). A field trial of 20 superior clones was raised in the experimental area in each year from 2011 to 2013 to identify stable clones for variable environmental conditions. Considering different years as a different location, stability of clones can be worked out (Sharma, 2006) to identify clones stable for variable environmental conditions.

MATERIALS AND METHODS

The experiment was carried at Naganji nursery area of the Department of Tree Improvement and Genetic Resources, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The nursery site is located at an elevation of 1200 m above mean sea level in the north-west of Himalaya and lies between 30°51'N latitude and

76°11'E longitude having well drained, sandy loam soil with pH of 7.20. The area experienced a wide range of temperature (Fig. 1a) with a minimum of 0.4°C in winters to a maximum of 32.3°C during summer. The annual rainfall ranges (Fig. 1b) between 298.3-1024.3 mm with maximum downpour during the monsoon season (July-September). The 20 clones were raised in three replications in Randomized Block Design with 16 ramets in each replication. Stem cuttings of 22.50 cm long and 1 cm thick were prepared from one year old nursery plants.

The spacing between rows was 50 cm and between cuttings in a row was 40 cm in a sunken bed of size 250 cm x 150 cm under the usual nursery conditions. Singling of stem was done. The plants were regularly watered and weeding and hoeing in beds were done whenever necessary.

The observations were recorded in the month of December when the saplings were nine months old. Plant height in centimeter and basal diameter in milimeter was measured. Volume index was calculated by multiplying plant height with square of basal diameter. The data was statistically analyzed with the statistical package for social sciences (SPSS), version 16.0.

Genotypic, phenotypic, environmental variances and coefficients of variability, expected genetic advance at 5 per cent of selection intensity was calculated by the formula given by Singh (2006). Genetic gain was worked out following the method suggested by Johnson *et al*. (1955).

RESULTS AND DISCUSSION

Plant survival and growth: Data revealed that clones and year varied significantly for all the traits (Table 1 and 2). The clone x year interaction was found non-significant except for plant survival. Growth of plants was recorded highest in the year 2013 (plant height, 337.78cm; basal diameter, 16.45mm and volume index, 1023 cm^3). Mean plant height, basal diameter and volume index of 309.28cm, 14.91mm and 775.37 cm^3, respectively was recorded for all the clones.

Data in table 2 revealed that clone J799 recorded maximum plant height in the year 2011 (347 cm) and 2013 (425.76cm), while it was recorded by clone J795 in the year 2012 (398.27cm). Plant height was recorded at par with clone J799, clones SE-63-016 (309 cm) and PN 731 (301 cm) in the year 2011, clone NZ 1002 (388.49 cm) in the year 2013 and clones J799 (396.88 cm) and 131/25 (360.94 cm) with clone J795 in the year 2012. Mean plant height was recorded maximum (389.77cm) in the clone J799 followed by clones J-795 (355.36 cm) and NZ 1002 (344.95 cm).

Basal diameter was recorded maximum in the clone SI-64-017 in the year 2011 (17.69 mm) and 2012 (16.28 mm) while in the year 2013, it was recorded by clone J799 (19.88mm). In the year 2011 clone J799 (17.47 cm) and in the year 2013 clones NZ 1002 (19.88 mm) and SI-64-017 and in the year 2012, clones 131/25, PN731, NZ1002, NZ1040, J799, NZ1140, J795 and V-311 recorded at par basal diameter with maximum recording clones.

Clone J799 recorded maximum mean volume index (Table 2) as well as volume index in the year 2011 (1169 cm^3), 2012 (17.59 cm^3), 2013 (17.59 cm^3), which was at par with clone SI-64-017 (2011:911.02 cm^3, 2012:1046 cm^3, 2013:1557 cm^3 with mean volume index of 1329 cm^3). As far as survival is concerned (Table1), in the year 2011 clones Kashmiri willow and NZ 1040 (97.9%) registered maximum survival, which was at par with other clones except clones J799 (87.5%), J172 (85.4%) and NZ 1179 (85.50%). In the year 2012 clone 131/25 showed best survival (97.9%) followed by clones J799, Austree and NZ1140 (95.83%). In the year 2013 clones J799 and NZ1179 recorded maximum survival (97.9%). Average plant survival was recorded maximum in the clones 131/25 and J799 (93.8%), which was at par with other clones except in clone J194 (72.20%). The differences in plant survival among the years may be ascribed to the difference in weather conditions particularly rainfall (Fig. 1b). Rainfall received in the initial months (Feb.–May) in the year 2011 was more than 2012 and 2013. In the present study, stem cuttings were raised under open nursery conditions, the environmental influence was reduced to minimal. Therefore, variation observed among the clones in morphological traits may be attributed to the genetic differences. Significant differences were also observed among provenances and clones of *Populus ciliata* (Singh and Devgiri, 1997, Sharma and Khurana, 2011), *P. deltoides* (Singh *et al.,* 2001) and *Salix* species (Singh *et al.,* 2012) for morphological traits in nursery. The significant difference in growth parameters observed among the years was due to the differences in weather conditions particularly rainfall pattern.

Genetic values: The genetic parameters furnished in Table 3 revealed that phenotypic coefficient of variation (PCV) is greater than genotypic coefficient of variation (GCV) for all growth parameters, which varied from 5.02 and 9.28 per cent in plant height in the year 2011 to 60.79 and 43.06 per cent in volume index in the year 2012, respectively. Maximum heritability (84.41 %) was found in basal diameter followed by plant height (70.27%), volume index (50.16 %) growth in the year 2012 and basal diameter in the year 2013. The genetic gain also recorded the same pattern as heritability with highest for basal area in the year 2012 (64.82) and lowest for plant height in the year 2011 (5.60%). The result shows

Table 1. Details of *Salix* clones and plant survival in nursery

S. No.	Clone	Species/hybrid	Source country/ originally developed	Plant survival (%)*			
				2011	2012	2013	Mean
1.	131/25	*S. babylonica x S. Alba*	UK/Argentina	89.6 (71.4)	97.9 (85.0)	93.8 (78.2)	93.8 (78.20)
2.	J172	*S. babylonica x S. alba x S.matsudana*	UK/China	85.4 (67.6)	89.6 (71.4)	93.8 (78.2)	89.6 (72.41)
3.	J-194	*S. matsudana x S.arbutifolia* x *S. Matsudana*	UK/China	93.8 (78.2)	64.6 (55.2)	58.3 (49.9)	72.2 (61.08)
4.	Austree	*S. matsudana x S. Alba*	UK/Newsland	93.8 (78.2)	95.8 (80.3)	75.0 (60.5)	88.2 (73.00)
5.	J-795	*S. matsudana x S. Alba*	UK/China	91.7 (73.4)	91.7 (76.6)	79.2 (63.1)	87.5 (71.03)
6.	J-799	*S. matsudana x S. Alba*	UK/China	87.5 (69.7)	95.8 (80.3)	97.9 (85.0)	93.8 (78.35)
7.	Kashmiri willow	*S. alba* cv. *Caerulea*	UK	97.9 (85.0)	89.6 (71.4)	83.3 (66.9)	90.3 (74.45)
8.	MB-368	*S. alba*	Croatia	91.7 (76.1)	87.5(70.4)	89.6 (71.4)	89.6 (72.30)
9.	NZ-1002	*S. matsudana x S. alba*	New Zealand	93.8 (78.2)	85.4 (71.4)	64.6 (53.8)	81.3 (67.80)
10.	NZ-1040	*S. matsudana x S. alba*	New Zealand	97.9 (85.0)	83.3 (66.6)	77.1 (61.4)	86.1 (71.03)
11.	NZ-1130	*S. matsudana x S. alba*	New Zealand	95.8 (83.0)	83.3 (71.3)	81.3 (73.7)	86.8 (75.07)
12.	NZ-1140	*S. matsudana* x *S.alba*	UK	89.6 (71.4)	95.8 (80.3)	81.3 (70.1)	88.9 (73.92)
13.	NZ-1179	*S. matsudana x S. alba*	UK	87.5 (69.7)	72.9 (58.9)	97.9 (85.0)	86.1 (71.21)
14.	PN-721	*S. matsudana x S. alba*	New Zealand	95.8 (80.3)	79.2 (64.0)	91.7 (76.6)	88.9 (73.62)
15.	PN-722	*S. matsudana*	New Zealand	93.8 (78.2)	83.3 (70.4)	89.6 (75.1)	88.9 (74.58)
16.	PN-731	*S. nigra*	New Zealand/USA	93.8 (78.2)	87.5 (73.8)	77.1 (62.0)	86.1 (71.03)
17.	SE-63-016	*S. jessoensis*	Italy/Japan	91.7 (76.1)	91.7 (76.6)	62.5 (52.6)	81.9 (68.44)
18.	SI-63-007	*S. alba*	Italy	93.8 (78.2)	81.3 (68.6)	89.6 (75.1)	88.2 (73.97)
19.	SI-64-017	*S. alba*	Italy	93.8 (78.2)	87.5 (69.7)	70.8 (57.4)	84.0 (68.44)
20.	V-311	*S. alba*	Croatia	95.8 (80.3)	89.6 (71.8)	60.4 (52.8)	81.9 (68.28)
	Mean			92.7 (76.8)	86.6 (71.7)	80.7 (67.4)	86.7 (71.98)
	$CD_{(0.05)}$	Year					3.96
		Clone					10.22
		Year x Clone					17.71

*Values in parentheses are arc sine transferred

Table 2. Nursery growth performance of *Salix* clones the years 2011-13

Clone	Plant height (cm)				Basal diameter (mm)				Volume index (cm^3)			
	2011	2012	2013	Mean	2011	2012	2013	Mean	2011	2012	2013	Mean
131\25	275.67	360.94	338.01	324.87	15.11	16.09	17.53	16.25	634.87	968.51	1099.0	900.70
J172	298.67	258.69	317.56	291.64	13.44	11.65	14.81	13.30	558.16	371.78	728.37	552.77
J194	268.67	242.00	276.88	262.51	15.28	11.30	15.23	13.94	630.96	368.55	752.23	583.91
Austree	269.67	264.50	317.36	283.84	13.54	12.25	15.3	13.70	497.94	441.54	795.23	578.24
J795	299.00	398.27	368.81	355.36	13.13	14.91	16.85	14.97	522.33	916.20	1144.0	860.87
J799	347.00	396.88	425.76	389.77	17.47	15.22	19.88	17.52	1069.0	1160.0	1759.0	1329.0
Kashmiri	296.33	296.71	375.10	322.71	15.18	13.72	17.63	15.51	686.36	682.05	1233.0	867.25
MB-368	267.33	296.62	289.07	284.34	12.79	11.18	12.03	12.00	438.34	384.05	496.39	439.59
NZ-1002	299.33	347.04	388.49	344.95	14.51	15.48	19.48	16.49	652.40	877.54	1514.0	1015.0
NZ-1040	280.33	341.91	324.03	315.42	13.37	15.47	14.39	14.41	511.80	892.09	780.15	728.01
NZ-1130	282.00	282.84	337.29	300.71	14.02	12.33	15.70	14.02	564.43	496.78	864.45	641.89
NZ-1140	274.33	314.81	340.33	309.83	15.39	15.17	17.78	16.11	652.60	856.99	1133.0	880.84
NZ-1179	281.00	230.10	318.76	276.73	13.60	10.58	14.66	12.95	525.07	318.96	664.70	502.91
PN721	258.00	289.92	348.76	298.89	13.80	13.71	16.53	14.68	505.68	606.48	1062.0	724.68
PN-722	278.33	261.57	299.58	279.85	15.09	13.27	15.62	14.66	644.04	498.77	726.06	622.96
PN-731	301.00	262.83	283.56	282.46	12.58	15.75	16.22	14.85	490.39	757.14	864.38	703.97
SE-63-016	309.00	308.36	347.43	321.60	15.54	13.97	17.34	15.62	751.00	771.04	1248.0	923.21
SI-63-007	275.67	302.16	348.67	308.83	13.33	14.02	16.42	14.59	492.09	656.73	1023.0	723.90
SI-64-017	285.00	324.53	366.28	325.27	17.69	16.28	19.00	17.66	911.02	1046.0	1557.0	1171.0
V-311	279.00	294.89	343.94	305.94	14.35	14.17	16.62	15.05	583.18	676.45	1010.0	756.59
Mean	286.27	303.78	337.78	309.28	14.46	13.85	16.45	14.91	616.06	687.36	1023.0	775.37
$CD_{(0.05)}$												
Year		17.77				0.66				99.26		
Clone		45.88				1.72				256.28		
Year x Clone		NS				NS				NS		

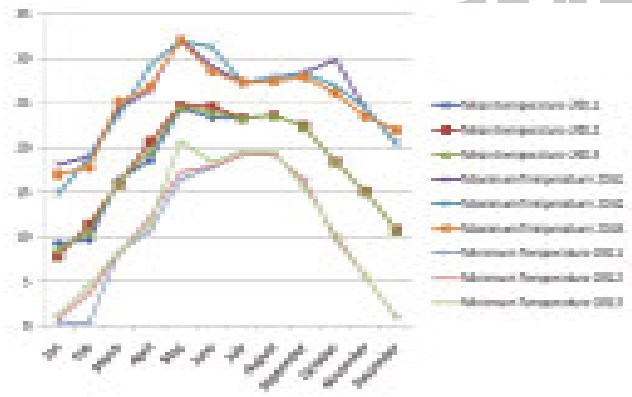

Fig. 1a. Temperature of experimental site

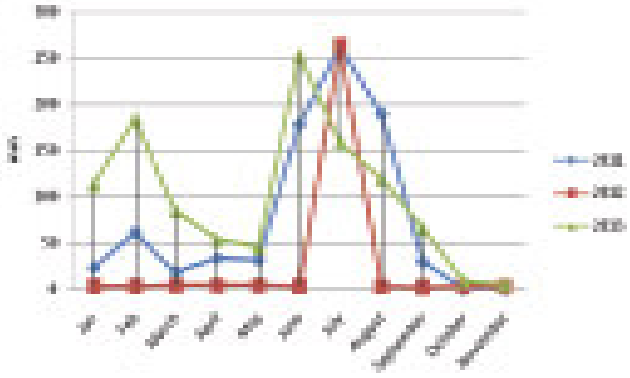

Fig. 1b. Rainfall in different years

the scope for improvement in these characters through clonal selection and control breeding. These results related to genetic parameters are in line as projected by Lin and Zsuffa (1993). High heritability estimates for height, basal diameter and survival are in line with the result obtained in in *Populus trichocarpa* (Heilman and Stettler, 1985), *P. deltoides* (Singh *et al.,* 2001) and *Salix* clones (Singh *et al.,* 2012; Huse *et al.,* 2008).

A significant positive correlation was observed between mean basal diameter and mean volume index (0.965) followed by basal diameter in 2013 and mean basal diameter (0.95) and basal diameter and volume index in the year 2013 (0.947). Present findings are in agreement with earlier results of Singh *et al.* (2012) in *Salix* clones.

Table 3. Genetic factors of nursery growth of willow clones

S. No.	Genetic Parameter	Plant height (m)			Basal diameter (cm)			Volume index (cm^3)		
		2011	2012	2013	2011	2012	2013	2011	2012	2013
1.	Genetic variance	207.89	8696	924.03	1.54	18.13	2.53	16210.25	71027.59	72358.60
2.	Environmental variance	501.55	3679	3834.94	2.03	3.35	2.64	30831.76	70565.28	102924.50
3.	Phenotypic variance	709.43	12376	4758.97	3.57	21.48	5.17	47042.01	141592.86	175283.10
4.	Genotypic coefficient of variation (%)	5.02	33.89	10.04	8.53	33.94	9.72	20.31	43.06	26.67
5.	Phenotypic coefficient of variation (%)	9.28	40.43	22.79	13.00	36.94	13.90	34.60	60.79	41.52
6.	Environmental coefficient of variation (%)	7.80	22.05	20.46	9.80	14.59	9.93	28.01	42.91	31.81
7.	Heritability (%)	29.30	70.27	19.42	43.12	84.41	48.92	34.46	50.16	41.28
8.	Genetic advance	16.08	161	27.59	1.68	8.06	2.29	153.96	388.84	356.03
9.	Genetic gain	5.60	58.53	9.12	11.54	64.23	14.01	24.56	62.82	35.31

CONCLUSION

In the resent findings, significant differences were observed in *Salix* clones among different years in nursery. The clone x year interaction was found non-significant except for plant survival. The growth of plants was recorded highest in the year 2013. Significant and positive correlation was observed between basal diameter and volume index. However, the selected clones will have to be tested in the field conditions to find the genotype x environment interaction and to identify the best suitable clones for different agro-ecological regions.

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Plant growth, Yield and Fruit Quality of Kinnow Mandarin on Ten Rootstocks

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Abstract: The effects of various rootstocks on vegetative growth, fruit quality, yield and yield efficiency of Kinnow mandarin variety was evaluated under the ecological conditions of Punjab during 2014. Canopy volume was the lowest for trees on CRH-12 and was maximum on Volkameriana. Most smooth union was noted on rough lemon followed by Carrizo. The trees on NRCC-2 were the most efficient in yield per cubic meter of canopy volume. The largest fruit size was obtained from the trees on NRCC-5. The highest total soluble solids and acidity were recorded on Carrizo followed by CRH-12. Yield per tree was the highest on Volkameriana, followed by NRCC-2 and NRCC-6 rootstocks. Trees on CRH-12 were least productive.

Key Words: Citrus, rootstocks, Kinnow, fruit yield, fruit quality, tree size

Citrus rootstocks have well-known effects on tree vigour, size, yield, fruit size and various quality factors (Wutscher, 1979; 1988). Rootstocks have been characterized according to the rate of vegetative development of tree's canopy on a particular rootstock, and scion precocity and productivity (Castle *et al*., 1993). The necessity of using rootstocks for citrus fruits is to have a profitable production against some limiting factors such as climate, bad soil conditions, diseases, etc. Besides these factors, use of the citrus rootstocks provides a large amount of choices to the growers to increase fruit quality and yield, obtain early fruiting, uniform cropping, avoidance of juvenility, control of the tree size and have the opportunity for high density planting, etc. These factors offer a lot of economic advantages to the growers and as a result, the citrus fruits are the most produced fresh fruits in the world since several decades (Tuzcu *et al*., 2005). Choosing a rootstock is an important decision and local climatic and soil conditions are important factors in rootstock selection. Although any citrus variety can be used as a rootstock, some of them are better suited to specific conditions than the others (Davies and Albrigo, 1994; Lawrence and Bridges, 1974). The ideal citrus rootstock must be compatible with the scion, be adaptable to the appropriate soil and climatic factors and should also improve one or more characteristics i.e., pest and disease resistance, cold tolerance, harvest date, internal and external fruit quality, yield and post-harvest quality. Ultimately, the value of a rootstock lies in its ability to improve production and/or quality of the fruit.

Likewise, a successful citrus cultivar must be adaptable to the harsh climate of Punjab (where high temperatures are often greater than 40°C), must be vigorous and must produce high yields of good quality fruit of marketable size. Kinnow as cultivar fits very well for the agro-climatic conditions of Punjab. Though Kinnow is highly successful cultivar but the main rootstock of Punjab rough lemon suffers due to its susceptibility to *Phytophthora* and poor quality of fruits produced on it. In order to overcome the problems associated with rough lemon, newly developed citrus rootstocks were introduced to determine growth performance, yield and fruit quality of Kinnow cultivar grafted on new rootstocks in comparison to well established rootstocks.

MATERIAL AND METHODS

The experiment was conducted in College Orchard of Department of Fruit Scince, Punjab Agricultrual University, Ludhiana (latitude 30° 53' N, longitude 75° 48' E; elevation 244 m). The soil is well drained deep alluvial which is common in Ludhiana. Ludhiana features a humid subtropical under the Köppen climate classification, with average maximum and minimum temperatures of 35.8 °C and 2.7 °C, respectively, and an annual rainfall of 733 mm. The plants were planted on flat beds in September 2010 and were irrigated by flood method. Distance between plants was 3 meter and between rows 6 meter, with a plant densiy of 220 tree/acre. The orientation of rows was north-south. The experimental design was randomized block design with five replicates and two trees per plot.

Kinnow (*Citrus nobilis* Lour X *Citrus deliciosa* Tenore) mandarin was budded on the following rootstocks (treatments): NRCC-1, NRCC-2 (Rough lemon X Troyer citrange), NRCC-3, NRCC-4 (Rough lemon X Trifoliate orange), NRCC-5 (Rough lemon X Troyer citrange), NRCC-6 (Rough lemon X Trifoliate orange], CRH-12, Carrizo citrange [*Citrus sinensis* (L.) Osbeck×*P. trifoliata*], Rough lemon (*Citrus jambhiri* Lush) and Volkameriana [*Citrus volkameriana* (*L.*)]. NRCC series of rootstocks have been

developed by National Research Centre on Citrus, Nagpur for their suitability to Indian agro-climatic conditions, similarly, CRH-12 has been developed by Indian Institute of Horticultural Research, Bangalore.

Standard culture techniques were used with mechanical weed control between rows and chemical control between trees. In the first three years of culture, trees were slighty pruned to give proper shape and remove sprouts from rootstock. In the fourth year no pruning was done. The experiment was managed according with regular cultural practices and fertilization schedule followed for Kinnow as per recommendation of Punjab Agricultural University. The experimental orchard was surrounded by several other citrus evaluation experiments.

Data on different fruit characters was recorded in January 2014. Tree height was measured from soil level to the top of the tree. Scion girth was measured in centimetres with the help of measuring tape at a height of 5.0 cm from the bud union and stock was measured 5.2 cm below the union. The canopy spread was measured in meters. Two readings were taken for tree spread in each replication and average was calculated. To measure canopy volume, tree was assumed to be one half of prolate spheroid (Jahn, 1979; Morse and Robertson, 1987) and volume was calculated by the equation: volume = 0.524 x height x width^2. Fifteen fruits were randomly selected from each tree for physico-chemical analysis. Fruit weight was measured with a scale sensitive to 0.01 g. Chemical analysis of the juice was carried out as previously reported by D'Aquino and Palma (2003) and included acidity expressed as grams of citric acid in 100 ml of juice, and total soluble solids (TSS) expressed as degrees Brix and TSS/acid ratio was calculated. The number of fruits born on each tree was counted manually. Fruit yield was measured at the time of harvest using scale sensitive to 1g. Yield efficiency was calculated by dividing the yield per tree with tree volume and data were suitably analyzed statistically.

RESULTS AND DISCUSSION

The rootstock clearly affected plant growth. The rootstock that produced the most vigorous Kinnow mandarin plants were Volkameriana, Rough lemon and Carrizo (Table 1). The plants in vigorous category had plant height in the range of 2.47 to 2.74 m, plant spread varied from 2.23 to 2.33 m and canopy volume ranged from 6.27 to 7.78 m^3. Intermediate vigour in Kinnow mandarin was induced by NRCC-2, NRCC-3, NRCC-4 and NRCC-6. Intermediate vigour category plant height ranged from 2.49 to 2.59 m, plant spread varied from 1.89 to 2.01 m and canopy volume ranged from 4.82 to 5.35 m^3. Canopy volume of Kinnow plans was reduced by two to three times by dwarfing rootstocks as compared to Rough lemon rootstock. The rootstocks that were least vigorous were NRCC-5, NRCC-1 and CRH-12. The canopy volume in dwarfing rootstocks varied from 1.80 to 3.03 m^3, plant spread was from 1.37 to 1.60 m and plant height ranged from 1.69 to 2.26 m. The results obtained regarding canopy volume are in agreement with those of Georgiou (2009) on Lapithkiotiki lemon, who reported that the highest volume was on sour orange and the lowest on Carrizo citrange.

Rootstocks significantly affected rootstock circumference, scion circumference and stock to scion ratio (Table 1). The scion circumference was the highest in Volkameriana, closely followed by Rough lemon. There was no significant difference in the scion circumference on rootstocks in categories vigorous and intermediate vigour. Scion girth in dwarf category ranged from 16.01 to 18.04 cm, rootstocks of this category viz. NRCC-5, NRCC-1 and CRH-12 were at par for scion circumference. However, the dwarfing rootstocks had significantly lower scion circumference as compared to vigorous rootstocks. Similar trend was observed for rootstock circumference. This study get support from the findings of Perez-Perez *et al.* (2005) who mentioned that trunk cross sectional area of three lemon varieties on sour orange was larger than that of trees on *Citrus macrophylla*. In addition, Georgiou (2009) reported that the highest trunk cross sectional area in Lapithkiotiki lemon was recorded on sour orange and the lowest on Carrizo citrange.

The Kinnow trees budded on NRCC-3 had significantly higher stock to scion ratio than those on other rootstocks. The lowest ratio was found with rough lemon followed by Carrio citrange and Volkameriana, indicating similar growth rate of scion and rootstock. High ratio indicates dissimilarity in growth rate of rootstock and scion as in NRCC-3 rootstock. Similar results were reported by several researchers (Georgiou and Gregoriou, 1999; Perez-Perez *et al*., 2005; Bassal, 2009; Georgiou, 2009).

Fruit quality: The rootstocks significantly influenced fruit weight (Table 2). Fruits from trees on NRCC-5 were significantly heavier than those from the other rootstocks, except NRCC-3, which was at par. The lightest fruits were obtained from the trees on NRCC-6 followed by NRCC-1. Also, Mendilcioglu (1986) on Satsumas found that Troyer and Carrizo citranges had heavier fruits when compared to sour orange. Similarly, the biggest fruits were found in Kütdiken lemon trees grafted on Yuzu, Volkameriana and Taiwanica, whereas, the smallest fruits were obtained from the trees on Benecke trifoliate orange and T. citrange by Tuzcu *et al*. (1992). The effect of rootstocks on fruit length and fruit diameter was not statistically significant and all of the rootstocks gave similar values (Table 2).

Table 1. Growth performance of Kinnow mandarin on different rootstocks

Rootstocks	Plant height (m)	Plant spread (m)	Rootstock girth (cm)	Scion girth (cm)	Stock: scion ratio	Canopy volume (m^3)
NRCC-1	1.69	1.43	19.33	16.01	1.21	1.80
NRCC-2	2.55	2.01	27.14	22.30	1.22	5.35
NRCC-3	2.55	1.92	29.57	22.24	1.33	4.92
NRCC-4	2.59	1.89	28.70	23.15	1.24	4.82
NRCC-5	2.26	1.60	21.48	18.04	1.19	3.03
NRCC-6	2.49	1.96	27.99	22.94	1.22	5.01
CRH-12	2.02	1.37	20.02	16.82	1.19	1.98
Carrizo	2.47	2.23	25.06	21.74	1.15	6.27
Rough lemon	2.74	2.33	27.69	24.61	1.13	7.78
Volkameriana	2.64	2.27	31.41	25.66	1.22	7.08
SEm±	0.12	0.13	1.64	1.36	0.02	0.70
LSD at 5%	0.41	0.43	5.41	4.50	0.05	2.30

Kinnow mandarin quality was significantly dependent upon the rootstock used. Fruits on Carrizo had significantly higher total soluble solids (TSS) than all other rootstocks, except CRH-12. The lowest TSS was recorded on NRCC-5 rootstock followed by NRCC-4 and NRCC-1 rootstocks. Carrizo resulted in about 10 per cent higher TSS in Kinnow than that recorded on rough lemon. Similarly, soluble solids of fruits from trees on Carrizo citrange was recorded to be more than 20 per cent higher than that of fruits from rough lemon (Wutscher, 1988; Barry and Castle, 2004). No other factor had such a large effect on soluble solids contents as rootstock (Barry, 2000; Barry *et al.,* 2000; 2003). While explaining that juice quality differences of fruit from trees borne on different rootstocks, Gardner (1969) concluded that the tree foliage supplies carbohydrates to fruit, but rootstock determines the amount. Although it is unclear how rootstocks exert their influence on juice quality in *Citrus* spp., plant water relations, mineral nutrition and phytophormones have been proposed as being among the most important factors involved (Castle, 1995).

Fruit juice acidity of Kinnow mandarin was affected significantly by the rootstocks used (Table 2). The fruits containing the highest acid were produced on CRH-12 followed by Carrizo and NRCC-5. The lowest acidity was recorded on NRCC-1. These results are in agreement with previous works, where juice acidity of scion has been found to be significantly influenced by rootstock used (Kaplankiran *et al.,* 2005b; Georgiou, 2009).

Fruit quality: The rootstocks differed considerable in their ability to influence fruit yield and quality (Table 2). Maximum fruit number per tree was counted on Volkameriana and it was significantly higher than the fruit number recorded on most commonly used rootstock in Punjab i.e. Rough lemon. Similarly, high fruit number was recorded on NRCC-2 and NRCC-6 rootstocks and both these stocks were at par with Volkameriana. Trees on CRH-12 had the lowest number of fruits per tree followed by NRCC-5. Similar trend was recorded for harvested fruit yield per tree. The results obtained regarding productivity are in agreement with Levy (1986) and Al-Jaleel *et al.* (2005) who reported significant

Table 2. Fruit quality of Kinnow mandarin on different rootstocks

Rootstocks	Fruit weight (g)	Fruit length (cm)	Fruit dia. (cm)	TSS (°Brix)	Acidity (%)	Fruit number $Tree^{-1}$	Yield (kg $tree^{-1}$)	Yield efficiency (kg m^{-3})
NRCC-1	203.5	6.5	7.7	9.6	0.72	76.9	15.6	8.68
NRCC-2	205.8	6.4	7.8	10.8	0.78	281.1	57.8	10.81
NRCC-3	218.1	6.6	8.0	10.7	0.75	213.4	46.5	9.47
NRCC-4	214.3	6.5	7.9	9.4	0.77	212.2	45.5	9.43
NRCC-5	224.0	6.6	7.7	9.3	0.81	57.3	12.8	4.23
NRCC-6	195.3	6.3	7.5	10.4	0.75	256.9	50.2	10.02
CRH-12	211.0	6.6	7.8	11.3	0.84	17.5	3.7	1.86
Carrizo	216.6	6.6	8.0	11.7	0.82	182.6	39.6	6.31
Rough lemon	209.8	6.4	7.8	10.6	0.78	196.0	41.1	5.28
Volkameriana	211.1	6.6	7.7	10.6	0.77	323.8	68.4	9.65
S Em±	2.34	0.03	0.04	0.23	0.01	28.9	6.0	1.01
LSD at 5%	7.36	NS	NS	0.7	0.04	91.0	18.8	3.33

differences among the rootstocks for yield per tree.

In the first year of fruiting, significant differences were recorded for yield efficiency of Kinnow mandarin on different rootstocks (Table 2). Trees on NRCC-2 produced the most fruit yield per unit canopy volume followed by NRCC-6 and Volkameriana. These three rootstocks were at par for yield efficiency. The trees on CRH-12 were the least productive, all other rootstocks produced more than 4 kg fruit per cubic meter of canopy. Differences in yield efficiency on different rootstocks have also been observed by Demirkeser *et al.* (2009) and Georgiou (2009).

Conclusively, rootstocks showed significant effects on plant growth, fruit quality, yield and yield efficiency. Many of rootstocks differ considerably from the main rootstock of Punjab i.e. Rough lemon. In the coming years there is high probability of selecting some good rootstock for this region from this trial.

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Availability of Lead as Influenced by Contamination Levels, Ageing and Amendment Regimes

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Abstract: A laboratory incubation study was conducted to investigate the effect of time and some soil characteristics on the availability of added lead. Three levels of Pb viz. 0, 20 and 200 mg Pb kg^{-1} soil were added through aqueous lead acetate $(CH_3COO)_2$ Pb $3H_2O$) to soils having different pH, organic matter, $CaCO_3$ and clay content. The treated soil samples were incubated for 0, 14 and 28 days at 25^{0}C and analyzed for DTPA-Pb. The results indicated that there was a linear decrease in the availability of Pb with ageing but the decrease varied with level of contamination. At zero period of incubation and no contamination minimum per cent recovery of added Pb was obtained with the addition of 5% lime and at 14 and 28 days it was obtained with the addition of 2 % FYM and 40 % finer fraction, respectively. In case of contamination at 20 mg Pb kg^{-1} soil the characteristics which curtailed maximum extraction were 2% FYM, pH 9.5 and 5% lime at 0, 14 and 28 days after incubation, respectively and at 200 mg Pb kg^{-1} soil it was 5% lime, 2% FYM and 40% finer fraction, respectively. The results enable us to understand the sink capacity of soils varying in characteristics.

Key Words: Lead, soil, incubation, contamination, characteristics, availability

Lead (Pb) is one of the major heavy metals that have gained considerable importance as a potent environmental pollutant (Sharma and Dubey, 2005). Apart from the natural weathering processes, Pb contamination of the environment has resulted from mining and smelting activities, Pb containing paints, gasoline and explosives as well as from the disposal of municipal sewage sludges enriched in Pb (Chaney and Ryan, 1994). Despite regulatory measures adopted in developed and industrialized countries to limit Pb input in the environment, it continues to be one of the most serious global environmental and human health hazard but more so in developing countries. As many of the Pb pollutants are indispensable for modern human life, soil contamination with Pb is not likely to decrease in the near future (Yang *et al.,* 2000). Significant increase in the Pb content of cultivated soils receiving sewage irrigation has been observed in industrial cities. It tends to accumulate in the surface ground layer and its concentration decreases with soil depth (Sikka, 2003). Lead concentration in soil solution is of great importance because plants are likely to take up labile metal from soil solution. Although Pb is not essential for plant growth, it is readily absorbed by plants in varying amounts depending upon its bioavailability in the soil. It inhibits photosynthesis, upsets mineral nutrition, water balance, changes hormonal status and affects membrane structure and permeability (Sharma and Dubey, 2005).

It is necessary to develop techniques to treat and stabilize heavy metals *in situ* in an effective manner. An approach towards this is to render the metals immobilized by altering some physico-chemical properties of soils using different amendments. Lime, phosphates, or organic matter residues are commonly employed for metal immobilization in soils (Ruby *et al.,* 1999). Lime is often chosen because it changes the forms of the metals by rendering them less bioavailable. Organic matter in soil strongly influences the bio-availability of heavy metals. Addition of farmyard manure may be a strategy to reduce the accumulation of metals in edible crops (McBride, 1994). However, Sidhu and Narwal (2006) suggested that the efficiency of the organic material in reducing metal uptake was generally small. On the contrary, Jin *et al.* (2005) found that addition of manure increased heavy metal uptake by plants. Therefore, we thought it imperative to investigate the effect of time and some soil characteristics on retention and availability of a range of lead contamination. We carried out an incubation study with a loamy sand soil, the characteristics of which were altered by modifying soil pH, addition of lime, organic matter and finer fraction. Extraction of Pb was estimated for different time periods.

MATERIALS AND METHODS

Surface soil sample was collected from a loamy sand soil. The original properties of the soils were altered by the addition of different rates of lime ($CaCO_3$), organic matter, and finer fraction (silt + clay) and by changing the pH of the soil (Table 1). The basic characteristics of soil were pH 7.65, OC 0.21%, $CaCO_3$ 0.14% and silt + clay 16.1%. The soil samples were mixed with 2.5 and 5% Analar grade $CaCO_{3,}$, well rotten and ground FYM@ 1 and 2.0% and 20 and 40% silt plus clay separated from a clay loam soil and 0.5 N NaOH and 0.5 N HCl to obtain pH levels of 5.5, 7.5 and 9.5. The treated soils were kept at room temperature at field capacity

Table 1. Physico-chemical characteristics of incubated soils following treatment with $CaCO_3$, organic matter, clay + silt and pH

Treatments		pH	Organic carbon (%)	$CaCO_3$ (%)	Silt + clay (%)
pH	5.5	5.42	0.21		
	7.5	7.62	0.20		
	9.5	9.38	0.21		
$CaCO_3$ (%)	2.5	8.22	0.20	2.42	
	5.0	8.51	0.19	4.91	
FYM(%)	1.0	7.67	0.43		
	2.0	7.61	0.63		
Clay + silt (%)	20	8.07	0.27	0.42	32.7
	40	8.17	0.36	0.55	53.8
Control soil		7.65	0.21	0.14	16.1

for 30 days for stabilization and analysed for their final characteristics (Table 1). Standard analytical procedures were adopted for the determination of $CaCO_3$ (Puri, 1950), organic carbon (Walkley and Black, 1934), soil texture and pH (Jackson, 1973). Twenty five gram soil samples so prepared were kept in polythene bottles. The soil samples with different characteristics were treated in duplicate with 0, 20 and 200 mg Pb kg^{-1} soil added through aqueous lead acetate $(CH_3COO)_2$ Pb $3H_2O$) and kept in an incubator at $25^o \pm 1^o$ C and maintained at field capacity for 28 days and the loss of moisture was compensated by adding distilled water after every second day. The treated soils after the addition of metal were drawn after 0, 14 and 28 days and were analyzed for DTPA-extractable Pb (Lindsay and Norvell, 1978) using Atomic Absorption Spectrophotometer (Model: Varian Spectra AA 20 plus). Farm yard manure was analysed by digesting two grams of oven dried FYM in 20 ml of distilled concentrated nitric acid at low heat on a hot plate to oxidize organic matter and digested the mixture with 20 ml of perchloric acid until dense white fumes of acid appeared and was analysed for various metals (Table 2).

Table 2. Chemical composition of oven dried farm yard manure

Composition	Content
Organic Carbon (%)	21.54
pH (1:4 water extract)	7.89
EC (dS/m)	4.15
Fe (mg kg^{-1} soil)	1795
Mn	205
Zn	60.5
Cu	10.5
Pb	0.52

RESULTS AND DISCUSSION

Effect of calcium carbonate on DTPA-Pb: The addition of lime ($CaCO_3$) and increase in period of incubation decreased the extractability of applied Pb (Table 3). Addition of 2.5 and 5% lime in 20 mg Pb kg^{-1} soil treatment decreased DTPA - Pb from 13.8 in control to 12.4 and 12.0 mg Pb kg^{-1} soil, respectively at zero period of incubation and the corresponding decrease at 14 and 28 days of incubation was from 12.0 in control to 9.92 and 8.23 mg Pb kg^{-1} soil and from 9.4 to 6.3 and 4.24 mg Pb kg^{-1} soil, respectively.

At 200 mg Pb kg^{-1} soil the respective decrease in DTPA-Pb extraction was 7.9 and 15.8 mg Pb kg^{-1} soil in 2.5 and 5% lime treatments over control at zero time of incubation and the corresponding value decrease at 14 and 28 days were 11.4, 16.2 and 2.8, 13.1 mg Pb kg^{-1} soil, respectively. So, maximum decrease in absolute terms (16.2 mg Pb kg^{-1} soil) was registered after 14 days of incubation in 5% lime treated soil receiving 20 mg Pb kg^{-1} soil. The extent of decrease in DTPA Pb at 2.5 and 5% level of lime was minimum in soil receiving 200 mg Pb kg^{-1} soil after 28 days of incubation and was found to be 2.8 and 13.1 mg Pb kg^{-1} soil over control, respectively.

Irrespective of reaction period, the mean DTPA-Pb in 20 mg Pb kg^{-1} soil treatment decreased by 2.16 and 3.52 mg Pb kg^{-1} soil, respectively at 2.5 and 5% lime addition over control. However, at 200 mg kg^{-1} Pb addition the mean values decreased by 7.4 and 15.1 mg Pb kg^{-1} soil at 2.5 and 5% lime addition over control. The values of DTPA-Pb, irrespective of $CaCO_3$ lime treatment decreased by 2.71 and 5.89 mg Pb kg^{-1} soil over control at 20 mg Pb kg^{-1} soil after 14 and 28 days of incubation, respectively and the corresponding decrease was 25.3 and 72.2 mg kg^{-1} soil at 200 mg Pb kg^{-1} soil.

This indicated that the period of contact of the added metal with the soil and the amount of lime are important factors that control the extractability of Pb in soils. The decrease in DTPA-Pb in soil with the addition of lime may be attributed to the stronger binding of it with $CaCO_3$, precipitation by $CaCO_3$ and rise in pH of the soils by addition of lime. The rapid fall in extractable Pb with time of incubation

Table 3. Influence of lime ($CaCO_3$) and incubation period on DTPA - Pb (mg kg^{-1}) at different levels of Pb addition

Pb added	Incubation time	Levels of $CaCO_3$ (%)			Mean
	(days)	0.14	2.42	4.91	
0	0	0.62	0.57	0.52	0.57
	14	0.60	0.58	0.52	0.57
	28	0.60	0.50	0.50	0.53
	Mean	0.61	0.55	0.51	
20	0	13.80	12.40	12.08	12.76
	14	12.00	9.92	8.23	10.05
	28	9.40	6.30	4.24	6.65
	Mean	11.73	9.54	8.18	
200	0	142.60	134.70	126.80	134.70
	14	118.60	107.20	102.40	109.40
	28	67.80	65.00	54.70	62.50
	Mean	109.67	102.30	94.63	

indicated that Pb takes time to react with soil and within 28 days more than 60 per cent of this change into unavailable forms. Ma and Uren (1998) observed that the proportion of recently added Pb in the DTPA-extractable fraction decreased markedly with time. They also observed that addition of lime decreased the extractability of added Pb through its effect on increase in pH. In the present study also there was an increase in pH of the soil. So, this increased pH and formation of $CaCO_3$.$PbCO_3$ kind of insoluble products might have curtailed the extractability of added Pb in soil.

Effect of organic matter on DTPA-Pb: At both the levels of added Pb, the content of DTPA-Pb decreased with the addition of organic matter (Table 4). The contents decreased from 12.02 in control to 10.5 and 10.0 mg Pb kg^{-1} soil at 14 days after incubation and from 9.4 in control to 5.2 and 5.05 mg kg^{-1} at 28 days after incubation in 1 and 2% FYM addition, respectively. The mean DTPA-Pb decreased from 11.7 in control to 9.03 mg Pb kg^{-1} soil with 2% FYM addition and from 13.14 at zero period of incubation to 6.55 mg Pb kg^{-1} soil after 28 days of incubation.

Similarly, considerable reduction in DTPA-Pb was observed at 200 mg Pb kg^{-1} soil. It decreased from 142.6 in control to 130 mg Pb kg^{-1} soil with 2% addition of FYM at zero period of incubation and from 118.6 to 95.8 mg Pb kg^{-1} soil and from 67.8 to 50.1 mg Pb kg^{-1} soil after 14 and 28 days after incubation, respectively. So compared to 142.6 mg kg^{-1} DTPA-Pb in control at zero period of incubation it decreased substantially to 50.1 mg Pb kg^{-1} soil in 2% FYM treated soil, which was incubated for 28 days representing a decrease of 2.84 times.

It indicated that at higher levels, the organic constituents and the DTPA might be competing with each other for the same metal and the increase or decrease in metal extraction would be the resultant of the net effect of these two factors. The data indicated that at low organic matter content DTPA was efficient in extracting the chelated and adsorbed Pb but

Table 4. Influence of organic matter and incubation period on DTPA - Pb (mg kg^{-1}) at different levels of Pb addition

Pb added	Incubation time	Levels of $CaCO_3$ (%)			Mean
	(days)	0.14	2.42	4.91	
0	0	0.62	0.74	0.77	0.71
	14	0.60	0.76	0.69	0.68
	28	0.60	0.76	0.59	0.65
	Mean	0.61	0.75	0.68	
20	0	13.80	13.60	12.04	13.15
	14	12.00	10.50	10.00	10.83
	28	9.40	5.20	5.05	6.55
	Mean	11.73	9.77	9.03	
200	0	142.60	132.40	130.00	135.00
	14	118.60	104.80	95.80	106.40
	28	67.80	57.90	50.10	58.60
	Mean	109.67	98.37	91.97	

Table 5. Influence of pH and incubation period on DTPA-Pb (mg kg^{-1}) at different levels of Pb addition

Pb added	Incubation time	Levels of pH			Mean
	(days)	5.42	7.62	9.38	
0	0	0.80	0.64	0.48	0.64
	14	0.62	0.56	0.46	0.55
	28	0.62	0.54	0.46	0.54
	Mean	0.68	0.58	0.47	
20	0	15.70	14.00	12.20	13.97
	14	13.20	11.50	7.60	10.77
	28	10.20	10.00	5.40	8.53
	Mean	13.03	11.83	8.40	
200	0	148.40	140.20	140.20	142.9
	14	127.30	112.10	100.60	113.35
	28	72.80	70.90	57.80	67.83
	Mean	116.17	107.73	99.53	

at higher levels of organic matter addition the efficiency of DTPA-Pb extraction decreased due to the formation of stable organo-metal complexes. Earlier, Bjerre and Schierup (1985) had reported that Pb is bound by organics and oxides and that despite the fact that organic soil the highest quantities of Pb the concentration and uptake of Pb, was lower in plants grown in organic soil compared with sandy soil. The extractability and plant uptake of Pb was found to be inversely related to the content of organic matter in soil, probably because of the increased capacity of the soil to adsorb metals (John *et al.,* 1972). Piccolo (1989) also found that humic substances in the organic matter efficiently immobilized soluble and exchangeable forms to a large extent in mineral soils and retention capacity was directly related to the amount of added humic substances and incubation period.

Effect of pH on DTPA-Pb: The data in Table 5 indicated that an increase in soil pH had a depressing effect on DTPA-Pb and vice-versa. The mean DTPA-Pb decreased from 0.68 mg Pb kg^{-1} soil in 5.5 pH soil to 0.58 and 0.47 mg Pb kg^{-1} soil in 7.5 and 9.5 pH, respectively, in soils where Pb was not applied externally. In 20 mg Pb kg^{-1} soil treatment, the mean DTPA - Pb was 13.0, 11.8 and 8.4 mg Pb kg^{-1} soil at 5.5, 7.5 and pH 9.5, respectively indicating 35.4 per cent decrease at 9.5 pH as compared to pH 5.5. The mean values of DTPA - Pb at 0, 14 and 28 days of incubation were 13.97, 10.77 and 8.53 mg Pb kg^{-1} soil. The corresponding values at 200 mg kg^{-1} Pb addition were 116.2, 107.7 and 99.2 mg Pb kg^{-1} soil, respectively at soil pH of 5.5, 7.5 and 9.5 thus registering a 14.6 per cent decrease in the extractability of Pb at pH 9.5 as compared to pH 5.5. Mean DTPA-Pb also decreased substantially with incubation period from 142.9 mg kg^{-1} at 0 time of incubation to 113.35 and 66.83 mg Pb kg^{-1} soil at 14 and 28 days after incubation, respectively, indicating a corresponding decrease of 20.6 and 53.2 per

Table 6. Influence of finer fraction and incubation period on DTPA-Pb (mg kg^{-1}) at different levels of Pb addition

Pb added	Incubation time	Levels of finer fraction (%)			Mean
	(days)	16.1	32.7	53.8	
0	0	0.62	0.54	0.52	0.56
	14	0.60	0.49	0.49	0.53
	28	0.60	0.50	0.43	0.51
	Mean	0.61	0.51	0.48	
20	0	13.80	13.00	12.80	13.20
	14	12.00	9.80	10.00	10.60
	28	9.40	4.80	4.80	6.33
	Mean	11.73	9.20	9.20	
200	0	142.60	132.60	128.20	134.47
	14	118.60	109.90	100.60	109.70
	28	67.80	60.20	42.20	56.73
	Mean	109.67	100.90	90.33	

cent, respectively over zero time of incubation. A maximum of 61.7 per cent decrease was recorded in DTPA-Pb at 9.5 pH and 28 days after incubation as compared to 5.5 pH and 0 period of incubation. Solution pH regulates the protonation and deprotonation of inorganic and organic COOH groups, thereby affecting the surface charge and the number of available sites in soils, minerals or organics for sorption of Pb and the ability of soils to sorb a metal is inversely related to the extent of extraction and availability of metals.

Cieslinski *et al.* (1996) reported that application of metal to soil significantly increased its extraction from soil but more was extracted at pH 5.1 than at pH 7.8 and was found to be more mobile in acid soils within a pH range of 4.5 to 6.5, whereas, it was more readily adsorbed by soil particles and bound by organic compounds when soil pH was increased. The stability constant of organic matter metal complexes increased with increasing pH as a result of increased ionization of functional groups especially COOH with increasing pH (Stevenson and Ardakani, 1992).

Effect of finer fraction on DTPA-Pb: At 20 mg kg^{-1} of added Pb the mean DTPA-Pb decreased to 2.53 mg Pb kg^{-1} soil over 11.73 mg Pb kg^{-1} soil in control when 20 and 40 per cent of finer fractions were added to the original soil (Table 6). Increasing the rate of Pb to 200 mg kg^{-1} soil the mean values of DTPA-Pb, irrespective of the incubation period were 109.7, 100.9 and 90.3 mg Pb kg^{-1} soil in untreated control and with 20 and 40 per cent of added finer fractions, respectively.

The increase in incubation period also decreased the DTPA-Pb in soils. Mean decrease in DTPA-Pb at 14 and 28 days of incubation over the start of incubation period irrespective of the addition of finer fractions was 5.4 and 8.9, 19.7 and 52.0 and 18.4 and 57.8 per cent at 0, 20 and 200 mg Pb kg^{-1} soil, respectively. The mean DTPA-Pb content irrespective of the rate of Pb application and added finer fractions was 48.1, 40.3 and 21.2 mg Pb kg^{-1} soil at incubation period of 0, 14 and 28 days, respectively.

The silicate clay minerals are known to have permanent and pH dependent charge sites. Permanent charges arise due to isomorphous substitution in the crystal lattice while pH dependent charges are assumed to be located on carboxyl and hydroxyl groups formed on the broken crystal edges. The heterogeneous nature of the negative charge associated with clay minerals is illustrated by variation in the observed cation preference, variation with cation concentration, surface saturation and pH (Inskeep and Baham, 1983). Ziper *et al.* (1988) observed that there are three possible locations on clay minerals viz. external planar,

Table 7. Per cent recoveries of 20 and 200 mg Pb kg^{-1} soil as affected by soil characteristics and incubation period

Soil Characteristic	Incubation period (days)		
	0	14	28
		20 mg Pb kg^{-1} soil	
2.5% $CaCO_3$	62.0	49.6	31.5
5% $CaCO_3$	60.4	41.2	21.2
1% Organic matter	68.0	52.5	26.0
2% Organic matter	60.2	50.0	25.2
20 % Finer fraction	65.2	49.0	24.0
40% Finer fraction	64.0	40.0	24.0
5.5 pH	78.5	66.0	51.0
7.5 pH	70.0	57.5	50.0
9.5 pH	61.0	38.0	27.0
Control soil	69.0	60.0	47.0
		200 mg Pb kg^{-1} soil	
2.5% $CaCO_3$	67.3	53.6	32.5
5% $CaCO_3$	63.4	51.2	27.3
1% Organic matter	66.2	52.4	28.9
2% Organic matter	65.0	47.9	25.0
20 % Finer fraction	66.3	54.9	30.1
40% Finer fraction	64.1	50.3	21.1
5.5 pH	74.2	63.6	36.4
7.5 pH	70.1	56.1	35.4
9.5 pH	70.1	50.3	28.4
Control soil	71.3	59.3	33.9

interlayer and edge surfaces where cation can be sorbed by ion exchange. The decrease in DTPA extractable Pb may be due to increase in the surface area which enhanced sorption of Pb as compared to control soil where a large part of the metal may have remained unadsorbed from the soil solution. The decrease in the extractability of Pb with increase in incubation period has been attributed to the greater contact of these metals with solid surfaces, which might have resulted in their greater fixation. Ziper *et al*. (1988) also reported that edges and high charge density planar sites contribute the greatest influence on metal extraction. They observed that increasing clay fraction resulted in an increase in edge to planar surface area ratio or the increase in edge to interlayer surface area ratio resulting in an enhanced sorption of metal. The relative retention of different metals by clays depends strongly on the kind of clay surface and the level of loading. In a study conducted by Gray *et al.* (1999), it was reported that pH was the most dominant soil variable affecting extractability of Cd in soil and sorption and desorption of native and added metal in soils of New Zealand followed by organic matter, clay content, cation exchange capacity and total soil metal. They also found that increasing organic matter, clay, CEC or pH resulted in a decrease in availability of metal and as was expected organic matter, clay and CEC were themselves found to be significantly correlated. It is clear from the above discussion that a range of soil properties control the extraction of Pb from soil.

Per cent recovery of added Pb as affected by soil characteristics and incubation periods: The per cent recovery of 20 mg kg^{-1} of added Pb was 69 in control soil and it decreased to 62, 68, 65.2 upon addition of 2.5% lime, 1% FYM and 20% finer fraction and further declined to 60.4, 60.2 and 64.0 per cent in 5% lime, 2% FYM and 40% finer fraction treated soil at zero time of incubation (Table 7). The per cent extraction, however, increased to 74.2 at pH 5.5 and decreased markedly to 61.0 at pH 9.5. Similarly, a considerable decrease in the per cent recovery of added Pb was observed at 14 and 28 days after incubation. A minimum recovery of 38.5 was observed in pH 9.5 soil at 14 days of incubation and 21.2 per cent for 5% lime treated soil at 28 days after incubation as compared to other treatments.

Similarly, a decrease in the per cent recovery of added Pb @ 200 mg Pb kg^{-1} soil was observed due to addition of lime, FYM and finer fraction at 0, 14 and 28 days after incubation. A minimum per cent recovery of added Pb was 63.4 with 5% lime at start of incubation, 47.9 with 2 % FYM at 14 days and 21.1 with addition of 40 % finer fraction at 28 days of incubation. The per cent recovery of added Pb decreased with rise in soil pH and its value at pH 5.5 and 9.5 were 74.2 and 71.1 at the start of incubation, 63.6 and 50.3 at 14 days and 36.4 and 28.4 at 28 days of incubation.

In case of 20 mg Pb kg^{-1} soil, the characteristics which curtailed maximum extraction were 2% FYM, pH 9.5 and 5% lime at 0, 14 and 28 days after incubation, respectively and at 200 mg Pb kg^{-1} soil it was 5% lime, 2% FYM and 40% finer fraction at 0, 14 and 28 days after incubation, respectively. So, specific soil characteristic was important in decreasing the availability of a Pb at a particular load of it in the soil.

Soil characteristics such as $CaCO_3$, organic matter, finer fraction and soil pH decreased the extraction of Pb from the soil due to formation of stable carbonate precipitates (Singh and Nayyar, 1989). Complexation of metals on the surface of solid organic matter or formation of stable organo-metal complexes (Deka *et al.,* 1997), protonation and deprotonation of inorganic and organic functional groups, which affect the surface charge and the number of available sites in soils, minerals or organics for sorption of Pb.

This investigation on effect of different soil characteristics provide useful information to know the mechanism of metal availability and the capacity of the soil to serve as a sink for Pb but the interdependence of these soil characteristics on one another needs to be carefully determined.

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Productivity of Gobhi Sarson (*Brassica napus* var. *napus*) and Oats Fodder (*Avena sativa* L.) Intercropping System in Relation to Planting Patterns and Row Spacing

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***Abstract*:** Fifteen intercropping systems were evaluated in a randomized block design with four replications. The findings of this study indicated that growing of oats fodder as an intercrop in *gobhi sarson* did not show any adverse effect on the seed yield of gobhi sarson sown at 45 and 60 cm row spacing. All the intercropping systems recorded significantly higher gobhi sarson equivalent yield and net returns as compared to sole cropping systems. It was also observed that variety GSL 1 at 45, 60, 75 and 90 cm row spacing with oats as an intercrop at planting patterns of 1:1, 1:2, 1:2 and 1:3, respectively and GSC 6 at 60 and 90 cm row spacing with oats at planting patterns of 1:2 and 1:3, respectively can be grown for getting higher total productivity and net returns per unit area per unit time.

Key Words: Gobhi sarson, land equivalent ratio, intercropping systems, oats fodder

With increasing population and improving purchasing power of people, the demand of edible oil in the country is increasing at the rate of 4-6% per annum (Rao, 2009). There is very little chance for horizontal growth of the crop. Thus, the production of rapeseed and mustard can be increased by vertical growth of the crop through intercropping with other crops. Various *Brassica* species have been successfully intercropped with different crops *viz*. chickpea, lentil, sugarcane, potato, wheat, etc. under various agro-climatic zone of the country. Gobhi sarson is a new emerging oilseed crop having limited area of cultivation confined to Haryana, Punjab and Himachal Pradesh. It is a long duration and widely spaced row crop. Because of photo-sensitivity and thermo-sensitivity, this crop is slow growing at the initial stage and as a result it evades the frost. So, there is a scope of growing oats fodder as an inter crop during its early growth stages to increase productivity per unit land and per unit time. Oats is an important rabi fodder grown under restricted conditions and in Punjab, it is next to berseem in importance because it provides balanced diet for cattle when mixed with berseem. Keeping these points in view, the present study was undertaken to find out the optimum row spacing and suitable variety of gobhi sarson for intercropping system and to work out a suitable planting pattern for gobhi sarson + oats fodder intercropping system.

MATERIAL AND METHODS

The present study was carried out at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during 2012-13. The soil of the experimental site was loamy sand in texture with pH 7.8, electrical conductivity 0.32 dSm^{-1}, organic carbon 0.29%, low in available N (224.5 kg ha^{-1}) and medium in available P (20.5 kg ha^{-1}) and K (226.9 kg ha^{-1}). The experiment was laid out in a randomized block design with fifteen intercropping systems replicated four times. Gobhi sarson and oats fodder were sown on October 25, 2012 at optimum soil moisture using recommended seed rate. Two varieties of gobhi sarson viz. GSL 1 and GSC 6 were grown at row spacing of 45, 60, 75 and 90 cm. Oats fodder variety "Kent" was sown as an intercrop in different ratio as per treatments with row to row spacing of 20 cm. In gobhi sarson, the uniform plant stand was maintained with decrease in intra-row spacing. The plant to plant spacing was kept at 10, 7.5, 6 and 5 cm in row spacing of 45, 60, 75 and 90 cm, respectively. A uniform dose of 75 kg N ha^{-1}, 20 kg P_2O_5 ha^{-1} and 15 kg K_2O ha^{-1} was applied before sowing of gobhi sarson. Second dose of nitrogen at the rate of 75 kg ha^{-1} was applied after 30 days of sowing. The recommended dose of fertilizer for oats fodder @37.5 kg P_2O_5 ha^{-1} and 37.5 kg N ha^{-1} before sowing and 37.5 kg N ha^{-1} after first cutting were applied on area basis for all the treatments. Weeds were kept under check with hand weeding. Irrigation and plant protection measure were applied as per recommendation. The intercrop was harvested twice for green fodder. The harvesting of gobhi sarson was done in first fortnight of April and seed yield was recorded. Gobhi sarson equivalent yield and net returns were calculated.

The plant samples of gobhi sarson as well as intercrops from each treatment were taken to estimate N, P, K uptake at harvest. To determine total nitrogen content, a sample of 0.5 g of plant material was digested in concentrated H_2SO_4 and digestion mixture (selenium dioxide + copper sulphate + potassium sulphate). The nitrogen content (%) of plant material was determined by Kjeldahl's method (Piper, 1966).

To determine the phosphorus and potassium content in seed and straw, sample from each treatment were grinded. The plant sample (0.5g) was digested with triple–acid mixture of HNO_3, $HCLO_3$ and H_2SO_4 in the ratio of 9:3:1. Phosphorus content was determined by using Spectronic-20 Colorimeter and potassium content was determined with Lange's Flame Photometer (Jackson, 1967).

RESULTS AND DISCUSSION

Effect on yield and yield attributes: The plant height recorded at harvest differed significantly among different intercropping systems. Maximum plant height was recorded by sole GSL 1 sown at 45 cm spacing and it was statistically at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1), GSL 1 at 60 cm + oats (1:2), GSL 1 at 75 cm + oats (1:2), GSL 1 at 90 cm + oats (1:2) and GSL 1 at 90 cm + oats (1:3) intercropping systems, but significantly higher than other intercropping systems (Table 1). Variety GSL 1 recorded higher plant height than variety GSC 6. Both gobhi sarson varieties in sole cropping gave statistically similar result of plant height as recorded in their respective intercropping systems. This may be due to their genetic makeup and interactive effect of genotypes with the environment. Dry matter accumulation is one of the most important parameter and has a marked influence on final yield realization of a crop. Sole GSL 1 sown at 45 cm row spacing recorded maximum dry matter accumulation, which was significantly higher than both GSL 1 and GSC 6 at 90 cm + oats (1:2 and 1:3) and GSC 6 at 75 cm + oats (1:2) intercropping systems, but was at par with all other intercropping systems. Variety GSL 1 at wider row spacing of 90 cm in intercropping systems recorded significantly lower dry matter accumulation as compared to sole GSL 1. Similarly, variety GSC 6 also recorded significantly lower dry matter accumulation in intercropping systems at wider row spacing of 90 cm.

Number of primary and secondary branches per plant of gobhi sarson was significantly influenced by different intercropping systems. The primary branches per plant were highest in sole crop of gobhi sarson variety GSL 1, which were statistically at par with that obtained in GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1 and 1:2), GSL 1 at 75 cm + oats (1:2) and GSL 1 at 90 cm + oats (1:2 and1:3), but significantly higher than all other intercropping systems. Variety GSC 6 also recorded statistically similar number of primary branches per plant in sole and its intercropping systems. The significant differences among different intercropping systems were due to varietal differences. Sole variety GSL 1 sown at 45 cm row spacing recorded highest number of secondary branches per plant (14.6), which was at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1 and 1:2), GSC 6 at 45 cm + oats (1:1), GSC 6 at 60 cm + oats (1:1 and 1:2) intercropping systems and sole cropping of GSC 6 at 45 cm, but significantly higher than all other intercropping systems. Reduction in number of secondary branches per plant of gobhi sarson under wider spacing may be due to more competition for growth resource

Table 1. Effect of intercropping systems on the growth and yield attributes of gobhi sarson

Intercropping system	Plant height (cm)	DMA* (q ha^{-1})	Primary branches $plant^{-1}$	Secondary branches $plant^{-1}$	Siliquae $plant^{-1}$	Seeds $siliqua^{-1}$	1000 seed weight (g)
T1-GSL 1 at 45 cm + oats (1:1)	179.5	91.1	6.9	14.5	270.8	23.8	3.74
T2-GSL 1 at 60 cm + oats (1:1)	175.9	88.9	6.9	14.3	267.8	23.7	3.73
T3-GSL 1 at 60 cm + oats (1:2)	175.9	87.7	6.8	13.7	261.3	23.5	3.71
T4-GSL 1 at 75 cm + oats (1:2)	175.7	85.3	6.8	12.9	257.0	23.1	3.69
T5-GSL 1 at 90 cm + oats (1:2)	173.9	82.5	6.6	12.0	238.8	22.9	3.64
T6-GSL 1 at 90 cm + oats (1:3)	173.8	82.3	6.6	11.5	237.0	22.8	3.62
T7-GSC 6 at 45 cm + oats (1:1)	141.8	86.8	5.8	13.8	252.0	23.1	3.67
T8-GSC 6 at 60 cm + oats (1:1)	141.5	85.7	5.7	13.7	248.5	22.9	3.65
T9-GSC 6 at 60 cm + oats (1:2)	138.6	84.4	5.6	13.6	244.2	22.8	3.62
T10-GSC 6 at 75 cm + oats (1:2)	136.7	81.8	5.5	12.2	238.6	22.5	3.59
T11-GSC 6 at 90 cm + oats (1:2)	136.3	79.1	5.3	11.9	229.9	22.3	3.58
T12-GSC 6 at 90 cm + oats (1:3)	135.9	78.9	5.2	11.8	228.1	22.3	3.48
T13-Sole GSL 1 at 45 cm	181.9	91.5	7.0	14.6	272.8	23.9	3.75
T14-Sole GSC 6 at 45 cm	142.2	87.0	5.8	13.9	258.3	23.2	3.68
T15-Sole oats fodder at 20 cm	-	-	-	-	-	-	-
CD (p=0.05)	10.1	7.3	1.0	1.5	26.6	NS	NS

*DMA= Dry matter accumulation

with closer intra-row spacing. Sole cropping of variety GSC 6 at 45 cm recorded higher number of secondary branches per plant (13.9), which was significantly higher than GSC 6 at 75 cm + oats (1:2), GSC 6 at 90 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems, but was at par with all its other intercropping systems.

Sole cropping of GSL 1 sown at 45 cm recorded significantly higher number of siliquae per plant, which was at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1 and 1:2), GSL 1 at 75 cm + oats (1:2), GSC 6 at 45 cm + oats (1:1), GSC 6 at 60 cm + oats (1:1) intercropping systems and sole GSC 6 at 45 cm, but significantly higher than all other intercropping treatments. Variety GSC 6 recorded significantly higher number of siliquae per plant in sole stand as compared to GSC 6 at 90 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems. Reduction in number of siliquae per plant under wider spacing may be attributed to closer intra-row spacing. Similarly, Rana (2006) also reported that *karan rai* in intercropping system produce less number of siliquae per plant than sole crop. Number of seeds per siliqua and 1000-seed weight was not significantly influenced by different intercropping systems. Similar trend was recorded in seed and straw yield. The effect of different intercropping systems was significant on the seed yield of *gobhi sarson*. The maximum seed yield (21.01 q ha^{-1}) was obtained in sole cropping of GSL 1 at 45 cm, which was significantly higher than GSL 1 at 90 cm + oats (1:2), GSL 1 at 90 cm + oats (1:3), GSC 6 at 75 cm + oats (1:2), GSC 6 at 90 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems, but remained at par with all other intercropping systems. Sole oats fodder recorded significantly higher green fodder yield than under all other intercropping systems. This happened at lower plant population of oats and shading effect of gobhi sarson in the intercropping systems as compared to their pure stand. Sarkar and Mahasin (2007) also reported that pure crop of oats gave higher green fodder yield than its intercropped stand.

Effect on gobhi sarson equivalent yield and net returns: All the intercropping systems recorded significantly higher gobhi sarson equivalent yield and net returns than sole gobhi sarson (GSL 1 & GSC 6) and sole oats fodder. Sole oats fodder recorded the lowest gobhi sarson equivalent yield (19.46 q ha^{-1}). Maximum gobhi sarson equivalent yield (28.73 q ha^{-1}) was recorded with intercropping system of GSL 1 at 90 cm + oats (1:3), which was at par with GSL 1 at 60 cm + oats (1:2), GSL 1 at 75 cm + oats (1:2), GSC 6 at 60 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems, but significantly higher than all other intercropping systems (Table 2). Sachan and Uttam (1992) reported that mustard intercropped with gram gave higher mustard equivalent yield than sole mustard. Intercropping system of GSL 1 at 90 cm + oats (1:3) recorded maximum net returns (Rs 57673 ha^{-1}), which was at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:2), GSL 1 at 75 cm + oats

Table 2. Productivity, economics and LER of gobhi sarson and oats fodder intercropping system

Intercropping system*	*Gobhi sarson*			Oats green fodder yield (q ha^{-1})	GSEY** (q ha^{-1})	Net returns (Rs ha^{-1})	LER
	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)				
T1	20.88	79.75	20.80	130.9	26.51	54555	1.28
T2	20.54	79.34	20.55	126.2	25.97	54397	1.26
T3	20.26	78.90	20.37	195.8	28.59	57540	1.39
T4	19.08	76.85	19.80	188.7	27.20	55206	1.33
T5	18.94	75.90	19.76	160.0	25.82	52333	1.26
T6	18.93	75.88	19.76	227.7	28.73	57673	1.41
T7	19.87	77.13	20.48	148.2	26.25	53621	1.33
T8	19.70	76.79	20.28	128.0	25.21	52074	1.28
T9	19.36	76.60	20.17	206.7	28.25	56394	1.44
T10	18.13	74.11	19.68	192.9	26.43	52832	1.34
T11	17.83	72.90	19.56	191.5	26.07	52794	1.32
T12	17.77	72.82	19.53	247.3	28.41	56556	1.45
T13	21.01	81.08	20.88	-	21.01	44834	1.00
T14	19.93	77.29	20.54	-	19.93	41520	1.00
T15	-	-	-	452.2	19.46	36425	1.00
CD (p=0.05)	1.65	4.68	NS	20.2	1.69	3250	0.12

* Treatment details in Table 1 **GSEY= *Gobhi sarson* equivalent yield

Price (Rs q^{-1}): *Gobhi sarson* = 2788; Straw of *gobhi sarson* = 80; Oats fodder = 120

(1:2), GSC 6 at 60 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems, but significantly higher than all other intercropping treatments. Singh *et al.* (1992) also reported that net return was higher in wheat + Indian mustard intercropping system than their pure crops.

Effect of land equivalent ratio (LER): Compared with sole cropping, all the intercropping systems resulted in significantly higher LER indicating the yield advantage in intercropping. Intercropping system of GSC 6 at 90 cm + oats (1:3) recorded maximum LER (1.45), which was at par with GSC 6 at 60 cm + oats (1:2), GSC 6 at 75 cm + oats (1:2), GSL 1 at 60 cm + oats (1:2) and GSL 1 at 90 cm + oats (1:3) intercropping systems, but significantly higher than all other intercropping systems.

Nitrogen, phosphorus and potassium uptake: Significant differences were observed among intercropping treatments for total nitrogen, phosphorus and potassium uptake. Maximum uptake of nitrogen (137.8 kg ha^{-1}) was observed in GSL 1 at 60 cm + oats (1:2) intercropping system, which was at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1), GSL 1 at 75 cm + oats (1:2), GSL 1 at 90 cm + oats (1:2 and 1:3), GSC 6 at 45 cm + oats (1:1) and GSC 6 at 60 cm + oats (1:2) intercropping systems, but significantly higher than sole and other intercropping treatments. The higher uptake of nitrogen by GSL 1 at 60 cm + oats (1:2) intercropping system may be due to higher total biomass production under this treatment. Sole oats fodder recorded significantly lower nitrogen uptake (52.8 kg ha^{-1}). Intercropping system of GSL 1 at 60 cm + oats (1:2) overlap to GSL 1 at 90 cm + oats (1:3) in total nitrogen uptake which was due to higher gobhi sarson biomass yield at 60 cm row spacing than at 90 cm row spacing. As the nitrogen content in gobhi sarson was higher than oats fodder that resulted in higher uptake by GSL 1 at 60 cm + oats (1:2).

Sole cropping and different intercropping systems recorded significant difference in phosphorus uptake. Intercropping system of GSL 1 at 60 cm + oats (1:2) recorded maximum phosphorus uptake (38.8 kg ha^{-1}), which was at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1), GSL 1 at 75 cm + oats (1:2), GSL 1 at 90 cm + oats (1:3), GSC 6 at 45 cm + oats (1:1), GSC 6 at 60 cm + oats (1:1), GSC 6 at 60 cm + oats (1:2), GSC 6 at 75 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems, but significantly higher than sole and other intercropping treatments.

Maximum potassium uptake (113.0 kg/ha) was recorded in GSL 1 at 90 cm + oats (1:3) intercropping system. Lower value of potassium uptake was recorded in sole crop of oats followed by sole GSC 6 and GSL 1 (Table 3). The higher uptake of potassium in intercropping systems was due to more biomass production as a result of more efficient utilization of resources by component crops. Between two varieties, GSC 6 based intercropping systems, GSC 6 at 60 cm + oats (1:2) intercropping system recorded significant highest uptake of potassium than rest of its intercropping systems except GSC 6 at 60 cm + oats (1:2) intercropping system.

Table 3. Effect of intercropping system on total uptake of N, P and K by plants and available N, P and K in soil

Intercropping system*	Total uptake (kg ha^{-1})			Available (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
T1	133.7	37.4	104.4	253.7	23.5	222.2
T2	130.3	35.7	102.0	244.8	23.1	217.8
T3	137.8	38.8	111.2	264.0	24.7	244.6
T4	131.8	36.3	110.8	259.9	24.3	236.3
T5	124.9	35.2	101.9	263.0	23.9	233.4
T6	133.0	36.2	113.0	265.8	26.2	263.8
T7	129.6	37.0	103.5	255.6	24.2	226.1
T8	125.7	36.1	97.5	247.2	22.8	224.0
T9	133.4	38.6	109.9	266.0	24.7	264.5
T10	126.9	35.7	103.8	263.4	24.6	247.4
T11	123.1	34.4	100.7	261.2	24.6	258.6
T12	129.1	36.4	110.7	266.2	26.0	265.1
T13	120.7	32.3	80.0	237.8	20.2	216.5
T14	114.1	30.3	76.5	241.6	22.0	224.8
T15	52.8	20.7	72.4	237.5	21.0	206.6
CD (p=0.05)	8.2	3.3	6.5	NS	NS	NS

*Treatment details in Table 1

Effect on soil status: The available nitrogen of surface soil after harvest of component crops was increased from its initial status. Intercropping systems did not significantly influence the available nitrogen status of surface soil. Available phosphorus status of surface soil did not significantly differ with different intercropping treatments. However, intercropping system of GSL 1 at 90 cm + oats (1:3) recorded higher value of available phosphorus status (26.2 kg ha^{-1}) of surface soil (Table 3). The available potassium of surface soil after harvest of crop was decreased from its initial potassium status. Effect of different intercropping systems on available potassium of surface soil was not significant. However, intercropping system GSC 6 at 90 cm + oats (1:3) recorded maximum value of available potassium (265.1 kg ha^{-1}) and lowest value (206.6 kg ha^{-1}) was recorded by sole oats fodder.

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Effect of Spacing and Nitrogen Levels on Growth, Flowering and Yield Parameters of Garden Rue (*Ruta Graveolens* L.)

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Abstract: A field investigation was carried out to study the effect of spacing and nitrogen levels on growth and yield of garden rue (*Ruta graveolens* L.). The plant height, fresh / dry herbage and root yield were significantly higher at 45 x 30 cm spacing compared to 45x45cm and 45x60cm. Improved growth parameters, flowers per plant, per cent dry matter, fresh/dry herbage and root yields were significantly higher in plants supplied with 150 kg nitrogen per hectare. Minimum days to first and fifty per cent flowering was recorded with application of 60 kg nitrogen per hectare. Plants grown at 45 x 30 cm + 150 kg N ha^{-1} combination registered maximum growth, fresh/dry herbage/ fresh root yield and per cent dry matter at harvest.

Key Words: *Ruta graveolens*, nitrogen, spacing, growth, yield

The Rutaceae family comprises of extremely wide variety of medicinal plants, mainly distributed in tropical regions. The most common medicinal plant of this family is garden rue (*Ruta graveolens* L.), which is used since times immemorial in Ethanobotany. Rue contains more than 120 natural compounds mainly including acridone alkaloids, coumarines, essential oils (0.5%), flavonoids (Rutin), and furoquinolines (1.4%) found in the roots and aerial parts of this plant and is the main source of furanocoumarins such as psoralen, xanthotoxin (8-meth- 8710 oxypsoralen; 8-MOP) and bergapten (5-methoxypsoralen; 5-MOP), which are valued in pharmaceutical industry. The compound responsible for the bitter taste is Rutin (7 to 8% in the dried leaves).

It has been used as an antispasmodic, as a treatment for menstrual problems, as an abortifacient, and as a sedative. The whole herb is anthelmintic, antidote, carminative, emetic, emmenagogue, expectorant, haemostatic, ophthalmic, rubefacient, strongly stimulant, mildly stomachic and uterotonic. Ruta in combination with calcium phosphate [$Ca_3(PO4)_2$] could be used as effective treatment for brain cancers, particularly glioma (Pathak *et al*., 2003). Spacing and nutrients are important factor, which can limit crop growth and yield. It is possible to produce higher yields by judicious practices in the supply of nutrients and adoption of proper spacing. Being an herbaceous crop, great potential exists for increasing the plant growth and yield through the application of inorganic nitrogenous fertilizer. In this context, the study was conducted to evaluate the effect of spacing and nitrogen levels on growth, flowering and yield parameters of garden rue (*Ruta graveolens* L.).

MATERIALS AND METHODS

Field experiment was conducted at the Department of Plantation, Spices, Medicinal and Aromatic Crops, Kittur Rani Channamma College of Horticulture, Arabhavi, Gokak Taluk, Belgaum district of Karnataka state from September 2012 to February 2013. This experiment was laid out in Factorial Randomized Block Design (FRBD) with twelve treatments and three replications. The treatments consisted of two factors viz., spacing with three levels (45 x 30 cm, 45 x 45 cm and 45 x 60 cm) and nitrogen fertilizer with four levels (60, 90, 120 and 150 kg ha^{-1}). The size of the experimental plot was 3.0 m x 1.8 m with different spacing levels. Well decomposed FYM was applied 15 days before transplanting, at the rate of 10 ton per hectare and mixed thoroughly into the soil. The treatments were allocated to individual plots at random. Spacing was adopted in each plot as per the treatment allocation. The nutrients were applied in the form of straight fertilizers with nitrogen in the form of urea, phosphorous in the form of single super phosphate and potassium in the form of muriate of potash. The seedlings were raised from seeds in two nursery beds of 15 cm height, 1 m width and 2.5 m length. Fifty days old, healthy and uniform sized seedlings were selected and transplanted in the experimental plots as per the treatments.

The fertilizer mixture was applied by broadcasting uniformly in rows to individual plots as per the treatment and mixed thoroughly in to the soil. Out of total quantity, half dose of nitrogen and full dose of phosphorous (30 kg ha^{-1}) and potash (30 kg ha^{-1}) were supplied as basal dose one day before transplanting. The remaining half quantity of nitrogen was given as top dressing at 45 days after transplanting.

The first irrigation was given immediately after transplanting and irrigated once in a week or fifteen days during the whole cropping period. The crop was harvested five months after transplanting at full flowering stage asit contains maximum percentage of active principles at this stage. Harvested herb was cut into pieces of convenient length along with flowers and immature capsules. This material was dried under partial shade for few hours and used for essential oil extraction. Observations were recorded on plant height, number of primary branches, plant spread, stem girth at harvest stage i.e., 150 days after planting (DAP). Flowering parameters like number of flowers and days to first and fifty per cent flowering were also recorded at flowering stage. Yield characters like per cent dry matter, fresh and dry herbage and fresh root yield per plant, plot and hectare were recorded during harvesting.

RESULTS AND DISCUSSION

Effect of spacing levels: A perusal of data in table 1 indicates that the wider spacing of 45 x 60 cm caused significant promotion in number of primary branches per plant (11.64), plant spread {E-W (48.91 cm) and N-S (45.76 cm)} and stem girth (12.96 mm) 150 DAP compared with other levels of spacing. The increase in various growth characters may be attributed to the availability of more spatial area for spreading, which helped in more interception of light due to higher surface area, which produced better growth. Meanwhile, the significant increment of plant height was recorded at narrow spacing (45 x 30 cm). The increased plant height in closer spacing might be due to competition among plants for solar energy (light). The plant height increases with an increase in plant density has also been reported by Gangadharappa (1987) in *Ammi majus* and Subbireddy *et al*. (1991) in *Solanum viarum*.

Flowering in garden rue was significantly influenced by spacing levels except days to 50 per cent flowering (Table 1). Earliest flowering was observed in plants spaced at 45 x 45 cm (S_2). While delayed flowering was observed in treatment 45 x 60 cm (S_3). This may be attributed to the

Table 1. Effect of spacing and nitrogen levels on growth and flowering characters of garden rue (*Ruta graveolens* L.)

Treatments	Growth parameters					Flowering parameters		
	Plant height (cm)	No. of primary branches	Plant spread {E-W (cm)}	Plant spread {N-S (cm)}	Stem girth (mm)	Days to first flowering	Days to fifty per cent flowering	Number of flowers per plant
Spacing level (S)								
S_1 : 45x30 cm	45.42	10.31	46.09	43.15	11.62	122.42	141.08	536.92
S_2 : 45x45 cm	43.48	10.74	47.01	44.80	12.07	120.00	140.08	545.83
S_3 : 45x60 cm	42.57	11.64	48.91	45.76	12.96	126.67	143.58	552.92
CD (0.05)	1.87	0.83	2.13	1.93	0.66	4.37	NS	7.57
Nitrogen level (N)								
N_1 : 60 kg N ha^{-1}	41.08	9.82	43.02	41.94	11.18	114.22	133.44	520.33
N_2 : 90 kg N ha^{-1}	41.88	10.50	45.25	42.42	11.67	123.44	141.78	541.78
N_3 : 120 kg N ha^{-1}	44.98	11.12	47.97	45.83	12.30	124.11	144.00	546.56
N_4 : 150 kg N ha^{-1}	47.35	12.14	53.11	48.10	13.71	130.33	147.11	572.22
CD (0.05)	2.16	0.96	2.46	2.23	0.77	5.04	6.98	8.75
Interaction (S x N)								
S_1N_1	43.33	9.47	41.74	40.44	10.75	112.33	129.33	511.67
S_1N_2	40.76	9.97	44.78	40.88	10.86	120.00	142.00	530.00
S_1N_3	47.11	10.03	48.01	44.22	11.50	127.67	144.33	538.33
S_1N_4	50.50	11.77	49.85	47.07	13.37	129.67	148.67	567.67
S_2N_1	38.93	9.12	42.00	41.91	11.10	111.33	133.00	522.67
S_2N_2	41.96	10.80	44.93	43.3	11.66	121.67	143.67	544.67
S_2N_3	44.65	11.20	47.37	45.79	12.37	116.33	143.00	542.67
S_2N_4	48.36	11.83	53.74	48.19	13.14	130.67	140.67	573.33
S_3N_1	40.98	10.87	45.33	43.47	11.69	119.00	138.00	526.67
S_3N_2	42.92	10.73	46.03	43.07	12.49	128.67	139.67	550.67
S_3N_3	43.17	12.13	48.52	47.47	13.04	128.33	144.67	558.67
S_3N_4	43.20	12.83	55.75	49.04	14.64	130.67	152.00	575.67
CD (0.05)	3.74	NS	NS	NS	NS	NS	NS	NS
CV (%)	5.05	9.09	5.33	5.13	6.46	5.19	5.04	5.64

NS: Non-significant

Table 2. Effect of spacing and nitrogen levels on yield parameters of garden rue (*Ruta graveolens* L.) at harvesting stage

Treatments	Fresh herbage yield hectare^{-1} (ton)	Dry herbage yield hectare^{-1} (ton)	Fresh root yield hectare^{-1} (ton)	Per cent dry matter
Spacing level (S)				
S_1 : 45x30 cm	16.00	3.63	2.06	21.49
S_2 : 45x45 cm	14.06	3.31	1.85	22.75
S_3 : 45x60 cm	12.53	2.72	1.76	23.85
CD (0.05)	0.80	0.21	0.16	0.97
Nitrogen level (N)				
N_1 : 60 kg N ha^{-1}	13.16	2.99	1.77	21.55
N_2 : 90 kg N ha^{-1}	13.57	3.17	1.83	21.91
N_3 : 120 kg N ha^{-1}	14.51	3.22	1.88	22.69
N_4 : 150 kg N ha^{-1}	15.54	3.49	2.09	24.64
CD (0.05)	0.92	0.24	0.19	1.12
Interaction (S x N)				
S_1N_1	14.52	3.43	1.83	20.43
S_1N_2	14.77	3.46	1.95	20.08
S_1N_3	17.31	3.45	2.13	20.72
S_1N_4	17.40	4.16	2.34	24.72
S_2N_1	13.74	3.01	1.87	22.03
S_2N_2	14.62	3.58	1.77	21.11
S_2N_3	15.25	3.53	1.97	23.33
S_2N_4	12.62	2.55	1.80	24.53
S_3N_1	11.22	2.52	1.61	22.18
S_3N_2	11.31	2.47	1.77	24.52
S_3N_3	10.98	2.12	1.53	24.02
S_3N_4	16.59	3.77	2.13	24.68
CD (0.05)	1.61	0.43	0.33	1.94
CV (%)	6.70	7.92	10.58	5.04

competition among plants for nutrients, water and sunlight thus forcing the plants to turn to reproductive phase early as reported by Marutiprasad (2002) in davana. Maximum number of flowers per plant (552.92) was registered at 45 x 60 cm and minimum (536.92) at 45 x 30 cm. This might be due to more number of branches, more plant spread, which produced more flowering branches by the utilization of more space by the plants for production of flowers at this spacing.

At harvest, significantly higher fresh and dry herbage (16.00t and 3.63t, respectively) and fresh root yield per hectare (2.06 t) was noticed in closer spacing (45 x 30 cm). This might be due to the luxuriant growth of plants during vegetative phase and accommodation of more number of plants per unit area due to closer spacing helped to accumulate higher dry matter resulting in higher herbage and root yields. Whereas, wider spacing of 45 x 60 cm recorded more per cent dry matter (Table 2). This might be due to the fact that widely spaced plants put up better vegetative growth and accumulated more dry matter content through better utilization of light, moisture and space resulting in higher per cent dry matter.

Effect of nitrogen levels: The application of nitrogen at different levels improved most of growth characters significantly at 150 DAP (Table 1).Generally, higher level of nitrogen (150 kg ha^{-1}) recorded significantly higher plant height (47.35 cm), more number of primary branches per plant (12.14), plant spread {E-W (53.11 cm) and N-S (48.10 cm)} and stem girth(13.71 mm) compared to other treatments. The least growth was noticed at lower nitrogen level of 60 kg ha^{-1}. The positive influence of nitrogen on plant height might be due to the fact that nitrogen is required for cell division and cell elongation, which triggers the growth of meristamatic tissue and the efficient utilization of this by the plants might manifested in production of taller plants with more number of branches, plants spread and stem girth. These results are in agreement with the findings of Kumar *et al.* (2006) and Malik *et al.* (2012) in garden rue.

Flowering was significantly influenced by nitrogen aoolication (Table 1). The least number of days to first (114.22) and 50 per cent flowering (133.44) was observed in

plants supplied with 60 kg N ha^{-1}, while the maximum number of days to first and 50 per cent flowering was recorded with 150 kg N ha^{-1}. This may be attributed to the positive role of nitrogen on vegetative growth which delayed the flowering. The identical results have been reported by Kavitha and Vadivel (2006) in *Mucuna pruriens*. More number of flowers per plant, higher fresh/dry herbage and fresh root yield was registered in plants supplied with the higher nitrogen level (150 kg N ha^{-1}) and minimum was noticed in plants supplied with 60 kg N ha^{-1} (Table 2). This could be attributed to the enhanced availability of nitrogen at the appropriate time, which might have resulted in increased photosynthetic rate and accumulation of metabolites in plants.

Effect of interaction between spacing level and nitrogen fertilization: The plants grown at spacing of 45 x 30 cm and supplied with 150 kg of N ha^{-1} registered significant increase in plant height (50.5 cm) at 150 DAP (Table 1).This may be due to positive effect of spacing and nitrogen individually on plant height and the same beneficial effect has been reflected in the combination also.

Significant differences were found among yield parameters due to interaction (Table 2). The combination of highest level of nitrogen and narrow spacing must have given the plants more scope to put better growth by producing increased plant height, branches, plant spread and accommodation of more number of plants per unit area resulting in higher herbage and root yields and per cent dry matter. The results are in line with the findings of Sherbeny *et al.* (2007) in garden rue.

It may be concluded that, among different spacing levels planting of garden rue at 45 x 30 cm spacing is beneficial for obtaining the maximum plant height, herbage and root yields. Among nitrogen levels, application of 150 kg nitrogen per hectare is favorable for getting improved growth characters, flowers per plant, higher herbage and root yields and per cent dry matter. Growing of garden rue at 45 x 30 cm spacing and supplemented the crop with 150 kg nitrogen per hectare is valuable for obtaining the highest herbage and root yields and per cent dry matter under northern dry zone of Karnataka.

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Performance of Cabbage Hybrids for Various Horticultural Traits in the Plains of Punjab

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Abstract: An experiment was conducted to assess the performance of eight cabbage hybrids from private source during winter season of 2010-11 and 2011-12. The ANOVA revealed that there existed significant differences among the hybrids for all the characters when analyzed for individual years and also when pooled over the years. The MS due to years were significant for all the characters except head length, number of outer leaves and stalk length indicating that the hybrids responded differently to the changing environmental conditions. The interaction between years x hybrids was significant for all the characters. Hybrid KTCBH-81 took minimum days (83.67) to reach maturity. Plant spread (49.18cm), stalk length (10.20cm), head width (16.13cm) and net weight of head (789.50g) was maximum in hybrid BC-76. Similarly head length (21.25cm) and net yield (288.75q ha^{-1}) was maximum with KTCBH-81. Therefore, hybrid KTCBH-81 and Bc-76 are most suitable for cultivation under Punjab conditions.

Key Words: Cabbage, hybrids, performance, head weight

INTRODUCTION

Cabbage is the second most important crop of the cole group grown under temperate to tropical climate conditions for its head in more than ninety countries throughout the world (Singh *et al*., 2010) and the leading countries are China, India, Russia, Korea, Japan and the USA. In India, it is cultivated in 389.62 thousand ha area with a production statistics of 8412.12 metric tones ha^{-1}. It is also rich source of ascorbic acid, carotene (pro. Vitamin A) and has high fiber content and calcium which reduces the risk of colon cancer (Swarup, 2006). It is a rich source of protein comprising all essential amino acids, especially sulphur containing amino acids, minerals such as calcium, iron, magnesium, sodium, potassium, phosphorus and antioxidant and is reported to have anti-carcinogenic properties (Singh *et al.,* 2009). Cabbage is cultivated for its head which is consumed as salad and cooked as well and its outer leaves are also used as animal fodder. Selective breeding has produced several distinct types of cabbage: early, midseason and late; green and purple; large and small heads; flat, oval, conical and globular; savoy types; and those with either smooth or crumpled leaves (Singh *et al.,* 2006).

Cabbage is a cool season crop and requires 18-25°C for germination of seed, 7-25°C for vegetative growth and 18-25°C for head formation (Dhaliwal, 2012). This range of temperature for cabbage production is available during winter months in Punjab. However, seed production in tropics and sub tropics is not feasible because of insufficient chilling to promote flowering. Cabbage needs temperature in the range of 4.4 to 10°C for 60 days for flowering, which is not feasible under subtropical conditions of India (Fang *et al.,* 2004). Therefore cabbage breeding and seed production takes place outside India. Seed is imported from Europe and is sold by seed companies and other retail outlets. Most of these hybrids/varieties are described to be high yielding and with varying levels of resistance to diseases. Important horticultural characters in cabbage are head size, shape and firmness, taste, maturity. Evaluating cabbage hybrids for adaptation and yield will help farmers, breeders and seed companies select and develop hybrids/varieties best suited to the local environment and market. Therefore the present investigation was carried out to evaluate the commercial hybrids acceptable for fresh market.

MATERIAL AND METHODS

The present investigation was conducted at the Vegetable Research Farm of the Punjab Agricultural University (PAU), Ludhiana during the crop seasons 2010-11 and 2011-12. The experimental materials comprised of 7 cabbage hybrids from different public sectors and private companies (Table1). Sowing in nursery beds was done in the last week of September and seedlings were transplanted in the field in the last week of October during both the years of testing. Each hybrid was planted in a plot having 3.6 × 2.4 m area in randomized block design with three replications. There were 30 plants in each plot planted at row and plant spacing of 60 × 45 cm. All the standard package of practices and plant protection measures were timely adopted to raise the crop successfully. Duration of crop, duration of 50% head maturity were recorded from the entire plot of each replication while ten plants were selected randomly from each replication for recording observations viz., plant spread (cm), head length

(cm), head width (cm), net weight of head (g), number of outer leaves, stalk length (cm) and net yield (q ha^{-1}). The data recorded for the individual years and pooled mean values were used for estimating the analysis of variance as suggested by Panse and Sukhatme (1978).

Table 1. Hybrids of cabbage from public and private source

Sr No	Name of hybrid	Source
1.	KTCBH-51	IARI(Katrain)
2.	KTCBH-81	IARI(Katrain)
3.	BC-64	Syngenta
4.	BC-76	Syngenta
5.	Godavari	Clause
6.	Nilgiri	Clause
7.	Quisto (C)	Syngenta

RESULTS AND DISCUSSION

The results pertaining to the analysis of variance for the experimental design are reported in Table 2. The Anova revealed that there existed significant differences among the hybrids for all the characters when analysed for individual years and also when pooled over the years. The MS due to years were significant for all characters except head length, number of outer leaves and stalk length. This suggested that the duration of crop, plant spread, head width, net head weight, yield were more influenced by the change in environment. The mean sum of square due to interaction between years x hybrids were significant for all the characters studied indicating that the hybrids responded differently to the changing environmental conditions. The relative performance (mean over years) of different cabbage hybrids for various economic characters is in individual years and their mean values are reported in Table 3 and Table 4. Cabbage entries also differed significantly in their life cycle expressed in number of days to harvest time in both the years indicating the effect of environment. In the first year of evaluation, the numbers of days to harvest were more than second year. This may be due to favourable temperature during growth of crop in second year. The minimum number of days to curd formation were found in hybrid KTCBH-81 (83.67) followed by hybrid Godavari (85.83). The variation in duration of crop among different hybrids may be due to their specific genetic make up, inherent properties and environmental factors. Meena *et al.* (2012) reported the range of 71.28 to 110.53 days to maturity in 30 cabbage genotypes. Similar results were reported by Obiadalla *et al* (2012) and Greenland *et al.* (2000). Plant spread is a desirable character in cabbage because the growth and head size depends upon the spread of the plant. It should be medium in size. Maximum mean value of plant spread was reported in hybrid BC-76 (49.18 cm) followed by hybrid BC-64 (45.28 cm). Minimum plant spread was recorded in hybrid KTCBH-51. The variation in plant spread among different hybrids is due to their different genetic make up. Number of outer leaves is an important trait and it should be restricted to minimum as excess vegetative growth reduces the head weight especially in early maturing hybrids. When a cabbage plant grows, it first increases the number of wrapper leaves and extends the area of each leaf. Second, it starts to express head formation in the middle of developmental stage and finally forms mature head with adequate size by increasing the number and weight of the head leaves during continous vegetative growth Tanaka and Nikiiura (2003). All the hybrids showed variation in respect to number of outer leaves. Minimum number of leaves were reported in hybrid BC-64 (12.67) followed by KTCBH-81 (14.50) and maximum were in Hybrid Quisto. Significant differences were found among cabbage entries in both seasons for stalk length. Hybrid BC-76 had maximum stalk length (10.20 cm) followed by hybrid BC-64 (9.75cm) and these were significantly better than other hybrids. Minimum stalk length was observed in KTCBH-81 (5.65cm). Meena *et*

Table 2. Analysis of variance for various growth and yield characters in cabbage over years

Year	Source of Variation	Degree of freedom	Mean squares							
			Duration of crop	Plant spread (cm)	Head length (cm)	Head width (cm)	Net weight of head (g)	Net yield (q/ha)	Number of outer leaves	Stalk length (cm)
2010-11	Hybrids	6	86.83*	67.79*	19.52*	3.38*	19703.87*	3095.27*	21.43*	41.42*
	Error	12	0.57	1.34	0.17	0.20	215.07	49.14	1.48	0.32
2011-12	Hybrids	6	81.42*	42.63*	14.00*	3.57*	19769.33*	2961.84*	22.43*	6.98
	Error	12	2.31	1.25	0.24	0.17	182.23	77.40	0.95	4.13
Pooled	Environments	1	1748.59*	11.31*	0.005	6.10*	5348.00*	614.25*	1.17	1.80
	Hybrids	6	92.80*	98.50*	32.06*	7.05*	40194.45*	6212.80*	42.52*	18.54*
	Interaction	6	77.92*	18.92*	1.08*	0.29*	960.22*	23.01*	1.33*	1.88*
	Error	24	1.39	1.29	0.21	0.19	205.10	63.88	1.21	2.23

* Significant at $P \leq 0.05$

Table 3. Relative performance of identified cabbage hybrids for various growth and yield characters for two years

Hybrids	Duration of crop			Plant spread (cm)			Number of outer leaves			Stalk length (cm)		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
KTCBH-51	100.33	77.33	88.83	34.83	37.00	35.92	16.33	17.00	16.67	6.37	6.53	6.45
KTCBH-81	91.00	76.33	83.67	45.33	41.67	43.50	14.00	15.00	14.50	5.73	5.57	5.65
BC-64	101.67	83.33	92.50	45.57	45.00	45.28	12.33	13.00	12.67	9.83	9.67	9.75
BC-76	98.67	81.67	90.17	50.36	48.00	49.18	20.00	19.33	19.67	10.67	9.73	10.20
Godavari	89.67	82.00	85.83	40.50	42.00	41.25	15.33	14.33	14.83	5.63	5.86	5.75
Nilgiri	88.67	85.00	86.83	40.47	44.00	42.23	16.33	16.33	16.33	5.70	5.70	5.70
Quisto (C)	98.00	92.00	95.00	40.67	47.33	44.00	19.00	20.67	19.83	8.07	8.03	8.05
CD at 5%	1.22	2.70	1.69	2.06	1.99	1.45	2.16	1.73	1.31	1.01	0.90	1.78

Table 4. Relative performance of identified cabbage hybrids for various growth and yield characters for two years

Hybrids	Head length (cm)			Head width (cm)			Net weight of head (g)			Net yield (q ha^{-1})		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
KTCBH-51	15.17	15.17	15.17	12.50	13.57	13.03	662.33	670.00	666.17	245.33	249.65	247.49
KTCBH-81	21.50	21.00	21.25	15.40	15.77	15.58	763.33	765.00	764.17	284.67	292.82	288.75
BC-64	19.20	19.40	19.30	15.60	16.67	16.13	608.33	626.67	617.50	226.00	230.32	228.16
BC-76	18.27	16.83	17.55	14.13	15.33	14.73	757.67	821.33	789.50	282.00	290.05	286.02
Godavari	16.57	17.00	16.78	14.70	15.40	15.05	688.33	698.33	693.33	254.33	259.76	257.05
Nilgiri	16.03	15.87	15.95	14.17	14.17	14.17	723.33	726.67	725.00	265.00	272.60	268.80
Quisto (C)	14.23	15.57	14.90	13.20	14.13	13.67	530.00	583.33	556.67	191.00	206.67	198.84
CD at 5%	0.76	0.87	0.49	0.82	0.72	0.58	26.87	24.02	22.17	12.63	15.66	13.75

al. (2012) and Obiadalla *et al.* (2012) reported variation in the stalk length of the cabbage hybrids. Head length is an important character that represents the shape of the head and appeals to the consumer. Data presented in Table 4 revealed that head length was not influenced by environments and maximum was observed in KTCBH-81 (21.25 cm) and is significantly better than all the hybrids. The minimum mean value of head length (15.17 cm) was found in hybrid KTCBH-51. Similarly head width was maximum in BC-64 (16.13 cm) followed by KTCBH-81 (15.58 cm) and these hybrids were significantly better than other hybrids. Greenland *et al.* (2000) reported the range of head length and width of 12.75 to 19.50 and 12-18 cm, respectively, while Meena *et al*. (2012) reported the range 12.10 to 31 cm and 12.43 to 27.40 cm for head length and width, respectively. Similar results were reported by Adeniji *et al*. (2010) and Janko *et al.* (2011).

Data presented in Tables 4 revealed significant differences among cabbage hybrids for net weight of head. Net weight of cabbage hybrid was more in second year than first year that may be due to early winter that caused favourable growth of the crop. Similarly net head weight is directly correlated with the head length and width (Janko *et al.* 2011). Maximum mean value of net weight of head (789.50g) was observed in hybrid BC-76, which is statistically better than all the hybrids. Cabbage hybrid Quisto gave lowest mean value (556.67g) of net weight of head. Data presented in Table 4 revealed significant differences among different hybrids of cabbage for net yield. Net yield in second year was higher than the first year which may be due to early winter in second year that resulted in better growth and weight of the head and increased the yield. The maximum mean value for net yield was observed in hybrid KTCBH-81 (288.75q ha^{-1}) followed by hybrid BC-76 (286.02 q ha^{-1}) and both were statistically at par with each other but better than other hybrids. Quisto recorded the minimum yield (198.84 q ha^{-1}). Meena *et al.* (2012) reported the variation in cabbage hybrid yield ranging from 111-566q ha^{-1}. Similar findings were reported by Obiadalla *et al.* (2012), Greenland *et al.* (2000), Adeniji *et al.* (2010). Based upon the field performance, the hybrid KTCBH-81 and hybrid BC-76 were found suitable for fresh fruit market.

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Influence of Sowing Dates on Phenotypic Traits in Sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract: The experimental material consisted of 35 elite sorghum genotype including hybrid parents (restorer and maintainer) hybrids and varieties. The experimental material was evaluated over six different dates of sowing ranging from 20th September to 27th October. The influence of dates of sowing on different phenotypic characters indicated that delayed sowing reduced the expression of all the traits. Flowering was early when genotypes were sown at 5th October. The grain yield in general was high in the genotype sown at 20-28th September compared to the remaining dates. The seed set percentage (irrespective of sowing dates) was more than 65 per cent as long as minimum temperature was more than 13ºC, whereas, it was drastically reduced when minimum temperature was dropped down below 10ºC. Mean performance of genotypes for the seed set percentage, test weight, grain number per panicle was lowest in the B lines compared to R lines. This suggests that there is need to improve the existing B lines for these traits. The genotypes AKMS14B, 101B, 296B, 116B and BJMS2B showed narrow range of mean grain yield per plant compared to the highest range recorded by CSH-19R across sowing dates and temperature regimes. These results revealed that the above genotypes could be used further for the development of new breeding lines, which are less sensitive to sowing dates and temperature regimes in *rabi* season.

Key Words: Temperature sensitivity, *rabi* sorghum, genotypes pollen fertility, seed setting, temperature regimes

Among major cereals in the world, sorghum ranks fourth after wheat, rice and maize in area. In India, it ranks third after wheat and rice. It is hardy and dependable crop that grows well under adverse conditions and can thus play a major role in increasing food production in the semi-arid tropics. The *Rabi* sorghum is cultivated using the conserved moisture in black soils and sowing is generally done at favorable moisture conditions that occur after the first week of September. The sowing dates vary from location to location and year to year, and usually extend up to the end of October. Minimum temperature declines from about 20˚C at sowing to 12˚C at flowering and increases to 18˚C during grain filling period. The post-rainy season adapted land races are photoperiod sensitive, thermo insensitive, tolerance to moisture stress and produce high biomass and possess bold and lustrous grains, however the productivity of these land races are low (Sanjari *et al.,*1994; Veerabadhiran *et al.,* 2001). The present experiment was planned and conducted to understand the effect of environmental factor on different phenotypic trait and to identify suitable/promising genotypes.

MATERIALS AND METHODS

The present investigation was carried out during *rabi* season at Regional Agriculture Research Station, Bijapur. The experimental material consisted of 35 elite sorghum genotypes including hybrid parents (restorers and maintainers), hybrids and varieties. The experimental material was evaluated over six different dates of sowing. Each sowing was taken with an interval of 7-8 days, so as to adjust flowering at different temperature regimes. The details of sowing were September 20,28, October,5,12,19 and 27. The experiment was laid out in a randomized complete block design (RCBD) with two replications in all test environments. The genotypes were allotted randomly within each replication. Each genotype was of two rows of four meter length. The inter and intra-row spacing of 60 cm and 15 cm was provided respectively. Sowing on first four dates was carried out under rainfed situation and for last two dates irrigation was provided at the time of sowing as the *in situ* soil moisture was insufficient for germination. In each replication and in each genotype, five plants were randomly selected for recording observations on twelve quantitative characters *viz.,* plant height (cm), days to 50% flowering, number of leaves per plant, length of the panicle (cm), panicle weight (g plant^{-1}), panicle diameter (cm), primary branches per panicle, grains per panicle, 500grain weight, grain yield per plant, seed setting percentage and pollen fertility percentage were considered for statistical analysis and data were analyzed using SPAR 1 software

RESULTS AND DISCUSSION

The comparison of means for plant height over six dates indicated that at 5th October sowing, plant height was not affected as compared to delayed sowing at 27th October but produced more number of leaves. When onset of cold temperature coincides with flowering, thus pollen fertility percentage was got affected. In this situation, delayed sowing to avoid cold injury helps in increased pollen fertility but seed

set percentage was low in genotypes with delayed sowing indicating that seed setting is not solely dependent on pollen fertility (Chuan Gen- Lu *et al.,* 2002, Powar *et al.,* 2003). Delayed sowing negatively affected the performance of the genotype by reducing number of seeds per panicle and ultimately the yield (Chikurte *et al.,*2003, Tiwari *et al.,* 2003). The yield was not so affected when sowing was done early i.e. 20th September, 28th September and 5th October by virtue of high seed setting indicating that this period is optimum for sowing to get highest productivity (Table 1).

Mean performance of genotypes across dates of sowing : The genotype, CSV-216R (78.33) required more number of days to 50% flowering followed by BRJ-358, DSV-5 and DSV-4, while DSH-3 was earliest in flowering followed by CSH16, CSH 15R , CSH 19R , 401B and across six dates (Table 2). Mean value over environments indicated that CSV-216R had highest panicle weight (78.33 g) followed by CSH19R and 101B had lowest panicle weight. With respect to panicle weight, CSV-216R had highest panicle weight (63.52 g) followed by M31-2B and BRJH 129. Pollen fertility is not affected much in genotype BRJ-358 , CSV216R, SPV-570 and M35-1 but drastic reduction in pollen fertility was observed in ICSB-37 , CSH-14 and 401B . Mean value of six dates indicated that CSH19R had maximum number of seeds per panicle (1921.24) followed by BRJ 358 and CSV126R. Performance across the dates indicated that, the genotype CSH 19R (65.51g plant^{-1}) was high yielder followed by CSV 216R and BRJ-358. These genotypes can be sown in wide range of sowing time starting from second fortnight of September to last week of October.

Comparative mean performance of maintainers (B lines), restorers (R lines), stay-green lines, hybrids and varieties for different characters: The average performance of B lines, R lines, varieties, hybrids and stay-green lines, as these groups are distinct in their origin and pedigree were compared to know their behavior across the dates of sowing and temperature regimes (Table 3). The results revealed that the average plant height of B lines was lowest (131.6 cm) followed by R lines, hybrids and the varieties. With respect to days to 50 per cent flowering, hybrids were earliest to flower (69.6 days) followed by B lines, R lines and varieties. The two traits plant height and days to flowering are considered important for successful hybrid seed production and the present material (B and R lines) appeared to be suitable and useful from this point of view. However, mean performance of genotypes for the seed set percentage, test weight, grain number per panicle was lowest in the B lines compared to R lines and other categories. This suggests that there is need to improve the existing B lines for these traits. The two stay-green lines *viz*., B35 (temperate type) and RSG03123 (derivative of temperate tropical cross) recorded lowest mean performance for all the characters indicating their unsuitability to *rabi* season. This indicates that, while introducing stay-green trait into R16 (tropical) from B35, as well as B lines derived from tropical temperate crosses the temperature sensitivity is introduced in tropical sorghum, the otherwise tolerant to temperature variations. The varieties which are tropical in origin are less sensitive to change in temperature regimes. Reddy *et al.* (2003) opined that the improved cultivars derived using temperate sorghums were found to be photoperiod insensitive and temperature sensitive. Because of this temperature sensitivity their growth is reduced and development is delayed in *rabi* season. Therefore, improved *rabi* season cultivars (which involves temperate blood) usually to fail to perform well in *rabi* season.

The genotype showing less range of variation across the dates of sowing and temperature regimes will be advantageous from the point of view of developing or identifying the genotypes for advanced or late sown situation (Reddy *et al.,*1987). Keeping this in view, comparison was made for four important traits *viz*., plant height, days to 50% flowering, seed set percentage and grain yield per plant (Table 4). The minimum variation in height between dates was recorded by the genotypes 116B, B35, 104B and DSH3 and highest variation by BRJH-129 suggesting that these can be used for developing genotypes with optimum plant height suited to irrigated condition or paddy fallow ecosystem. Similarly, for days to 50% flowering, the genotypes 296B, AKR150, R 16, DSH4 and M35-1 exhibited a narrow range compared to the highest range recorded by DSH3 across

Table 1. Pollen fertility and seed set percentage across different dates of sowing

Date of sowing	Pollen fertility percentage		Seed set percentage	
	Mean	Range	Mean	Range
20th September	91.18	58.6-97.5	65.40	36.5-86.0
28th September	93.87	85.5-98.9	74.12	31.4-92.8
5th October	92.70	72.6-98.4	70.94	24.9-95.1
12th October	93.05	81.2-97.9	73.77	6.4-95.5
19th October	94.41	79.5-99.0	64.85	9.1-90.8
27th October	95.35	82.6-99.7	57.79	17.0-79.0

Table 2. Mean and range for different parameters among different genotypes across dates of sowing

Genotypes	PH	NLS	50%F	PW	PL	PD	NP	PF(%)	SS(%)	TW	NS	YPP
401B	119.32 (94.4 -130.50)	6.08 (5.30-7.15)	70.92 (64.0-76.50)	47.47 (24.60-72.30)	22.73 (19.20-25.10)	12.69 (10.60-14.30)	47.15 (33.10-55.50)	90.82 (86.29-94.92)	65.71 (48.70-66.72)	14.94 (14.05-15.95)	1370.12 (576.57-2122.16)	40.64 (17.65-59.65)
104B	134.75 (117.50-150.0)	6.35 (5.30-7.30)	73.33 (64.50-80.50)	55.00 (30.40-68.30)	21.52 (18.10-23.60)	13.12 (11.60-14.20)	53.55 (45.70-61.40)	92.70 (85.58-97.62)	65.35 (53.75-78.23)	14.63 (13.25-15.90)	1478.08 (606.11-2209.34)	42.48 (19.15-63.20)
296B	129.08 (107.50-39.50)	6.16 (5.15-7.75)	74.17 (73.00-77.00)	40.78 (34.20-53.80)	23.10 (17.90-28.0)	12.60 (11.90-13.70)	49.59 (38.80-59.30)	88.46 (58.69-95.80)	57.70 (48.59-81.85)	13.66 (11.40-16.45)	1104.10 (894.15-1629.640	29.31 (23.80-37.30)
AKMS 14B	107.53 (69.35-123.0)	6.19 (5.45-7.15)	73.83 (69.00-83.50)	33.59 (18.30-41.80)	22.20 (18.40-24.90)	11.65 (9.70-13.10)	44.89 (35.70-48.70)	96.21 (85.25-99.0)	52.92 (24.92-69.77)	11.18 (8.45-13.30)	1182.34 (782.79-1499.05)	24.50 (18.50-31.40)
1409B	114.96 (83.65-134.0)	5.86 (5.15-6.80)	71.08 (65.00-77.00)	47.66 (21.30-68.25)	26.38 (18.40-31.20)	11.81 (9.80-14.70)	46.25 (35.50-52.80)	90.80 (81.23-98.15)	64.33 (52.07-76.45)	12.17 (11.10-12.90)	1217.41 (730.83-1854.39)	29.32 (15.90-41.35)
116B	119.21 (108.5-134.5)	6.53 (5.50-8.45)	75.50 (68.50-84.00)	51.12 (27.10-63.40)	21.10 (14.60-24.40)	13.88 (11.00-15.35)	51.42 (31.90-59.30)	94.32 (91.17-95.65)	82.61 (77.25-94.70)	13.50 (10.35-15.60)	1295.55 (644.45-1676.12)	33.70 (20.00-38.10)
M31-2B	176.92 (137.5-202.0)	7.62 (6.80-8.80)	75.00 (71.00-83.50)	57.64 (35.20-74.10)	16.36 (13.90-18.60)	14.43 (12.20-17.00)	60.39 (48.60-62.50)	96.00 (93.29-98.46)	77.95 (61.95-91.36)	14.99 (12.70-15.95)	1569.86 (746.07-2041.19)	46.53 (23.75-61.45)
BJMS-1B	158.08 (112.0-188.5)	6.48 (4.80-7.65)	71.17 (65.00-81.00)	49.41 (17.80-72.20)	23.85 (17.80-26.80)	12.95 (8.50-15.50)	53.67 (37.00-60.80)	92.98 (87.50-96.46)	77.56 (65.50-95.57)	12.92 (9.25-16.65)	1252.70 (323.95-1878.85)	33.47 (7.20-45.65)
BJMS-2B	152.67 (119.5-179.5)	6.42 (5.95-7.65)	70.33 (66.00-77.50)	52.83 (33.10-68.50)	23.77 (19.60-26.40)	13.28 (11.30-14.50)	56.77 (53.00-60.40)	93.57 (90.46-96.50)	75.60 (59.18-93.24)	14.43 (10.75-18.90)	1209.54 (898.68-1426.26)	34.68 (21.10-43.00)
ICSB-37	141.92 (116.5-166.0)	6.79 (5.65-8.10)	70.83 (65.00-80.00)	52.63 (20.20-69.90)	25.67 (19.20-29-70)	12.33 (8.70-15.20)	56.63 (37.90-66.30)	89.85 (80.65-97.44)	46.47 (17.19-83.0)	14.89 (13.35-17.90)	1175.70 (583.52-1862.79)	34.90 (17.35-55.80)
27B	93.65 (69.5-128.0)	6.47 (5.30-8.30)	71.75 (65.50-82.00)	33.02 (12.70-44.80)	21.27 (14.70-30.40)	10.15 (8.70-12.70)	41.02 (27.70-60.20)	95.95 (92.97-97.98)	60.56 (45.15-70.60)	10.53 (7.85-12.10)	1145.64 (468.47-1572.12)	24.20 (9.38-36.40)
101B	78.78 (61.60-95.50)	5.22 (4.30-5.90)	70.92 (66.50-79.50)	27.38 (18.30-37.10)	18.98 (15.40-21.40)	9.53 (7.20-11.00)	39.02 (28.30-47.50)	94.77 (87.68-99.40)	56.70 (57.00-77.79)	13.01 (11.50-14.60)	759.96 (450.21-894.17)	19.85 (11.15-24.35)
BRJ 204B	183.75 (134.0-218.0)	8.06 (6.80-9.00)	73.58 (66.50-86.00)	60.73 (17.40-89.90)	16.02 (11.30-18.40)	13.08 (8.40-16.60)	57.87 (31.30-79.00)	97.00 (94.81-98.71)	67.38 (58.50-77.23)	15.00 (12.80-17.80)	1639.94 (359.19-2435.38)	50.98 (11.45-80.20)
SPV-570	198.00 (151.50-238.0)	8.05 (7.15-9.00)	72.00 (65.50-79.50)	56.98 (21.20-81.60)	18.45 (13.50-21.30)	14.08 (8.80-17.00)	55.27 (36.60-65.20)	97.18 (94.87-98.57)	74.78 (56.00-91.21)	17.03 (14.05-20.05)	1406.19 (390.81-2034.39)	49.38 (13.25-68.85)
BRJ 62	165.17 (129.0-203.0)	7.76 (6.65-9.30)	74.08 (68.50-81.00)	46.22 (29.30-59.30)	16.32 (13.00-20.80)	13.10 (10.80-15.20)	48.95 (40.70-57.90)	95.36 (87.67-98.72)	73.95 (48.90-86.01)	16.35 (13.08-19.30)	1196.71 (640.09-1638.71)	39.66 (20.90-63.25)
R-354	164.92 (120.50-190.50)	7.84 (7.00-8.50)	74.92 (69.50-81.50)	61.17 (19.10-97.20)	19.20 (12.80-24.0)	13.00 (7.80-18.00)	52.36 (31.60-63.25)	93.22 (80.23-96.65)	82.23 (73.70-86.85)	14.23 (12.50-16.10)	1744.81 (509.02-2979.30)	50.80 (13.95-90.95)
C-43	109.78 (73.90-133.0)	6.96 (6.30-8.45)	74.42 (67.50-86.50)	43.00 (16.00-59.90)	20.97 (14.40-23.80)	11.66 (8.00-14.30)	43.60 (25.60-55.50)	94.36 (90.62-98.29)	64.38 (52.25-91.19)	16.69 (13.85-19.10)	1102.16 (263.57-1484.60)	35.90 (8.90-50.80)
RS 29	136.10 (103.0-159.0)	7.33 (6.00-8.80)	75.17 (68.00-83.50)	62.15 (11.70-94.00)	19.48 (11.10-24.10)	12.83 (7.30-16.20)	55.60 (32.00-70.60)	96.91 (94.96-99.62)	71.71 (58.80-78.24)	12.44 (10.30-15.55)	1766.11 (385.44-3365.81)	47.05 (7.70-79.00)

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AKR-150	96.85 (69.25-123.50)	6.42 (6.80-7.30)	74.17 (72.00-78.50)	38.28 (11.50-56.00	21.63 (12.10-26.40)	11.84 (7.15-17.00)	47.98 (31.00-62.05)	87.53 (79.92-95.15)	45.24 (9.15-85.69)	12.38 (10.80-14.75)	1157.74 (570.41-1603.19)	28.98 (13.25-40.85)
RS 585	171.42 (143.50-190.0)	7.47 (6.15-9.50)	71.33 (68.50-76.00)	60.69 (30.40-93.70)	18.67 (13.70-21.80)	14.43 (9.90-17.30)	56.12 (37.60-69.20)	96.48 (92.43-99.60)	74.18 (65.05-94.42)	17.43 (14.55-19.15)	1526.89 (654.86-2068.95)	54.04 (21.50-80.80)
R-16	168.76 (112.50-209.50)	7.04 (6.30-8.00)	72.55 (63.00-78.00)	57.67 (24.80-81.20)	19.12 (14.50-24.20)	13.23 (9.00-16.70)	56.88 (38.30-72.90)	93.74 (89.31-97.43)	59.15 (45.35-75.95)	15.03 (12.10-18.28)	1466.2 (496.67-2051.82)	43.57 (13.65-64.05)
B-35	92.89 (73.20-102.55)	6.94 (5.65-7.80)	73.17 (64.50-82.00)	35.62 (14.50-51.00)	20.88 (14.70-26.20)	11.20 (8.00-14.10)	44.25 (29.30-55.10)	94.61 (91.48-96.48)	61.00 (41.11-88.49)	13.22 (11.60-14.85)	1014.58 (274.86-1633.70)	26.47 (7.06-41.15)
RSG-03123	124.40 (76.80-166.0)	7.22 (6.50-7.80)	71.42 (64.50-76.50)	41.97 (1.20-59.50)	19.33 (13.70-22.50)	12.69 (7.10-17.65)	47.48 (30.70-56.40)	93.52 (79.29-98.44)	49.14 (25.50-70.00)	15.08 (12.55-18.00)	832.91 (271.89-1307.90)	25.79 (7.40-41.65)
BRJ-358	183.08 (135.50-216.0)	8.64 (7.50-9.45)	76.75 (70.50-86.50)	66.62 (18.25-106.90)	13.03 (10.20-15.30)	15.27 (10.10-21.00)	55.90 (30.60-65.40)	97.49 (95.65-99.72)	83.66 (75.64-90.42)	15.01 (13.50-17.05)	1822.55 (347.98-2790.67)	54.29 (9.95-75.15)
CSV 216R	200.92 (144.50-228.50)	8.18 (7.15-9.45)	78.33 (70.50-85.50)	79.13 (30.20-114.70)	19.15 (14.70-21.90)	15.05 (11.30-18.60)	63.52 (40.10-82.10)	97.48 (97.07-98.12	83.31 (75.96-95.12)	16.31 (14.35-18.00)	1809.50 (461.04-2535.54)	58.14 (16.65-83.50)
DSV-5	187.67 (146.50-229.50)	8.20 (6.50-9.15)	77.83 (70.50-86.00)	60.65 (16.00-100.20)	18.95 (13.00-22.60)	13.38 (8.90-16.70)	55.72 (34.00-70.80)	96.72 (94.67-98.10)	85.84 (74.20-92.82)	16.65 (12.96-18.35)	1564.03 (203.43-2867.34)	49.15 (7.40-74.50)
DSV-4	192.92 (155.0-223.50)	8.18 (6.30-10.25)	77.42 (70.00-81.50)	59.50 (26.30-80.60)	22.25 (16.90-25.90)	13.87 (9.50-18.10)	57.42 (40.30-64.50)	95.59 (88.59-98.59)	80.46 (70.88-90.83)	16.95 (14.00-19.05)	1367.67 (500.92-1965.40)	47.49 (14.30-68.20)
M35-1	179.98 (149.50-196.0)	8.20 (7.50-9.50)	73.25 (67.00-78.50)	54.18 (37.20-58.20)	17.23 (14.15-19.70)	14.04 (12.60-15.90)	55.20 (46.80-63.70)	97.17 (95.26-98.57)	67.59 (17.00-93.27)	16.70 (13.95-18.55)	1378.99 (741.83-1640.20)	44.92 (26.05-59.60)
DSH-4	195.08 (133.0-231.50)	7.35 (6.30-8.95)	69.83 (66.00-75.50)	54.45 (30.30-72.20)	21.33 (16.20-23.90)	12.63 (9.90-13.70)	54.97 (43.70-61.40)	94.08 (90.69-96.26)	72.22 (63.30-83.49)	15.08 (14.15-16.70)	1430.04 (609.46-1878.35)	43.93 (19.80-62.40)
BRJ H 129	179.17 (119.50-218.5)	7.77 (6.80-9.10)	70.17 (64.00-78.00)	69.40 (34.20-95.40)	20.92 (15.80-24.80)	14.03 (10.50-17.00)	60.00 (42.90-75.90)	95.10 (92.18-97.90)	83.66 (75.03-92.11)	15.40 (13.85-17.55)	1697.48 (679.38-2538.01)	52.43 (21.90-89.00)
CSH-14	134.05 (82.50-161.0)	6.38 (5.65-6.95)	68.83 (61.50-76.50)	43.43 (19.00-70.00)	24.58 (18.80-29.10)	11.62 (8.30-13.70)	47.30 (33.70-62.70)	95.39 (92.68-97.07)	58.11 (29.25-88.92)	13.42 (11.30-16.05)	1265.63 (636.52-2317.08)	33.48 (15.50-57.60)
CSH-16	151.28 (114.65-177.50)	7.25 (6.45-7.95)	70.00 (62.50-78.00)	66.08 (29.40-95.40)	23.33 (17.70-27.30)	13.50 (10.80-16.80)	56.17 (47.40-63.10)	84.53 (75.67-88.54)	46.73 (31.10-79.20)	17.21 (15.05-20.95)	1569.33 (688.21-2232.63)	54.15 (22.20-80.50)
DSH-3	136.67 (115.50-150.50)	5.91 (4.95-7.30)	67.50 (59.00-80.00)	58.15 (33.20-75.60)	21.17 (16.60-24.60)	13.08 (9.80-15.30)	58.35 (49.80-63.59)	93.57 (85.95-98.35)	68.71 (60.50-80.99)	14.14 (12.20-16.00)	1542.25 (1076.89-2211.69)	43.47 (26.30-64.55)
CSH 15R	177.83 (136.0-200.0)	7.74 (7.00-8.95)	70.58 (63.50-77.00)	63.33 (31.90-86.90)	23.91 (19.40-28.75)	13.28 (10.20-15.60)	54.64 (43.30-63.70)	84.64 (75.18-90.26)	70.38 (56.09-86.74)	15.72 (15.35-17.10)	1658.33 (876.45-2559.84)	52.51 (25.40-86.35)
CSH 19R	172.83 (103.0-199.50)	7.28 (6.65-8.95)	70.33 (62.50-76.50)	76.41 (28.80-118.30)	23.91 (19.40-28.75)	14.98 (10.00-17.20)	59.28 (49.70-60.40)	82.00 (72.66-89.79)	66.70 (49.23-83.00)	15.80 (12.10-17.90)	1921.24 (998.96-2595.69)	65.51 (24.20-117.40)

PH- Plant height(cm),NLS- No. of leaves, D 50%F -Days to 50% flowering, PW -Panicle weight (g), PL -Panicle length (cm), PD -Panicle diameter (cm), NP -No. of primaries /panicle, PF(%)-Pollen fertility (%),SS(%)-Seed set (%),TW -500 seed weight (g), NS -No. of seeds/ panicle, YPP -Yield (g/plant)

Table 3. Comparative mean performance of maintainers, restorers, stay green lines, varieties and hybrids for different character across six dates of sowing

S. No.	Genotypes	Plant height (cm)	No. of leaves	Days to 50% flowering	Panicle weight (g)	Panicle length (cm)	Panicle diameter (cm)	No. of primaries panicle^{-1}	Pollen fertility (%)	Seed set (%)	500 seed weight	No. of seeds panicle^{-1}	Yield (g plant^{-1})
1	B lines (13)	131.6	6.5	72.5	46.9	21.8	12.4	50.6	93.3	65.4	13.5	1261.6	34.2
2	R line (9)	144.9	7.5	73.9	54.8	18.5	13.3	52.5	94.7	69.9	15.2	1465.5	44.9
3	Stay green lines (2)	108.6	7.1	72.3	38.8	20.1	11.9	45.9	94.1	55.1	14.2	923.7	26.1
4	Varieties (4)	190.4	8.2	76.7	63.4	19.4	14.1	58.0	96.7	79.3	16.7	1530.0	49.9
5	Hybrids (7)	163.8	7.1	69.6	61.6	22.7	13.3	55.8	89.9	66.6	15.3	1583.5	49.4

Table 4: Genotypes showing less range of variation across dates of sowing for four important traits in rabi sorghum

Characters	Narrow range						Max. range
	Genotype	116 B	B 35	296 B	104B	DSH 3	BRJH129
Plant height (cm)	Range	108.50 -134.50	73.20-102.55	107.50-139.50	117.50-150.0	115.50-150.50	119.5-218.85
	Mean	119.2	92.89	129.08	134.75	136.67	179.17
Days to 50%	Genotype	296B	AKR-150	RS 585	DSH 4	M35-1	DSH3
flowering	Range	73.00-77.0	72.00-78.0	68.50-76.0	70.00-81.50	67.00-78.50	59.00-80.00
	Mean	74.17	74.17	71.33	69.83	73.25	67.50
Seed set	Genotype	R-354	BRJ-358	BRJH 129	116 B	401 B	AKR150
percentage(%)	Range	73.70-86.85	75.64-90.42	75.30-92.11	77.25-94.70	48.70-66.72	9.15-85.69
	Mean	82.23	83.60	83.66	82.61	65.71	71.71
Grain yield	Genotype	AKMS14B	101B	296B	116B	BJMS 2B	CSH19R
plant^{-1} (g)	Range	18.50-31.40	11.50-24.35	23.80-37.30	20.00-38.10	21.10-43.00	24.20-117.40
	Mean	24.50	19.85	29.31	33.70	34.68	65.51

dates of sowing and temperature regimes indicating that these can be used to develop genotypes for late sowing. The narrow range of mean seed set percentage was observed in R-354, BRJ 358, BRJH 129 and 401B compared to the highest range recorded by AKR150 indicating that these are less sensitive to temperature variations. Similarly, the genotypes AKMS14B, 101B, 296B, 116B and BJMS2B registered narrow range of mean grain yield per plant compared to the highest range recorded by CSH-19R across sowing dates and temperature regimes. These results revealed that the above genotypes could be used further for the development of new breeding lines which are less sensitive to sowing dates and temperature regimes in *rabi* season.

The present study indicated that, pollen fertility decreased much when temperature goes below 10-13^{o}C. Some of the genotypes viz., BRJ-358, CSV216R, SPV-570 and M35-1 are less sensitive to low temperature and this can be utilized in the breeding program to improve the efficiency of pollen fertility. Genotypes which recorded consistent yield performance throughout the different dates of sowing viz., AKMS14B, 101B, 296B, 116B and BJMS2B can be used in crop improvement program to develop genotypes for late sowing.

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Shift in Character Association under Different Water Stress Environments in Sunflower (*Helianthus annuus* L.)

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Abstract: The present investigations were undertaken to find out association among the economically important characters in different moisture regimes. Under normal irrigation level, seed yield exhibited significant positive correlation with 100-seed weight, early vigour and photosynthetic capacity, however, its association with canopy temperature was significantly negative. The significant positive association of seed yield with 100 seed weight, leaf water potential, plant height and head diameter was observed in second water stress environment. In third water stress environment, seed yield had significant positive correlation with early vigour, canopy temperature, head diameter and 100-seed weight but a significant negative correlation with leaf area index and number of days to maturity. In fourth stress condition, seed yield was found to have significant positive association with head diameter, 100 seed weight and leaf water potential. This indicated a shift in correlations under changing water stress environments. The study revealed that while selecting for high seed yield under different water stress conditions, the selection criteria should be based on the changing correlations among different characters, under different stress environments.

Key Words: Correlation, photosynthetic capacity, canopy temperature, leaf water potential

Breeding for high yielding crop varieties requires information on association of component characters with yield and among themselves. Yield, under stress, can be considered as a function of yield potential, maturity and susceptibility index. Depending upon the timing and intensity, water stress could decrease yield directly by affecting grain setting or grain filling rate or indirectly by decreasing leaf expansion and photosynthesis or increasing leaf senescence. Practical selection for drought tolerance frequently relies on the use of a selection index of secondary traits as well as grain yield. The use of secondary traits is considered beneficial when the trait can be identified prior to flowering or can be measured more rapidly and easily than yield or when the trait is strongly correlated with yield with high heritability. However, most of the characters of economic interest show polygenic inheritance, hence their correlation changes with changing environments. There are many reports available on correlation studies for morphological, physiological and yield characters in sunflower (*Helianthus annuus* L.) in a particular environments, however, the studies related to shift in character association over environments (particularly water stress environments) is not available. Keeping this into consideration, the present work was planned with the objective to study the change in association of different traits influencing yield, under different stress environments.

MATERIAL AND METHODS

The experiment was conducted at the Punjab Agricultural University, Ludhiana, India. The experimental material comprised of 41 lines of sunflower comprising 16 maintainer lines and 25 restorer lines planted during spring season 2009 in a randomized block design with three replications. Each parental line was represented by a plot of two rows of 3m length. The inter and intra-row spacing was maintained at 60 cm and 30 cm, respectively. The experiment was repeated four times to create four different environments by providing following irrigation regimes:

W_1 (Irrigation level 01) : Irrigating the plots during the entire growth cycle to maintain the soil water content close to field capacity.

W_2 (Irrigation level 02): Withholding of 2nd irrigation i.e. before button stage and there after complete withholding of irrigations after soft dough stage.

W_3 (Irrigation level 03): Withholding of irrigation at 50 per cent flowering stage and soft dough stage, thereafter complete withholding of irrigations after hard dough stage.

W_4 (Irrigation level 04): Withholding of irrigation at anthesis completion stage and there after complete withholding of irrigation after soft dough stage.

The list of genotypes evaluated is given in table 1. Two seeds were dibbled in each hill to facilitate better emergence and to provide uniform plant stand. A recommended manure dosage was applied. Thinning was attended to 15 days after sowing to retain one plant per hill. The plants were grown under protective irrigation. All the recommended agronomic

practices were followed to facilitate good growth and to raise a successful crop. From each line in each replication, five competitive plants were tagged at random. Except for early vigour and days to 50% flowering, all other observations on quantitative characters were recorded at maturity. The mean data of all the characters was subjected to statistical analysis.

Phenotypic and genotypic correlation coefficients were worked out by the formulae suggested by Al Jibouri *et al.* (1958). The significance of phenotypic correlation coefficients were tested against r values from the r table of Fisher and Yates (1963) at P = 0.05 and P = 0.01.

RESULTS AND DISCUSSION

The correlation values of different parameters under individual stress level have been presented in Table 2-5 for reference. Under pooled over environments (Table 6), days to 50 per cent flowering had positive and significant positive correlation with days to maturity, plant height and leaf area index. Days to maturity has positive association with 100-seed weight but as reported earlier (Kaya *et al.*,2007) correlated negatively with oil content. Seed yield had significant positive correlation with head diameter, 100 seed weight and leaf water potential as discussed by Khan *et al.* (2003). 100 seed weight exhibited the highest negative direct load on oil content, which was fully in accordance with the results of correlation analysis discussed by Iqbal *et al.* (2009). Oil content recorded significant positive correlation with photosynthetic capacity and a positive and non-significant association with seed yield per plant as reported by Iqbal *et al.* (2005). But, contrary to our results Ashoke *et al.* (2000) have reported positive and significant correlation of oil content with achene yield.

Further, it was observed that there was change in correlations among different characters with the change in irrigation schedule (stress environment).

In W_1, days to 50 per cent flowering showed significant positive correlation with days to maturity, photosynthetic capacity and leaf water potential, while in W_2, W_3 and W_4 this association was non-significant (Table 2-5). In W_3, days to 50 per cent flowering had significant positive correlation with leaf area index, which was non-significant in case of W_1. Days to maturity was observed to have significant positive correlation with leaf area index in control (W_1), while in W_2 and W_4 there was no association among these characters. Plant height exhibited positive significant correlation with head diameter and seed yield per plant only in W_2 and non-significant in other stress treatments. Whereas, with leaf water potential, it (plant height) showed positive correlation in W_1, W_3 and W_4 and non-significant in W_2; with early vigour, positive correlation in W_1 and W_3 but non-significant in W_2 and W_4; with photosynthetic capacity positive correlation in W_1 and non-significant in other treatments. Head diameter had significant positive correlation with early vigour and canopy temperature in W_1 only, which was non-significant in other stress treatments (W_2, W_3 and W_4). There was significant positive association of canopy temperature with head diameter and leaf water potential in W_1, whereas, non-significant in W_1, W_2 and W_3.

In control (W_1), seed yield had significant positive correlation with early vigour, canopy temperature and photosynthetic capacity, whereas, in W_2 no correlation with above parameters was recorded except with leaf water potential. In W_3, it did not have any correlation with photosynthetic capacity and leaf water potential while in W_4 positive correlation with leaf water potential was observed. 100 seed weight was associated positively with

Table 1. List of genotypes

S.No.	Inbred line	S.No.	Inbred line	S.No.	Inbred line
1	P-61-R	17	P-112-R	33	47-B
2	R-273	18	P-115-R	34	48-B
3	P-93-R	19	P-119-R	35	49-B
4	95-C-1-R	20	P-121-R	36	50-B
5	P-91-R	21	P-124-R	37	52-B
6	P-107-R-P_1	22	NDLR-2	38	53-B
7	P-107-R- P_2	23	NDLR-1	39	36-B
8	P-69-R	24	44-B	40	RCR-8297
9	3376-R	25	40-B	41	RHA-297
10	P-100-R	26	10-B		
11	P-110-R	27	234-B		
12	P-87-R	28	11-B		
13	P-89-R	29	304-B		
14	P-75-R	30	395-B		
15	P-94-R	31	7-1-B		
16	P-111-R	32	45-B		

Table 2. Correlations among different characters at irrigation level 01 (W_1)

	DF	DM	PH	HD	SY	SW	OC	EV	CT	PS	LAI	LWP
DF		0.1879*	0.4819**	0.1312	0.0468	0.1469	-0.1001	0.0607	-0.0527	0.2385**	0.0914	0.2676**
DM	0.1934		0.0061	0.0139	-0.0162	0.0574	-0.1515	0.1116	-0.2484**	0.0509	0.2484**	0.2594**
PH	0.5006	0.0107		0.0472	0.1516	0.0134	-0.0896	0.1860*	-0.1560	0.2147*	0.0215	0.2386**
HD	0.1416	0.0285	0.2456		0.6333**	0.4945**	-0.0150	0.1761*	-0.1951*	0.0854	-0.0562	0.0841
SY	0.0550	-0.0120	0.1533	0.6751		0.2708**	-0.1348	0.2353**	-0.2471**	0.2309**	0.0924	0.1568
SW	0.1648	0.0900	0.0089	0.5499	0.2781		-0.0223	0.0971	-0.0772	0.1789*	-0.0726	0.0390
OC	-0.0938	-0.1654	-0.1276	-0.0873	-0.1837	-0.0424		0.0451	-0.0709	0.0787	0.1999*	0.0687
EV	0.0863	0.0434	0.1857	0.1153	0.3223	0.1355	0.2393		0.0377	0.0889	0.1148	-0.0454
CT	-0.1085	-0.4880	-0.0497	-01793	-0.3712	-0.1065	-0.2397	0.0857		0.1037	-0.0689	0.0529
PS	0.3326	0.1995	0.2086	0.1796	0.3418	0.1835	0.1918	0.1356	0.2358		0.0847	-0.5000**
LAI	0.1080	0.2166	0.0283	-0.0569	0.1974	0.2879	0.1625	0.2173	-0.1263	0.1061		-0.2860**
LWP	0.5352	0.7728	0.1916	0.6453	0.8271	0.2549	0.2388	-0.5075	-0.3420	-0.5187	-0.1726	

*Above diagonal value indicate phenotypic correlation & below diagonal value indicate genotypic correlation

Critical value of 'r' at 5%= .1761 and that at 1%= .2289

*, ** - significant at 5 % and 1 % level respectively

DF: Days to 50% Flowering; DM: Days to maturity; PH: Plant height ; HD : Head diameter ; SY : Seed yield per plant ; SW : 100 Seed weight; OC : Oil content ; EV : Early vigour ; CT : Canopy temperature ; PS : Photosynthetic capacity ; LAI : Leaf area index ; LWP : Leaf water potential.

Table 3. Correlations among different characters* at irrigation level 02 (W_2)

	DF	DM	PH	HD	SY	SW	OC	EV	CT	PS	LAI	LWP
DF		0.0543	0.4520**	0.1313	0.0428	0.1468	-0.0676	0.0859	0.0060	0.0205	0.0871	0.0754
DM	0.0825		-0.0967	0.1286	0.0468	0.0842	-0.1167	-0.0879	-0.1957*	0.0786	-0.1104	0.1569
PH	0.4753	-0.1343		0.3253**	0.1981*	-0.0445	-0.0093	0.0376	-0.0258	0.1262	-0.0680	0.1277
HD	0.1556	0.1293	0.3362		0.5956**	0.4772**	-0.0264	0.1217	-0.0472	-0.0809	-0.1322	0.1786*
SY	0.0434	0.0636	0.2011	0.6185		0.2708**	-0.1348	-0.0289	-0.0407	-0.0512	-0.0890	0.2812**
SW	0.1519	0.0802	-0.0359	0.4981	0.2781		-0.0223	0.2051**	0.0019	-0.2011*	-0.1165	0.2334**
OC	-0.1208	-0.1498	-0.0258	-0.0492	-0.1837	-0.0424		0.2245**	0.0127	-0.0477	0.1134	-0.2037*
EV	0.0992	-0.1904	0.0655	0.1408	-0.0399	0.2547	0.5054		-0.0944	-0.0312	-0.0963	-0.1589
CT	-0.0043	-0.2434	-0.001	-0.0808	-0.0656	-0.0064	0.0729	0.0087		-0.1876*	-0.1433	-0.0278
PS	0.0167	0.1181	0.1623	-0.0923	-0.0643	-0.2264	-0.0488	-0.0988	-0.2589		-0.0304	-0.0363
LAI	0.0572	-0.2299	-0.1106	-0.1874	-0.1042	-0.1410	0.1944	-0.2692	-0.2144	-0.0819		-0.1786*
LWP	0.1073	0.2181	0.1549	0.2092	0.3118	0.2498	-0.3567	-0.2302	0.0437	-0.0992	-0.2229	

*See table 2 for details

Table 4. Correlations among different characters* at irrigation level 03 (W_3)

	DF	DM	PH	HD	SY	SW	OC	EV	CT	PS	LAI	LWP
DF		0.0936	0.4019**	0.1548	-0.0706	-0.0009	-0.0748	0.1054	-0.0600	0.0621	0.1826*	0.0100
DM	0.0772		0.1576	0.0583	-0.2503**	0.1252	0.1029	0.0384	-0.0302	0.0466	0.0628	0.0418
PH	0.4273	0.1605		0.1551	-0.0785	-0.0519	-0.1230	0.2461**	0.0049	-0.0367	0.0408	0.2122**
HD	0.1729	0.059	0.1657		0.5190**	0.4840**	-0.0209	-0.1151	0.0484	0.0559	0.0111	0.0599
SY	-0.0743	-0.2688	-0.0807	0.5503		0.3430**	-0.1047	0.2291**	0.1875*	-0.0419	0.1793*	0.0684
SW	0.0045	0.1591	-0.0569	0.5697	0.3675		0.0235	0.0464	0.0339	0.0446	-0.1445	-0.0486
OC	-0.1391	0.122	-0.1953	-0.0511	-0.1505	0.0133		0.0855	-0.0088	-0.0117	0.1849*	0.0142
EV	0.1653	0.0784	-0.3668	-0.1391	-0.3386	0.0441	0.2845		-0.0737	-0.0352	0.1002	0.0600
CT	-0.1203	-0.0295	0.0137	-0.0283	0.3135	0.1297	-0.0049	-0.2396		0.0978	-0.1294	0.0023
PS	0.6065	0.484	-0.3712	0.3182	-0.079	0.5109	0.3257	-0.5045	0.1988		-0.0298	0.0176
LAI	0.2199	0.0752	0.0425	0.0178	0.2211	-0.1823	0.2642	0.1535	-0.1609	-0.4446		0.0421
LWP	0.0061	0.2557	0.2898	0.0709	0.1005	-0.0527	-0.1366	-0.1038	0.0972	-0.9313	0.0557	

*See Table 2 for details

Table 5. Correlations among different characters* at irrigation level 04 (W_4)

	DF	DM	PH	HD	SY	SW	OC	EV	CT	PS	LAI	LWP
DF		0.1502	0.4739**	0.1279	-0.0061	0.0477	0.0118	0.0007	-0.1004	-0.0161	0.1539	-0.0196
DM	0.1813		0.0385	0.1260	0.1166	0.0720	-0.0589	-0.2537**	0.0649	0.0554	-0.0438	0.1278
PH	0.5035	0.0429		0.0675	0.0733	-0.0095	0.0891	0.0235	0.0504	0.0426	0.0856	0.1928*
HD	0.1351	0.1432	0.0764		0.5701**	0.4562**	0.1524	0.1065	-0.2948*	-0.0269	-0.0981	-0.0238
SY	-0.0006	0.1131	0.0738	0.6015		0.2594**	0.1420	-0.0625	-0.1509	-0.0870	-0.0430	0.1961*
SW	0.0519	0.0967	-0.0105	0.4831	0.2700		0.2432**	0.1337	-0.2906**	-0.1750	-0.1497	0.2258*
OC	0.0246	-0.1022	0.096	0.1894	0.1481	-0.2917		-0.0062	-0.0137	0.2081*	0.1615	0.1061
EV	0.0299	-0.3263	0.0355	0.1435	-0.0751	0.1615	-0.0532		-0.0926	-0.0510	-0.2821**	-0.0597
CT	-0.1254	0.0292	0.0487	-0.4027	-0.2108	-0.4148	0.0296	-0.1886		-0.0290	0.2053*	0.0115
PS	-0.0830	0.1608	0.0495	-0.0142	0.1305	0.2507	0.3822	-0.0902	-0.0127		0.1955*	-0.0426
LAI	0.1551	-0.0482	0.0986	-0.0884	-0.0587	-0.1738	0.1700	-0.3922	0.2898	0.2586		-0.0769
LWP	0.0171	0.1624	0.3882	0.1092	0.2901	0.0739	0.2830	-0.0710	0.1022	-0.0659	-0.1468	

*See Table 2 for details

Table 6. Correlations among different characters* pooled over environments

	DF	DM	PH	HD	SY	SW	OC	EV	CT	PS	LAI	LWP
DF		0.1927*	0.5081**	0.1607	0.0012	0.1351	-0.1125	0.0602	-0.0262	-0.1541	0.1977*	0.1386
DM	0.2020		0.0377	0.0876	-0.0597	0.1715*	-0.1819*	-0.1785	-0.0746	0.0857	-0.0704	0.0904
PH	0.5131	0.0384		0.1508	0.0982	0.1342	-0.1150	-0.1485	-0.0851	-0.1347	0.0261	0.2831**
HD	0.1640	0.0827	0.1502		0.6310**	0.3820**	-0.1318	0.0236	-0.1447	0.0191	-0.0387	0.1018
SY	0.0034	-0.0611	0.0987	0.6392		0.2508**	-0.1340	-0.1770*	-0.1447	0.0191	-0.0387	0.1018
SW	0.1712	0.1002	-0.0359	0.4056	0.2401		-0.0424	0.1355	-0.1743*	0.0644	-0.0892	0.1555
OC	-0.1215	-0.1015	-0.0196	-0.0498	-0.1890	-0.2015		0.2393**	-0.0064	-0.2264**	-0.1823*	-0.0527
EV	0.0871	-0.1203	-0.2128	0.0038	-0.2348	0.2140	0.2492		0.1120	0.0137	-0.1141	-0.0408
CT	-0.0496	-0.0483	-0.1031	-0.1729	-0.2089	-0.1514	-0.2151	0.1879		0.0023	-0.1162	0.1370
PS	-0.2670	0.1307	-0.2185	0.0344	0.1170	-0.1950	0.1842	-0.0927	-0.2054		-0.0072	0.0551
LAI	0.2207	-0.0941	0.0292	-0.0375	-0.0966	-0.1693	0.1321	-0.1751	-0.1986	-0.0788		0.0106
LWP	0.5970	0.3116	1.0564	0.3818	0.6313	0.2351	0.2422	-0.4638	0.4689	0.2025	0.9240	

*See Table 2 for details

photosynthetic capacity in case of W_1 and W_2, whereas, in W_3 and W_4, there was no association. Oil content correlated positively with leaf area index in W_1 and W_3 however, W_2 and W_4 it was non- significant. Oil content correlated positively with early vigour in W_2 only while in other environment it was non-significant.

On the basis of present study, it can be concluded that shift in correlations among various parameters occurs with changing environments and under normal irrigation level, the yield potential of genotypes could be improved by direct selection for early vigour, 100 seed weight, photosynthetic capacity, leaf area index and leaf water potential, while under water stress conditions, direct selection for head diameter, delayed flowering, leaf water potential and 100 seed weight could improve the yield ability.

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Influence of Tillage and Weed Management on Soil Properties of Rice Fields

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Abstract: A field study was conducted in a rice – wheat cropping system, rotated for three consecutive years with different tillage systems vis-à-vis weed control practices. In the fourth year of study, their effect was evaluated in terms of physico-chemical, bio-chemical and microbiological properties of rice rhizosphere soil. The results of the investigation revealed that different type of tillage operations exhibited their effects on physio-chemical properties, organic carbon status, enzymes' activity, basal respiration rate and microbial population of rhizosphere soil of rice. Soil reaction (pH) tend towards normality due to conventional-conventional tillage system, however, EC was least affected by different tillage systems. Maximum organic carbon was found in rhizosphere soil under conventional-conventional tillage system. It was found that soil enzymes' activity and basal soil respiration was maximum under conventional-conventional tillage system, whereas, minimum under zero-zero tillage system. The acid phosphatase activity was found more than alkaline phosphatase activity. The microbial population study showed that conventional-conventional tillage system promoted the growth of fungal and bacterial population whereas zero-zero tillage system did not show any promotional activity of the concerned microbial population. Data of above microbial population were also supported by microbial biomass carbon status of soil. The results of weed management study envisaged that the use of recommended herbicides (Butachlor as pre-emergence and fenoxaprop-p-ethyl + ethoxysulfuron as post-emergence) significantly affected the EC, organic carbon status, enzymes activity (acid, alkaline phosphatase and dehydrogenase), basal soil respiration rate, microbial population and microbial carbon status in rhizosphere soil of rice. The above parameters were found significantly lower in herbicide treated plots compared to hand weeded and weedy check plots in all the growth periods of crop.

Key Words: Tillage system, rice, herbicide, phosphatase, dehydrogenase enzyme

In India, rice-wheat cropping system is most commonly adopted cereal based cropping system. There are several techniques are adopted by the farmers for rice sowing as per their feasibility and resource availability. Line sowing is one of them, which is not only economical but also time saver. The most common problem associated with this system is the density of weed flora. Different tillage practices vis-à-vis herbicides are adopted by the rice growers to minimize the above problem. These tillage practices have been shown to alter the chemical and microbiological properties of soils, which is supposed to create a great impact on agricultural production (Ferreira *et al*., 2000). Generally herbicides are not harmful when it is applied in recommended levels in soil but reports show that herbicidal application has adverse effect on microbial activities and microbial population. However, the effect of herbicide application under different tillage systems was not adequately studied elsewhere. Therefore, the present study was conducted to evaluate the influence of different tillage systems on herbicide degradation in terms of microbial population, their different activities in rhizosphere of rice and other soil properties.

MATERIAL AND METHODS

Rice-wheat cropping system was rotated for four consecutive years (2005-2008) at research farm of Indira Gandhi Agricultural University, Raipur and during the fourth year a study was conducted to find out the effect of different tillage systems and weed control practices on soil properties of rice rhizosphere. Four types of tillage systems (*kharif* followed by *rabi*) viz. (i) conventional-conventional (ii) conventional-zero (iii) zero-conventional and (iv) zero-zero were evaluated and put in main plots. Among weed control measures performance of hand weeding and recommended herbicidal application (Butachlor as pre emergence @1.5 kgha^{-1} and fenoxaprop-p-ethyl and ethoxy sulfuron as post emergence herbicide @ 56.25 and 15.00 gm ha^{-1}, respectively) were compared with weedy check and put in sub plots. The pre emergence and post emergence herbicides were applied at 3 and 20 days after sowing of the crop, respectively. The experiment was conducted on *Kharif* rice (O*ryza stativa* L.) with test variety MTU-1010. The soil was Inceptisol (pH : 6.7, EC : 0.16 m mhos cm^{-1}, organic carbon : 0.50%, available N: 220.50 kg ha^{-1}, available P: 14.42 kg ha^{-1} and available K : 348.00 kg ha^{-1}). The treatments were replicated thrice under split plot design. Rhizosphere

soil was collected at a depth of 7.5-15 cm from six locations at different stages of crop growth from the same plot and pooled together for the purpose of analysis. Soil sampling was done at 30, 50 days after sowing of crop and harvest stage of crop. The soil samples were subjected to analysis for pH, EC, organic carbon (OC), phosphatase (Acid P and Alk P) and dehydrogenase (DHA) activity, basal respiration rate (BSR), microbial population (bacteria and fungi) and microbial biomass carbon content (MBC). The estimation of total bacteria (TB) and fungi in soil was done by serial dilution technique and pour plate method (Pramer and Schmidt, 1965). Enumeration of bacteria was done on Nutrient Agar and fungi on Rose-Bengal agar (Martin, 1950). EC was determined by conductivity bridge method (Jackson,1973), organic carbon content in soil by rapid dichromate oxidation, basal soil respiration by measuring the CO_2 evolution rates (Anderson, 1982), biomass carbon by fumigation extraction method (Jenkinson and Powlson,1976). Enzymatic activities (dehydrogenase and phosphatase) were estimated by UV/VIS Spectrophotometer with the wavelength of 485 nm. Three per cent solution of TTC (triphenyl tetrazolium chloride) and 0.025M p-nitrophenyl phosphate were used as a substrate to measure the activity of dehydrogenase and phosphatase, respectively.

RESULTS AND DISCUSSION

It is apparent from the results that different type of tillage operations exhibited their effect on physio-chemical properties, organic carbon status, enzymes' activity, basal soil respiration rate and microbial population of rhizosphere soil of rice (Table 1-3). It was visualized that soil reaction (pH) showed an increasing trend from 30DAS to harvest stage of the crop but it was found near to neutral in conventional-conventional tillage system at harvest stage of the crop (Table 1). EC was least affected by different tillage systems. Maximum organic carbon was found in rhizosphere soil under conventional-conventional tillage system. Ferreira *et al.* (2000) also reported relatively higher availability of soil organic matter at lower soil profile under conventional tillage, which may be due to even distribution of crop residues and other nutrients throughout the plough zone. In soil enzymatic study, it was found that the activity of phosphatase (acid and alkaline phosphatase) and dehydrogenase enzymes was found significantly higher in conventional-conventional tillage treatments compared to other three tillage treatments. The activity of above three enzymes was found lowest under zero-zero tillage treatment (Table 2). Mijangos *et al.* (2005) also concluded that biological parameters have great value as early and sensitive indicator of change in soil properties induced by different soil management strategies. During the study of basal soil respiration, it was noticed that under conventional-conventional tillage system, significantly higher CO_2 evolution was recorded compared to other tillage treatments which was an indicator of greater microbial activities under this system. Alternate conventional-zero and zero-conventional tillage systems were found at par *w.r.t.* of basal soil respiration rate during the whole crop growth stages (Table 2).

The microbial population study showed that conventional-conventional tillage system promoted the growth of fungal and bacterial population, whereas, zero-zero tillage system did not show any promotional activity of the concerned microbial population (Table 3). Singh *et al.* (2007) also found higher microbial populations under conventional tillage system at lower soil depth (7.5 to 15 cm). They also reported that at lower layer i.e., more than 7.5 cm depth from soil surface, *Azotobacter spp.* counts were significantly higher under conventional tillage as compared

Table1. Effect of tillage practices and herbicides on physico-chemical properties and organic carbon status of rhizosphere soil of rice

Treatment	Days after sowing								
	30			50			At harvest		
	pH	EC	OC(%)	pH	EC	OC(%)	pH	EC	OC(%)
Tillage									
Conventional-Conventional tillage system	6.84	0.17	0.66	6.85	0.18	0.67	6.88	0.17	0.69
Conventional-Zero tillage system .	6.76	0.19	0.63	6.77	0.20	0.64	6.79	0.18	0.66
Zero-Zero tillage system	6.59	0.16	0.46	6.59	0.17	0.47	6.62	0.16	0.49
Zero-Conventional tillage system	6.48	0.19	0.56	6.49	0.20	0.56	6.51	0.18	0.58
CD (0.05)	0.20	NS	0.02	0.19	0.02	0.06	0.22	0.02	0.01
Weed Management									
Hand weeding	6.60	0.25	0.61	6.61	0.26	0.61	6.64	0.24	0.63
Recommended herbicide application	6.58	0.18	0.50	6.60	0.18	0.50	6.61	0.18	0.52
Weedy check	6.82	0.13	0.63	6.83	0.14	0.65	6.85	0.13	0.67
CD (0.05)	0.16	0.02	0.01	0.14	0.01	0.03	0.15	0.01	0.01

Table 2. Effect of tillage practices and herbicides on phosphatase (µg *p*-NP h^{-1} g^{-1} soil), dehydrogenase (µg TPF h^{-1} g^{-1} soil) activity and basal soil respiration rate (mg CO_2 h^{-1} $100g^{-1}$ soil) of rhizosphere soil of rice

Treatment	Days after sowing											
	30				50				At harvest			
	Acid P	Alk P	DHA	BSR	Acid P	Alk P	DHA	BSR	Acid P	Alk P	DHA	BSR
Tillage												
Conventional-Conventional tillage system	155.4	118.7	47.5	0.203	256.3	208.9	79.8	0.248	126.4	99.8	29.4	0.108
Conventional-Zero tillage system	149.0	114.5	45.1	0.189	250.8	213.3	75.0	0.232	122.2	93.5	26.6	0.098
Zero-Zero tillage system	139.4	102.8	39.2	0.180	243.2	190.6	68.6	0.224	115.3	88.6	21.4	0.090
Zero-Conventional tillage system	145.3	109.0	43.8	0.188	248.1	203.3	73.0	0.230	121.7	92.7	24.4	0.095
CD (0.05)	0.8	1.1	2.3	0.002	1.5	2.4	0.5	0.002	1.5	1.8	1.2	0.003
Weed Management												
Hand weeding	148.2	112.2	42.7	0.208	251.8	202.0	75.3	0.238	122.2	95.1	26.1	0.100
Recommended herbicide application	134.5	96.3	37.0	0.143	238.5	195.0	69.8	0.208	115.7	88.0	22.5	0.086
Weedy check	159.1	125.3	52.0	0.220	258.6	215.1	77.2	0.255	126.4	97.9	27.8	0.107
CD (0.05)	0.8	0.9	1.1	0.002	1.4	1.2	0.8	0.001	0.8	1.4	1.3	0.002

Table 3. Effect of tillage practices and herbicides on the proliferation of fungi (x 10^3), total bacteria (x 10^5) and microbial biomass carbon status (µ g) of rhizosphere soil (per gram dry soil) of rice

Treatment	Days after sowing								
	30			50			At harvest		
	Fungi	TB	MBC	Fungi	TB	MBC	Fungi	TB	MBC
Tillage									
Conventional-Conventional tillage system	100.4	113.4	194.2	135.2	159.4	251.7	67.9	70.7	81.9
Conventional-Zero tillage system .	92.7	96.7	190.8	126.0	145.7	242.4	64.3	64.3	75.2
Zero-Zero tillage system	79.3	82.9	184.0	126.5	122.6	231.0	58.4	59.6	69.4
Zero-Conventional tillage system	84.7	91.4	187.7	120.8	136.3	238.6	62.0	62.0	70.4
CD (0.05)	2.0	0.8	5.1	2.1	1.2	2.2	0.6	0.8	2.5
Weed Management									
Hand weeding	106.2	116.6	195.9	130.7	152.9	243.2	66.5	66.1	76.9
Recommended herbicide application	50.9	43.5	169.5	98.3	97.8	226.8	53.5	58.1	63.9
Weedy check	110.7	128.2	202.1	152.4	172.3	252.9	69.6	68.2	81.9
CD (0.05)	1.3	1.2	2.7	2.2	0.7	2.3	1.0	0.6	1.4

to minimum tillage. Janusauskaite *et al.* (2013) demonstrated that bacteria and fungi decreased in no tillage system by 25.5 and 22.7%, respectively in comparison to conventional tillage. It can be concluded that conventional tillage system provides stimulating effects for microbial growth due to uniformly distributed residues in the arable layer and increases the rate of supplied oxygen to soil micro sites. Data of microbial population recorded under the present study were also supported by microbial biomass carbon status of soil.

The results of weed management envisaged that the use of recommended herbicides (Butachlor as pre emergence and fenoxaprop-p-ethyl and ethoxy sulfuron as post emergence herbicide) significantly affected the EC and organic carbon content in rhizosphere soil of rice (Table 1). However, soil pH was found unaffected due to application of herbicides. These observations are in close agreement with Sebiomo *et al.* (2010) who found that the herbicide treatments had significant effect on per cent organic matter of the soils treated with herbicides, which reduced significantly as compared to control. The activity of enzymes i.e. acid and alkaline phosphatase, dehydrogenase, basal soil respiration rate (Table 2), microbial population and microbial carbon status in rhizosphere soil of rice (Table 3) found significantly

lower in herbicide treated plots compared to hand weeded and weedy check plots in all the growth period of crop.

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Bioaccumulation of Heavy Metals and its Effects on the Quality of Rice Grown in the Tannery Polluted Soils

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Abstract: This study aims to determine accumulation of heavy metals in the soil and their translocation to the rice crop grown in the fields irrigated with contaminated water of the Kalasinghia drain, which is rich in discharges from tannery units. For comparison, soil and rice plants of a tube-well irrigated field far away from the polluted field were used as control. All observations were taken from the same field and crop twice, i.e. vegetative phase of the crop (before flowering) and at the time of harvest. Physicochemical parameters of the crop were also studied. The results showed the accumulation of heavy metals in the polluted soils more than the control soils. The concentration of heavy metals in the samples was also found to be as follows soil > root > shoot > grain. A significant difference was observed between heavy metal contents in the vegetative plants and mature plants. The Cr, Cu and Ni concentrations in rice grains were more than the values permitted by international health organizations and thus not acceptable for human consumption.

Key Words: Heavy metals, rice, polluted water, quality

Tannery industry effluents are causing serious pollution in Punjab. During tannery process, a substantial amount of acids, alkalies, salts of chromium and sodium, dyes, etc. are used. Leather and sports complex located at Jalandhar is generating huge quantity of tannery effluents. The common effluent treatment plants (CETP) can treat only 1.5 million litres of discharge per day while more than 5 million litres of discharge is expelled out every day. Kalasinghia drain passing through this area carries the treated, partially treated and untreated waste waters of this sports complex.Due to lowering of water table and also shortage of power for tubewells, the irrigation of crops with the water of this drain is an easy option. The rice crop is one of the most effected crops as this crop requires more frequent irrigation. Since the rice crops have been reported to accumulate heavy metals from soil and water, this study was aimed to asses the accumulation and translocation of heavy metals fron the tanner effluent irrigated rich soil to the rice crop

MATERIAL AND METHODS

The area selected for investigation is located at village Bhudopinder about 15km away from the Jalandhar, India (31° 23' N and 75° 25' E) on Kapurthala-Jalandhar highway. The Kalasighia drain carries the effluents from leather and sports complex, Jalandhar and moves through village Bhudopinder, the one selected for investigation as polluted fields. The tubewell irrigated field at village Vandala, which is 10km away from the polluted areas on other side of Jalandhar –Kapurthala highway, was taken as control. PR118 rice cultiver was selected for investigation.

Soil analysis: From each of the selected field, one Kg of soil was taken from five randomly selected sites. Hundred grams of the soil sample was acid digested and total metal estimation was done using Inductively Coupled Argon Plasma Atomic Emission Spectrophotometer (ICAP-AES) method (AOAC, 1984).

Metal uptake in rice plant: Sampling of rice was done from same field twice i.e. pre-flowering stage (vegetative plants) and post-flowering stage (mature plants at harvest stage). The well washed plants were oven dried at 55±5^0 C for 24 h, grounded and kept in air tight containers. Each oven dried sample (1 g) was digested with 15 ml of diacid mixture of nitric acid and perchloric acid in the ratio of 4:1 in a conical flask. The digested samples were filtered and stored in decontaminated dried labeled and air tight polythene bottles. The samples were analyzed using ICAP-AES method (AOAC, 1984).

Biochemical analysis: The fresh leaves collected at pre-flowering and post-flowering stage were washed thoroughly to remove all traces of soil particles and were used for estimation of various nutritive constituents like total soluble proteins (Lowry *et al,* 1951), carbohydrates (Ashwell, 1957) and chlorophyll (UV-Visible Spectrophotometer (U.S. EPA, 1994). Mature grains were used for estimation of protein and carbohydrate content.

RESULTS AND DISCUSSIONS

Physical and chemical characteristics of soils: The order of abundance of metals in control fieldl was Cr>Ni>>Pb Cu>Cd. There was many fold increase in the metal

Table 1. Physico-chemical analysis of the tannery polluted and the tubewell irrigated soils

Soil Characteristics	Control fields	Tannery polluted field
Soil texture	Sandy loam	Sandy loam
Soil pH	7.80	8.01
Cr (mg kg^{-1})	11.70	420.15
Cu (mg kg^{-1})	3.65	19.45
Ni (mg kg^{-1})	7.50	16.5
Pb (mg kg^{-1})	4.80	26.05
Cd (mg kg^{-1})	0.35	0.45

contamination in the polluted fields in compare to the control field soils (Table 1). In polluted soils, Cr,Cu,Cd,Ni and Pb were 35.91,5.33,2.2,5.43 and 1.28 folds more, respectively than the control fields soil.The chromium in soil increased to 420.15mg Kg^{-1} in the polluted fields.The pattern of abundance of various metals in polluted soil were Cr>Pb>Cu>Ni>Cd. Overall there was no change in the profile of the soil type as it was sandy loam in both the cases with high humas content in the tannery polluted soils.

Metal accumulation in rice: The tannery polluted rice accumulated many folds heavy metals in comparison to the tubewell irrigated rice shoot, root and particularly in grains. The mean concentration of various elements in the rice plants showed that various metals were present significantly high in the roots as compared to shoots during flowering as well post flowering stage. There was many fold increase in the metal concentration in the rice plants growing in the polluted fields in comparison to the control fields (Table 2). The order of metal abundance in polluted rice crop wasCr>Cu>Pb>Ni>Cd. There are reports of hyper toxic metal accumulation in crops in different parts of world. Frost and Ketchum (2000); Bose and Bhattacharyya (2008) reported heavy metal accumulation in durum wheat. Zn uptake was observed in wheat (Santa-Mairia and Cogliatti, 1998). Rice cultivars and other crops are reported to accumulate Cd (Liu *et al.,* 2003; McBride, 2003). In Present investigations, in the consumable grains of polluted rice, the Cr,Cu,Cd,Ni and Pb were 1.75, 1.38, 1.39, 2.71 and 1.53 folds more, respectively than control. As per standard dietry intake given for the theses heavy metals, some of them (Cr,Cu and Ni) are more than the maximum allowed concentrations values. It is a great concern for health risk factors as this crop is

Table 2. Concentration of metals in the rice plants in tubewell and tannery effluents irrigated fields

Metal	Pre-flowering stage		Harvest stage		
	Root	Shoot	Root	Shoot	Grain
Rice from control fields					
Cr	211.7	65.7	34.0	23.1	8.6
Cu	146.0	145.0	121.0	101.5	90.5
Cd	1.07	0.55	0.7	0.27	0.18
Ni	18.6	5.0	14.4	9.2	4.5
Pb	32.3	15.6	20.9	18.7	11.9
Rice from pollutes fields					
Cr	274.6	101.5	55.4	40.3	15.1
Cu	189.2	147.3	138.0	110.3	125.0
Cd	0.92	0.65	0.92	0.38	0.25
Ni	19.5	8.4	19.8	11.4	12.2
Pb	110.3	22.8	27.8	34.1	18.2

CD (0.05)			Root	Shoot			Grains
	A (Metals)	:	0.99	1.57	A(Metals)	:	0.81
	B (Stages)	:	1.58	2.48	B(Site)	:	0.51
	C (Site)	:	0.99	1.57			
Interaction	AxB	:	2.23	3.51	AXB	:	1.14
	BXC	:	2.23	3.51			
	AXC	:	1.41	NS			
	AXBXC	:	3.16	4.96			

Table 3. Data on the biochemical estimations of rice plants collected from the tannery polluted fields and the tubewell irrigated fields.

Sites	Plant parts	Protein (mg g^{-1})	Carbohydrates (mg g^{-1})	Chlorophyll (mg g^{-1})
Preflowering				
Control	Leaves	0.34	0.45	50.53
Polluted	Leaves	0.19	0.33	26.90
Post Flowering				
Control	Leaves	0.62	0.75	43.3
Control	Grains	67.0	771.0	—
Polluted	Leaves	0.53	0.63	22.3
Polluted	Grains	54.0	742.0	—
CD (0.05)				
A (Stage of sampling)	:	0.03	0.11	0.41
B (Plant parts)	:	0.032	0.11	0.41
AXB (Interaction)	:	NS	NS	0.58

one of staple food in India.

Biochemical analysis: There was significant decrease in the contents of these biochemicals like carbohydrates, proteins, chlorophyll in the grains and leaves harvested from rice plants from tannery polluted field as compared with control rice crops (Table 3). This ultimately effected the normal physiological functions of the crops, hinders normal growth and development including the photosynthetic capacity of crops and causing decease in the yields. Many reports are avaialble where it is seen that the metal toxicity have effected the biochemical profile of the crop plants. According to Prasad (1995), Cd effects chlorophyll, carotenoids and gas exchanges in the maize crops. Enzyme induction got effected due to heavy metal accumulation in plants (Van assche *et al.,*1988). According to Ewais (1997), Cd, Ni and Pb can effects the contents of chlorophyll, protein and growth of weeds. In present investigations, in the polluted grains the carbohydrates, proteins decreased to 742 (mg g^{-1}), 54 (mg g^{-1}) from 771 (mg g^{-1}),67 (mg g^{-1}), respectively, which was reported in the control rice grain. The chlorophyll content also decreased to 22.3 (mg g^{-1}) in the polluted rice leaves from 43.3 (mg g^{-1}), which was reported in the control rice leaves.

Due to the tannery pollution, the soils and rice crops are getting contaminated beyond the advisable limits. The degenerating biochemical profile due to metal toxicity is also a great concern. This all leads to great threat to human health and environment due to dietry intakes and also effecting the qualitative and quantitative crop production. The source of pollution should be checked and the polluted soils should be remediated for further use for cultivation.

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Nutrient Uptake, Root Density and Yield of Direct Seeded Rice-Wheat as Affected by Tillage Systems and N Levels

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Abstract: The maximum grain yield of rice was obtained with zero tillage with wheat straw at 100 kg N ha^{-1}, statistically at par with zero tillage without wheat straw at 125 kg N ha^{-1}. The 125 kg N ha^{-1} in zero tillage without wheat straw gave significantly higher yield than other N levels. The maximum grain yield was obtained in conventional tillage without wheat straw at 150 kg N ha^{-1}, which was significantly better than lower levels of N. The lowest weed number and dry matter was observed in zero tillage with wheat straw. The significantly more weed number and dry matter before and after spray was recorded at 150 kg N ha^{-1} than other N levels. The zero tillage with wheat straw recorded significantly higher uptake of N and P by grain at 100 kg N ha^{-1}. Conventional tillage with wheat straw at 150 kg N ha^{-1} registered higher potassium uptake by grains. Highest root density was recorded in zero tillage with wheat straw and zero tillage without wheat straw, but it slightly decreased under zero tillage without wheat straw than zero tillage with wheat straw. Maximum root density was observed with the application of 100 kg N ha^{-1}, but further increase in N did not increase the root density and 90 % of the roots were confined in top 0-15 cm soil layer. Tillage system had no significant effect on available N, P and K in soil at harvest. However, available N and K in the soil in all the treatments decreased but P improved from initial values. N, P and K in soil were significantly higher at 150 kg N ha^{-1} than other N levels. During *rabi* 2012-13, maximum grain yield of wheat was obtained in zero tillage with paddy straw at 150 kg N ha^{-1}.

Key Words: Grain yield, nitrogen levels, NPK uptake, planting methods, rice, root density, wheat straw

Rice-wheat is a dominant cropping system on fertile and irrigated alluvial soils of North-West India, particularly in Punjab and Haryana. In this region, conventional crop establishment practices in rice involves manual transplanting of rice in puddle soil, whereas, wheat is seeded in well puddle fine seedbed. These practices involve excessive tillage and hence, result not only in high-energy consumption but also in deterioration of soil structure. Puddling, a pre-requisite for rice transplanting, decreases the soil aggregates and pore size, thereby restricting germination and rooting of the succeeding crop (Giri *et al.,* 1993). In many parts of Punjab, water is increasingly becoming scarce. Poor quality irrigation systems and greater reliance on ground water have led to decline in water table. Rice requires continuous ponding of water for the first 15 days. This in turn leads to nutrient loss through leaching, besides causing high evapo-transpiration (ET) losses during hot summer. In view of the adverse effect of puddling, now-a-days the concept of no till and direct seeded rice are being popularized among farmers. Lal (1989) reported that the no tillage system mainly improve the soil biotic and soil physio-chemical environment but also increased the yield of different crops.

MATERIALS AND METHODS

Field experiment was conducted at Punjab Agricultural University, Ludhiana during *kharif* season of 2012-13 to see the influence of tillage and nitrogen on the productivity of rice-wheat cropping system. Treatments consisted of four tillage systems i.e., zero tillage with wheat straw (ZTWS), zero tillage without wheat straw (ZTWOS), conventional tillage with wheat straw (CTWS) and conventional tillage without wheat straw (CTWOS) and four levels of nitrogen as 0,100, 125 and 150 kg ha^{-1} were laid out in split plot design with three replications. In case of wheat, the treatments comprised as zero tillage with paddy straw (ZTPS), zero tillage without paddy straw (ZTPOS), conventional tillage with paddy straw (CTPS) and conventional tillage without paddy straw (CTPOS) and four levels of nitrogen as 0,100, 125 and 150 kg ha^{-1} were laid out in split plot design with three replications. The soil was loamy sand, neutral in reaction, low in organic carbon (0.17 %) and available N (214.8 kg ha^{-1}), medium in available P (19.5 kg ha^{-1}) and K (225.7 kg ha^{-1}) at sowing of direct seeded rice. The tillage systems were kept in main plots and nitrogen levels in sub plots. In *kharif*, crop was sown according to the treatments in the month of June using PR 115 variety of rice with recommended agronomic practices. The height of plant was measured from the base to the tip of last leaf till panicle emergence. After panicle emergence, height form the base to apex of the panicle was taken as height of the plant. Tillers were counted by using 50 cm x 50 cm quadrate from each plot. In each plot, fresh sample was taken from 25 cm area from row with the help of scale to ensure the increase in biomass production overtime. The collected plant biomass was first sun dried then oven dried at 62.5^0 C till the constant weight, was expressed as q ha^{-1}. In *rabi*, wheat cv. PBW 550 was sown

on November 14, 2012 using recommended practices.

RESULTS AND DISCUSSION

The maximum weed number before spray was recorded in CTWOS, which was significantly differed from other tillage systems. However, the lowest weed number was observed in ZTWS, it might be due to the mulching effect of wheat straw that reduces the germination of weeds. However, an increasing trend in weed number before and after spray was observed with an increase in N levels (Table 1). The maximum weed number before spray was in 150 kg N ha^{-1}. The weed dry matter before spray was significantly higher in CTWOS than other tillage systems. However, the lowest weed dry matter was recorded in ZTWS, it could be due to suppression of weed growth by wheat straw. It had also been observed that weed dry matter increased as the N increased and highest weed dry matter was recorded at 150 kg N ha^{-1}.

NPK uptake in rice: N uptake of grain was not influenced by tillage system. The different levels of N had significant effect on N uptake in grain. The N uptake in grain was significantly higher at 150 kg Nha^{-1} than control and 125 kg N ha^{-1}, but it was statistically at par with 100 kg N ha^{-1} (Table 2). The interaction effect of tillage systems and N levels was found significant for N uptake in grain. The maximum uptake of N was observed in grain in ZTWS at 100 kg N ha^{-1}, which was significantly better from other treatment combinations. Laroo *et al.* (2007) compared different levels of N and reported that the N uptake was more by rice grains as compared to straw; it might be due to higher concentration of N in grains as compared to straw.

The maximum phosphorus uptake in grain was recorded in ZTWS and was significantly varied from ZTWOS, CTWS and CTWOS tillage systems, however, uptake in straw in ZTWS and CTWS were at par. The phosphorus uptake in grain and straw was highest at 125 kg N ha^{-1}, and significantly differed from 0 and 150 kg N ha^{-1}, but was statistically at par with 100 kg N ha^{-1}. It was significantly higher with ZTWS at 100 kg N ha^{-1} than other treatment combinations. The application of 125 kg N ha^{-1} in CT and ZT with and without wheat straw gave significantly higher phosphorus uptake by grain than other N levels. The phosphorus uptake by grain was significantly higher in CTWOS at 150 kg N ha^{-1} than other N levels, whereas, CTWS at 150kg N ha^{-1} recorded higher phosphorus uptake in straw.

The potassium uptake in grain showed significant variation with tillage systems and N levels but non-significant variation in straw under different tillage system. Potassium uptake by grain in ZTWS was significantly higher than CTWS and CTWOS, but was statistically at par with ZTWOS. Potassium uptake by rice grain was higher at 125 kg N ha^{-1}, which was statistically at par with 100 and 150 kg N ha^{-1}, but significant better than control. The potassium uptake by grain in ZTWS at 100 kg Nha^{-1} was significantly higher than other treatment combinations. The application of 125 kg N ha^{-1} under ZTWOS was recorded significantly higher potassium uptake by grain than control and was statistically at par with 100 and 150 kg N ha^{-1}. Increase in potassium uptake in rice grain and straw might be due to increase in levels of N, which resulted in increased potassium concentration favorably. Similar results were observed by Laroo *et al.* (2007). Majumdar *et al.* (2005) observed that N has complimentary effect on availability of other nutrients especially phosphorus and potassium. Enhancement in the uptake of N naturally

Table 1. Influence of tillage systems and nitrogen levels on weed number and dry matter before and after spray in direct seeded rice

Treatment	Weed number (m^2)		Weed dry matter(q ha^{-1})		N uptake by straw
	Before spray	After spray	Before spray	After spray	(kg ha^{-1})
Tillage system					
ZTWS	22.8	1.5	1.39	0.06	41.30
ZTWOS	24.4	1.8	1.38	0.06	37.63
CTWS	23.8	1.8	1.38	0.06	42.94
CTWOS	27.4	3.5	1.48	0.05	36.29
CD (0.05)	2.5	0.8	0.01	NS	2.27
Nitrogen level (kg ha^{-1})					
N_0	21.9	1.6	1.34	0.06	27.08
N_{100}	23.0	2.0	1.39	0.06	40.45
N_{125}	25.9	2.3	1.44	0.06	47.40
N_{150}	27.6	2.7	1.47	0.05	43.24
CD (0.05)	1.2	0.8	0.01	0.003	4.16

ZTWS- zero tillage with wheat straw, ZTWOS- zero tillage without wheat straw, CTWS- conventional tillage with wheat straw, CTWOS- conventional tillage without wheat straw

Table 2. Effect of tillage systems and nitrogen levels on nitrogen, phosphorus and potassium uptake by grain* of direct seeded rice

Tillage system**	Nitrogen level (kg ha^{-1})				
	N_0	N_{100}	N_{125}	N_{150}	Mean
			Nitrogen uptake (kg ha^{-1})		
ZTWS	24.06	61.18	53.96	54.42	48.41
ZTWOS	24.83	48.92	51.29	49.79	43.71
CTWS	33.72	44.26	51.34	50.75	45.02
CTWOS	32.70	51.92	40.70	52.51	44.46
Mean	28.83	51.57	49.32	51.87	
CD (0.05)	Tillage system = NS; Nitrogen level = 2.21; Tillage system x Nitrogen level = 4.43				
			Phosphorus uptake (kg ha^{-1})		
ZTWS	7.91(5.25)	12.58(8.16)	10.42(6.30)	9.99(5.61)	10.22(6.33)
ZTWOS	7.40(4.47)	9.57(5.62)	10.13(7.43)	8.85(5.51)	8.99(5.76)
CTWS	7.89(5.59)	9.43(6.58)	10.48(7.59)	8.73(6.43)	9.13(6.52)
CTWOS	7.50(4.59)	8.05(6.13)	8.67(6.20)	10.04(7.41)	8.56(6.08)
Mean	7.67(4.95)	9.90(6.62)	9.92(6.88)	9.40(6.24)	
CD (0.05)	Tillage system = 0.13 (0.30); Nitrogen level = 0.16 (0.35); Tillage system x Nitrogen level = 0.33 (0.70)				
			Potassium uptake (kg ha^{-1})		
ZTWS	11.90 (95.92)	19.47(134.70)	14.74(128.33)	13.09(126.00)	14.80(121.24)
ZTWOS	12.18(92.23)	14.64(127.33)	16.17(135.33)	15.85(125.01)	14.71(119.98)
CTWS	12.49(101.53)	13.66(120.23)	14.52(128.00)	14.77(125.00)	13.86(118.69)
CTWOS	10.84(94.56)	13.44(120.13)	15.84(127.67)	15.73(129.61)	13.96(117.99)
Mean	11.85(96.06)	15.30(125.60)	15.32(129.83)	14.86(126.41)	
CD (0.05)	Tillage system = 0.75 (NS); Nitrogen level = 1.02 (3.77); Tillage system x Nitrogen level = 2.05 (7.55)				

* Straw uptake in parentheses

** For treatment details, check table 1

results in enhancement in the uptake of the phosphorus and potassium.

NPK in soil: The available N, P and K in soil after the harvest of crop varied significantly with varying N level but did not vary under different tillage systems. It was observed that available N in the soil in all the treatments decreased from initial value (214.8 kg ha^{-1}). However, it was significantly higher at 150 kg N ha^{-1} than other N levels. The available P status in the soil was improved in all the treatments over the initial status (19.5 kg ha^{-1}) except control (Table 3). It continued to increase with increase in N fertilizer from 0 to 150 kg N ha^{-1}. The available K in the soil showed decrease in K than initial value of (225.7 kg ha^{-1}). The N levels had significant effect on available K in soil. Data indicated that the highest available K in soil at 150 kg N ha^{-1}, which was significantly varied from other N levels.

Root density: The data on root density from soil profile at panicle initiation was presented in table 4 revealed that highest root density was recorded in ZTWS and ZTWOS, but it slightly decreased under ZTWOS than ZTWS. This may be due to the availability of moisture for longer period in the presence of wheat straw, which resulted in better development of roots. However, root density was lowest under CTWOS. Root density increased with the increase in N up to highest level over the control. However, the maximum root density was observed with the application of 100 kg N ha^{-1}, but further increase in N did not increase the root density. It was also observed that 90 per cent of the roots were confined in top 0-15 cm soil layer, and observed reduction in root density after this layer.

Grain and straw yield rice: The tillage systems had significant influence on the grain yield of rice. The grain yield observed in ZTWS significantly higher than CTWS and CTWOS, but it was statistically at par with ZTWOS. Similar results were obtained by Bhattacharyya *et al.* (2008). With the increase in N levels, the grain yield increased significantly and maximum grain yield was obtained with 125 kg N ha^{-1}, and was significantly differed from control and 150 kg N ha^{-1}, but statistically at par with 100 kg N ha^{-1}. It might be due to more attack of insect pest like leaf folder, brown leaf spot and sheath blight at higher dose of N (150kg N ha^{-1}). The beneficial effect of N application on various yield attributing characters led to increased grain yield with increasing levels of N. Similar results were reported by Rammohan *et al.* (2002).

The straw yield was significantly influenced by tillage

Table 3. Influence of tillage systems and nitrogen levels on available nitrogen, phosphorus and potassium (kg ha^{-1}) in soil

Treatment*	Available N	Available P	Available K	Bulk density (g cm^{-3})
Tillage system				
ZTWS	180.18	22.37	159.26	1.42
ZTWOS	176.94	21.26	156.16	1.44
CTWS	179.17	21.72	157.65	1.44
CTWOS	176.15	20.98	155.74	1.46
CD (0.05)	NS	NS	NS	NS
Nitrogen level (kg ha^{-1})				
N_0	155.77	19.16	137.81	1.44
N_{100}	173.41	21.64	157.34	1.45
N_{125}	183.95	22.34	164.58	1.46
N_{150}	199.31	23.18	169.07	1.45
CD (0.05)	5.30	0.84	2.46	NS

*See table 1 for treatment details

systems and followed the trend of grain yield. The straw yield increased significantly up to 125 kg N ha^{-1} thereafter decreased but at par with 150 kg N ha^{-1} (Table 5). The interaction between tillage system and nitrogen levels was significant. The straw yield registered maximum in CTWS at 125 kg N ha^{-1} than other treatment combinations, but it was statistically at par with ZTWS at 100 kg N ha^{-1}, ZTWS, ZTWOS and CTWOS at 125 kg N ha^{-1} and ZTWS, CTWS and CTWOS at 150 kg N ha^{-1}.

Grain yield of wheat: The grain yield of wheat was significantly influenced by tillage systems. The grain yield of wheat was significantly higher in ZTPS as compared to ZTPOS, CTPS (Table 6). Higher wheat yield was also obtained under zero tillage over the conventional tillage by Singh *et al*. (2010); Singh *et al.* (2011); Kaushal *et al.* (2012a,b); Singh *et al*. (2012a,b,c). However, CTPS produced considerable higher grain yield than CTPOS. Similarly, ZTPOS produced significantly less grain yield than ZTPS. The results are inconformity with the findings of Kumar *et al.* (2004). They found that incorporation and retention of rice residue on soil surface in succeeding wheat field remarkably enhanced the grain yield over residue removal. With increase in N, the yield of wheat also increased and the highest grain yield was obtained with the application of 150 kg N ha^{-1}, which significantly differed from other N levels. Grain yields were increased significantly with increasing increment of N up to 150 kg N ha^{-1} (Yadav *et al.,* 2005; Kaushal *et al.,* 2012a,b; Singh and Kaur, 2012).

On the basis of above discussion, it could be concluded that rice can be sown with ZTWS at 100 kg N ha^{-1} and ZTWOS at 125 kg N ha^{-1} for higher grain yield. However, wheat should be sown with ZTPS and ZTPOS at 150 kg N ha^{-1} for higher productivity.

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Table 4. Influence of tillage systems and nitrogen levels on root density (g m^{-3}) at panicle initiation

Treatment*	Soil profile depth (cm)			
	0-15	15-30	30-60	60-90
Tillage system				
ZTWS	2624.7	250.5	46.3	9.5
ZTWOS	2548.1	232.6	36.4	9.0
CTWS	2494.3	221.5	33.5	8.6
CTWOS	2445.2	219.4	29.5	8.3
Nitrogen (kg ha^{-1})				
N_0	2468.8	220.2	30.0	8.2
N_{100}	2572.5	239.9	42.7	9.2
N_{125}	2566.8	237.1	41.6	9.1
N_{150}	2504.2	226.8	31.4	8.9

*See Table 1 for treatment detals

Table 5. Effect of tillage systems and nitrogen levels on grain and straw yields (q ha^{-1})of direct seeded rice

Tillage system*	Nitrogen level (kg ha^{-1})				
	N_0	N_{100}	N_{125}	N_{150}	Mean
			Grain yield (q ha^{-1})		
ZTWS	32.2	52.4	47.5	45.2	44.3
ZTWOS	31.7	46.9	49.8	44.7	43.3
CTWS	35.4	43.1	46.6	44.6	42.4
CTWOS	32.9	42.3	43.5	46.5	41.3
Mean	33.1	46.2	46.8	45.2	
CD (0.05)	Tillage system = 1.5; Nitrogen level = 1.4; Tillage system x Nitrogen level = 2.8				
			Straw yield (q ha^{-1})		
ZTWS	50.9	70.8	66.8	67.7	64.1
ZTWOS	47.7	61.2	69.1	61.8	59.9
CTWS	57.2	61.7	72.4	70.4	65.4
CTWOS	52.8	61.3	68.2	70.6	63.2
Mean	52.1	63.8	69.1	67.6	
CD (0.05)	Tillage system = 3.1; Nitrogen level = 3.3; Tillage system x Nitrogen level = 6.7				

*See table 1 for treatment details

Table 6. Interaction effect of tillage systems and levels of nitrogen on grain yield (q ha^{-1}) of zero-till wheat

Tillage system*	Nitrogen (kg ha^{-1})				
	N_0	N_{100}	N_{125}	N_{150}	Mean
ZTPS	28.3	45.0	48.5	55.2	44.3
ZTPOS	23.7	37.6	41.6	54.5	39.4
CTPS	29.5	36.2	44.2	51.4	40.3
CTPOS	25.1	38.2	43.4	42.8	37.4
Mean	26.7	39.3	44.4	51.0	
CD (0.05)	Tillage system = 3.4; Nitrogen level = 1.3; Tillage system x Nitrogen level = 2.5				

*See table 1 for treatment details

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Response of Knolkhol cv. Early White Vienna to Drip Irrigation and Fertigation in Kashmir Region

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Abstract: The experiment consisted of sixteen treatment combinations and replicated four times in a factorial randomized block design. The treatments include four levels of irrigation and fertilizer application. The growth and yield characteristics of knolkhol cv. Early White Vienna were significantly influenced by drip irrigation and fertigation levels. However, the treatment combination of 80% ET through drip (40.04 cm) + 80% recommended NPK (100:48:64 kg ha^{-1}) through fertigation proved significantly superior over rest of the treatments in terms of growth and yield contributing characteristics with maximum knob yield (281.50 q ha^{-1}), which was found 68.5% higher than that of surface irrigation and manual fertilizer application. It was further concluded that the treatment combination of 60% ET through drip + 80% recommended NPK through fertigation recorded maximum water use efficacy (8.92 q ha^{-1} cm), whereas, the maximum fertilizer use efficiency (NUE-3.61 q kg^{-1} N, PUE-7.52 q kg^{-1} P and KUE-5.64 q kg^{-1} K) was observed with the treatment combination of 80% ET through drip + 60% recommended NPK through fertigation.

***Key Words*:** Drip irrigation, fertigation, water use efficiency, fertilizer use efficiency, knolkhol

Knolkhol (*Brassica oleracea* cv. *gongylodes* L.) is a temperate vegetable and very popular in Kashmir region. Although Kashmir is rich in its water resources and there are several methods of providing irrigation to vegetable crops, yet drip irrigation is very useful for the region, because most of the orchard crops exist in the uplands where the scarcity of water is felt largely by the farmers throughout the year. Drip irrigation can be very effectively utilized in such land situations of the region. The research work on adoption of drip irrigation and fertigation practices in different vegetable crops revealed the efficiency of the system in reducing the water and fertilizer requirement with increased yield. However, very little literature is available pertaining to performance of knolkhol under drip system. The results of the present study revealed a significant and positive response of knolkhol under drip irrigation and fertigation system. In view of importance of drip irrigation system and need for its diversification, the present study was conducted to assess the performance of knolkhol for increased yield and effective use of irrigation water and fertilizers for Kashmir region.

MATERIAL AND METHODS

The present investigation was carried out at the Experimental Farm of Division of Olericulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar (J&K). Factorial randomized block design was followed with sixteen treatment combinations and four replications. The treatments comprised of four levels of irrigation *viz*. 100%, 80% & 60% ET through drip and 100% surface irrigation; and 4 levels of fertilizers application such as 100%, 80% & 60% recommended NPK through fertigation and 100% recommended NPK through traditional approach. Surface irrigation and manual application of fertilizers were treated as control. The volume of water required under drip irrigation system was computed using following equation: V = [DE x CF x AA x PC]/IE

Where, V= Volume of water required (l $plant^{-1}$ day^{-1}), DE = Daily pan evaporation (mm), CF = Crop factor, AA = Area allotted per plant (m^2), PC = Pan coefficient and IE = Irrigation efficiency as a decimal. The crop factor (CF) is related to relative water demand to crop growth stages and the respective CF value for knolkhol was taken as 0.30, 0.60, 0.95 and 0.80, respectively for initial, development, mid-season and during late-season stage. The pan factor value was 0.75 as suggested for USDA class-A pan. The area allotted per plant was 0.12 m^2.

Twenty-two days old seedlings of knolkhol cv. Early White Vienna were transplanted on 22nd September 2007 with 6 rows per plot keeping row to row and plant to plant distance of 30 and 40 cm, respectively. Drip system was laid out parallel to the crop rows and each lateral with emitter distance at 40 cm and 2.2 l h^{-1} discharge rate. The amount of water actually applied by way of drip irrigation was based on climatologically approach and pan evapo-transpiration. Irrigation was scheduled on alternate day in case of drip irrigation and need based surface irrigation was applied. Fertigation with RFD 125:60:80 kg NPK ha^{-1} was given

according to the treatments in eight split doses at ten days interval beginning 10 days after transplanting. However, in case of manual fertilizer application, half dose of nitrogen (as urea) and full doses of phosphorus (as SSP) and potassium (as MOP) were applied as basal doses while the remaining half dose of nitrogen was applied at 20 and 40 days after transplanting as top dressing. All the other packages and practices were adopted as recommended for the region (Anonymous 2005). Observations were recorded for various growth, yield and quality traits. Volumetric method was used for calculating the uniformity coefficient of drip irrigation system (Raina *et al.,* 1999). The water use efficiency was computed by dividing yield (q ha^{-1}) with total water applied (cm) including effective rainfall. The fertilizer use efficiency was worked out separately for N (NUE-nitrogen use efficiency), P (PUE-phosphorus use efficiency) and K (KUE-potassium use efficiency) by dividing total yield (q ha^{-1}) with total fertilizer applied (kg ha^{-1}).

RESULTS AND DISCUSSION

In order to check the efficiency of drip irrigation system, uniformity coefficient (UC) of drip irrigation system was worked out and was found to be 93.8%. The high value of UC indicates the excellent performance of the system in supplying water uniformly throughout the laterals.

Drip irrigation levels significantly influenced the growth and yield characteristics (Table 1). Drip irrigation at 80% ET proved significantly superior over other treatments by recording the maximum plant height (30.30 cm), no. of leaves $plant^{-1}$ (14.09), plant spread (41.19 cm), leaf length (27.90 cm), leaf breadth (10.04 cm), knob length (6.11 cm), knob diameter (7.35 cm), root length (15.71 cm), root diameter (1.09 cm), average root weight (16.73 g), average leaf weight (11.20 g), average knob weight (328.09 g), gross weight per plant (486.1 g), knob weight (17.25 kg $plot^{-1}$) and knob yield (266.31 q ha^{-1}), whereas, the surface irrigation noticed minimum values for these mentioned characters with lowest yield (185.56 q ha^{-1}). The improved growth and yield of knolkhol under drip irrigation might be due to the regular availability of water around the root zone at very low moisture tension, reduced runoff and leaching losses, hence available fully to plants.

The response of various fertigation levels in knolknol cv. Early White Vienna showed that all the fertigation levels exhibited significant improvement in various growth and yield characters in comparison to manual fertilizer application (Table 2). However 80% recommended NPK through fertigation produced maximum values for plant height (28.72 cm), no. of leaves/plant (13.48), plant spread (42.02 cm), leaf length (26.62 cm), knob length (5.62 cm), knob diameter (6.75 cm), average knob weight (305.35 g), grass weight $plant^{-1}$ (426.0 g), knob weight $plot^{-1}$ (16.02 kg) and knob yield (248.26 q ha^{-1}) whereas 100% recommended NPK through fertigation recorded maximum leaf breadth (9.71 cm), root length (15.53 cm), root diameter (1.03 cm), average root weight (15.84 g) and average leaf weight (10.60 g). The minimum knob yield (207.82 q ha^{-1}) was found with the manual fertilizer application. Fertigation allows more controllable application of nutrients during the crop growing season and also restricts leaching losses of nutrients as compared to other methods of fertilizers application including traditional broadcasting method, and hence realizes higher yield. Increased growth and yield of cabbage, lettuce and cauliflower under fertigation system was earlier reported by Titular (1995).

Combined drip irrigation and fertigation, supply and maintain an optimum level of both moisture and nutrients within the root zone, with irrigation water acting as a vehicle for the nutrients required by the crop. The results of the present study confirm the superiority of combined effect of drip irrigation and fertigation over their individual effects in knolkhol (Table 3). The treatment combination of 80% ET through drip + 80% recommended NPK was found best among all other treatment combinations with maximum knob yield (281.50 q ha^{-1}), which was found 68.5% higher than that control. The same treatment combination also recorded maximum plant height, no. of leaves $plant^{-1}$, plant spread, knob length, diameter and weight, gross weight $plant^{-1}$. However, leaf length, leaf breadth, root length, root diameter, average root weight and average leaf weight registered maximum values with the treatment combination of 80% ET through drip + 100% recommended NPK through fertigation. Our findings are in accordance with the findings of Rubeiz *et al.* (1989) and Burnette *et al.* (1993) in cabbage and broccoli, Hochmuth *et al.* (1994) in lettuce, Thompson *et al.* (2000) in cauliflower and Ristimaki *et al.* (2000) in cabbage.

Water use efficiency: Results obtained revealed that drip irrigation substantially decreased the consumptive use of water in knolkhol in comparison with surface irrigation (Table 1 and Table 4). Drip irrigation at 100%, 80% and 60% ET consumed 50.05, 40.04 and 30.03 cm ha^{-1} water throughout the cropping season; while the surface irrigated plots consumed 66.2 cm ha^{-1} water and saving of irrigation water in the tune of 24.3%, 39.5% and 54.6%, respectively through drip irrigation over surface irrigation, leading to a significant increase in water use efficiency. However, the maximum water use efficiency (8.07 q ha^{-1} cm) was observed with 60% ET though drip followed by 80% ET through drip (6.65 q ha^{-1} cm) and 100% ET through drip (4.58 q ha^{-1} cm), whereas, the lowest water use efficiency (2.80 q ha^{-1} cm)

Table 1. Effect of drip irrigation on growth, yield and water use efficiency in knolkhol cv. Early White Vienna

Treatment*	Plant height (cm)	No. of leaves plant^{-1}	Plant spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Knob length (cm)	Knob diameter (cm)	Root length (cm)	Root diameter (cm)	Av. root weight (g)	Av. leaf weight (g)	Av. knob weight (g)	Gross weight plant^{-1} (g)	Knob weight. plot^{-1} (kg)	Knob yield (q ha^{-1})	Water applied (cm)	WUE (q ha^{-1} cm)
I_1	26.58	11.75	39.29	27.15	9.53	4.88	5.97	15.20	0.94	15.74	10.63	273.93	356.9	14.79	229.37	50.05	4.58
I_2	30.30	14.09	41.19	27.90	10.04	6.11	7.35	15.71	1.09	16.73	11.20	328.09	486.1	17.25	266.31	40.04	6.65
I_3	27.83	13.15	40.48	24.05	8.43	5.24	6.47	13.47	0.83	12.44	8.60	290.84	401.0	15.70	242.36	30.03	8.07
I_4	22.81	10.06	35.79	21.99	7.48	3.75	4.74	12.55	0.75	10.02	7.46	222.77	278.2	12.02	185.56	66.2	2.80
CD (0.05)	1.67	0.89	1.50	1.40	0.68	0.31	0.40	0.78	0.01	0.74	0.72	29.90	13.52	1.61	24.92	-	-

*I_1 = 100% ET through drip irrigation; I_2 = 80% ET through drip irrigation; I_3 = 60% ET through drip irrigation; I_4 = 100% Surface irrigation

Table 2. Effect of fertigation on growth, yield and fertilizer use efficiency in knolkhol cv. Early White Vienna

Treatment*	Plant height (cm)	No. of leaves plant^{-1}	Plant spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Knob length (cm)	Knob dia-meter (cm)	Root length (cm)	Root dia-meter (cm)	Av. root weight (g)	Av. leaf weight (g)	Av. knob weight (g)	Gross weight plant^{-1} (g)	Knob weight plot^{-1} (kg)	Knob yield (q ha^{-1})	NUE (q kg^{-1} N)	PUE (qkg^{-1} P)	KUE (qkg^{-1} K)
F_1	25.90	11.88	39.43	27.20	9.71	4.86	5.89	15.53	1.03	15.84	10.60	272.04	371.1	14.68	226.69	1.81	3.77	2.83
F_2	28.72	13.48	42.02	26.62	9.34	5.62	6.75	14.99	0.97	15.20	10.27	305.35	426.0	16.02	248.26	2.48	5.17	3.87
F_3	27.85	13.03	41.12	24.86	8.60	5.28	6.33	13.90	0.85	13.29	9.19	288.93	399.5	15.60	240.83	3.21	6.68	5.01
F_4	25.05	10.66	35.19	22.40	7.82	4.22	5.56	12.50	0.77	10.60	7.83	249.30	325.5	13.46	207.82	1.66	3.46	2.59
CD (0.05)	1.67	0.89	1.50	1.40	0.68	0.31	0.40	0.78	0.01	0.74	0.72	29.90	13.52	1.61	24.92	-	-	-

*F_1 = 100% RFD through fertigation; F_2 = 80% RFD through fertigation; F_3 = 60% RFD through fertigation; F_4 = 100% RFD through manual application

Table 3. Effect of drip irrigation and fertigation on growth and yield characters of knolkhol cv. Early White Vienna

Treatment combination*	Plant height (cm)	No. of leaves plant^{-1}	Plant spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Knob length (cm)	Knob diameter (cm)	Root length (cm)	Root diameter (cm)	Av. root wt. (g)	Av. leaf wt. (g)	Av. knob wt. (g)	Gross weight plant^{-1} (g)	Knob weight plot^{-1} (kg)	Knob yield (qha^{-1})
I_1F_1	25.57	11.73	39.31	28.80	10.13	4.57	5.67	16.07	1.03	17.50	11.70	267.22	334.40	14.43	222.77
I_1F_2	28.87	13.33	41.98	28.07	9.80	5.67	6.67	15.73	0.99	16.87	11.50	293.51	422.90	15.85	244.68
I_1F_3	27.20	12.47	40.17	26.97	9.33	5.07	6.05	15.17	0.94	15.60	10.60	285.74	366.80	15.43	238.17
I_1F_4	24.70	9.47	35.79	24.77	8.87	4.23	5.00	13.83	0.83	13.00	8.73	249.25	303.80	13.46	207.87
I_2F_1	29.07	13.27	41.67	29.77	11.10	6.13	7.45	16.93	1.37	18.50	12.50	322.70	504.00	17.42	268.80
I_2F_2	32.20	15.20	44.77	29.30	10.47	6.60	7.90	16.53	1.18	18.33	12.00	377.80	537.00	18.24	281.50
I_2F_3	31.40	14.97	43.97	27.33	9.67	6.33	7.63	15.33	0.97	16.30	11.20	325.18	510.40	17.56	270.98
I_2F_4	28.53	12.93	38.46	25.23	8.93	5.40	6.03	14.07	0.89	13.80	9.10	292.70	393.00	15.81	243.99
I_3F_1	26.33	12.07	39.82	26.10	9.43	4.90	5.87	14.87	0.93	14.87	10.00	267.90	357.30	14.46	223.13
I_3F_2	29.93	14.20	43.19	25.83	9.20	6.05	7.10	14.50	0.90	14.50	9.70	321.29	445.90	17.35	267.87
I_3F_3	29.33	13.77	42.67	22.90	7.77	5.80	6.83	12.87	0.79	12.00	7.73	319.07	430.30	17.23	265.99
I_3F_4	25.73	12.60	36.37	21.40	7.33	4.23	5.10	11.67	0.70	8.40	7.00	255.10	370.80	13.77	212.49
I_4F_1	22.63	10.47	36.99	24.17	8.20	3.87	4.59	14.27	0.82	12.50	8.23	230.37	289.00	12.44	192.07
I_4F_2	23.90	11.20	38.22	23.30	7.90	4.17	5.33	13.20	0.81	11.13	7.90	234.81	298.50	12.68	195.80
I_4F_3	23.47	10.93	37.80	22.27	7.67	3.95	4.83	12.27	0.73	9.27	7.23	225.74	290.80	12.19	188.23
I_4F_4	21.27	7.67	30.33	18.23	6.17	3.03	4.23	10.47	0.67	7.20	6.50	200.18	234.50	10.81	166.97
CD(0.05)	3.35	1.79	3.01	2.81	1.36	0.63	0.80	1.57	0.02	1.49	1.45	59.8	27.49	3.23	49.84

*I_1 = 100% ET through drip irrigation; I_2 = 80% ET through drip irrigation; I_3 = 60% ET through drip irrigation; I_4 = 100% Surface irrigation

F_1 = 100% RFD through fertigation; F_2 = 80% RFD through fertigation; F_3 = 60% RFD through fertigation; F_4 = 100% RFD through manual application

Table 4. Effect of drip irrigation and fertigation on yield enhancement, water and fertilizer use efficiency in knolkhol cv. Early White Vienna

Treatment combination*	Yield (q ha^{-1})	Increase in yield (%)	Water applied (cm)	Water saving (%)	WUE (q ha^{-1} cm)	Fertilizer applied (NPK kg ha^{-1})	Fertilizer saving (%)	Fertilizer use efficiency		
								NUE (q kg^{-1} N)	PUE (q kg^{-1} P)	KUE (q kg^{-1} K)
I_1F_1	222.77	33.3	50.05	24.3	4.45	125:60:80	-	1.78	3.71	2.78
I_1F_2	244.68	46.5	50.05	24.3	4.96	100:48:64	20	2.48	5.18	3.88
I_1F_3	238.17	42.6	50.05	24.3	4.75	75:36:48	40	3.17	6.61	4.96
I_1F_4	207.87	24.4	50.05	24.3	4.15	125:60:80	-	1.66	3.46	2.59
I_2F_1	268.80	60.9	40.04	39.5	6.17	125:60:80	-	2.15	4.48	3.36
I_2F_2	281.50	68.5	40.04	39.5	7.03	100:48:64	20	2.81	5.86	4.39
I_2F_3	270.98	62.2	40.04	39.5	6.76	75:36:48	40	3.61	7.52	5.64
I_2F_4	243.99	46.1	40.04	39.5	6.09	125:60:80	-	1.95	4.06	3.04
I_3F_1	223.13	39.6	30.03	54.6	7.43	125:60:80	-	1.78	3.71	2.78
I_3F_2	267.87	60.4	30.03	54.6	8.92	100:48:64	20	2.67	5.58	4.18
I_3F_3	265.99	59.3	30.03	54.6	8.85	75:36:48	40	3.54	7.38	5.54
I_3F_4	212.49	27.2	30.03	54.6	7.07	125:60:80	-	1.69	3.54	2.65
I_4F_1	192.07	15.0	66.20	-	2.90	125:60:80	-	1.53	3.20	2.40
I_4F_2	195.80	17.2	66.20	-	2.95	100:48:64	20	1.95	4.07	3.05
I_4F_3	188.23	12.7	66.20	-	2.84	75:36:48	40	2.50	5.22	3.92
I_4F_4	166.97	-	66.20	-	2.52	125:60:80	-	1.33	2.78	2.08

* See table 3 for details

was found with surface irrigation. More benefits of water use efficiency were observed with the combined application of drip irrigation and fertigation. Among various treatment combinations, 60% ET through drip + 80% recommend NPK though fertigation recorded maximum water use efficiency (8.92 q ha^{-1} cm). Since the rate of water losses through evaporation, percolation and leaching was much lower under drip irrigation, hence water use efficiency was higher as compared to surface irrigation. These results are in agreement with the earlier findings of Sharanappa *et al.* (2000), Thompson *et al.* (2000), Anil *et al.* (2001) and Gupta *et al.* (2010).

Fertilizer use efficiency: Among different fertigation levels, fertigation with 60% recommended NPK saved a considerable amount (40%) of fertilizers with maximum fertilizer use efficiency (NUE-3.21 q kg^{-1} N, PUE-6.68q kg^{-1} P and KUE-5.01 q kg^{-1} K) (Table 2 and 4). In case of combined application of drip irrigation and fertigation, the treatment combination of 80% ET through drip + 60 % recommended NPK through fertigation recorded the maximum fertilizer use efficiency (NUE-3.61 q kg^{-1} N, PUE-7.52 q kg^{-1} P and KUE-5.64 q kg^{-1} K). Fertilizer use efficiency under drip irrigation and fertigation system might have increased due to higher and readily availability, the efficient use of nutrients at various stages of crop growth and practically no leaching of nutrients in the form of runoff. Similar benefits of fertilizers use efficiency were also reported by Everaarts (1993) in broccoli, Kaniszewski *et al.* (1999) in white cabbage, Thompson *et al.* (2000) in cauliflower and Gupta *et al.* (2009) in sprouting broccoli.

It was concluded that the treatment combination of 80% ET through drip + 80% recommended NPK through fertigation proved significantly superior over rest of the treatments in terms of growth and yield contributing characteristics with maximum knob yield (281.50 q ha^{-1}), which was found 68.5% higher than that of surface irrigation and manual fertilizer application (166.97 q ha^{-1}). The treatment combination of 60% ET through drip + 80% recommended NPK through fertigation recorded maximum water use efficacy (8.92 q ha^{-1} cm), whereas, the maximum fertilizer use efficiency was observed with the treatment combination of 80% ET through drip + 60% recommended NPK through fertigation.

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Studies on Nest Architecture and Pollination Potential of Bumble Bee (*Bombus haemorrhoidalis*)

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Abstract: Pollination potential of bumble bee *Bombus haemorrhoidalis* Smith was studied along with their rearing. Bumble bee queens were trapped from different flora during spring. During 2009-2010, eleven queens raised their progeny successfully in confinement (incubator) and three colonies raised their progeny for the first time under room temperature (control). Domiciles 16x12x10cm and 15x12x8cm with different nesting materials (cotton, moss and filter paper with bottle lid) were accepted to the level of 75 per cent, however, the per cent acceptance was 41.66 for the domiciles having 25x20x15cm dimensions. Hoarding cages were not accepted by the queens. The average time for wax secretion and development from egg to adult was 6.7 days and 26.21 days. Reared bumble bee colonies were successfully used for pollinating cucumber grown under polyhouse in increased fruit set, healthy fruits, fruit length, diameter, weight, seed number and weight with reduction in crooked fruits. The cost benefit ratio was 1:2.02 and an increase of 22 per cent in the total returns from bumble bee pollinated crop over non-pollinated crop.

Key Words **:** Bumble bees, nest architecture, pollination, cucumber, protected conditions

In horticulture and agriculture, honey bees are mainly utilized for the pollination of crops. Over the last few decades, the trend of cultivating crops has shifted towards protected cultivation. Besides, due to changing climatic conditions and increased *Varroa* mite infestation, the apiculture industry received a setback. Under such critical situations, it becomes obvious to take into account the immense role and utility of native pollinators in pollinating various economically important crops. Bees can be used for the pollination of crops under protected conditions. Bumble bees are found to be the most efficient and reliable pollinators under protected conditions and work well under adverse conditions of temperature and cool weather. It is also valuable in buzz pollinating the crops such as tomato (Corbet *et al*., 1982; Erikson and Buchmann, 1983). Bumble bees lives either underground in pre-existing small, mammal nests or above ground in dry vegetation comprising of thick dry leaves and wooden twigs. Several attempts have been made earlier by different workers to raise bumble bee colonies in captivity by artificial methods and utilize them for pollination in both open and protected conditions (Plowright, 1996). But in India, no attempts were made till first decade of this century.

Attempts to rear bumble bees were started in 2002 and were successfully reared in captivity during 2005-2008 (Kashyap, 2008). To avoid several problems such as increased humidity and moisture, several advances have been made. Techniques have been developed to rear bumble bees for pollination of high value crops under protected conditions to increase productivity (Berezin and Beiko, 2000; Anonymous, 2009). As the Indian agriculture is shifting towards protected cultivation to make available the crops throughout the year with quality produce, the present study was formulated to know the pollination efficiency of bumble bee with the refinement of its rearing technology for the successful domestication of this native pollinator, which is a highly commercial pollinator under protected cultivation conditions in the Eastern and Western countries.

MATERIALS AND METHODS

The studies were carried out in the Department of Entomology and Apiculture (February to June and August to October in 2009-2010) and Experimental Farm of the Department of Vegetable Science (June to August in 2009-2010); Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh.

Natural nest architecture studies: These studies were conducted at Sarot, Jubbal (2300 meters above mean sea level, 31.1094667^{0}N; 77.662996^{0}E) and Nauni (1250 metres above mean sea level) at a longitude of 77^0 11' 30" E and a latitude of 30^0 52' 30 N". Nests of bumble bees were located at different altitudes by listening to the buzzing sounds of the bumble bees in the forest and field areas (cultivated and barren lands). The bumble bee nests were observed regularly till the activity ceased. The nests were, then dug out and brought to the laboratory for studying the composition, structure, nesting materials and type of cells in the nests. The outer covering of the composite nest i.e. nesting material was isolated from the brood area to know the composition of nests. The nests were evaluated to determine the variations in the shape of the nests collected from different altitudes.

Different cells of bumble bee nests were separated to study the dimensions of different cells (queen cells, worker cells and honey-pots) with digital Vernier calliper. The average of cells was taken to know the difference in the dimensions of different cell types.

Refinement of bumble bee rearing technique: Four types of boxes each with three different nesting materials having three replications for each box were taken. The domiciles had different dimensions with different nesting materials. The domiciles were made up of ply-wood, divided into two equal chambers viz., brood chamber and defecating chamber and had a sliding glass at the top to observe the nest construction and brood activity without disturbing the queen. The glasses were covered with inner covers from above to avoid the entry of direct light. The base of the defecating chamber was made sliding and perforated for easy removal of debris from the colony and to maintain hygiene in the nest along with removing excess moisture to the outside. Two holes were provided in the side wall for proper ventilation. The dimensions of different domiciles were 15x12x 8cm, 16x12x10cm and 25x20x15cm. Hoarding cages had dimensions of 33x20x10cm. All cages had a small hole in the centre, which provided a free space for the queen and workers for movement between brood and defecating chambers.

With the onset of spring, the bumble bee queens were collected in the early morning and evening during foraging for pollen and nectar with the help of insect collecting nylon net. The queens were brought to the laboratory in plastic vials having perforated lids and were placed in refined domiciles with proper feeding provisions. Spring captured bumble bee queens were put in the wooden domiciles having different nesting materials (moss, thermo-cole, cotton, filter paper and sponge sheets) and kept in controlled conditions in the incubator at 26.9°C temperature and 65 per cent relative humidity. Queens were fed with honey bee-collected pollen and 50 per cent sucrose solution. Similarly, queens were kept at room temperature to know the success of rearing the bumble bees under room temperature ranging between 32-36°C and 50-60 per cent relative humidity. These queens were fed with both 50 per cent sugar/sucrose solution and grinded or pollen pellets. Time taken by the queens for wax secretion and emergence of workers was recorded.

Utilization of bumble bee under protected conditions for the pollination of cucumber: For pollination studies under protected conditions, the experiment was conducted in a 200m^2 plastic greenhouse using randomized block design. Total 32 blocks were made out of which 24 blocks were exposed to bumble bee pollination while eight blocks were left out for control treatment. The cucumber (Punjab Naveen) crop was sown in the first week of April. In each block, twelve plants were planted, thus making a total of 384 plants in three replications. An insect proof net was placed between the experimental and control plots to avoid pollination in control plots. Cucumber plants were also planted in open conditions during the last week of February in randomized block design to know the effect of natural pollination on cucumber productivity under open conditions. A total of sixty blocks were made and in each block twelve plants were planted. The plants came to bloom during the month of June.

Artificially reared bumble bee colony was introduced in blooming cucumber crop (with 5-10% flowers opened) in the polyhouse by placing it inside a big box (30x30x30cm) to which a plastic tube was attached, which served as a passage for entry and exit for bumble bee foragers. Foraging activity of bumble bees was recorded on cucumber grown inside polyhouse from early morning hours (0600h) till late evening (1800h) at two hour interval for 20 days continuously. For comparative studies, similar data were recorded under open conditions.

For studying the crop productivity, the female flowers per vine were pre-counted. Ten plants from each treatment viz., bumble bee pollinated, control and open pollinated were selected randomly. The fruit set on these plants were then recorded and total yield was calculated on fruit set basis. The per cent healthy fruits crooked fruits were calculated by counting the number of healthy/crooked fruits from the total fruit set. Fruit length, fruit diameter and fruit weight were measured using scale, digital Vernier calliper and digital weighing balance, respectively.

The average of 10 fruits was taken for each pollination treatment. The seeds from each fruit were removed and kept separately in water for 24 hours. After washing, the seeds were dried by keeping them in temperature controlled chambers for 24 hours, and then counted. One thousand dried seeds from each treatment were taken separately in the petriplate and weighed. Per cent increase in the fruit set, healthy fruits, crooked fruits, length, diameter, weight, number of seeds, weight of 1000 seeds was calculated as per cent increase in bumble bee pollinated cucumbers over control.

Cost-benefit ratio was worked out for cucumber grown under polyhouse conditions and the per cent increase in total returns was calculated for increase in the cucumber productivity and production in bumble bee pollinated plants over control.

RESULTS AND DISCUSSION

Nest architecture: The nest located at Sarot, Jubbal (Nest 1) was dug out in the month of November when the activity of bumble bees ceased before snowfall. The nest was built inside the abandoned, old rodent burrow having one small opening. Nest was attached to the roots of an adjoining apple tree. An involucrum made of waxy substance was found covering the nest from top. Some pine needles were found in the tunnel and the tunnel end, leading into a wide cavity where the brood having different scattered cells were found. The nest was circular with diameter and height of 12.56 and 6.8cm (Table 1). The nest located at Nauni (Nest 2) was dug out in the month of December. It was located in the abandoned nest of some rodent beneath heap of big stones with broad opening and was interwoven with long grass. Single entrance of nest was found bifurcated into a number of tunnels. The nest was found at a depth of 90cm and the length of the tunnel was found to be 150cm. Nest was rested on the flat surface and was attached to roots of nearby tree. It was built with interwoven dry grass, leaves, small wooden twigs and some plastic material. The involucrum of wax covered the nest. The nest had three entrances from the involucrum. The diameter and height of the nest were found to be 17.25 and 7cm, respectively. Beneath the involucrum the worker, queen and honey pot cells were observed. The brood filled most of the cavity beneath the nest canopy. The surface of nest was completely dry and free of mold. The nest contained both sealed and unsealed brood. The brood batches were arranged in circular manner. Some beetles were found in the colony at Nauni and were identified as *Antherophagus* sp., which was found to be pollen feeder. The dimensions of the different brood cells (queen, worker and honey pots) observed in the natural nest are presented in Table 1.

Similar observations were recorded by Thakur (2002) who reported bumble bee *B. haemorrhoidalis* nests underground. Taylor and Cameroon (2003) also studied the nest construction and architecture o*f B. transversalis*. They found that nests were constructed from leaf pieces and grass which kept the nest dry during high humidity. In similar studies, Katayama *et al.* (1995) observed the nests of Japanese bumble bee (*B. deuteronymous maruhanobachi)* and found that the honey pots were framed on the periphery and worker cells on the inner side of the nest.

At higher altitude (2300m), the average length and width of queen cells, honey pots and worker was 16.56±2.1 and 12.55±0.27; 15.31±0.25 and 12.91±0.23; and 13.16±0.79 and 10.15±1.07 mm, while at lower altitude (1250m), the above measurements were 20.57±0.75 and15.20±0.97; 20.35±0.68 and 16.32±0.83; and 14.24±0.86 and 10.01±1.03mm, respectively (Table 2). Honey pots were located at the periphery of both the nests. Gonzalez *et al*. (2004) also found the similar observations in the nest architecture of bumble bees. Hoffmann *et al.,* (2004) also recorded similar dimensions of worker cells, queen cells and honeypots of *B. melaleucus* to the size of 16.0±3.39; 23.9±0.33 and 20.6±4.24mm, respectively.

Refinement of bumble bee rearing technique: The rearing of bumble bees under laboratory conditions started with the capturing of fecundated bumble bee queens, which came out of hibernation and searched for new habitat or during collection of pollen and nectar at the onset of spring. During February–March, the major flora sustaining bumble bee queen population was found to be *Caryopteris bicolor*, *Scutellaria linearis*, *Salvia moorcroftiana*, *Lavendula* sp., *Lupinus mutabilis*, *Delphinium* sp. and *Jasminum humile* (Table 2). During April-May, the queens were found to collect pollen from *Salvia moorcroftiana*, *Nicotiana tobaccum*, *Punica granatum* and *Jakaranda mimmosaefolia* and the queens were trapped while foraging on these plants. Some queens were also collected when they were searching for the new home sites by chasing them. The flora enlisted above was found to play an important role in sustenance of bumble bee

Table 1. Observations on different features and dimensions of the nests at different altitudes

Features	Nest 1 (2300m) Jubbal	Nest 2 (1250m) Nauni		
Dimension of nest (cm)	12.x 6.8cm	17.25cm (diameter) and 7cm (height.)		
Shape	Circular	Oval		
Nesting material	Pine leaves and small twigs	Grass, leaves, small wooden pieces and some plastic material		
Water Saturation	Wet at bottom (saturated)	Dry at bottom		
Compactness	Scattered	Compact		
Nest depth	62cm	90cm		
Tunnel length	139.4cm	150cm		
Queen cell length	16.56±2.1	12.55±0.27	20.57±0.75	15.20±0.97
Worker cells	13.16±0.79	10.15±1.07	14.24±0.86	10.01±1.03
Honey pots	15.31±0.25	12.91±0.23	20.35±0.68	16.32±0.83

Table 2. Important flora harbouring bumble bee queens during different months

Month	Botanical Name	Common name	Trapping Time	No. of queens collected
February	*Caryopteris bicolor*	Caryopteris	Evening	2
	Rosmarinus officinalis, Lupinus mutabilis	Rosemary, Lupin	Morning, Evening	2, 4
March	*Caryopteris bicolor, Lavendula* sp.	Lavendula	Evening, Morning	5,1
	Delphinium sp.	Larkspur	Morning	4
	Scutellaria linearis	Scutellaria	Evening, Morning	2
	Jasminum humile	Chameli	Evening	1
April	*Salvia moorcroftiana*	Salvia	Evening	3
	Salvia moorcroftiana Nicotiana tobaccum	Wild tobacco	Morning, Evening	2, 2
	Punica granatum	Wild pomegranate	Evening	3
May	*Jakranda mimmosaefolia*	Gulmohar	Morning	5

population in nature (Table 2). Similar results were observed by Kashyap (2008) who also observed bumble bee queens on these flora during the months of February, March and April, respectively. Refined domiciles for initiation of bumble bee colonies revealed (Table 3) that two- chambered boxes with sliding base and top D1 and D2 were preferred as all the spring collected queens initiated their colonies. The acceptance (100 per cent) was significantly higher as compared to D3 and D4 with partial acceptance. Colony rearing, wooden two-chambered box with perforated base (25 ×20×15cm) have no acceptance during February while during March, April and May, it was found to be 66.66, 33.33 and 66.66 per cent, respectively. Similarly, hoarding cages with sliding perforated base having feeding provisions (33x20x10cm) had zero per cent acceptance in February, 33.33 per cent in March, 66.66 per cent in April and no acceptance during May. The wax secretion was earlier in queens captured during April and May (5.91 and 4.25 days, respectively) than February and March (6.58 days), while the queens captured during early spring (February-March) had more acceptability for artificial domiciles (Table 4), which is in conformity with the observations of Kashyap (2008). Domiciles with dimensions 15×12×8cm (D1) and 16×12×10cm (D2) were found to be most acceptable by the queens captured during early spring and the acceptances for these domiciles were found to be 100 per cent but the mean difference was found non-significant (Table 4). Horber (1961) observed that small boxes of size 7.5x7.5x5cm can be successfully utilized for the domestication of bumble bees with 60-100 per cent acceptability.

Queens collected during February-March took more time for wax secretion and have cent percent acceptance for the domiciles D1 and D2. However, during April-May, partial acceptance of domiciles D1 and D2 was observed and queens took less time for acceptance of domiciles at this time (Table 4). Similarly, domiciles D3 and D4 did not showed any acceptance during February, whereas showed partial acceptance during March, April and May. Acceptance was found to be early in the domiciles D3 and D4 during April-May than in February-March collected queens. During May, the workers emergence took place earlier (24.44 days) while in April, March and February the time for emergence after wax secretion was observed to be 26.77, 27.22 and 26.44 days, respectively. Similar results were observed by Kashyap (2008). During the rearing experiment, the queens captured fed with pollen pellets/ powder and sucrose/ sugar solution. During February-March required more amount of pollen (10g), whereas the queens captured during April-May

Table 3. Acceptance of artificial bumble bee rearing boxes during different months

Months	Acceptance (%) of bumble bees for different refined domiciles*				
	D1	D2	D3	D4	Mean
February	100	100	0	0	50
March	100	100	66.66	33.33	75
April	33.33	33.33	33.33	66.66	41.66
May	33.33	66.66	66.66	0	41.66
Mean	66.66	75	41.66	25	
CD(P=0.05)					
Domiciles	=	35.11			
Month	=	37.15			

* D1 = Damicile 1 (15x12x8cm); D2 = Damicile 2 (16x12x10cm); D3 = Damicile 3 (25x20x15cm); D4 = Damicile (33x20x10cm)

Table 4. Time required (days) for initiation and emergence of bumble bee after captivating queens during different months

Months	Initiation					Emergence				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean*
February	9.33	9.00	9.66	8.67	9.16	25.67	25.67	28.00	Nil	26.44
March	5.66	7.00	7.00	6.66	6.58	27.67	26.67	27.33	Nil	27.22
April	6.00	5.33	7.00	5.33	5.91	27.33	27.33	25.67	Nil	26.77
May	3.66	5.00	4.00	4.33	4.25	24.67	24.67	24.00	Nil	24.44
Mean	6.16	6.58	6.91	6.25		26.33	26.25	26.25	Nil	
CD(P=0.05)										
Domiciles					1.34					2.91
Month					2.04					2.76

*Mean of D_1, D_2 and D_3

required 5g pollen. With an increase in activity of queen and the emergence of workers, the quantity of pollen and sucrose fed to the queen was increased (5-12g pollen and 2-10ml sucrose solution) under laboratory conditions (Table 5). Similarly under room temperature, the average quantity of sugar solution and pollen fed 5-15g and 2-10ml per three days, respectively. These results were found to be in conformity with the results of Thakur *et al*. (2005) and Pridal and Hofbaeur (1998).

Utilization of bumble bee under protected conditions for the pollination of cucumber: The fruit length was significantly longer (20.75cm) from vines pollinated by bumble bees being on a par with the open pollinated ones (20.00cm), followed by 16.44cm length in control block.

Bumble bee pollination resulted in significant increase in fruit weight (413.62g) and diameter (11.01cm) being on a par with the fruit weight (548.88g) and diameter (11.89cm) of fruits obtained in open pollination conditions. In control pollination, the fruit weight (262.75g) and diameter (8.39cm) were significantly lower as compared to open and bumble bee pollination (Table 8). Similar results were observed by Stanghellini *et al*. (2000) who noticed an increase in the weight and diameter of cucumber when bumble bees were utilized for the pollination. Bumble bees and open pollinated flowers yielded fruits having significantly more seeds The number of seeds per fruit were 331.20 from control plots, which were significantly less as compared to other treatments. Similarly, the weight of 1000 seeds was significantly higher (31.50g) in fruits of bumble bee pollinated plots, followed by 29.20g and 27.55g extracted from open pollinated and control plots, respectively (Table 6).

The fruit yield (76.97%) in bumble bee-pollinated and open pollinated crop (66.16%) was significantly higher than in the plants excluded from pollinators (control).

Bumble bee pollinated plants had significantly lowest crooked fruits (16.18%), followed by 25.20 per cent in open pollinated plants, whereas, significantly highest number of crooked fruits (36.45%) were observed in plots devoid of pollinators. The results are in conformity with the results of Stanghellini *et al*. (1997) who reported less abortion of cucumber fruits in bumble bee pollination. Similarly, Hodges and Baxendale (1991) reported less crooked fruits in bee-

Table 5. Feeding of bumble bees under artificial conditions

	Feeding material	Quantity
Laboratory conditions	Sucrose (50%)	2-10ml sucrose (50%)
(26.9^{0}C; 65%RH)	Pollen pellets	5-12g pollen pellets
Room Temperature conditions	Sugar (50%)	2-10ml sugar (50%)
(32-36^{0}C and 50-60%RH)	pollen pellets	5-15g pollen pellets or pollen powder

Table 6. Effect of different modes of pollination on cucumber grown under protected conditions

Pollination Type	Length (cm)	Diameter (cm)	Weight (g)	Seeds/fruit (No.)	Weight (1000 seed g)	Fruit yield (%)	Crooked fruits (%)	Healthy fruits (%)
Bumble bee	20.75	11.01	413.62	422	31.50	76.97	16.18	83.62
Open	20.00	11.89	548.88	434	29.20	55.10	36.45	64.55
Control	16.44	8.39	262.75	331.20	27.55	68.16	25.20	74.80
CD(P=0.05)	2.39	0.88	165.387	45.44	0.54	9.97	5.78	5.14

pollinated plants because of proper pollination of flowering crop plants and observed more number of crooked fruits in control and open conditions due to inappropriate pollination.

In bumble bee pollinated plants, the per cent increase in the fruit set and healthy fruits were 27.64 and 22.81 over the control (Table 7). However, percentage of crooked fruits was reduced to 65.62 per cent in bumble bee-pollinated plants than the plants which were excluded of pollination.

Similarly, an increase in the percentage of fruit length, diameter and weight of cucumber fruits was recorded in the cucumber vines pollinated by bumble bees was 20.78, 23.80 and 36.48 per cent, respectively as compared to the plants with no pollination (control). Simultaneously, per cent increase in the seed number and weight (1000 seeds) was 21.52 and 12.54 per cent, respectively in bumble bee pollinated plants. Similar results were observed by Stanghellini *et al*. (2000) who noticed an increase in the weight and diameter of cucumber when bumble bees were utilized for the pollination resulting in increased fruit set and yield.

Table 7. Effect of bumble bee pollination on fruit and seed parameters of cucumber grown under polyhouse conditions

Parameters	Per cent increase (%)
Fruit set	27.64
Healthy fruits	22.81
Crooked fruits*	65.62
Fruit length	20.78
Fruit diameter	23.80
Fruit weight	36.48
Seed number	21.52
Weight (1000 seeds)	12.54

*Reduction in per cent of crooked fruits

There is an increase in the cost benefit ratio in poly house and was found to be 1: 2.02 with 22% increase in the total returns in bumble bee pollination cucumbers than control (Table 8).

The present study on bumble bee nest architecture revealed the complex composition of nests which can be utilized in creating more efficient rearing domiciles with

Table 8. Cost-benefit ratio of cucumber grown under protected conditions

Parameter	Cost/100sq m	Fixed Costs (Rs.) per polyhouse (100m^2)	
Human labour	2400	Rental value of polyhouse @Rs. 800/month	4000
Land preparation	150	Management cost	1000
Nursery Raising	40	Risk margin	500
Transplanting	40	Total fixed cost	5500
Weeding	600		
Irrigation	400		
Inter-culture operations	300		
Harvesting	240		
Seed	50		
Fertilizer	1000		
Crop protection	400		
Miscellaneous	1000		
Total variable cost	6620		
Total	12,120		
Total Output	1228.8 kg		
Total returns @ Rs. 20/kg	24,576		
Net profit	12,456		
Crop benefit ratio	1:2.02		

Bumble bee pollination		
Total yield from bumble bee pollinated plots	=	1175.04 kg
Total returns @ 20Rs/kg	=	23,500
Control		
Total yield from control plots	=	302.7 kg
Total returns@ 20Rs/kg	=	6054

Hypothetically, if number of control (no pollination) plots taken equal to bumble bee pollinated plots (24) then,

Total yield	=	921.6 Kg (total plants yield)
Total returns@20Rs/kg	=	18,432 Rs

Difference between Bumble bee pollinated and control returns = 5068 Rs (23,500-18,432=5068 which is 22 per cent more than returns from control blocks).

complete acceptability. Refined domiciles provide a better opportunity for the researchers to carry their bumble bee rearing experiments smoothly without making unwanted disturbances to the developing colonies leading to healthy bumble bee colonies for the pollination of crops. Bumble bee pollination was found to be better than other modes of pollination in cucumber under protected conditions yielding good and high quality fruits as compared to the one grown in open and control conditions. Cost- benefit ratio determining the benefit to the farmers was found to be double as compared to open conditions. This study highlight the immense importance and role played by bumble bees in the pollination of crops and opens new vision and opportunities for the farmers to utilize them for crop pollination which would ultimately benefit them in increasing their economy.

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Effect of Growth Hormones on Rooting of Branch Cuttings in Dek (*Melia azedarach* Linn.)

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Melia azedarach Linn., dek is a moderate-sized deciduous tree with a short trunk and spreading crown of deep green feathery foliage, reaching a height of 9-18m and a girth of 1-1.2m with a straight cylindrical bole upto about 2.5m long. It is doubtfully indigenous to north-west India along the sub-Himalayan tract, but now is naturalized throughout the tropics where it is planted in the arid, semi-arid and also in the semi-moist areas. It is also found in Iran, Pakistan, Burma, Malaysia, Philippines, the Hawaiian Islands, Cuba and China. In India, it occurs in eastern alluvial secondary evergreen forests (2B/2S2) and southern dry mixed deciduous forests (5A/C3) as reported by Champion and Seth (1968). As evidenced by its wide distribution, it is capable of withstanding wide climatic variations.

In Punjab, dek is considered as an important agroforestry tree because of its adaptability to varied climatic and soil conditions. *Melia azedarach* based agroforestry systems has great acceptability among farmers of the state for its diversified uses, relatively fast growth, compatibility with agricultural crops and economic returns, which are comparable with other promising agroforestry tree species. This tree has a great potential in diversification of dominated poplar and eucalypt based agroforestry systems in Punjab in the years to come. However, the availability of quality planting stock of the species is a big question and the material developed through seed has enough variability due to its cross-pollinated behavior therefore, necessitated its vegetative propagation. Vegetative propagation technology helps in producing true to type plants for better quality and higher yield. The potential to bulk up high genetic gains within short period at an early age, favours the operational use of vegetative propagation (Libby, 1974). Vegetative propagation can be done either by macro-propagation (cuttings, layering, grafting, etc.) or by micro-propagation (through tissue culture). Tissue culture is more expensive, technical and laborious method of reproduction than macro-propagation. Vegetative propagation through stem cuttings has been commercially exploited in poplar, willow, mulberg and many other fast growing hard wood species but in *Melia azedarach,* cuttings do not root easily. Species is also rated in a 'difficult to root' category (Rawat *et al.,* 1994).

The rooting of cuttings is a complex process; growth hormones, season of planting the vegetative propagules, position of excision of stem cuttings, micro-environment, etc. play a crucial role in successful rooting of any tree species. The efforts for development of suitable methodologies for vegetative propagation especially, which are hard to root for rapid and mass production of clonal material are at its beginning. In *Melia azedarach,* very few studies have been carried out in comparison to neem (another important member of Meliaceae family) and other species like poplars and eucalypts across the globe. With the consideration of many limitations in macro-propagation of dek, the present study was attempted to know the response of different concentrations of growth hormones for rooting of branch cuttings for mass propagation.

The present study was carried out at the experimental area of the Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana during spring (February) and rainy seasons (August) to know the suitable season and root initiating hormones. The climate of the area is sub-tropical to tropical. The temperature is maximum during summer months i.e., May and June and means monthly day temperature is 39.1°C. On the other hand, it is lowest during winter months i.e. December and January (means daily temperature is 6°C). Average annual rainfall of area is 704 mm of which 75-80 per cent is received during the rainy season i.e. July to August.

During each season, current year's growth was used to make cuttings. The branches were collected in the morning at about 0900 hours. These were kept in a bucket containing water. The cuttings of uniform length (20-22 cm) and diameter (1.5-2.0 cm) with alteast 3-4 buds on each cutting were prepared with the help of secateur. The cuttings were immediately kept in water before giving treatments. The branch cuttings used for vegetative propagation were treated with six concentrations of auxins i.e., 500 ppm IAA, 1000 ppm IAA, 2000 ppm IAA, 500 ppm IBA, 1000 ppm IBA and 2000 ppm IBA for 15 seconds and one control (untreated

cuttings) during both the seasons under two environments i.e., open nursery and mist chamber.

The experiments were laid out in a Split Plot Design with three replications. Observations were recorded on sprouting initiation, total time taken for complete sprouting, sprouting percentage, callusing percentage, decaying percentage, rooting percentage, number of roots per cutting, length of longest root, shoot length, shoot diameter, fresh and dry weight of root and shoot, total plant dry biomass and root : shoot ratio. Pooled data of both the environments are discussed here.

As evidenced from the data presented in Table 1, there were significant variations among treated and untreated branch cuttings for sprouting initiation. Among treated cuttings, maximum 11.54 days were taken for sprouting at 1000 ppm IBA concentration followed by statistically at par values of 11.25 days 2000 ppm IBA and minimum (9.87 days) 500 ppm IAA. The untreated cuttings took same minimum number of days (9.87) for sprouting initiation. The total time taken by stem cuttings for complete sprouting varied from 15.62 to 18.87 days. The untreated cuttings took minimum number of days (15.62 days) to complete sprouting, whereas, maximum days i.e. 18.87 were taken by 2000 ppm IBA treated cuttings. The total time for completion of sprouting was significantly less in IAA treated cuttings as compared to IBA treated cuttings. The sprouting percentage of the cuttings varied between 50.20 (untreated) to 64.99 per cent (1000ppm IBA). Overall, the sprouting percentage in IAA treated cuttings was better than IBA treated cuttings with the exception in 1000 ppm of IBA.

Rooting percentage did not vary significantly in the cuttings treated with different concentrations of IAA and recorded lower values for rooting in comparison to IBA except IBA 2000 ppm, where the rooting percentage was minimum among all the hormonal treatments (13.33%). Highest rooting (23.33%) was noticed in the 1000 ppm IBA treated cuttings followed by the significantly lower value (19.16 %) with IBA 500 ppm. The root numbers per cutting was highest in 1000 ppm IBA (8.81) followed by significantly lower value of 8.05 in 500 ppm IBA. Comparatively, the root numbers per cutting were more in IBA treated cuttings than that of IAA treated cuttings. The maximum length of longest root (15.65 cm) was recorded in 1000 ppm IBA treated cuttings followed by significantly lower value (12.39 cm) in 500 ppm IBA, whereas, other values within and between different concentrations of IAA and IBA for length of longest root did not show significant variations. Untreated cuttings did not produce any root. Similar differential behaviors for rooting response in the branch cuttings of *Melia azedarach* have been reported by Gupta *et al.* (1989); in *Melia composita* by Luna and Kumar (2006a,b); Luna *et al.* (2007) and in *Azadirachta indica* by Palanisamy *et al.* (1998); Singh and Chander (2001); Gill *et al.* (2006). Haissig (1986) has explained that division of first root initial cells depends upon either exogenous or endogenous auxins. As early as root initial cell start showing response in stem cuttings, it results in increase in number of root in cuttings. It indicates that the application of IBA may have mobilized total soluble sugars and phenols to the rooting zone more efficiently and utilized them for differentiation. It has been reported in several other species also that auxins generally promote rooting at particular concentration, which varied with plant species and nature of auxins (Hartmann and Kester, 1983). The reduction in rooting at higher auxin concentration was attributed to super optimal level by Bhardwaj (2000), which might also be true in the present study.

The maximum shoot length (16.98 cm) and diameter (0.76mm) was recorded in 1000 ppm IAA treated cuttings followed by at par value of 16.84 cm in 1000 ppm IBA. There were no significant variations in shoot length at 500 ppm and 2000 ppm concentration of IBA. Minimum shoot diameter of 0.55 mm was noticed at 2000 ppm IAA. Shoot diameter of sprouts decreased significantly with increase in concentration of auxins beyond 1000 ppm in IAA and IBA. These findings confirm the earlier reports of Verma *et al.* (1996) and Gill *et al.* (2006) in *Azadirachta indica*.

The highest fresh shoot weight per cutting (12.50 gm) was recorded in 1000 ppm IBA treated cuttings followed by non-significant values of 12.02, 10.52, 9.75 and 9.41 gm in 500 ppm IAA, 500 ppm IBA, 1000 ppm IAA and 2000 ppm IBA, respectively. Whereas, minimum fresh weight of shoot (8.40 gm) was recorded in the cuttings treated with IAA 2000 ppm. The fresh and dry root weight followed the same trend and recorded higher values at IBA 1000 ppm followed by 500 ppm IBA, 1000 ppm IAA and 500 ppm IAA. Palanisamy *et al.* (1998) also observed similar results with IBA and IAA treatments in *Azadirachta indica*. The differences in shoot and root dry weight were reflected in total dry weight. The untreated cuttings initially sprouted but then dried up probably because of breakdown of reserve food material.

The values of root:shoot ratio on dry weight basis presented in Table 1 ranged from 0.015 (500 ppm IAA) to 0.036 (2000 ppm IBA). The overall root : shoot ratio was significantly better in IBA concentrations, which indicated that rooting was more in IBA treated cuttings than IAA treated cuttings. Auxins are involved in plant root formation, lateral bud inhibition and activation of cambial cells. It has been well accepted and confirmed many times that auxins naturally or artificially applied are required for initiation of adventitious roots on stem cuttings (Nanda, 1970). Division of first root

Table 1. Effect of growth hormones on rooting of branch cuttings and other related parameters

Growth hormones/ Parameters	IAA			IBA			Control	CD (0.05)
	500 ppm	1000 ppm	2000 ppm	500 ppm	1000 ppm	2000 ppm		
Days of sprouting initiation	9.87	10.08	10.20	10.58	11.54	11.25	9.87	0.38
Days taken for completion of sprouting	16.20	16.79	17.04	17.58	18.25	18.87	15.62	0.52
Sprouting percentage*	64.16 (56.35)	63.74 (56.49)	62.49 (55.24)	62.49 (55.83)	64.99 (57.48)	59.99 (53.41)	50.20	2.45
Rooting percentage*	15.55 (18.96)	16.24 (20.10)	15.06 (18.26)	19.16 (22.17)	23.33 (25.10)	13.33 (18.41)	00.0	1.82
Number of roots per cutting	7.05	7.95	7.27	8.05	8.81	7.99	0.00	0.17
Length of longest root (cm)	11.68	12.23	11.21	12.39	15.65	11.12	0.00	2.75
Shoot length (cm)	15.97	16.98	15.35	14.71	16.84	14.57	0.00	0.55
Shoot diameter (mm)	0.65	0.69	0.55	0.74	0.76	0.67	0.00	0.04
Shoot fresh weight (gm)	12.02	9.75	8.40	10.52	12.50	9.41	0.00	3.62
Shoot dry weight (gm)	1.91	1.49	1.29	1.81	1.96	1.46	0.00	0.53
Root fresh weight (gm)	0.11	0.11	0.10	0.13	0.14	0.10	0.00	NS
Root dry weight (gm)	0.03	0.04	0.03	0.06	0.07	0.05	0.00	NS
Total fresh biomass (gm)	12.14	9.87	8.50	10.65	12.64	9.46	0.00	3.62
Total dry biomass (gm)	1.94	1.54	1.33	1.87	2.04	1.51	0.00	0.53
Root : shoot ratio	0.015	0.026	0.023	0.033	0.036	0.034	0.00	0.015

*Arc sine transformed values in parentheses

initiation cell are dependent upon either applied or endogenous auxins. However, formation of root initials in stem depends upon the nature, auxins in plant plus synthetic auxin applied in solution or powder formulation, together lead to synthesis of ribonucleic acid, which are involved in initiation of root primordia (Hartmann and Kester, 1983).

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Genetic Variability for Physico-chemical Characterization in Jackfruit Collection of Karnataka

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Jackfruit (*Artocarpus heterophyllus* Lam.) native to Western Ghats of India, is found up to 1500 m and has tremendous diversity. The popularity of jackfruit as a commercial crop is very meager due to wide variation in fruit quality (Medagoda, 2007). In order to assess the diversity in this crop, there is a need to study the variability of jackfruit. In the present investigation, our goal was to study the variability existing in physico-chemical qualities jackfruit selection in different parts of Karnataka.

In the present study, 13 jackfruit types selected from different places of Karnataka (Table1). The fruits were harvested at mature ripe stage and then transported to the laboratory to study the physico- chemical characters of bulbs at edible ripe stage.

Highest total number of fruits per tree (125), fruit weight (15.03 kg), fruit length (48cm), fruit breadth (29.0cm) number of bulbs per fruit (404), pulp weight (6.36 kg) and pulp percentage (48.20%) was recorded in SKP-1 genotype. Bulb weight (45.67 g) was highest in SNG-1 followed by AVT-3 the lowest bulb weight was in SMG-1 (14.67 g). Bulb length (6.85 cm) was highest in SNG-1 followed by SKP-1. The lowest bulb length was in RMD-5 (4.57 cm). Bulb width was found highest in SNG-1 followed by AVT-1 and was lowest in RMD-4. Seed weight was highest in SNG-1 and lowest in SMG-1(3.60 g). Similar seed length (4.05 cm) was in SNG-1 and followed by KLD-1. Seed width (2.03 cm) was highest in SNG-1, whereas lowest in SMG-1(1.52 cm). The chemical characters showed huge variation among 13 collections (Table 2). TSS was maximum in RMD-2 (32.48^{0}B) followed by KLD-1 (32^{0}B). It was significantly less in SKP-2 (13.5^{0}B) which is not a desirable character for desert purpose (Gangamma, 2005; Jagadeesh *et al*., 2010). Significantly maximum total sugar and reducing sugar content was recorded in the genotype RMD-2 (25.10 % and 11.43% respectively). The minimum total sugar and reducing sugar content was recorded in the genotype AVT-1 (15.42% and 6.21% respectively). Conclusively above results many desirable characters were found in SKR-1 for desert purpose and such genotypes need to be conserved and multiplied for dissemination for plantation to enhance fruit productivity.

Table 1. Physical characters of desert type jackfruit selections

Genotypes	No of fruits tree^{-1}	Fruit weight (kg)	Fruit length (cm)	Fruit breadth (cm)	No. of bulbs fruit^{-1}	Pulp weight (kg)	Pulp percentage
AVT-1	100	8.58	38.2	20.50	92.00	4.10	47.17
KLD – 1	90	11.28	39.00	24.50	209.00	3.53	41.40
KLD – 2	95	4.00	24.80	18.00	34.00	0.83	20.80
RMD – 1	100	6.16	30.00	25.50	288.00	2.83	46.03
RMD – 2	80	5.35	35.00	16.00	153.00	1.92	36.00
RMD – 3	75	13.50	47.00	27.00	159.00	5.80	38.61
RMD – 4	50	9.96	38.00	20.00	212.00	1.82	18.27
RMD – 5	25	6.78	30.00	19.00	160.00	2.85	42.03
SKP – 1	125	15.03	48.00	29.00	404.00	6.36	48.20
SKP– 2	75	12.03	38.00	24.50	288.00	6.44	34.90
SMG – 1	100	7.24	37.20	21.50	247.00	1.35	18.64
SNG-1	70	13.34	44.00	24.50	156.00	5.56	41.60
SRS-1	120	8.70	42.00	20.00	227.00	3.60	41.30
Variance	1017.3	11.96	45.44	14.60	8904.02	3.01	112.52
Mean	81.15	9.56	38.33	21.75	823.70	3.39	41.96
S.D.	31.89	3.45	6.74	3.87	94.36	1.73	10.60

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Table 2. Bulb, seed and chemical characters of jackfruit genotypes

Genotypes	Bulb weight (g)	Bulb length (cm)	Bulb width (cm)	Seed weight (g)	Seed length (cm)	Seed width (cm)	TSS (^{0}B)	Total sugars (%)	Reducing sugars (%)
AVT-1	39.00	6.48	3.76	5.00	2.85	2.01	17.00	15.42	6.21
KLD – 1	25.33	6.17	3.19	7.33	3.67	1.76	32.00	21.24	8.73
KLD – 2	35.67	5.61	3.85	7.33	3.20	2.02	25.80	20.78	8.62
RMD – 1	25.00	4.66	2.81	4.33	2.92	1.61	30.30	24.72	10.92
RMD – 2	18.33	4.68	2.97	5.00	2.91	2.02	32.48	25.10	11.43
RMD – 3	37.33	6.40	3.40	6.33	3.01	1.93	31.00	22.36	10.42
RMD – 4	20.00	5.50	2.39	4.67	2.88	1.95	28.99	24.53	9.46
RMD – 5	24.00	4.57	2.60	4.00	2.92	1.52	20.00	21.66	8.11
SKP – 1	25.00	6.70	2.96	3.67	2.84	1.74	21.10	23.11	10.48
SKP– 2	16.33	6.36	2.67	6.67	4.05	1.87	13.50	19.49	7.13
SMG – 1	14.67	4.58	2.64	3.60	2.95	1.60	17.80	18.43	7.10
SNG-1	45.67	6.85	3.99	7.50	3.91	2.03	25.50	21.62	8.17
SRS-1	19.00	5.42	2.88	5.33	3.10	1.90	22.00	21.43	8.26
CD (0.05)	3.11	0.76	0.40	1.14	0.30	0.23	0.97	0.26	0.13

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Effect of Container Types and Potting Media on the Growth of *Melia composita* Willd. Seedlings

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Melia composita Willd., a fast growing deciduous tree commonly reported from the tropical moist deciduous forests of the Sikkim Himalayas, North Bengal and upper Assam, the Khasi hills, and the Western Ghats, at altitudes of 1,500-1,800 meters (Brandis, 1906; Parthiban *et al*., 2009) belongs to family Meliaceae. The tree is a good source of useful timber. Its wood can also be used as packaging cases, cigar boxes, ceiling planks, building and construction materials, agricultural implements, pencils, matchboxes/ splints, musical instruments, tea boxes and ply board. It is also a good fuel wood with calorific value of 5.043-5,176 calories. It seeds every year and can be propagated either by direct sowing or by planting out nursery seedlings. The tree is capable of withstanding wide range of climatic conditions. Since, tree grows rapidly, therefore can be used for onfarm plantation. It is used on boundary and for shade purpose as well. It is being cultivated in the arid and semi-arid as well as semi-moist areas of the country. Due to its fast growth and multiple uses, it is emerging as a favourite tree for agroforestry plantations not in northwestern states but extending in all four directions of the country.

Increasing interest of farmers in *Melia* will certainly create a demand for quality seedlings in the coming years. The success of any plantation program largely depends on the production of quality seedlings, which in turn depends upon the quality of seeds, the growing medium and even on the containers in which seeds are sown. Thus, the present study was conducted at the Experimental Farm of the Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu at Chatha to find the best container types and potting media for the growth of *M. composita* seedlings. The nursery site is located in sub-tropical zone, characterized by cool winters and hot summers. The average annual precipitation is 1000 mm, most of which is received in during July-September months in the form of rains. Maximum temperature rises up to 45°C and minimum temperature falls upto 2°C. Three different potting mixtures were prepared by using Soil, Sand, Farm Yard Manure (FYM) and Vermicompost (VC). The various potting mixture and their proportionate ingredients used are presented in table 1. The aeration porosity, water holding porosity and total porosity of the growing media was determined for containers as described by Gessert (1976) and Whitcomb (1988).

Two different root trainers with a volume of 300 cc and 250 cc (C1 and C2, respectively) and polythene bags of two different sizes of 28 x 23 cm and 24 x 16 cm (C3 and C4, respectively) were used. The experiment was laid in CRD factorial (Completely Randomized Design), having two factors i.e., container type and growing media at four and three levels, respectively, replicated thrice. There were thirty six plants and observations were recorded on nine randomly selected plants per treatment per replication. The entire data generated from the present investigations were analyzed statistically.

The findings of the present investigation revealed that irrespective of potting media, seedlings raised in bigger sized polybags and root trainers performed best. The *M. composita* seedlings grown in polybags of size 28 x 23 cm registered maximum biomass among all the treatments. The use of FYM and Vermicompost in the potting mixtures greatly benefited

Table 1. Details of potting mixture, ingredients and their proportions, nutrient status and aeration, water holding and total porosity of different growing medium

Medium	Ingredients	Proportion	pH	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Aeration porosity (%)	Water holding porosity (%)	Total porosity (%)
M1	Soil	1	7.90	208.12	15.20	158.00	7.6	48.0	41.6
M2	Soil + Sand + FYM	2:1:1	7.35	278.63	15.90	165.55	8.1	58.3	50.2
M3	Soil + Sand + VC	2:1:1	7.48	290.45	16.10	172.50	7.8	49.5	41.7

Table 2. Effect of container types and potting media on the growth of *M. composita* seedlings

Treatmentscombinations	Height (cm)	Collar diameter (mm)	Shoot dry weight (g)	Root dry weight (g)	Total seedling dry weight (g)	Root : shoot ratio
C_1 (Root trainer size 300 cc) M_1 (Soil)	16.55	1.67	0.22	0.12	0.35	0.58
C_1 (Root trainer size 300 cc) M_2 (Soil+ Sand+ FYM)	17.98	2.22	0.51	0.18	0.69	0.37
C_1 (Root trainer size 300 cc) M_3 (Soil+ Sand + VC)	15.88	2.05	0.31	0.25	0.56	0.93
C_2 (Root trainer size 250 cc) M_1 (Soil)	13.11	1.33	0.20	0.02	0.22	0.15
C_2 (Root trainer size 250 cc) M_2 (Soil+ Sand + FYM)	15.00	1.55	0.35	0.03	0.39	0.10
C_2 (Root trainer size 250 cc) M_3 (Soil+ Sand + VC)	12.33	1.58	0.30	0.04	0.34	0.13
C_3 (Polybag 28 cm x 23 cm) M_1 (Soil)	27.22	2.63	0.60	0.09	0.70	0.13
C_3 (Polybag 28 cm x 23 cm) M_2 (Soil+ Sand+ FYM)	31.00	3.26	1.05	0.10	1.15	0.10
C_3 (Polybag 28 cm x 23 cm) M_3 (Soil+ Sand +VC)	28.00	2.71	0.19	0.13	0.32	0.72
C_4 (Polybag 24 cm x 16 cm) M_1 (Soil)	15.11	1.98	0.04	0.05	0.10	0.68
C_4 (Polybag 24 cm x 16 cm) M_2 (Soil+ sand+ FYM)	18.00	2.03	0.09	0.06	0.15	0.62
C_4 (Polybag 24 cm x 16 cm) M_3 (Soil+ sand +VC)	17.55	2.18	0.11	0.06	0.17	0.48
CD (0.05)	NS	NS	0.10	0.33	0.10	0.22

the growth and quality of the plants as compared to the potting mixture containing only soil. Comparatively higher values were recorded for plant height, collar diameter, shoot dry weight, total seedling dry weight and root:shoot ratio in large polythene bag of size 28 x 23 cm and in bigger root trainers of size 300 cc as compared to their smaller sized counter parts though the differences were non-significant for height and diameter. Similar results have been reported by Ferdousee *et al*. (2011). Container depth and water retention are strongly related and can affect the water-holding capacity of the potting mixture. The taller the pot, the higher the column of medium, usually resulting in proportionally more medium in the pot that is well drained compared to short or squat pots. This could also probably be attributed to higher water and nutrient availability in containers with higher volumes. Similar results have also been reported by Hopkins and White (1984) and Milks *et al*. (1989) while studying the growth of plants in containers.

Further, comparatively better results were observed in media containing Soil+Sand+FYM in 2:1:1 ratio. This may be possibly due to the fact that this media had higher air porosity, water holding porosity and total porosity than other treatments (Table 1). Bragg and Chambers (1988) have reported that aeration porosity is considered to be the most important physical property of any growing mixture. Therefore, in the present study, the medium containing Soil + Sand + FYM (2:1:1) was found to be more suitable because of the better physical properties and enhanced nutrient level.

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Growth Behavior of Poplar and Fruit Crops in Silvi-Horticulture System under Arid-Irrigated Conditions of Punjab

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In the present scenario of increasing population and shrinking land resources, the integrated production systems have emerged as a key factor for sustainable production in India to meet the multiple requirements. In Punjab, due to paddy-wheat rotation, the natural resources has been exhausted to a great extent; underground water level is depleting, the fertility status of soil is reducing and biotic as well as abiotic stress is increasing. Therefore, the emphasis on diversification has focused to bring more area under perennial components i.e., fruit crops and forest trees. Horticulture is one of the best options for the farmers of Punjab owing to its economic profitability, nutritional security, employment generation, etc. However, due to long juvenile phase of fruit trees, the farmers have to grow suitable intercrops for income generation during initial phase. Tree (fruit)–Tree (timber) combination may be the another option for diversification in agriculture. Poplar cultivation may be accentuated due to its ease of propagation and planting, easy establishment, fast growth, straight cylindrical bole, deciduous nature and high returns (Chandra, 2011). Poplar trees are characterized to the addition of organic matter as well as nutrients to soil through litter fall as compared to other tree species. Extensive research work on cultivation of agricultural crops as an intercrops for first 3-4 years in poplar and fruit crops has been done in various parts of India to explore the possibility of income generation. However, the work on cultivation of fruit crop as an intercrop in poplar is limited particularly in arid and semi-arid conditions. Poplar can be grown on a short rotation of 5–7 years and the farmers can make use of inter-space of fruit plants judiciously for economic gains (Chauhan and Mangat, 2006). Multiple cropping has been found economically feasible than traditional rice-wheat rotation and many progressive farmers have adopted such type of cropping system (Chauhan *et al.,* 2007). However, the selection of crops must be based on the principle of minimizing the competitive effect and maximizing the complimentary effect among themselves. Proper care and management are indispensable factors to exploit suitable productivity in the system of intercropping. Therefore, the present investigation has been initiated to study the plant growth behavior of poplar as well as fruit crops when planted in an integrated system under arid-irrigated conditions of Punjab.

The planting of fruit crops viz. peach (*Prunus persica* L. Batsch.) cv. Shan-e-Punjab, guava (*Psidium guajava* L.) cv. Allahabad safeda, plum (*Prunus salicina* L.) cv. Satluj Purple and citrus; Kinnow (*Citrus reticulata* Blanco) was done made in the middle of rows of poplar (*Populus deltoides* Bartr. Ex Marsh.) plants at 6×6 m spacing. The plantation of sole poplar crop and sole fruit crops was also made for comparison to find out best suitable combination. The investigations on plant growth behaviour in terms of scion girth, stock girth, plant spread and canopy volume were carried out. In fruit crops, the scion and stock girth measurements were taken at 6 cm above and below the graft union, respectively. Plant height was measured by measuring pole, while canopy spread was calculated using the formula of Roose *et al.* (1986) after measuring the plant spread in both North-South and East-West. Similarly, in poplar, the total height was measured with measuring pole (in meters) from ground to top and the diameter at base (DAB) and diameter at breast height (DBH i.e., 1.37 m above the ground level) was taken with the help of a digital caliper.

The rootstock and scion girth of peach, plum and guava plants was significantly higher under poplar plantation while, in kinnow, the scion girth was significantly less in comparison to sole crop (Table 1). About 20 per cent increment in stock and scion girth was recorded in peach on inter-cultivation under poplar. Similarly, in plum and guava upto 10 per cent increment in stock and scion girth was recorded. However, significant reduction in scion girth was observed in citrus under poplar plantation, although, the stock girth was not affected significantly. Maximum stock and scion increment was observed in peach under poplar plantation. However, Dhillon *et al.* (2010) reported increment in stock diameter and height of kinnow inter-cultivated with poplar. The height of fruit plants was also effected under poplar plantation; increase in plant height of all fruit plants was recorded under poplar plantation as compared to sole crops. The rate of increment of vertical growth was more in deciduous fruit crops

Table 1: Vegetative growth parameters of different fruit crops in Silvi-Horticulture system

Crops	Stock girth (mm)	Scion girth (mm)	Height (m)	Spread (N-S)(m)	Spread (E-W)(m)	Canopy Volume (m^3)
Poplar + Peach	51.67	45.33	1.60	1.31	1.03	1.15
Poplar + Plum	40.33	35.00	1.58	1.07	1.10	0.98
Poplar + Guava	32.00	28.33	1.34	1.02	1.23	0.89
Poplar + Citrus	30.33	23.67	1.29	0.95	1.05	0.67
Sole Peach	38.33	36.33	1.16	1.65	1.46	1.47
Sole Plum	32.30	32.50	1.09	1.59	1.38	1.27
Sole Guava	26.66	25.87	1.11	0.97	1.44	0.85
Sole Citrus	32.00	30.80	1.05	1.10	1.06	0.64
CD (5%)	3.21	2.26	0.08	0.13	0.07	0.12

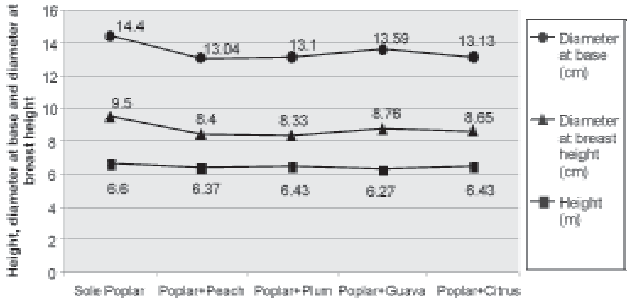

Fig.1. Growth of sole poplar and under Inter-cropping system

(peach and plum) than evergreen (citrus and guava) under poplar plantation. The plant spread in north-south direction was significantly reduced in deciduous fruit plants under poplar canopy, but in evergreen fruit plants, the spread was statistically at par in sole crops. Similarly, the plant spread of deciduous fruit plants in east-west direction was also reduced significantly under poplar plantation. The reduction in spread in peach and plum may be due to vertical growth at the expense of horizontal plant spread. The canopy volume of plant was significantly higher in sole deciduous fruit crops but it remains significantly same in case of evergreen fruit crops. Dhillon *et al.* (2010) also reported no effect of poplar canopy on growth of fruit plants except in guava where height and tree spread was significantly higher.

The girth of poplar plants was significantly affected with inter-cultivation of fruit plants. The diameter at base (DAB) of plant was maximum (14.4 cm) in sole poplar crop and minimum (13.04 cm) in peach-poplar combination (Fig.1). Similarly, the diameter at breast height (DBH) was also maximum in sole crop (9.5 cm) as compared to poplar inter-cultivated in all the fruit crops. Trunk girth of poplar in deciduous fruit plants was more affected than evergreen fruit plants. The microclimatic changes due to intercropping are known to affect growth and performance of trees (Tang, 1996). Height of poplar as a sole crop and inter-cultivated with all fruit plants was not affected significantly (Fig.1). However, Dhillon *et al* (2012) reported that growth increment of poplar was significantly higher when planted with fruit plants as compared to sole poplar planting. However, these are initial observations, which may change with time due to perennial nature of both the components.

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Root Rejuvenation in Shoot Cuttings of *Tectona grandis* Under Protected Conditions in New Locality of Western Himalayas

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Tectona grandis Linn. is the most important timber tree species of Indian tropics. Its cultivation has been extended to the sub-tropical parts of Himachal Pradesh and Gangatic plains of northern India. It has some peculiar qualities such as strength, durability and resistance to termites. Propagation by stem cutting is promising techniques of vegetative propagation for establishment of clonal teak plantation on commercial scale. This technique can provide the adequate supply of superior clones in this sub-tropical region and has the potential to provide the clonal material for mass scale propagation for future plantation of the species with assured wood characters.

Quality teak stumps can be produced from seeds, however, the seed yield per tree is low including seed germination, and only few seedlings are produced per 100 seeds. Therefore, propagation through cuttings has been widely used to multiply the elite teak trees obtained from the natural population to exploit the genetic variability. Attempts have been made to understand and improve the adventitious rooting efficiency of cuttings in selected plant species including teak because various intrinsic as well as extrinsic factors are responsible for root formation (Leaky, 1985; Husen and Pal, 2003).

Cutting thickness has significant effect on the rooting per cent of *Populus deltoides* cuttings (Kachlenz, 1958). The branch cuttings of 18-22 mm diameter of *Morus alba* have shown improved survival, rooting and growth performance (Dhiman *et al.,* 1988). Husen and Pal (2001) and Nautiyal *et al.* (1991) found the maximum rooting per cent and shoot growth in *Tectona grandis* with 2000ppm IBA before planting. In general, the rooting behavior of different types of cuttings is affected by nature of species, metabolic behavior response to external stimulus and the reserve food material. Therefore, the present study was conducted to study the effect of cutting diameter and protected environment on the adventitious rooting capacity of shoot cuttings of teak.

The experiment was conducted at Jachh in subtropical region of western Himalayas at an altitude of 667 m above m.s.l., which receives average annual rainfall of 1500 mm. The average temperature under the poly house ranged from 24-41°C and humidity was maintained around 85 ± 2% during the period of study. The cuttings were taken from the 15-year-old tree in the month of February. These cuttings were prepared by excising the twigs having at least two nodes without leaves. The cuttings were graded into different diameter classes. The four diameter classes viz; <20mm, 20-30mm, 30-40mm and >40mm were used to estimate the potential of shoot/root regeneration in cuttings. The experiment was conducted in completely randomized block design with four replications. These cuttings were dipped in 0.3 per cent bavistin (carbandzin) solution for 30 minutes. Thereafter, the cuttings were treated with 2000ppm IBA in talcum powder (Husen and Pal, 2001). So treated cuttings were planted in raised nursery bed in poly-house, prepared by mixing soil, sand and FYM in 1:1:2 ratio, the beds were presoaked with water for 24 hrs. The 50 cuttings in each treatment were planted for study. After 90 days, the cuttings were carefully removed from the rooting medium and observations were recorded on callus formation, sprouting, rooting, number of roots per cutting and the mean length of roots per cutting (cm). However, the callus formation in the cuttings was studied at regular intervals. The data were analyzed by two-way analyses of variance. Comparisons between the mean values were made by the least significance difference (LSD test) at $P < 0.05$. The SPSS/PC software Ver. 12.0 was used to process all the data.

Diameter of cuttings had significant effect on the shoot and root growth of the teak cuttings. Perusal of data in Table 1 showed that all types of cuttings showed callus formation however, cuttings with diameter less than 20mm failed to root. Diameter class of 30-40 mm had maximum callusing of 93.25 per cent. Conversion rate of callous to roots ranged from 17.90 to 80 per cent in cuttings having diameter of 20-30 mm and 30-40mm, respectively. Cutting size had direct effect on the rooting of the teak cutting in the protected conditions in subtropical conditions of western Himalayas. Dhiman *et al.* (1988) and Bowersox (1970) have reported the significant effect of cutting diameter on the shoot and

Table 1. Effect of shoot cutting diameter on the shoot and root growth of *Tectona grandis* under polyhouse conditions

Parameters	Diameter class (mm)			SE±	CD (0.05)	
	<20	20-30	30-40	>40		
Callusing (%)	70	68.75	93.25	85.75	3.27	7.39
Rooting (%)	0	17.50	80.00	68.00	4.46	10.09
Number of leaves	0	4.75	5.50	8.25	1.19	2.70
Shoot length (cm)	0	5.75	12.50	14.25	1.65	3.74
Root length (cm)	0	4.56	7.25	6.75	1.20	2.81
No. of roots	0	3.00	7.00	7.25	1.14	2.55

Table 2. Correlation among different characters of *Tectona grandis*

Parameters	Callusing (%)	Rooting (%)	No. of leaves	Shoot length (cm)	Root length (cm)	No. of roots
Callusing (%)	1.00	0.910*	0.513	0.839*	0.432	0.378
Rooting (%)	-	1.00	0.613*	0.839*	0.659*	0.532
Number of leaves	-	-	1.00	0.666*	0.420	0.661*
Shoot length	-	-	-	1.00	0.725*	0.549*
Root length	-	-	-	-	1.00	0.236
No. of roots						1.00

root growth of callusing of *Morus alba* and *Populus deltoides*, respectively. Similarily, Husen (2011) reported the enhanced sugar have positive effect on the rooting and imbalance of sugar and auxin affect the rooting in adverse manner in *Tectona grandis*. Maximum number of leaves (8.25) were found in cuttings having diameter of >40mm. However, the cuttings having diameter of 20 to 30mm recorded the lowest number of leaves. Cuttings with 30-40mm diameter registered the maximum root length of 7.25 cm, however, cuttings with diameter >40mm recorded the maximum number of roots (7.25). Callusing, rooting per cent, shoot length, number of leaves, number of roots and root length showed positive correlation (Table 2) among themself. Correlation between callusing and rooting per cent was found to be positive and significant. Shoot length was found significantly correlated with rest of the characters. Rooting per cent had highly significant correlation with callusing, number of leaves, shoot length and root length. The enhanced rooting efficiency is probably due to high sugar content in bigger sized shoot cuttings, and possibly due to increased mobilization of carbohydrates from starch.

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Biomass Production and Carbon Mitigation Potential of Different Shrubs in Urban Landscaping

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Anthropogenic emission of carbon dioxide (CO_2) led to global warming and climate change affecting the biodiversity and destabilizing food and livelihood security (Malhi and Grace, 2000). Global warming risks have increased the need for the identification of ecosystems with high carbon sink capacity as an alternative mitigation strategy of terrestrial carbon sequestration (Kumar *et al.,* 2009). Shrub species play an important role on carbon sequestration in forest and grassland ecosystems. For example, in temperate and subtropical areas, the encroachment of woody species into herbaceous ecosystems has been reported to increase ecosystem carbon sequestration and soil organic carbon probably due to the high productivity (Archer *et al.,* 2001; Brantley and Young, 2010). The biomass of herbs, shrubs, and trees is an important ecosystem attribute for herbivores, their subsequent predators and for ecosystem management as well. For individual trees or forest stands, information on biomass is essential for understanding the changes in energy, carbon, and nutrient flows resulting from changes in forest land use (Brown 1997; Marland *et al.,* 1997; Schimel *et al.,* 2000). Shrub biomass is an important component of the total forest biomass, especially in natural stands. However, compared with arboreal biomass, shrub biomass is often neglected in biomass research because of the lack of methodology and difficulty in calculation. Some research has gone into estimating the biomass of individual shrub species (Paton *et al.,* 2002) but due to lack of reliable shrub data on standing biomass, the net carbon emission estimates for India are highly variable (Ravindernath *et al.,* 1997). Carbon dioxide is captured and stored naturally by the plants through the process of photosynthesis, hence, estimation of this carbon content in vegetation becomes imperative to access the carbon mitigation potential. Considering the thrust area, present investigation was undertaken to quantify the carbon storage in the shrub biomass.

The field study was carried out in the Punjab Agricultural University, Ludhiana during 2012. The experiment site is situated at 30°56' N latitude and 75°52' E longitude with a mean height of 247 meters above the mean sea level. The study was designed to evaluate the carbon mitigation potential in ten different shrub species viz; *Calliandra spp, Ervatamia divaricata, Ervatamia coronaria, Hibiscus rosasinensis, Hamelia patans, Cassia glaucca, Thevetia peruviana, Murraya paniculata, Gardenia jasminoides* and Bougainvillea. The height of shrubs in meters was measured with a long measuring scale. Collar diameter (cm) of all shrubs was measured five cm above the ground level with tree caliper. Canopy spread (m^2) of each shrub was measured with a measuring tape at perpendicular directions i.e., North to South and East to West. Above ground biomass of shrubs by non-destructive estimation was measured by using the standard regression equation for shrub biomass (Thakur *et al.,* 1993). Carbon content in shrubs was calculated by multiplying above ground biomass with 0.4524 as average carbon content in biomass (Chhabra and Dadhwal, 2004) and converted on area scale accordingly.

It is evident from Table 1 that all variables showed statistically significant differences among species for growth of shrubs. The reason of in shrub growth and biomass may be genetic variation and differences in requirements of climatic and site conditions. *Bougainvillea* showed maximum height of 5.10 m and canopy spread of 27.37 m^2 than other shrub species. Maximum collar diameter was observed in *Murraya paniculata* (15.37 cm), which was statistically at par with *Bougainvillea* (14.97 cm) but was significantly different than other species. Telfer (1969) found stem diameter at ground level to be closely related with both leaf and total weight of shrubs.

Above ground biomass also showed significant variation (Table 2). The maximum total above ground dry biomass was recorded in *Murraya paniculata* (12.74 kg $shrub^{-1}$) i.e., 31.85 t ha^{-1}, which was statistically at par with *Bougainvillea* (12.32 kg $shrub^{-1}$) i.e., 30.79 t ha^{-1}. However, it was significantly higher than other shrubs. Minimum value for total biomass was observed in *Calliandra spp.* (1.79 kg $shrub^{-1}$) i.e., 4.28 t ha^{-1}. Similarly, the mean total carbon content ranged between 0.80 to 5.81 kg $shrub^{-1}$ with maximum total carbon content in *Murraya paniculata* (5.81 kg $shrub^{-1}$) i.e., 14.10 t ha^{-1}, which

Table 1. Height (m), diameter (cm) and canopy spread (m^2) of different shrub species

Shrub species	Height (m)	Diameter (cm)	Canopy spread (m^2)
Calliandra spp.	1.47	5.43	8.43
Ervatamia divaricata	2.60	10.20	11.30
Ervatamia coronaria	2.90	13.93	8.83
Hibiscus rosasinensis	2.50	7.80	5.53
Hamelia patans	3.40	13.40	9.00
Cassia glaucca	2.73	8.19	9.97
Thevetia peruviana	2.77	6.33	7.40
Murraya paniculata	4.23	15.37	24.70
Bougainvillea	5.10	14.97	27.37
Gardenia jasminoides	3.83	12.10	10.40
CD (0.05)	0.46	0.55	1.40

Table 2. Dry biomass (kg $shrub^{-1}$) and carbon content (kg $shrub^{-1}$) of different shrub species

Shrub species	Above ground biomass (kg $shrub^{-1}$)	Above ground biomass (t ha^{-1})	Carbon content in above ground biomass (kg $shrub^{-1}$)	Carbon content in above ground biomass (t ha^{-1})
Calliandra spp.	1.71	4.28	0.80	1.92
Ervatamia divaricata	5.80	14.50	2.65	6.73
Ervatamia coronaria	10.83	27.07	4.82	12.02
Hibiscus rosasinensis	3.48	8.69	1.59	4.00
Hamelia patans	9.63	24.08	4.49	10.73
Cassia glaucca	3.79	9.47	1.77	4.22
Thevetia peruviana	2.34	5.86	1.37	2.65
Murraya paniculata	12.74	31.85	5.81	14.10
Bougainvillea	12.32	30.79	5.76	13.88
Gardenia jasminoides	8.06	20.16	3.75	9.19
CD (0.05)	0.36	3.92	0.26	0.29

was statistically at par with *Bougainvillea* (5.76 kg $shrub^{-1}$) i.e., 13.88 t ha^{-1} and significantly higher than other species. Bilewu (2008) also reported statistically significant difference among shrub species for the amount of carbon being absorbed. Green bush (*Duranta* spp.) absorbed the highest amount of carbon (32.18mg l^{-1} with a range of 25.15 to 40.37 mg l^{-1}). Croton (yellow variegated) absorbed the lowest amount of carbon with a value of 2.84mg l^{-1} on the average (ranging from 0.811 and 4.869 mg l^{-1}). The above ground biomass in bamboo was found as 1.66 t ha^{-1}, whereas, the soil carbon sequestration was found to be 230.32 t ha^{-1} (Dhruba, 2008).

On the basis of research findings, it can be concluded that shrubs help in sequestering a large amount of atmospheric carbon with minimum resource use. These shrubs find their place in all the ecosystems including city landscape. However, the selection of species varies as per the ecosystem suitability and adaptation.

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Indian Journal of Ecology

Differential Seasonal Response to Pre-sowing Treatments by Drupes of *Melia azedarach*

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The seeds having hard seed coat always give delayed and non-uniform germination. The success of nursery depends upon quick and uniform germination of seeds. Longer the germination period shortest will be the growing period available to seedlings, therefore, seeds must germinate within a week or so. Inspite of favourable conditions, many seeds do not germinate and need some pre-sowing treatment (Prasad and Kandya, 1997). This situation is also faced by seeds of *Melia azedarach,* where the seeds are enclosed in a hard shell. *M. azedarach* (dek) is highly valuable species and much popular among the farmers due to its fast growth, adaptability in diverse conditions, compatibility with inter-cultivated crops, market acceptability, etc. Keeping in view the low germination and hard to root nature of the species, a study has been planned with the objective to find out best pre-sowing treatment for these seeds so that maximum and early germination could be obtained.

The seeds collected during the month of January were sown in two different months i.e., February and May, when the atmospheric average monthly temperature is quite low and comparatively high, respectively. Twenty seeds for each treatment with three replications were sown in hyko trays (100cc cup size). These hyko trays were numbered for each treatment and were kept in open. The detail of the treatments is given in Table 1 and 2 for the month of February and May, respectively. The treatments were selected with the objective that most appropriate treatments were continued and rest of the treatments were improved further with some changes.

The data on seed germination, number of seedlings per drupe, height of seedlings, length of main root and number of lateral roots were recorded after three months of sowing. The data on germination was recorded at two days interval to calculate the germination value.

There was a very wide variation in germination of seed when the drupes were given various pre-sowing treatments (Table 1 & 2). In February, maximum seed germination (80.00%) was recorded from the drupes kept in FYM for one week and drupes cut with secateur after keeping seed in FYM for one week. There was no germination in seeds, which were given heat and pressure treatments and 50 per cent sulphuric acid treatment. Drupes were kept in FYM for one week and cut with secateur registered the highest germination value (1.61).

Five treatments in which drupes were kept in FYM in this experiment exhibited significantly higher values for seedling height growth than the control (2.83 cm) but at par among themselves. Maximum height (6.39 cm) was recorded in FYM treatment for one week and drupe cut longitudinally. The minimum value of seedling height (3.25 cm) among the germinated drupes was recorded in sulphuric acid treated drupes, which was at par to untreated drupes. Similar treatment response was recorded for root parameters.

The drupes responded to sulphuric acid treatments during February month, therefore, these treatments were modified during May experiment. Maximum seed germination (70%) was recorded from the drupes treated with concentrated sulphuric acid for 15 minutes and cold water dipping for 24 hours. In control, seed germination was counted upto 31.67 per cent, which was almost similar to the results of February month. There were significant differences for germination among different treatments. Maximum germination value (0.935) and maximum average number of seedlings per drupe (1.97) were also recorded with concentrated sulphuric acid treatment for 15 minutes and cold water dipping for 24 hours. Three treatments, concentrated sulphuric acid treatment for 30 minutes and cold water dipping for 24 hours, concentrated sulphuric acid treatment for 15 minutes followed by cold water dipping for 24 hours and concentrated sulphuric acid treatment for 30 minutes exhibited significantly higher value for height (33.59, 25.29 and 24.18 cm, respectively) than the control (12.34 cm). Concentrated sulphuric acid treatment for 30 minutes and cold water dipping for 24 hours gave maximum values for most of the seedling characteristics like height (33.59 cm), main root (27.42) and number of lateral roots (19.60).

In the present studies, since the experimental conditions were different during both the months, the drupes pre-sowing

Table 1. Seed germination and seedling traits after different drupe treatment (February month)

Treatment	Seed germination (%)	Germination value	No. of seedlings per drupe	Seedling height (cm)	Main root length (cm)	No. of lateral roots
Drupes heated upto 1st whistle in pressure cooker	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
Drupes heated up for 5 minutes after Ist whistle in pressure cooker	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
50% sulphuric acid treatment for 30 minutes	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
Concentrated sulphuric acid treatment for 15 minutes	45.00 (42.10)	0.30	1.98	3.25	7.99	11.10
Dipping in hot water and kept for 48 hours at room temperature	50.00 (44.98)	0.41	1.70	3.66	7.93	12.00
Dipping in hot water and kept for 24 hours at room temperature	70.00 (57.08)	0.80	1.96	3.54	8.17	10.70
Dipping in cold water for 48 hours at room temperature	65.00 (53.91)	0.77	2.25	3.78	6.25	10.20
Dipping in cold water for 24 hours at room temperature	62.50 (52.23)	0.56	2.11	4.01	7.44	11.40
Drupes kept in FYM for two weeks	75.00 (60.09)	1.43	2.62	5.95	10.02	14.30
Drupes kept in FYM for two weeks and cut longitudinally with secateurs	70.00 (57.08)	1.50	1.76	6.15	10.70	15.50
Drupes kept in FYM for one weeks	80.00 (63.58)	1.24	2.39	5.40	9.98	16.10
Drupes kept in FYM for one weeks and cut longitudinally with secateurs	80.00 (63.41)	1.61	1.58	6.39	10.50	13.80
Control (untreated)	30.00 (33.20)	0.16	1.54	2.83	6.98	7.63
CD 5%	9.61	0.23	0.42	1.16	2.79	6.33

* Arc sine transformed values in parentheses

treatments exhibited differential responses i.e., in the month of February good response was recorded in FYM treatments, whereas, in the month of May, FYM treatment had no impact, whereas, fairly good response was noticed with sulphuric acid treatment (Table 1 & 2).

The differential response shown by the drupes in the present study to the pre-sowing treatment given during February and May, can be correlated to the external environmental conditions and thus, drupes should be treated accordingly for better germination. One of the requirements for seed germination is a favorable temperature. Although, the seeds of many species can germinate across a wide range of temperatures, others have specific temperature requirements. In any case, germination involves a minimum temperature, an optimum and a maximum temperature. Temperatures below or above are usually lethal and inactivate metabolic activities. The optimum temperature is the temperature at which maximum seeds germinate in a short period and for most of the seeds, this temperature is 15-30°C. The maximum temperature for most of the species is 35-45°C. Species like *Fagus* germinate at temperatures approaching the freezing point, whereas, some species of *Pinus* and *Eucalyptus* in which seeds remain within the fruit bodies until released by fire to colonize burned-over areas (Thompson, 1991). Germination of *Pinus taeda* and *P. echinda* was higher at alternating temperature than at constant temperature of 22°C (Dunlap and Barnett, 1982). The germination study in trees on interaction of temperature and stratification are equally important. Adkins *et al.* (1984) reported that germination of *Abies fraseli* was stimulated by stratification and increasing temperature. The germination rates of *Leptospermum scoparium* increased with increasing

Table 2. Seed germination and seedling traits after different drupe treatment (May month)

Treatment	Seed germination* (%)	Germination value	No. of seedlings per drupe	Seedling height (cm)	Main root length (cm)	No. of lateral roots
Drupes cut longitudinally with secateur and kept in FYM for 30 days	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
Drupes kept in FYM for 30 days	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
Drupes cut longitudinally with secateur and kept in FYM for 20 days	3.33(6.14)	0.007	1.33	5.25	4.75	5.7
Drupes kept in FYM for 20 days	1.67 (4.31)	0.002	1.00	5.33	6.67	6.3
Concentrated sulphuric acid treatment for 15 minutes and cold water dipping for 24 hours	70.00 (57.21)	0.935	1.97	25.29	16.38	23.4
Concentrated sulphuric acid treatment for 30 minutes and cold water dipping for 24 hours	58.33 (49.87)	0.702	1.64	33.59	19.60	27.4
Concentrated sulphuric acid treatment for 15 minutes	56.67 (48.83)	0.524	1.61	18.97	18.36	17.5
Concentrated sulphuric acid treatment for 30 minutes	65.00 (54.30)	0.759	1.42	24.18	19.33	22.2
Drupes cut longitudinally with secateur	58.33 (49.87)	0.611	1.28	18.62	16.96	24.1
Dipping in cold water for 24 hours at room temperature	33.33 (34.99)	0.177	1.42	9.98	12.04	12.1
Dipping in boiling hot water and kept for 24 hours at room temperature	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
Control (untreated)	31.67 (34.17)	0.156	1.63	12.34	19.09	16.6
CD 5%	11.46	0.278	0.57	9.84	7.40	8.7

* Arc sine transformed values in parentheses

temperature from 12 to 25°C (Mohan *et al*., 1984). These various optimum temperatures can be related to the climatic conditions in which these species mature and disseminate their seeds. In the present study also, the external temperature played important role in treatment selection, and a high atmospheric temperature during May did not respond to FYM treatments, where the temperature is still higher than the external temperature. Therefore, the same seed treatment cannot be found suitable in all the conditions but selected as per the prevailing environmental conditions.

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Indian Journal of Ecology

Isolation and Identification of Yeast from Grapes

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Yeast as a versatile model organism approaches us with a vast majority of industrial and medical applications beneficial to human life (Zott *et al*., 2010). The ability of yeast to convert sugar into ethanol has been harnessed by biotechnology industry to produce ethanol fuel (Barata *et al*., 2012). The useful physiological properties of yeast have lead to their use in the field of alcoholic beverages, baking, bioremediation, non-alcoholic beverages, nutritional supplements and probiotics (Botstein and Fink, 2011).

The major objectives of the present day study was isolation of different yeasts species from fruits surfaces of grapes, cultural characterization of isolated yeasts, morphological characterization of yeasts and biochemical characterization of yeasts.

Grapes were collected in polythene bags from different locations of Dehradun for the isolation of yeast. The grapes samples were taken to laboratory of Microbiology Department of SBSPGI, Balawala, Dehradun. The samples collected from different locations were subjected to streaking on YEPD (yeast extract peptone dextrose agar) medium using chloramphenicol antibiotic. After maintaining pure culture of yeast, identification was done by employing various morphological and biochemical methods. Morphological methods include gram staining and capsule staining. Biochemical methods are further classified as:

Sugar fermentation test: Yeast fermentation broth is used as an aid in the identification yeast based on fermentation pattern. Most yeast will produce acid and gas as by product of fermentation of certain carbohydrates.

Carbon assimilation test: Basically this test is used for identification of yeast. Yeast uses carbon as a sole substrate for growth. In practical terms, yeast shows growth on carbon assimilation media.

Urease test: Urea is a diamide of carbonic acid. Urease, the enzyme produced by bacteria and fungi, hydrolyses and releases ammonia and carbon dioxide. Ammonia reacts in solution to form ammonium carbonate, which is alkaline leading to an increase in the pH of medium. Phenol red that is incorporated in the medium changes its color from yellow to red in alkaline pH, thus indicating the presence of urease activity.

All the 52 isolates were evaluated and identified morphologically on the basis of colony characteristics. The surface, margin and color of the colonies were observed. The most of the yeast isolates have smooth and mucoid surface while three isolates were having raised and dry surface. Similarly the margins of the yeast colonies were also observed. Most of the isolates have circular margin while irregular margins were also found in some yeast. Colony color is also observed by interpreting the plates. Majority of yeast are giving creamy white color colony where as one yeast is orange in color (Fig.1). Microscopic evaluation is also done by simple staining for yeast identification on the basis of cell shape. All yeast isolates were giving mixed response some are round shaped some isolates are oval in shape and bean pod shape is also observed (Fig.2).

Carbon assimilation test: In the carbon assimilation study, nime sugars were used (glucose, sucrose, lactose, maltose, mannitol, xylose, glycerol, sorbose and fructose). 52 isolates were identified on the basis of assimilation of these sugars (Fig.3). All the 52 isolates were able to utilize glucose as a growth substrate. Sucrose were utilized by most of the isolates i.e., 33 isolates, after glucose. Other carbon sources like sorbose, xylose, and glycerol were utilized by 19, 25 and 30 isolates, respectively. Among all the carbon sources maltose was only to be utilized by maximum 36 isolates. On the other hand, sorbose is utilized by 19 isolates. seven isolates were found, utilizing all of these sugars.

Sugar fermentation test: In the sugar fermentation study, the eight sugars were used (glucose, maltose, sucrose, mannitol, lactose, trehalose, inulin, fructose). 52 isolates were identified on the basis of fermentation by utilization of sugars and the color of medium changes from red to yellow. All the 52 isolates were able to ferment glucose and produce acid. The maltose were utilized by most of the isolates i.e. 44 isolates after glucose. The other sugars sucrose, trehalose, mannitol and lactose were utilized by 28, 25, 21and 24 isolates, respectively. Among all the sugars, inulin was the

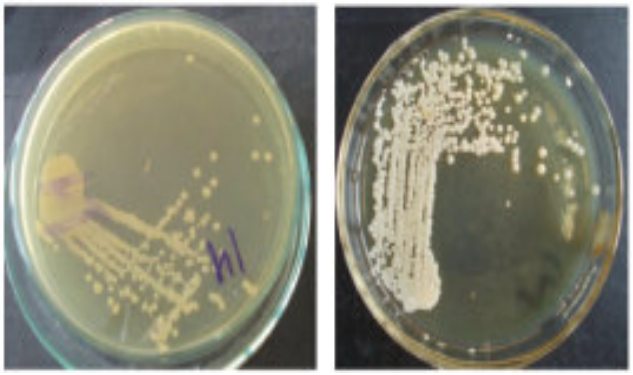

Fig.1. Cultural characteristics of isolated yeast on YEPD agar medium

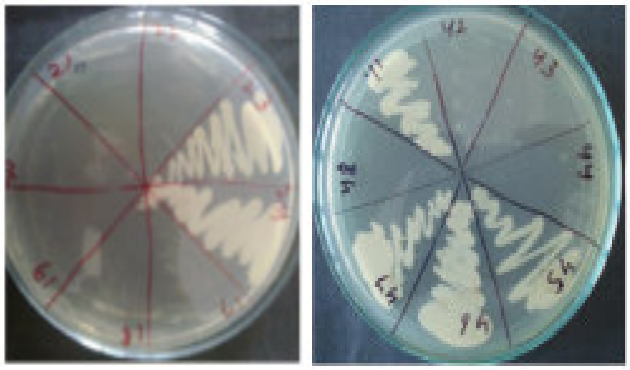

Fig. 3. Growth of yeast isolates on medium containing different sugars as source of carbon

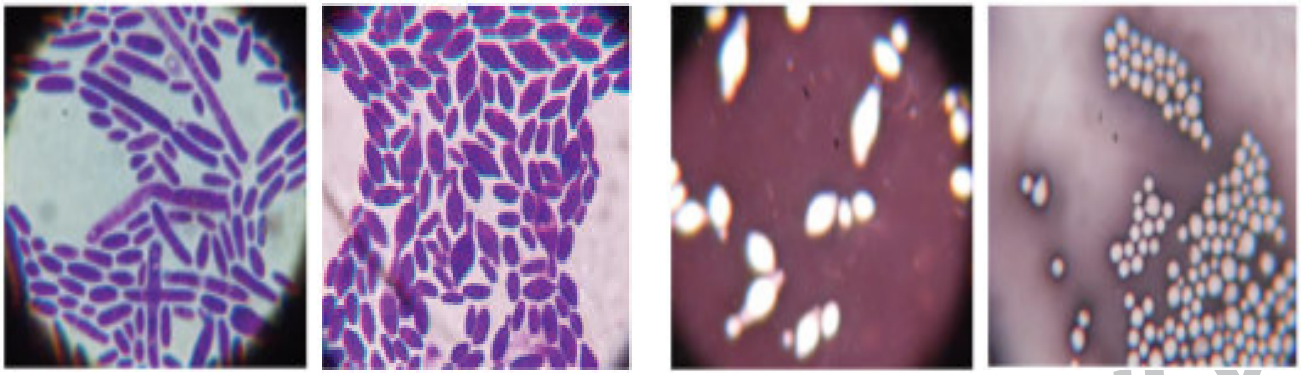

Fig.2. Microscopic features of isolated yeast under 100x

only one to be least utilized by isolates i.e., 11 isolates.

Urease test: Urease test is performed to detect the capsule around the yeast cell on the basis of color change from yellow to pink purple (in case of positive). Among 52 isolates, 29 were found positive for urease test i.e., these produces urease enzyme and hydrolyse urea and released ammonia and carbon dioxide.

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A Shield for the Pesticide Applicators : Eco-Friendly Starched Fabric

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The environmental impact of pesticides is often greater than what is intended by those who use them. Over 98 per cent of sprayed insecticides and 95 per cent of herbicides reach a destination other than their target species, including non-target species, air, water, bottom sediments, and food (Miller, 2004). They may cause acute and delayed health effects in those who are exposed. These effects can range from simple irritation of the skin and eyes to more severe effects including damage to the lungs and central nervous system, failures of reproductive organs and dysfunctions of the immune system, endocrine system, and exocrine system, as well as potential cancer risks and birth defects. Exposure of pregnant women to organophosphate pesticides may be associated with decreased gestational age and lower birth weight (Chillymanjaro, 2012).

In general, knowledge of the main determinants of pesticide exposure in developing countries is often poor and also exposure situations may differ among countries. A major factor of pesticide contamination or poisoning in developing countries is the unsafe use or misuse of pesticides. So this study was conducted to protect the unprotected pesticide applicators from the harmful effects of pesticides by giving barrier treatment through an eco-friendly starch to reduce the penetration of pesticides into the fabric.

Selection of materials: Pure white cotton and cotton/ polyester blended fabric with plain weave was procured and its physical properties were examined. Fenvalerate 20 EC was used for the experiment. A barrier treatment was provided to the cotton and cotton/ polyester blended fabric with locally available eco-friendly starch. After spraying the pesticide on fabric given barrier treatment with 10%, 20% and 30% starch solution, the pesticide was stripped with the laboratory grade chemicals, acetone and hexane.

Procedure of work: Thirty test fabric samples measuring 15x15 cm were cut from the scoured fabric. Five (cotton and cotton/ polyester blended fabric each) samples were given barrier treatment with the application of 10%, 20% and 30% starch solution each and allowed to dry. Pesticide spray solution was prepared and applied on all the starched samples. The undisturbed samples were allowed to dry overnight. All the starched samples were laundered i.e., Control – Unlaundered samples, 5% salt water at 50ºC, and 80ºC, 2% detergent at 50ºC and 80ºC.

These samples were separately steeped in salt and heavy duty detergent and separately washed at 50ºC and 80ºC temperatures for one hour each. Later, each sample specimen was rinsed separately in a beaker to avoid cross contamination and dried in sunlight. A solution of hexane: acetone (250:250ml) was prepared. Each sample was separately dipped in separate beaker and the solution was allowed to evaporate till only 5 ml of hexane: acetone was left. The experiment was repeated three times for each condition.

The per cent transmittance was observed for all the samples i.e., their control samples and the samples when washed under different laundering conditions using UV/VIS spectrophotometer (UV 3000+). The more the value of transmittance, the lesser is the pesticide residue left in the sample.

After the samples were treated with 10% starch solution, it was found that the value of transmittance was more in case of cotton samples than the cotton/ polyester blended samples when kept under control (without giving any laundering treatment), laundered with 5% salt water at 50°C and 80ºC, whereas, it was more in case of cotton/ polyester blended samples than cotton when laundered with 2% heavy duty detergent at 50°C and 80°C (Fig. 1). The maximum value of per cent transmittance (64.20%) was observed in the case of 10% starched cotton/polyester blended sample when treated with 2% heavy duty detergent at 80°C. The difference among all the values of transmittance (%) of pesticide residue was significant (CD 0.05). The value of per cent transmittance was more in case of cotton samples when compared with cotton/polyester blended samples in all the laundering treatments i.e., when kept under control (without giving any laundering treatment), laundered with 5% salt water at 50°C and 80°C, 2% heavy duty detergent at 50°C and 80ºC (Fig. 2) when the samples were treated with 20% starch solution. The maximum value of per cent transmittance (66.60%) was observed in the case of 20% starched cotton sample when

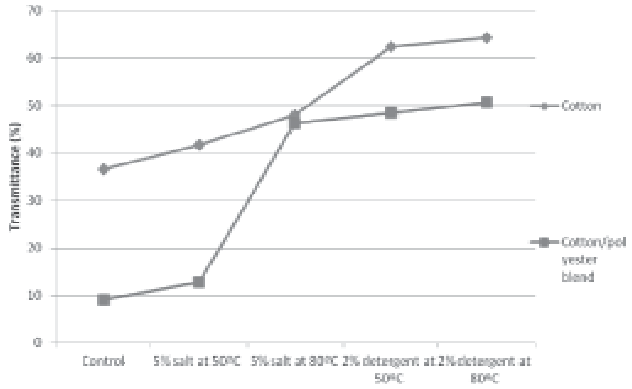

Fig. 1. Comparison of pesticide residue (per cent transmittance) between cotton and cotton/ polyester given barrier treatment with 10% starch solution

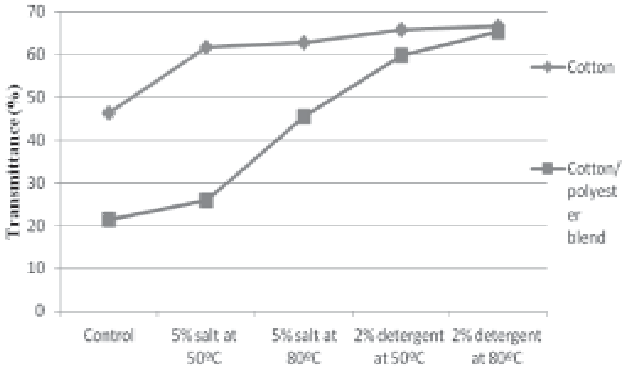

Fig. 2. Comparison of pesticide residue (per cent transmittance) between cotton and cotton/ polyester given barrier treatment with 20% starch solution

treated with 2% heavy duty detergent at 80ºC. All the values of transmittance (%) of pesticide residue were significant (CD 0.05.05).

After treating the samples with 30% starch solution, it was observed that the value of per cent transmittance was more in case of cotton samples than cotton/polyester blended samples in all the laundering treatments i.e., when kept under control (without giving any laundering treatment), laundered with 5% salt water at 50°C and 80°C, 2% heavy duty detergent at 50°C and 80°C. The maximum value of per cent transmittance (98.40%) was observed in the case of 30% starched cotton sample when treated with 2% heavy duty detergent at 80ºC (Fig 3). All the values of transmittance (%) of pesticide residue were significant (CD 0.05). Regarding the laundering treatments, the value of per cent transmittance was the maximum in case of samples laundered with 2% heavy duty detergent at 80°C in case of both cotton and cotton/polyester blended samples.

A comparison between the two fabrics shows that the maximum value of per cent transmittance was in cotton/ polyester blended samples given barrier treatment with 10% starch solution, whereas, in case of cotton fabrics the maximum value of per cent transmittance was found when fabric was given barrier treatment with 20% and 30% starch solution. While comparing the amount of starch, the fabric with barrier treatment with 30% starch solution had maximum per cent transmittance as compared to the samples with 10% and 20 % starch solution.

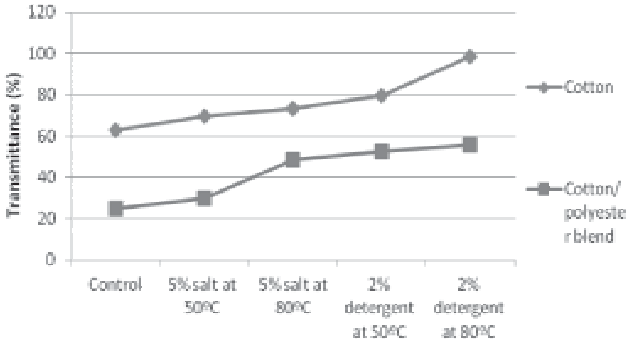

Fig. 3. Comparison of pesticide residue (per cent transmittance) between cotton and cotton/ polyester given barrier treatment with 30% starch solution

Thus, the value of per cent transmittance for the amount of barrier treatment (starch) with 30% starch solution had maximum per cent transmittance (98.40%) when laundered with 2% heavy duty detergent at 80ºC for one hour. Obendorf *et al.* (1991) observed that starch act as a pesticide trap, preventing transfer and increasing removal by laundering. The intriguing theory supports that starching effectively reduces the area of contamination on the fabric surface by decreasing pesticide transfer and enhancing pesticide removal.

Exposure to pesticides is one of the most important occupational risks among farmers in developing countries (Coronado *et al.,* 2004). In Punjab, excessive and unregulated use of pesticides since the Green Revolution has led to high cancer and birth defect rates among the farmers. On an average, the use of pesticide by a farmer in Punjab is 923 g ha^{-1} (grams per hectare), whereas, the national average is 570 g ha^{-1} (Sengupta, 2011). With the State indebted to new technologies and a lack of awareness among the population with regard to the use of new agricultural interventions, it is high time to educate the families regarding their protection by altering laundering practices for the clothes contaminated with pesticides and using locally available eco-friendly starch to save the environment.

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Effects of Summer Season Intercrops on Growth, Yield and Quality of Turmeric (*Curcuma longa* L.)

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India is major producer and exporter of spices with a major part of its produce is consumed within the country. Turmeric (*Curcuma longa* L.), an ancient and sacred spice known as 'Indian saffron' is an important commercial spice crop grown in India**.** It offers good scope in diversification of cereal based cropping system of Punjab. The cultivation of turmeric in the state will not only help to meet its own requirement but will help the country to boost its export. The economy of Punjab state is based on the cereal production. Due to the rise in cost of inputs, it seems probable that the existing cropping pattern of the state may not last long. So there is need to diversify and find alternatives crops for the state. Hence the study on effect of summer season intercrops on growth, yield and quality of turmeric was under taken with an objective to find most efficient intercropping system for higher productivity.

A field experiment was conducted to assess the effect of summer season intercrops on growth, yield and quality of turmeric (*Curcuma longa* L.) in Department of Agronomy, Punjab Agricultural University, Ludhiana, during 2009 -10 and 2010-11.The experimental field is situated at an elevation of 247 m above sea level with geographical co-ordinates at 30° 56'N and 75° 52'E. The soil of experimental field was categorized as loamy-sand typic Ustochrept order and Samana series. The experimental field tested low in organic carbon (0.32 %) and available nitrogen (250.7 kg ha^{-1}). However, available phosphorus (13.8 kg ha^{-1}) and potassium (163.1 kg ha^{-1}) status were medium. The soil pH and electrical conductivity values were 7.3 and 0.21 dSm^{-1}, respectively. The experiment was laid out in randomized block design with ten treatments replicated thrice. The planting of turmeric crop was done on 20th April 2009 and 1st May, 2010 at optimum soil moisture using recommended seed rate of 20q ha^{-1} in rows 30 cm apart with plant to plant spacing of 20 cm. Sathi moong, sathi maize, cowpea fodder, maize fodder, bajra fodder were sown in between the two rows of turmeric as per treatments on the very next day after planting of turmeric in both the years. In mulch treatments, 6.25 tonnes of rice straw was applied for one hectare as mulch immediately after the sowing of crops as per treatments. A fertilizer dose of 25 kg ha^{-1} each of phosphorous and potassium was applied to turmeric at the time of planting. Two weedings were done at 45 and 90 days after planting. The first irrigation was given immediately after planting, subsequently light and frequent irrigations were applied to keep soil moist till the rhizome sprouted. Thereafter, irrigation was applied as per the need of the crop. At maturity the leaves were harvested just near the ground followed by digging of rhizome with the help of spade. Crop was harvested manually on January 30 and 2nd February during 2010 and 2011, respectively and the fresh rhizomes were collected, cleaned and weighed for fresh weight. The sathi moong and sathi maize were harvested on June 25, 2009 and July 5, 2010 and all fodder crops were harvested on June 15, 2009 and 25 June 2010, respectively. The rhizome sample from each plot was taken for analysis of curcumin content. The curcumin content of processed samples was determined using the method described by Thimmaiah (1999).

Yield: A significant reduction in turmeric rhizome yield was observed due to inter-cropping of different summer crops (Table 1). The reduction in yield was more pronounced with inter-cropping of bajra for fodder purpose. Bajra fodder caused 40 % reduction in fresh yield as compared with sole crop of turmeric. The reduction in turmeric rhizome may be due to more aggressive nature of bajra fodder, which competed for the resources at initial stages of the crop and ultimately led to lesser number and weight of rhizome per plant. Likewise inter-cropping of cowpea fodder and maize fodder also caused drastic reduction in rhizome yield as compare to sole crop of turmeric indicating the severity of competition for the resources.

Intercropping of sathi maize with mulch and sathi moong with mulch being at par with each other produced significantly higher dry turmeric yield as compared to turmeric alone (25.77 q ha^{-1}). Mulching in these intercropping treatments is the probable reason for higher turmeric yield over sole crop, indicating its beneficial effects for long duration crops like turmeric. Dry turmeric yield in turmeric + sathi maize with mulch and turmeric + sathi moong+ mulch was 41.5 and 34% higher than sole turmeric. The increase in yield might

Table 1. Effect of different summer intercrops on growth and yield of turmeric, intercrop yield and net returns (pooled data)

Treatments*	Plant height (cm)	Tillers plant^{-1}	No.of rhizome plant^{-1}	Wt of fresh rhizome plant^{-1} (g)	Turmeric fresh yield (q ha^{-1})	Turmeric dry yield (q ha^{-1})	Intercrop yield (q ha^{-1})	Net Returns (Rs ha^{-1})
T+SMF	39.9	2.06	7.43	86.00	86.41	22.32	3.43	2,48,716
T+SM	37.0	1.48	6.90	77.71	75.99	19.52	3.07	2,18,215
T+SMM	47.5	2.80	10.28	161.00	151.89	39.12	4.33	4,94,536
T+SMZF	35.2	2.03	7.25	90.72	85.06	21.22	5.50	2,19,345
T+SMZ	36.0	1.73	7.01	75.25	80.75	18.48	4.18	1,94,600
T+SMZM	48.3	2.96	10.42	197.53	169.25	44.09	6.88	5,28,061
T+CF	33.3	1.41	6.66	57.61	61.77	15.21	205.04	1,88,661
T+BF	29.7	1.38	5.33	50.11	56.84	14.58	494.60	1,90,375
T+MF	30.5	1.51	6.44	52.37	72.48	15.68	365.03	1,85,491
ST	36.4	1.75	6.68	107.21	94.80	25.77		3,44,875
C D (p=0.05)	7.35	0.43	1.46	8.82	22.86	5.43		

*T+SMF= turmeric + one row of sathi moong with recommended fertilizer to sathi moong, T+SM= turmeric + one row of sathi moong with no fertilizer to sathi moong, T+SMM= turmeric + one row of sathi moong with mulch, T+SMZF= turmeric + one row of sathi maize with recommended fertilizer to sathi maize, T+SMZ= turmeric + one row of sathi maize with no fertilizer to sathi maize, T+SMZM= turmeric + one row of sathi maize with mulch, T+CF= turmeric + one row of cowpea fodder, T+BF= turmeric + one row of bajra fodder, T+MF= turmeric + one row of maize fodder and ST= sole turmeric

be due to the beneficial effect of mulch. Similar trend was observed in fresh rhizome yield of turmeric. The results indicated that intercropping of summer crops like sathi moong and sathi maize without fertilizer to intercrops maize fodder, bajra fodder and cowpea fodder in turmeric reduced the dry turmeric yield significantly. The reduction in yield attributed to less number and weight of rhizome per plant as a result of intercrops of summer crops. The application of recommended fertilizers to sathi moong and sathi maize had increased the grain yield of intercrops.

Yield attributes: Sole crop of turmeric showed significantly less yield attribute values as compared to mulched inter crop treatments. Different summer inter-crops without mulching significantly reduced the yield attributing characters of turmeric. The maximum plant height of 48.3 cm was recorded when turmeric was inter-cropped with sathi maize with mulch, which was at par when turmeric was inter-cropped with sathi moong with mulch (47.5 cm). It might be due to beneficial effect of mulch. These results were in accordance with the findings of Gill *et al.* (1999). The lowest plant height of 29.7 cm was observed when turmeric was intercropped with bajra fodder, which might be due to more exhaustive nature of bajra fodder for nutrient removal. The practice of mulching resulted in more number of leaves per plant (10.55 and 10.11) when turmeric was inter-cropped with sathi maize and sathi moong with mulch, respectively, which was significantly better than sole crop of turmeric. Similarly, number of rhizome per plant and weight of rhizome per plant were significantly better in mulch treated plots than sole crop as well as rest of the treatment. Similar results were obtained by Manhas (2009) and Verma and Sarnaik (2009).

Quality: The curcumin content ranged from 2.81 to 2.88 per cent under different treatments. However, the differences in the curcumin content of turmeric under different intercrop treatments were found non-significant when compared with sole turmeric (2.84 %). The quality of turmeric in term of curcumin content was not influenced with different intercrops, since, curcumin content is inherent character of turmeric, which could be the probable reason for non-significant effects.

Economics: Intercropping of sathi maize with mulch and sathi moong with mulch enhanced the net returns as compare to sole crop of turmeric. Inter-cropping with sathi maize with mulch, sathi moong with mulch resulted in higher net return Rs. 5,28,061, 4,94,536 per hectare than the sole crop, respectively. Minimum net return occurred from turmeric + maize fodder. Turmeric + sathi moong and turmeric + sathi maize both with recommended fertilizer gave net return of Rs. 2,48,716 and Rs. 2,19,345 per hectare, respectively, the net return was comprehensively decreased without recommended fertilizer.

The present study revealed that turmeric can be successfully inter-cropped with sathi maize and sathi moong with mulch for higher total productivity and profitability. The practice of mulching with summer intercrops in turmeric has proved its beneficial effects for enhancing the productivity of the intercropping system. Therefore, it would be an important alternative for farmers for diversification, resource

conservation efficiency, productivity and higher income.

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Response of Clusterbean [*Cyamopsis tetragonoloba* (L.)] to Growth Substances in Sub-tropical Climate of Rajasthan

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Guar [*Cyamopsis tetragonoloba* (L) Taub] is a drought tolerant summer annual legume. Being a deep rooted and drought hardy, clusterbean has occupied large areas in arid and semiarid tracts. This crop is mainly grown in Rajasthan, Gujarat, Haryana, Punjab and Uttar Pradesh. Rajasthan ranks first in respect of both area and production, occupying an area of 30.94 lakhs ha and production of 18.47 lakhs ton during 2011-12 (ASDA, 2013). Unlike the seeds of other legumes, guar seed contains sufficient amount of galactomannan gum, which form a viscous gel in cold water. Guar gum has 5-8 times the thickening power of starch. It is used in textile, paper manufacture, stamps, cosmetics, pharmaceuticals, food products, like bakery products, ice cream, stabilizer for cheeses and meat binder. Also, it is used in oil wells, mining industries, explosives, and other industrial applications (Undersander *et al.,* 2006). On the other hand, guar is considered as an excellent soil improvement crop, like other legumes, with respect to available nitrogen, which improve yield of succeeding crops. Several researchers working on different crop have reported that the use of growth substances is one of the effective means of delaying the senescence of leaves as well as retarding the abscission of reproductive organs. Application of growth regulator also increase flower, fruit setting, grain filling and test weight in different crops. The use of agro-chemicals have been started to modify various metabolic or physiological processes to regulate plant growth. Several researchers working on different crop have reported that the use of growth substances is one of the effective means of delaying the senescence of leaves as well as retarding the abscission of reproductive organs. Application of growth regulator also increase flower, fruit setting, grain filling and test weight in different crops (Patel and Singh, 1980).

An experiment was conducted at the Department of Agronomy, Rajasthan College Agriculture, Udaipur during *kharif* seasons. Twenty eight treatment combinations i.e. four varieties (RGC-936, RGC-1002, RGC-1003 and RGC-1017) as main plot treatment and seven growth substances (control, seed treatment with thiourea 500 ppm, foliar application of thiourea 500 ppm, Seed + foliar application of thiourea 500 ppm, Seed treatment with TGA 100 ppm, foliar application of TGA 100 ppm and Seed + foliar application of TGA 100 ppm) as sub-plot treatment were laid out in split-plot design with three replications. The soil of the experimental site was clay loam in texture having 250.12 kg ha^{-1} alkaline permanganate oxidizable N (Subbiah and Asija, 1956), 17.04 kg ha^{-1} available P (Olsen *et al*. 1954), 340.24 kg ha^{-1} 1 N ammonium acetate exchangeable K (Stanford and English 1949) and 1.17% organic carbon (Jackson, 1973). The pH of soil was 7.6 (1:2.5 soil and water ratio) and bulk density recorded 1.46 Mg m^{-3} in 0-30 cm soil depth

Effect of cultivars: Plant population of clusterbean recorded at 30 DAS and at harvest were not affected significantly due to varieties. Plant height/plant are the genetic characters and hence, different cultivars varied with respect to these characters, which ultimately brought about variation in dry matter accumulation (Table 1). Variety RGC-936 recorded significantly higher plant height at harvest and dry matter accumulation at all the growth stages as compared to other varieties exceppt RGC-1017, which was statistically at par with RGC-936. This might be due to fast growth habit of variety RGC-936 and RGC-1017, which continuously increased in height, dry matter accumulation and also took less time to mature than RGC-1017, RGC-1003 and RGC-1002. Further the differential behaviour among the varieties could be explained solely by the variation in their genetic make up and their differential behaviour under different conditions. This may be because of the long duration and fast later growth of these cultivars and it was also evident by significantly higher crop growth rate at later stages of growth. Similar results were also reported Meena *et al.* (2013).

Effect of growth substances: Seed treatment + foliar spray of thiourea and thioglycolic acid applied at initiation of branches and flowering stages brought about significant improvement in growth parameters during two years of experimentation. Seed treatment + foliar spray of 500 ppm of thiourea recorded significantly higher value of growth attributes of clusterbean crop but this treatment was statistically at par with 100 ppm thioglycolic acid. It may also be noted that not only accumulation of dry matter was

Table 1. Effect of varieties and growth substances on plant population and plant height of clusterbean (pooled data of 2 years)

Treatment	Plant population (lakh ha^{-1})		Plant height (cm)	Dry matter accumulation (g plant^{-1})			
	30 DAS	At harvest	At harvest	30 DAS	45 DAS	60 DAS	At harvest
Varieties							
RGC 936	3.17	2.83	93.69	3.55	10.74	48.69	64.28
RGC 1002	2.93	2.62	85.75	2.79	8.76	39.05	56.65
RGC 1003	3.08	2.67	86.48	2.96	9.26	41.53	58.20
RGC 1017	3.15	2.77	90.78	3.46	10.56	47.45	62.47
CD (*P*=0.05)	NS	NS	2.76	0.12	0.55	2.37	2.31
Growth substances							
Control (Water spray)	2.99	2.67	79.79	2.22	6.97	30.84	49.70
Seed treatment thiourea 500 ppm	3.05	2.70	83.72	2.64	8.26	36.97	55.40
Foliar application of thiourea 500ppm	3.11	2.74	91.79	3.34	10.43	46.55	61.64
Seed + foliar application of thiourea (500ppm each)	3.16	2.77	96.83	4.07	12.45	55.99	67.76
Seed treatment TGA 100ppm	3.08	2.72	89.49	3.12	9.60	43.23	61.16
Foliar application of TGA 100ppm	3.06	2.69	86.82	2.99	9.04	41.19	60.32
Seed + foliar application of TGA (100ppm each)	3.15	2.76	95.78	3.94	12.05	54.50	66.81
CD (*P*=0.05)	NS	NS	2.03	0.11	0.44	1.69	2.23

increased due to the effects of thiourea and thioglycolic acid spray, but translocation of dry matter as well as its efficiency were also found to be higher in crop plants sprayed with thiourea and thioglycolic acid as compared to unsprayed crop (Table 1). Thus, improvement in plant height and dry matter accumulation is sufficient to indicate that dry matter partitioning was favorably influenced by thiourea and thioglycolic acid spray. The growth attributes increased under foliar as well as thiourea and thioglycolic acid may be attributed to the better availability of nutrients. In the light of these observations, it is fairly conceived that thiourea might have stimulated the photosynthetic carbon fixation mechanism and hence might have increased canopy photosynthesis. Significant increase in dry matter accumulation obtained with thiourea treatment provide ample support to such effects.

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Effect of On-farm Nutrient Sources on Organic Maize Productivity and Soil Health

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The aim of nutrient management in organic systems is to optimize the use of on-farm sources and minimize losses (Kopke, 1995), and the emphasis is stressed on the use of on-farm inputs rather the off-farm inputs. The philosophy is to feed the soil rather than the crops to maintain the soil health and it means giving back to the nature what has been taken from it (Funtilana, 1990). Organic farming is practiced with in crops, which have either low nutrient requirements or are more responsive to application of organic manures and maize crop highly suits to this aspect on account as its response to organic source of nutrition. The research investiations revealed that the productivity of a crop is controlled by many factors of which the mineral nutrition especially of nitrogen is of prime significance. The availability of organic manures is limited so the other available options for organic nutrition management are crop residue recycling and vermicompost. Cereal crop residues on an average retain 25% of N and P, 50% of S and 75% of K of their total uptake (Prihar *et al*., 2000). The present investigation was aimed at studying the nutrient supplying potential of different on-farm organic sources and their combination to maize and soil health.

The field experiment was conducted on maize in maize (*Zea mays* L.)-wheat (*Triticum aestivum* L. emend Fiori & Paol.) cropping system at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana on a sandy loam soil in a randomized block design. The soil of experiment site was low in organic carbon (0.33%) having 240.0, 35.1 and 135.4 kg ha^{-1} available (alkaline permanganate oxidisable) nitrogen, phosphorus (0.5 M $NaHCO_3$ extractable) and potassium (1 M ammonium acetate exchangeable), respectively. On-farm organic sources used were farmyard manure (FYM), wheat residues (WR), vermicompost (VC) and combination of FYM, WR and VC in equal proportion. Green manuring with sunnhemp (*Crotalaria juncea* L.) was done in all the plots and the organic sources were used to supply half of the recommended 125 kg N ha^{-1}. The quantity of organic sources was applied on the basis of the respective nitrogen content of organic source. The average N, P and K contents on dry weight basis in FYM, VC, wheat straw and sunnhemp were 0.81, 0.80, 1.40; 1.25, 0.46, 1.25; 0.41, 0.17, 1.40 and 2.10, 0.4, 1.53, respectively. Maize hybrid cv. *Paras* was sown as per recommended practices. The maize was followed by wheat which received 10 t FYM, 6 t crop residue and 150 kg rock phosphate ha^{-1}. The average dry mass of green manure crop was 3.50 t ha^{-1}. The insect-pest management in maize was done by using *Trichogramma*-cards @ 100 cards ha^{-1} as one time application after 15 days of sowing. The data on different crop and soil parameters for two years were pooled.

Effect on soil properties: Soil organic carbon was highest with FYM and it was statistically at par with combination of nutrient sources but was significantly better than WR, VC and unfertilized control. WR and VC were statistically at par with each other. Meelu *et al.* (1994) also reported improvement in soil health with application of crop residues. Soil chemical properties except EC were influenced significantly after four crop cycles. All the nutrient sources had significantly lower pH than the unfertilized control. FYM had significantly lower pH than WR and combination of nutrient sources but was statistically at par with VC. The highest available N was with FYM and it was statistically at par with WR and combination of nutrient sources but was significantly higher than the VC. The highest available P was with combination of nutrient sources and it was statistically at par with all the other sources and significantly better than the unfertilized control. The highest available K was with WR and it was statistically at par with FYM and combination of nutrient sources but was significantly better than VC and unfertilized control.

Growth and yield of maize: The highest mean grain yield of maize (42.6 q ha^{-1}) was obtained with combined application of FYM, WR and VC and it was statistically at par with FYM and VC applications alone. Crop residue gave significantly lower grain yield than all the other sources of nutrition but was significantly better than the unfertilized control (Table 1). The poor grain yield with crop residue might be due to immobilization of available and applied nutrients, whereas, FYM, VC and combination of FYM+WR+VC might have supplied nutrients in a sustained manner. Yadav *et al.* (2013) and Davari and Sharma (2010) also reported similar seed yields of crops with FYM and vermicompost. Beri *et al.* (1995) reported reduction in grain yields with incorporation of crop residues. The stover yield also observed the similar

Table 1. Growth, yield attributing characters, grain yield of maize and soil health as affected by different sources of nutrition

Treatment	Crop growth and yield (Pooled data)								Soil health after 4 crop cycles					
	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	Grain rows cob^{-1}	Grains Cob^{-1}	Thousand grain weight (g)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	pH	EC (dSm^{-1})	Available nutrients (kg ha^{-1})			OC (%)
											N	P	K	
FYM	186.4	18.0	4.1	12.2	336.9	306.0	40.7	96.2	7.10	0.144	280.8	62.4	179.2	0.723
WR	173.6	17.3	4.1	11.9	338.9	283.2	34.1	80.7	7.33	0.147	238.9	63.6	184.8	0.566
VC	195.0	18.2	4.3	12.5	325.9	326.2	42.1	94.0	7.27	0.150	212.1	58.1	154.9	0.537
FYM+WR+VC	190.6	18.5	4.1	12.2	363.8	314.9	42.6	95.8	7.33	0.175	268.8	66.9	168.0	0.666
Control	143.3	15.1	3.9	11.5	280.3	254.6	17.8	42.5	7.57	0.218	179.6	34.0	112.0	0.283
CD(P=0.05)	22.3	1.2	NS	0.4	42.7	28.5	4.4	13.2	0.23	NS	54.6	13.2	28.9	0.100

trend as that of grain yield.

The mean plant height at maturity, cob length and grains cob^{-1} did not vary significantly among different nutrient sources but all the nutrient sources were significantly better than unfertilized control. Cob diameter was not influenced significantly with different treatments. Thousand grain weight was highest with VC and it was statistically at with FYM and combination of nutrient sources but was significantly better than the WR and unfertilized control. WR was statistically at par with FYM and significantly better than unfertilized control. Aulakh *et al.* (2013) reported statistically similar yields of maize when grown with organic nutrition sources and chemical fertilizers, whereas, Walia and Kler (2005) reported higher grain yield of organically grown maize than that under inorganic system after five crop cycles.

Organic maize, thus, can be grown by using FYM, vermicompost or combination of FYM+vermicompost+wheat residue but soil organic improvement is highest with use of FYM alone.

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Effect of Spacing on Growth, Yield and Quality of Guava cv. Sardar

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High density orcharding system is a very intensive form of fruit production with great relevance to the food and nutritional prosperity of the ever increasing human population. There are several advantages of high density planting (HDP) such as early production, high returns per ha, efficient use of fertilizers and irrigation water. Spacing of the plants in the system depends on fertility of the soil, availability of water, intensity of sunlight and wind exposure, which will affect growth parameters in guava (Singh, 2008). It differs in many ways from the traditional technology involving system of fruit growing which accommodates a few but large sized trees per unit land area. Such conventional orchards, although require low establishment cost, involve less labour efficiency and incur higher production expenses per unit area of production. They also need longer duration to start giving economical yields and have low and irregular production of fruits. Besides, fruit quality is also affected due to meager sunlight penetration into the dense canopies and the large sized trees pose difficulties in orchard management practices. High density orchards on the other hand, accommodates more of plants per hectare, and are easier/safer to manage, leading to reduced cost of production in the long run. It is a intensive technology, which requires more capital to establish and trees must be precocious with high regular yields to be highly profitable. The technology HDP needs to be tested and fine tuned to the regions of its cultivation under tropical ecosystem of South India including guava growing areas of Karnataka.

The present investigation was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi (University of Horticultural Sciences, Bagalkot), Gokak taluk of Belgaum district, Karnataka during 2012-2013. In present investigation, five different spacing (2x1, 3x1.5, 3x3. 6x3 and 6x6m), were used and observations on growth, yield and quality were recorded at monthly interval in randomly selected uniform healthy plants. The experiment was conducted in Randomized block design (RBD) wth three replications.

The plant height was significantly higher with wider spacing as compared to closer spacing. The plants at 6 x 3 m registered significantly highest plant height of 1.78, 1.87, 1.94, and 2.03 m at 2, 3, 4 and 5 MAP (months after pruning), respectively (Table 1). This was followed by plants accommodated at 3 x 3 m and 6 x 6 m spacing at different months of its growth (Table1). Increase in plant height under wider spacing may be due to the vigorous growth in wider spacing as a result of less competition for light, water and nutrition. Further the plantation was in its initial years of growth and establishment as such has shown higher plant height. Similar findings were reported by Bal and Dhaliwal (2003) Singh and Channana (2005) who got higher plant height at 6 x 6 m spacing compared to 6 x 4 and 6 x 5 m spacing in guava. Contrary, Kundu (2007) reported that the increase in plant density markedly increase the plant height in guava cv. Sardar.

Among the different spacing treatments the plants with wider spacing recorded highest number of secondary and tertiary branches compared to closer spacing. The plants at

Table 1. Effect of different spacing on plant height (m) in guava cv. Sardar

Spacing	Months after pruning (MAP)				
	1	2	3	4	5
2 x 1 m	1.43	1.57	1.66	1.74	1.80
3 x 1.5 m	1.47	1.58	1.67	1.75	1.82
3 x 3 m	1.63	1.71	1.78	1.85	1.90
6 x 3 m	1.61	1.78	1.87	1.94	2.03
6 x 6 m	1.61	1.72	1.84	1.94	2.02
C D at 5%	0.13	0.14	0.16	0.17	0.17

Table 2. Effect of different spacing on number of secondary and tertiary branches in guava cv. Sardar

Spacing	Number of secondary branches (Number of tertiary branches)					North - South (East - West)				
	Months after pruning (MAP)					Months after pruning (MAP)				
	1	2	3	4	5	1	2	3	4	5
2 x 1 m	10.49	12.64	15.32	16.81	18.46	1.12	1.34	1.42	1.48	1.53
	(19.46)	(25.11)	(26.99)	(30.12)	(33.66)	(1.14)	(1.35)	(1.39)	(1.47)	(1.53)
3 x 1.5 m	7.75	11.75	15.80	18.32	19.62	1.26	1.43	1.49	1.54	1.60
	(15.57)	(22.07)	(24.57)	(27.43)	(30.29)	(1.19)	(1.46)	(1.50)	(1.55)	(1.61)
3 x 3 m	8.39	13.93	16.88	18.43	18.75	1.59	1.75	1.81	1.85	1.95
	(17.89)	(25.23)	(26.68)	(29.83)	(33.86)	(1.52)	(1.62)	(1.64)	(1.78)	(1.83)
6 x 3 m	8.75	14.83	16.79	19.28	19.75	1.46	1.64	1.69	1.73	1.79
	(19.00)	(27.25)	(30.17)	(34.00)	(36.50)	(1.43)	(1.55)	(1.61)	(1.69)	(1.75)
6 x 6 m	8.94	12.18	13.71	16.64	18.01	1.25	1.37	1.44	1.50	1.55
	(17.84)	(24.31)	(26.81)	(30.77)	(34.02)	(1.32)	(1.49)	(1.54)	(1.58)	(1.63)
C D at 5%	NS	NS	NS	1.92	1.16	0.15	0.21	0.20	0.20	0.21
	(NS)	(NS)	(NS)	(3.92)	(3.63)	(0.20)	(0.26)	(0.18)	(0.18)	(0.18)

6 × 3 m registered significantly maximum number of secondary and tertiary branches and was at par with 3 × 3 m spacing (Table 2). Increase in number of secondary and tertiary branches in wider spacing may be due to availability of both spatial and floor space resulting in less competition between the plants for light, nutrition and water. Therefore, plant under spacing of 6 x 3 and 3 x 3 m putts up more vigorous growth producing higher number of secondary and tertiary branches. These results are in agreement Bal and Dhaliwal (2003) who reported wider canopy spread in plants with wider spacing.

The plants with intermediate spacing of 3 × 3 m recorded higher canopy spread in both North- South and East-West directions compared to other spacing. This was found on par with plants at 6 × 3 m spacing (Table 2). Higher canopy spread in intermediate spacing may be due to availability of sufficient space for canopy spread in the initial stages of establishment. In the present investigation also the plants are of 3 years old and are in the initial stages of establishment. Bal and Dhaliwal (2003) found maximum canopy spread (N-S and E-W) in plants spaced at 6 x 6 m, but Kundu (2007) was of opinion that increased in plant density showed decreased canopy spread in guava cv. L-49.

The results on fruit set revealed that plants at intermediate spacing of 3 × 3 and 3 × 1.5 m produced significantly higher number of flowers and their by set maximum number of fruits as depicted by higher percentage of fruit setting (Table 3). Higher flowering and fruit setting may be attributed to production of optimum number of flower and fruit bearing tertiary shoots (Table 2) in plants under the above population density. Further at 3 x 3 and 3 x 1.5 m spacing the light penetration in to the canopy was also optimum for better initiation of flower and higher fruit setting. Investigations also revealed significantly highest number of fruits per plant (43.31) at 3 × 3 m, which was at par with 3 x 1.5 m. Similar results were found by Bal and Dhaliwal (2003) and Gorakhsingh (2007) in guava. In the present investigation, significantly highest yield per ha were noted in plants at closer spacing due to higher yielding ability per unit area occupied.

Table 3. Effect of different spacing on yield and quality parameters during mrig bahar in guava cv. Sardar

Spacing	Per cent fruit set	No. of fruit set plant^{-1}	Number of fruits harvested plant^{-1}	Yield (tons ha^{-1})	TSS(^{o}B)	Ascorbic acid (mg 100 g^{-1})
2 x 1 m	80.96	36.18	34.23	34.93	13.25	119.78
3 x 1.5 m	85.63	45.18	42.98	19.98	13.73	133.33
3 x 3 m	85.45	45.74	43.31	9.90	12.10	156.18
6 x 3 m	81.18	38.59	36.92	4.26	12.25	178.83
6 x 6 m	74.25	27.26	25.83	1.50	13.24	227.50
C. D. at 5%	6.97	11.48	10.97	5.84	0.71	7.81

The quality parameters like TSS and ascorbic acid content in fruits recorded significant changes with planting densities. But contrary to present investigation Kundu (2007), Bal and Dhaliwal (2003) reported that fruits from wider spacing had superior quality parameters to closer spacing in well established guava plantation. The results are in agreement with those of Ajithpal and Dhaliwal (2004) who reported that plants under 6 x 6 m and 6 x 4 m spacing produced fruits with high vitamin C content due to interception of more radiation in the canopy. Similar results were also reported by Gorakhsingh (2007) in guava.

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Evaluation of Moisture and Moisture Retention Capacity of Castor (*Ricinus communis* L.) in Different Storage Duration

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Castor (*Ricinus communis*) is the primary host plant of Eri silkworm, *Samia ricini* Boisd and widely distributed and cultivated as oilseed. The silkworm is polyphagous and feeds on the leaves of different food plants and castor is the most preferred food plants compared to others rearing of eri silkworm. Quality and quantity of food as well as the highly nutritious and nutrient balanced foods play an important role in the survival, longevity, distribution, reproduction, healthy growth and development of any insect (Purohit and Pavankumar, 1996; Prasad, 2009). Nutrition is the most important physiological factors, which is derived from the host plant leaf (Sundar Raj *et al*., 2000). So better the quality of leaves greater would be quality of cocoons. The nutritional parameters like moisture and moisture retention capacity plays major role in keeping the preserved host plant leaves fresh till they are consumed by the silkworm. Duration of storage, temperature, humidity, light, aeration, quality of leaves or shoots in a given space (density of storing) and many other conditions greatly influence the quality of leaves. The present study deals with an attempt to see the changes in moisture and moisture retention capacity of castor leaves in different storage duration for effective utilization in eri silkworm rearing.

The present study was carried out at Assam Agricultural University, Jorhat, during autumn and spring season 2010-11. According to the method suggested by Muniraju *et al*. (1999), the tender, medium and mature leaves of castor were harvested separately in the morning hours and heaped on mat with wet gunny cloth covering for 24 hours. Moisture and moisture retention capacity were determined on dry weight basis by the method suggested by Ninge Gowda and Sudhakar (2002). One hundred fresh leaves comprising of tender, medium and mature leaves weighed immediately after harvested. They were then kept at room temperature weighed again after 4, 8, 12 and 24 hours. The leaves were then dried in hot air oven at 60°C for 48 hours for the dry weight and moisture retention capacity.

The leaf storage had significant effect on nutrient contents of castor leaves (Table 1). The moisture content was found in decreasing trend and had significant effect with the maturity of the leaves (79.60-76.85%). During spring, the moisture content in fresh leaves was maximum (81.01%), which was significantly higher than the autumn (74.96%) season leaves. The moisture retention capacity (%) exhibited decreasing trend with the maturity of leaves (91.01-88.64%) as well as with the advancement of storage duration. After 4 hours, moisture retention capacity was highest in tender leaves (91.01%), being significantly more than the medium and mature leaves and the lowest value was recorded after 24 hours (68.10%). Significantly, the moisture retention capacity was observed maximum in spring season than the autumn and decreased gradually with the increasing storage

Table 1. Moisture and moisture retention capacity of castor leaf in different storage duration

Factor	Moisture	Moisture retention capacity (%)			
	content (%)	4 Hr	8 Hr	12 Hr	24 Hr
Leaf type					
Tender	79.60	91.01	86.97	81.40	78.30
Medium	77.50	89.12	86.11	79.81	69.63
Mature	76.85	88.64	84.34	76.67	68.10
CD (5%)	4.64	4.24	4.31	7.83	5.02
Season					
Spring	81.01	93.28	88.75	84.00	78.31
Autumn	74.96	91.24	87.05	82.25	75.80
CD (5%)	7.72	7.73	6.51	6.97	6.12

duration. In both the seasons, it was found highest after 4 hours and the lowest after 24 hours of storage duration. The results are in conformity with the findings of Mir *et al*. (2012).

The present study indicates that storage of leaf considerably decreased moisture and moisture retention capacity. Therefore, during preservation of castor leaves, care has to be taken to minimize moisture loss of leaves to maintain quality and healthy growth and development of eri silkworm.

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Synthesis and Antifungal Evaluation of N-Benzylidenenaphthalen - 1-amines

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Carbon-nitrogen double bond is widely distributed in nature, in the form of biological compounds which are important for the vital metabolism of the living organisms and in various synthetic compounds of pharmaceutical and agricultural importance. N-substituted imines, also known as Schiff bases were first reported by Hugo Schiff in 1864. The synthesis and assaying of bio-potential of imines have received considerable interest in past decades (Chen and Brown, 2000). The imines, due to the presence of carbon-nitrogen double bond in their molecules, provide a potential site for both chemical and biological activity (Matharu *et al*., 2005; Khera *et al.,* 2005). The nature of substitutes, its position in the phenyl ring and the extent of conjugation play a vital role in determining the chemical and biological behaviour of the compound, which is required to overcome the increasing fungal infestations and growing resistance in pathogens (Annapoorni and Krishnan, 2011; Rai *et al*., 2006; Sandhar *et al*., 2006a; Gupta *et al*., 2012). The new combinations are needed to be synthesized. The present work involves the synthesis of novel series of imines by condensing naphthalen-1-amine with respective aryl aldehydes and their antifungal evaluation against various phytopathogenic fungi.

Melting points were taken in open capillaries in an electric melting point apparatus and were uncorrected. Purity of the compound was checked by TLC. Infrared spectra were recorded on a Perkin Elmer FT-IR spectrometer using KBr discs. Proton Nuclear Magnetic Resonance spectra and ^{13}C Nuclear Magnetic Resonance spectra were recorded on a Bruker Avance II 400 NMR spectrometer in $CDCl_3$ with TMS as internal solvent. Mass spectra were recorded on Waters LC-MS-MS Quattro Micro™ API. Elemental analysis (C,H,N) were recorded on Thermo Scientific Elemental Analyser for CHN.

Synthesis of N-benzylidenenaphthalen-1-amines: Benzaldehyde (I) (0.25 mol) and naphthalen-1-amine (0.25 mol) were dissolved in 10 ml of ethanol in a round bottom flask. The mixture was refluxed until a clear solution was obtained. The clear solution was cooled to get the crude solid. This crude product was then recrystallized from ethanol to obtain N-benzylidenenaphthalen-1-amine (Ia). Reaction of naphthalen-1-amine with 2-nitrobenzaldehyde (II), 3-nitrobenzaldehyde (III), 4-nitrobenzaldehyde (IV), 4-methoxybenzaldehyde (V), 3,4-dimethoxybenzaldehyde (VI), 3,4,5-trimethoxybenzaldehyde (VII), 2-hydroxybenzaldehyde (VIII), 3-hydroxybenzaldehyde (IX) and 4-hydroxybenzaldehyde (X) was carried out by above procedure to give N-(2-nitrobenzylidene) naphthalen-1-amine (IIa), N-(3-nitrobenzylidene) naphthalen-1-amine (IIIa), N-(4-nitrobenzylidene) naphthalen-1-amine (IVa), N-(4-methoxybenzylidene) naphthalen-1-amine (Va), N-(3,4-dimethoxybenzylidene) naphthalen-1-amine (VIa), N-(3,4,5-trimethoxybenzylidene) naphthalen-1-amine (VIIa), N-(2-hydroxybenzylidene) naphthalen-1-amine (VIIIa), N-(3-hydroxybenzylidene) naphthalen-1-amine (IXa) and N-(4-hydroxybenzylidene) naphthalen-1-amine (Xa), respectively.

In *vitro* screening for antifungal potential: Each compound (20 mg) was dissolved in 1 ml Tween 20 (Polyoxyethylene sorbitan) and 9 ml sterilized distilled water to prepare stock solution of 2000µg ml^{-1}. The stock solution was serially diluted to obtain the required concentrations of 1000, 500, 250, 100, 50 and 25 µg ml^{-1} of the test compounds. Cavity slides were used for studying the antifungal activity. The spore suspension of test fungi was prepared in sterilised distilled water to from fresh spores of *Ustilago hordei, Bipolaris sorokiniana and Puccinia striiformis.* Suspension was filtered through three layers of sterilised cheese cloth in order to remove mycelial particles under aseptic conditions. Haemocytometer was used to form standardized spore suspension (1 x 10^6 spores ml^{-1}). Small droplets (0.02 ml) of test solution and spore suspension in equal amount were seeded in the cavity of cavity slides. These slides were kept in Petri dishes lined with moist filter paper and incubated for 24-72 hr at 24±1 °C for *U. hordei, B. sorokiniana* and at 10±1°C for *P. striiformis*. The germination of spores was recorded and the per cent spore germination inhibition was calculated.

Antifungal activity for *P. grisea* and *H. oryzea* was

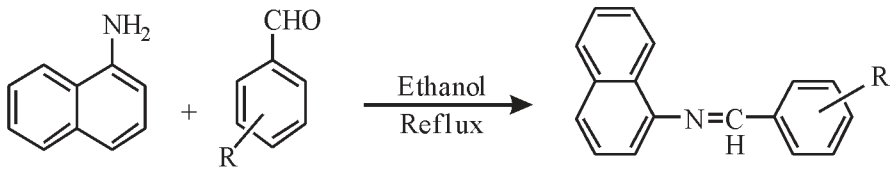
evaluated for fungi toxicity by applying poisoned food technique. Approximately 99 ml of PDA medium was taken in the round bottom flask, 1 ml (different concentrations) of each compound was added to different flasks and the contents were mixed thoroughly. The contents of the flask were poured aseptically into the Petriplates. Test compound was, however, replaced by an equal amount of DMF (Dimethylformamide) only in the control set. After the medium solidified, one inoculum disc of the test fungi, was aseptically placed / inoculated to each, petriplate and incubated at 24±1°C. The average diameter of fungal colonies was measured on the 7th day after inoculation and percentage mycelial growth inhibition was calculated. The results were compiled in terms of ED_{50} values (effective dose to inhibit 50% spore germination).

Condensation of benzaldehyde (I), 2-nitrobenzaldehyde (II), 3-nitrobenzaldehyde (III), 4-nitrobenzaldehyde (IV), 4-methoxybenzaldehyde (V), 3,4-dimethoxybenzaldehyde (VI), 3,4,5-trimethoxybenzaldehyde (VII), 2-hydroxybenzaldehyde (VIII), 3-hydroxybenzaldehyde (IX) and 4-hydroxybenzaldehyde (X) with naphthalen-1-amine resulted in the formation of N-benzylidenenaphthalen-1-amine (Ia), N-(2-nitrobenzylidene) naphthalen-1-amine (IIa), N-(3-nitrobenzylidene) naphthalen-1-amine (IIIa) , N-(4-nitrobenzylidene) naphthalen-1-amine (IVa) , N-(4-methoxybenzylidene)naphthalen-1-amine (Va), N-(3,4-dimethoxybenzylidene) naphthalen-1-amine (VIa), N-(3,4,5-trimethoxybenzylidene) naphthalen-1-amine (VIIa), N-(2-hydroxybenzylidene) naphthalen-1-amine (VIIIa), N-(3-hydroxybenzylidene) naphthalen-1-amine (IXa) and N-(4-hydroxybenzylidene) naphthalen-1-amine (Xa), respectively. The reaction sequence for the formation of Schiff base is given in Scheme 1.

The products were characterized on the basis of elemental analysis and spectral studies. The infrared spectra of the compounds Ia-Xa showed bands in the range of 1617-38 cm^{-1} indicating the presence of azomethinic linkage. The ^{1}H NMR spectra of the synthesized N-benzylidenenaphthalen-1-amines in $CDCl_3$ exhibited signals at d 8.02, 7.86, 7.86, 8.13, 8.37, 7.70, 7.13, 7.40, 7.59 and 8.13 for compounds Ia-Xa, attributed to CH=N protons, respectively. The multisignals within the range of d 6.80-9.9 were assigned to the aromatic protons of both rings. The ^{13}C NMR spectra provide further support for the structural characterization of the synthesized compounds. According to the ^{13}C NMR spectra, compounds Ia-IVa and VIIIa-Xa have 17 signals and compounds Va, VIa, VIIa have 18, 19, 20 signals, respectively. The peaks in ^{13}CNMR spectrum for compounds Ia-Xa appeared at 100-160 ppm. The carbons of methoxy group were observed at the 55-60 ppm range. These ^{13}CNMR peaks corroborated well with ^{1}HNMR spectra data. The mass spectra of all the synthesized compounds showed the molecular ion peak m/z at M^++1 region. The N-benzylidenenaphthalen-1-amine and its C-phenyl derivatives along with their characteristics are recorded in Table 1 and molecular ion peak with their elemental analysis are recorded in Table 2.

The synthesized compounds were screened *in vitro* for their antifungal activity against *U. hordei, P. striiformis* and *B. sorokiniana* by applying spore germination inhibition technique (Nene and Thapliyal, 1993) and by poisoned food technique (Sandhar *et al.,* 2006b) against *P. grisea, D. oryzae*. The results have been expressed in terms of ED_{50} values (Table 3).

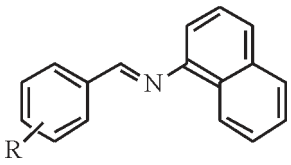
The data presented in Table 3 showed that all the test compounds possessed promising to moderate fungi toxic potential against all the test fungi. N-(4-nitrobenzylidene)naphthalen-1-amine (IVa) was most effective against *B. sorokiniana* with ED_{50} value 220 mg/ml. Rest all the compounds possessed ED_{50} value less than 712 mg/ml against the test fungi in *B. sorokiniana* and less than 600 mg/ml in *P.grisea*. Against *D. oryzae* five test compounds inflicted promising antifungal potential *viz.* N-(2-nitrobenzylidene) naphthalen-1-amine (IIa), N-(4-nitrobenzylidene) naphthalen-1-amine (IVa), N-(3,4-dimethoxybenzylidene) naphthalen-1-amine (VIa), N-(2-hydroxybenzylidene) naphthalen-1-amine (VIIIa) and N-(4-hydroxybenzylidene) naphthalen-1-amine (Xa) posessed with



Scheme 1

R=H, 2-NO_2, 3-NO_2, 4-NO_2, 4-OCH_3, 3,4-OCH_3, 3,4,5-OCH_3, 2-OH, 3-OH, 4-OH

Table 1. Characteristics of N-benzylidenenaphthalen-1-amine and its C-phenyl derivatives



Compound	R	Molecular wt.	Colour	Yield (%)	m.p. (^{0}C)
Ia	H	231	Yellow	80	67-70
Iia	2-NO_2	276	Brown	68	108-110
IIIa	3-NO_2	276	Lemon	65	97-100
IVa	4-NO_2	276	Yellow	70	146-148
Va	4-OCH_3	261	Flesh	66	83-85
VIa	3,4-OCH_3	291	Cream	63	95-97
VIIa	3,4,5-OCH_3	321	Light yellow	79	118-120
VIIIa	2-OH	247	Orange	67	105-107
Ixa	3-OH	247	Yellow	72	93-95
Xa	4-OH	247	Brick red	78	142-145

Table 2. Molecular ion peak and elemental analysis of the synthesized compound

Compound	Molecular formula	Molecular ion peak	Elemental analysis		
		m+1	C% Found (Cal.)	H% Found (Cal.)	N% Found (Cal.)
Ia	$C_{17}H_{13}N$	232	88.13(88.28)	5.42(5.67)	5.92(6.06)
IIa	$C_{17}H_{12}N_2O_2$	277	72.8(73.90)	4.16(4.38)	11.02(10.14)
IIIa	$C_{17}H_{12}N_2O_2$	277	73.07(73.90)	4.33(4.38)	10.06(10.14)
Iva	$C_{17}H_{12}N_2O_2$	277	72.1(73.90)	4.27(4.38)	10.06(10.14)
Va	$C_{18}H_{15}NO$	262	80.78(82.73)	5.66(5.79)	5.13(5.36)
Via	$C_{19}H_{17}NO_2$	292	77.9(78.33)	5.42(5.88)	4.99(4.81)
VIIa	$C_{20}H_{19}NO_3$	322	73.56(74.75)	6.02(5.96)	4.23(4.36)
VIIIa	$C_{17}H_{13}NO$	247	81.06(82.57)	5.41(5.30)	5.38(5.66)
IXa	$C_{17}H_{13}NO$	247	82.55(82.57)	5.27(5.30)	5.38(5.66)
Xa	$C_{17}H_{13}NO$	247	81.03(82.57)	5.09(5.30)	4.97(5.66)

ED_{50} values 100, 170, 170, 128 and 198 g/ml, respectively. Against *P. grisea*, compound N-(4-nitrobenzylidene) naphthalen-1-amine (IVa) showed maximum potential with ED_{50} value 175 mg/ml. Compounds N-(4-hydroxybenzylidene) naphthalen-1-amine (Xa) and N-(4-nitrobenzylidene) naphthalen-1-amine (IVa) were the most active ones against *P. striiformis* with ED_{50} value of 115 and 162 mg/ml, respectively. Against *U. hordei,* only compound (Va) possessed moderate potential with ED_{50} value 185 mg/ml.

It is concluded from the data given in Table 3 that the substituted compounds were more potent against all the test fungi as compared to unsubstituted one. In case of nitro substituted N-benzylidenenaphthalen-1-amines, the relative order of antifungal potential is according to their position of the nitro group in the synthesized compounds. Against *P.grisea, U. hordei, P. striformis* and *B. sorokiniana,* the order of fungitoxicity was IVa > IIIa > IIa but for *H. oryzae,* was IIa > IVa > IIIa.

In case of compounds Va, VIa, VIIa, VIIIa, IXa and Xa order of reactivity also varie accordingly with different substitution. In compounds containing methoxy group as substitution, the order of reactivity for *P.grisea, U. hordei, P. striformis* and *B. sorokiniana* was Va > VIa > VIIa but for *H. oryzae* order of reactivity was VIa > Va > VIIa. Compounds having hydroxyl group at various position have the order of reactivity Xa > IXa > VIIIa for *P.grisea, U. hordei, P. striformis* and *B. sorokiniana* and VIIIa > IXa > Xa for *H. oryzae.* In terms of substituents the order of bioefficacy against *P.grisea and H.oryzae* was: -NO_2 > -OH > -OCH_3; for *U. hordei*: -OCH_3 > -NO_2 > -OH; for *P. striformis* was –OH > -NO_2 > -OCH_3 and for *B. sorokiniana* was –NO_2 > -OCH_3 > -OH.

Table 3. Antifungal activity of N-benzylidenenaphthalen-1-amine and its C-phenyl derivatives

Compound	*B. sorokiniana*	*D. oryzae*	*P. grisea*	*P. striiformis*	*U. hordei*
Ia	*	*	*	*	*
IIa	600	100	400	450	400
IIIa	525	450	350	250	375
Iva	220	170	175	162	300
Va	350	250	250	300	185
Via	400	170	375	625	500
VIIa	513	397	418	694	667
VIIIa	712	128	437	345	564
IXa	629	505	397	286	498
Xa	461	198	215	115	401
**Tilt 25 EC	40	45	45	25	-
***Raxil	-	-	-	-	7

*more than 1000 mg/ml

** Standard fungicide for *P.grisea, D.oryzae, B.sorokiniana and P.striiformis*

*** Standard fungicide for *U.hordei*

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Comparative Development of *Spodoptera litura* (Fabricius) on Different Cultivars of Cabbage

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Cabbage, *Brassica oleracea* var. capitata (Linnaeus) is the fourth most widely grown vegetable crop of India, grown over an area of 397.41 thousand ha with a production of 8603.09 thousand MT (Anonymous, 2013). It is a biennial crop that originated from wild cliff cabbage. It is attacked by many insect pests. Among all, tobacco caterpillar, *Spodoptera litura* (Fabricius) has emerged as the most destructive insect pest on cabbage. The larva is polyphagus and feeds on mungbean, soybean and various vegetables recorded as hosts (Qin and Ye, 2007). Outbreaks of the pest occurs due to its resistance to insecticides and favourable weather conditions (Thanki *et al*., 2003). The pest is widely distributed throughout tropical and temperate Asia, Australia and Pacific islands (Monobrulla and Shankar, 2008). Its wide spread and pest status has been attributed to its polyphagy and its ability to undergo both facultative diapause and seasonal migration (Devanand and Rani, 2008).

Keeping in view the economic importance and the emerging problem of *S. litura* on cabbage, studies were conducted on biological parameters of the insect on various cabbage cultivars. The biological parameters can help us evaluate suitability and unsuitability of different cultivars. The cultivar least preferred by the insect pest may be recommended for cultivation after field trials.

Studies on development of tobacco caterpillar, *S. litura* on different cultivars of cabbage were conducted in laboratories of the Department of Entomology, Punjab Agricultural University, Ludhiana during 2012-13. The nursery was sown on raised seed beds (150 cm x 60 cm x 20 cm) as well as in earthen pots (22.5 cm dia). The initial culture of *S. litura* was developed by collecting a large number of larvae from castor plants. The field collected larvae were reared for three generations in laboratory conditions (24 ± 1°C; 65 ± 5% R.H.) on fresh cabbage leaves. To prevent microbial infection in the culture, the cabbage leaves were washed with 0.001% potassium permanganate solution followed by rinsing with water and air drying. All the glassware used in the experiments were treated with 2% formalin and then dried in an oven at 30°C for 8 hrs. Investigation on various aspects of biology were carried out at a constant temperature of 24 ± 1°C and relative humidity of 65 ± 5% using a BOD incubator.

Larvae were reared separately on the respective hosts upto adult stage and eggs were obtained with a view to determine the incubation period and hatching percentage. The egg masses were surface sterilized with 0.02% sodium hypochlorite solution, dried and allowed to hatch. The petri-plates (7.5 cm x 1.25 cm) having leaves of different cultivars with eggs were kept in an incubator. The egg duration and number of larvae hatched were recorded. To determine, duration of different larval instars, total larval duration and larval survival percentage, the individual larvae in four replications with fifty larvae in each were transferred in a plastic vial (2.5 cm x 7.5 cm) and provided with fresh food. The food was changed daily in the morning and observations for the exuviae as well as head capsule were taken to confirm moulting. The number of larvae which successfully pupated were counted to work out the larval survival. The initiation of pre-pupal stage was confirmed by the presence of a sluggish and dark coloured larva that stopped feeding. The pre-pupa was transferred to the jars containing sterilized soil to facilitate pupation. The pupae formed were transferred to another set of vials containing sponge covered with blotting paper. Out of the total pupae, the pupae from which the moths emerged were counted and per cent pupal survival was worked out. The observation was taken daily to record the pupal period, pupal weight and adult emergence. The male and female adults emerged from the respective hosts on the same day were paired in mating chambers and provided with 10 per cent honey solution on cotton swab as food. The adult longevity was taken as the time interval between the emergence of adults and its death. To know the fecundity, the eggs oviposited on the leaves were counted daily under the microscope. Fresh leaves were introduced for subsequent oviposition. The total life cycle was calculated from the time of egg laying till the emergence of moths.

Significantly lower incubation period was recorded on

Pusa Mukta (4.27 days) followed by Golden Acre and KGMR-1 being at par with each other as compared to other cultivars (Table 1). Maximum incubation period was observed on Pride of India (4.87 days) followed by Pusa Drum Head being on par with each other. More or less similar result has been reported by Soni *et al*. (2001) who observed the mean incubation period of 5.60 days on cabbage. The maximum hatchability (86.66 %) was on Pusa Mukta being on par with Golden Acre. Minimum hatchability was on Pride of India followed by Pusa Drum Head and KGMR-1.

The larvae moulted four times and passed through five instars. The mean duration of first instar larvae varied significantly from 2.75 to 3.90 days with a minimum duration on Pusa Mukta which was statistically on par with Golden Acre. These were followed by KGMR-1, Pride of India and Pusa Drum Head (Table 1). The minimum mean duration of second instar larvae was on Pusa Mukta (3.66 days) with non significant variation from Golden Acre, but differed significantly from KGMR-1, Pusa Drum Head and Pride of India. The duration of third instar larvae was minimum on Pusa Mukta (3.37 days). It was statistically on par with Golden Acre but differed significantly from KGMR-1, Pusa Drum Head and Pride of India which were on par with each other. The durations of fourth and fifth instar larvae showed a similar trend to that of third instar. The total larval duration was found to be minimum on Pusa Mukta (15.55 days) which was statistically on par with Golden Acre and it differed significantly from KGMR-1 and Pusa Drum Head. Maximum larval duration was observed on Pride of India (20.09 days) and it varied significantly from other cultivars. The findings of the present study are similar to the results reported by Shahout *et al.* (2011) on cabbage.

The minimum survival of larvae was on Pride of India (71.00%) followed by Pusa Drum Head and was lower significantly from KGMR-1 and Golden Acre. Maximum larval survival was however recorded on Pusa Mukta (89.00 %). Xue *et al*. (2010) found larval survival of 75.04 per cent on Chinese cabbage whereas Chand and Tripathi (2008) had reported 91.00 per cent larval survival on cabbage. Minimum pre-pupal period was observed on Pusa Mukta (2.26 days) followed by Golden Acre, KGMR-1, Pusa Drum Head and Pride of India (Table 1). Maximum pupal period was recorded on Pride of India (9.08 days) which varied significantly from KGMR-1 and Pusa Drum Head. The minimum pupal period was observed on Pusa Mukta (6.38 days) which was on par with Golden Acre.

The female pupae weighed heaviest on Pusa Mukta,

Table 1. Effect of cabbage cultivars on incubation period and hatchability of eggs; larval duration and survival; pre-pupal, pupal period, pupal weight and survival; adult longevity, pre-oviposition, oviposition, post oviposition period and fecundity of *S.litura* (Mean ± SE)

Cultivar Stage	Pride of India	Pusa Drum Head	KGMR-1	Golden Acre	Pusa Mukta	CD (p=0.05)
Incubation period (days)	4.87±0.10	4.75±0.11	4.53±0.11	4.38±0.07	4.27±0.09	0.29
Hatchability of eggs (%)						
Laval stage	81.76±1.06	82.74±1.03	83.80±0.85	85.18±0.90	86.66±0.82	2.82
I instar	3.85±0.15	3.90±0.05	3.74±0.06	2.85±0.05	2.75±0.04	0.54
II instar	4.68±0.12	4.60±0.011	4.49±0.096	3.67±0.07	3.66±0.09	0.68
III instar	4.15±0.04	4.06±0.05	3.96±0.07	3.39±0.09	3.37±0.06	0.20
IV instar	4.01±0.06	3.87±0.11	3.84±0.06	3.06±0.05	3.03±0.07	0.57
V instar	3.40±0.04	3.37±0.04	3.35±0.03	2.78±0.05	2.74±0.09	0.17
Total larval duration (days)	20.09±0.14	19.80±0.21	19.38±0.16	15.75±0.26	15.55±0.12	0.56
Pre pupal period (days)	2.89±0.10	2.79±0.05	2.78±0.01	2.32±0.02	2.26±0.02	0.16
Pupal period (days)	9.08±0.05	8.94±0.03	8.89±0.03	6.43±0.08	6.38±0.03	0.15
Pupal survival (%)	80.00±2.42	80.00±2.08	84.00±2.04	88.00±2.16	92.00±1.83	6.37
Pupal weight (g)						
Male	0.349±0.003	0.350±0.00202	0.354±0.002	0.359±0.003	0.362±0.003	0.008
Adult longevity (days)						
Male	4.90±0.07	4.87±0.03	4.82±0.13	4.75±0.09	4.70±0.07	NS
Female	6.31±0.05	6.27±0.10	6.27±0.10	6.14±0.03	6.04±0.06	NS
Pre-oviposition period (days)	2.02±0.06	2.12±0.03	1.97±0.05	2.10±0.04	2.12±0.03	NS
Oviposition period (days)	2.52±0.05	2.45±0.09	2.55±0.10	2.47±0.09	2.42±0.05	NS
Post oviposition period (days)	1.77±0.08	1.70±0.04	1.75±0.10	1.57±0.07	1.50±0.04	NS
Fecundity	137.82±2.94	140.55±2.59	142.35±1.38	144.47±1.69	144.80±2.31	NS
Total life cycle (days)	36.93±0.25	36.28±0.35	35.58±0.14	28.88±0.43	28.46±0.54	1.11

which was on par with Golden Acre but was significantly higher than that on KGMR-1, Pusa Drum Head and Pride of India. Similar trend was observed in case of male pupae also.

The maximum pupal survival of 92.00 per cent was observed on Pusa Mukta followed by Golden Acre, which was significantly higher than all other cultivars (Table 1). Xue *et al.* (2010) also reported a high pupal survival of 91.4 per cent to 95.9 per cent on different host plants, which was attributed to climatic and host variations.

There were no significant differences among five cultivars in pre-oviposition, oviposition and post-oviposition periods (Table 1). The pre-oviposition period ranged from 1.97 days on KGMR-1 to 2.12 days on Pusa Drum Head and Pusa Mukta. Maximum oviposition period was recorded on KGMR-1 followed by Pride of India, Golden Acre, Pusa Drum Head and Pusa Mukta whereas post-oviposition period was found to be the minimum on Pusa Mukta and maximum on Pride of India.

Longevity of adult moths did not differ significantly on different cultivars of cabbage. However, in general, females lived longer than males. Adult longevity ranged from 4.70 days to 4.90 days in males and 6.04 days to 6.31 days in case of females on different cultivars (Table 1). In contrast to present findings, Xue *et al*. (2010) reported males to live longer (7.4 days) than females (6.6 days) on Chinese cabbage. There were non significant differences in the fecundity of *S. litura* on different cultivars. Maximum fecundity was observed in case of Pusa Mukta (144.80 eggs/ female) followed by Golden Acre, KGMR-1, Pusa Drum Head and Pride of India. In contrast Soni *et al*. (2001) reported a higher fecundity of 557.06 and 397.63 on cabbage and cauliflower, respectively. Total life cycle was found to be minimum on Pusa Mukta (28.46 days) followed by Golden Acre being on par with each other (Table 1). Maximum life cycle duration was on Pride of India differing significantly from Pusa Drum Head and KGMR-1 (35.58 days)

From the present study, it may be concluded that out of five cultivars of cabbage, Pride of India recorded lowest fecundity, hatchability of eggs with maximum incubation, larval, pre-pupal and pupal periods while the cultivar Pusa Mukta recorded maximum fecundity, hatchability of eggs with minimum period of various developmental stages. Thus, the cultivar Pride of India, due to lower suitability, can help in reducing the population of *S. litura* on cabbage. The reasons for lower suitability need to be elucidated further investigations.

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Efficacy of Plant Extracts Against Fusarium Wilt of Tomato

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Fusarium species caused a huge range of diseases on an extraordinary range of host plants. The fungus can be recovered from any part of the plant from the deepest root to the highest flower (Booth, 1997 and Summeral *et al*., 2003). Wilt of tomato (*Lycopersicon esculentum*) caused by *Fusarium oxysporum* f.sp. *lycopersici* is a disease that cause serious economic losses (Agrios, 2005). The fungus causes vascular wilts by infecting plants through the roots and growing internally through the cortex to the stele (Bowers and Lock, 2000). Control of wilt diseases depends mainly on fungicides (Minton, 1986). Several fungicides have been used for control of different plant pathogens including fusaria (Liggit et al., 1997) and the number of effective fungicides with negligible effect on the environment is rare. Fungicides are expensive, can cause environmental pollution and may cause the selection of pathogen resistance (Zhonghua and Michailides, 2005). Due to the aforementioned considerations, there is a need to develop new management systems to reduce the dependence on synthetic agrochemicals. Recent trend favour the use of alternative substances derived from natural plant extracts to control diseases (Xuan *et al*., 2003 and Islam *et al*., 2004). The dried leaves of *Ocimum sanctum* L. have been mixed with stored grains to repel insects (Biswas and Biswas, 2005). Alternative methods of controlling the disease have been studied with emphasis on novel compounds derived from plant sources (Albouvettle, 1999). Plants are good alternatives to chemical pesticides, as they are readily biodegradable in nature.

The aim of the present study was to compare the effect of extracts of *Ocimum sanctum, Aegle marmelos, Citrus limon, Putranjiva roxburghii* and fungicide Bavistin (Carbendazim 50% WP) on *F. oxysporum* f.sp. *lycopersici* mycelial growth and spore germination *in vitro*.

Preparation of extracts: Extracts from leaves of four plants namely *Citrus limon, Putranjeeva roxburghii, Ocimum sanctum* and *Aegle marmelos* were collected from field of Punjab Agricultural University, Ludhiana and tested for their efficacy in reducing the mycelial growth and spore germination of *Fusarium oxysporum* f.sp. *lycopersici in vitro* using the poisoned food technique (Nene and Thapliyal, 1993). Plant leaves extract was prepared according to Sallam (2011). Ten grams of fresh leaf material of each plant species were collected, washed with water and crushed in a grinder by adding sterile distilled water at the rate of 10 ml gm^{-1} of plant tissue and the homogenates were centrifuged at 10,000 rpm for 15 minutes and the supernatant solutions were collected. The plant extract was diluted further to have 10 and 20% concentration (v/v). These fractions were sterilized using 0.22 µm milipore filter assembly and used for assay of antifungal activity as described below.

The filtrate of each plant extract was mixed with autoclaved PDA medium at 10 and 20% concentration. Plant extract supplemented medium was poured in sterilized Petri plates and allowed to solidify. These Petri plates were inoculated at the centre with a 5 mm agar disc from the 7 days old fungal culture of *F. oxysporum* f.sp. *lycopersici*. In control, a Petri plate containing PDA media with requisite amount of sterilized water instead of a plant extract was also inoculated with a plant pathogen. Bavistin (Carbendazim 50% WP) was used as positive control of fungi and sterilized water was used to prepare stock solution. The inoculated Petri plates were then incubated at $25\pm2^{o}C$ for 7 days. The diameter of the fungal colony was measured using a meter rule along two diagonal lines drawn on the reverse side of each Patri plate 24 hrs after inoculation. Each treatment was replicated three times with three plates per replication. Percentage inhibition of mycelia growth was calculated and statistical analysis of the data was done using Completely Randomized Block Design (CRD).

In the present study, 20% concentration of aqueous extracts of plant leaves of *Citrus limon, Putranjeeva roxburghii, Ocimum sanctum* and *Aegle marmelos* and 0.2% fungicide Bavistin were evaluated for their effect on the spore germination of test fungus. Spore suspension of each isolates of fungus containing 30-40 spores per microscopic field was prepared from 10 days old culture. One drop of about 0.1 ml of spore suspension was placed in a cavity glass slide containing a drop (about 0.1 ml) of 20% concentrations of plant extract. These slides were kept in moist chamber prepared putting two folds of filter paper in both sides of Petri

plates. These plates were incubated at 24±2°C and reading in terms of germinated and spores were taken at 2 hours intervals up to 24 hours.

Effect of Plant Extracts on Radial Growth and Spore Germination of *Fusarium oxysporum* f.sp. *lycopersici*

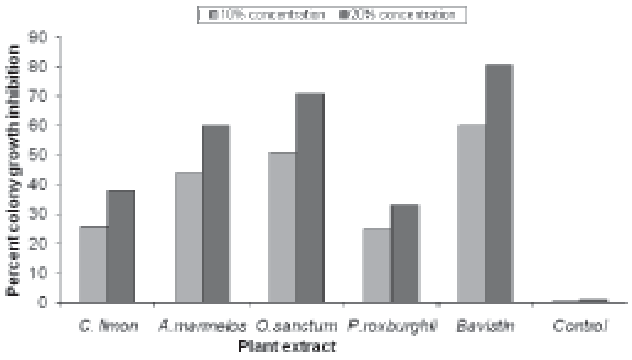
Four plant species were selected and evaluated for their antifungal activity against *F. oxysporum* f.sp. *lycopersici*. All the leaf extracts of tested plants at 10% and 20% concentration were effective in inhibiting the radial growth of test pathogen compared to control. The leaf extract of *O. sanctum* and *A. marmelos* at 20% concentration caused highest reduction of mycelial growth of *F. oxysporum* f.sp. *lycopersici* i.e. 70.9 and 60%, respectively followed by *C. limon* and *P. roxburghii* at10 and 20% concentration. Overall the Bavistin at 0.2% caused the highest reduction of the pathogen by 80.5% (Figure 1).

Present investigation showed that *O. sanctum* extract have potential to inhibit mycelia growth and spore germination of *F. oxysporum* f.sp. *lycopersici*. Amadioha (2000) proved that *O. gratissimum* leaf extracts has ability to inhibit spore germination and mycelial growth of *Rhizopus oryzae*. Mycelial growths of various *Fusarium* spp. were inhibited by plant extracts *of Adhatoda vasica, Azadirachta indica, Cinnamomum camphora* and *Ocimum sanctum* (Prasad and Ojha, 1986). The presence of antifungal substances in the different extracts, which caused the inhibition of radial growth and spore germination *in vitro* and reduction in rot development by the pathogen *in vivo*. Vijayan (1989) reported that the bulb extract of *A. sativum*, leaf extract of *Aegle marmelos* and flower extract of *Catharanthus roseus* inhibited the spore germination and mycelial growth of *Alternaria solani*. Daya and Ram (1997) reported that leaf extracts of *O. sanctum* was found most effective against *Alternaria brassicae* as compared to other tested extracts.

Leaf extracts of *O. sanctum* inhibited the spore germination of *F. oxysporum* f. sp. *lycopersici* 76.67 per cent maximally and *P. roxburghii* leaf extracts inhibited the least. Overall the Bavistin showed the highest inhibitory effect on spore germination of test pathogen (Table 1).

Table 1. Effect of plant extracts on the spore germination of *F. oxysporum* f.sp. *lycopersici*

S. No.	Plant extracts	Spore germination (%)	Spore germination inhibition (%)
1.	*Citrus limon*	75.57 (60.43)	22.96
2.	*Aegle marmelos*	61.67 (51.73)	37.14
3.	*Ocimum sanctum*	23.00 (28.67)	76.55
4.	*Putranjeeva roxburghii*	76.67 (61.69)	21.85
5.	Bavistin (Positive control)	4.47 (11.87)	95.44
6.	Control	98.10 (82.23)	0.0
	CD (0.05)	4.31	-



The present study concludes that aqueous extracts of *Ocimum sanctum*, *Aegle marmelos* and *Citrus limon* contain antifungal constituents for the control of *F. oxysporum* f.sp. *lycopersici* with varying degree of efficacy. *Ocimum sanctum* was found to be the highly effective plant extracts amongst tested crude plant extracts. Further green house and field experiments are suggested to investigate the *in vivo* effects of these extracts as compared to some commercial chemical fungicides for the management of *Fusarium* wilt of tomato.

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Indian Journal of Ecology

Effect of Propagation Media on Growth of Turmeric Sprouts

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India is the world's largest producer and exporter of turmeric and it produces nearly 50 per cent of global turmeric. It is grown in an area of 1.92 lakh hectares with an average production of 8.93 lakh MT (Anon., 2012). The cost of planting material amounts to 50 % of crop production in turmeric. Studies on the use of different rhizome size, propagation media and growth regulators are scanty. Hence, there is a need to study the effect of propagation media on the turmeric sprouts, rhizome size and growth regulators on growth, yield and quality under field conditions. The effect of growing media on sprouting and growth of turmeric is important to know the best suited potting media for growth of turmeric.

The study was carried out in the laboratory of Plantation, Spices, Medicinal and Aromatic Crops Department of Kittur Rani Chennamma College of Horticulture, Arabhavi during May of 2012-2013. There were twelve treatments (Table 1) in complete randomized design with three replications. The composition of the different media were incorporated in trays with 20 holes and rhizomes of 25 g size each, which were used for planting in trays. Out of twenty plants, observation on growth parameters were recorded in five randomly selected uniform healthy plants.

Days taken for germination were significantly highest in FYM (15.00) and the least number of days taken for germination was recorded in coco peat + sand (6.33), which was at par with vermicompost (Table 1). Plant height was significantly higher in red soil + sand + coco peat (41.56 cm) and least where rhizomes were planted in FYM (12.67 cm). Pseudostem girth was significantly highest (8.48 mm) in Red soil + sand + coco peat, which was at par with Red soil + sand + vermicompost and the least pseudostem girth (2.53 mm) was recorded in FYM. Highest number of leaves and sprouts were recorded in red soil + sand + coco peat, which differed significantly from all other treatments. The minimum number of leaves were recorded in FYM and the least sprouts in coco peat. Similarly, the maximum (120.64 cm^2) was in the red soil:sand:coco peat in equal proportion, which significantly differed from all other treatments and the least leaf area was recorded in FYM (29.37 cm^2). Early germination was observed in coc-peat + sand and vermicompost might be due to improvement in physico-chemical property of growing media i.e., coco peat + sand. These results confirm the earlier findings in nutmeg by Abirami *et al*. (2010 a) and Ali *et al*. (2012), wherein improved

Table 1. Effect of type of media on days taken for germination, plant height, pseudostem girth, leaves per plant, number of sprouts and leaf area in turmeric var. Suroma

Treatments	Days taken for germination	Plant height (cm)	Pseudo stem girth (mm)	No. of leaves $plant^{-1}$	No. of sprouts	Leaf area (cm^2)
Coco peat	10.33	21.67	4.55	0.87	0.93	54.19
Coco peat + Sand (1:1)	6.33	21.61	6.52	0.97	1.00	58.88
FYM	15.00	12.67	2.53	1.00	1.00	29.37
FYM + Sand (1:1)	7.66	23.90	5.30	0.80	1.00	33.31
Vermicompost	6.66	27.61	6.78	1.00	1.07	78.95
Vermicompost + Sand	7.33	30.60	6.25	1.00	1.00	67.97
Red soil	10.00	29.67	5.43	1.03	1.07	64.72
Red soil + Sand (1:1)	9.33	35.85	6.34	1.20	1.07	77.34
Red soil + Sand + FYM (1:1:1)	8.34	20.51	5.47	1.27	1.00	62.91
Red soil + Sand + Vermicompost (1:1:1)	9.00	25.78	7.67	1.50	1.00	73.76
Red soil + Sand + Coco peat (1:1:1)	8.66	41.56	8.48	3.13	2.03	120.64
Sand	7.66	26.79	6.56	1.20	1.10	66.20
CD (1%)	1.61	3.50	0.73	0.31	0.15	10.57

physico-chemical properties of the soil resulted in early germination. This may be attributed to the moisture retention property of coco peat and the mixture of sand and red soil, which improved the texture of the growing media for better root growth, resulting in production of more number of roots for better absorption of nutrients from the growing media leading to synthesis of more photosynthates due to increased leaf area. Similar results were reported by Abirami *et al*. (2010 b) in nutmeg, Thankamani *et al*. (1996) in clove and Mutiarawati (2001) in asparagus.

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Heterosis Studies in Near Homozygous Lines of Brinjal (*Solanum melongena* L.) for Yield and Yield Attributing Traits

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Brinjal (*Solanum melongena* L.), an important member of family *Solanaceae* is an important crop in the tropical regions of world and being grown extensively. A number of cultivars are grown in India based on consumer preference for fruit color, size, shape and taste. The phenomenon of heterosis in plants is well known today and breeders exploit it for higher yield in crop plants and is an efficient approach for improvement of vegetable crops brinjal continues to be a choice of breeders for exploitation of heterosis due to hardy nature of crop, comparatively large size of flowers and large number of seeds in a single act of pollination. Hybrids offer opportunities for improvement in earliness, uniformity, productivity, quality, wider adaptability and rapid deployment of dominant genes for resistance to disease and pests. Information on the magnitude of heterosis in different cross combination is a basic requisite to assess for identifying crosses that exhibit high amount of exploitable heterosis. With these points in view, the present investigation was undertaken to study the heterosis in hybrids for plant growth, earliness, yield and its components.

Fifteen lines (KB-12-01, KB-12-02, KB-12-03, KB-12-04, KB-12-05, KB-12-06, KB-12-07, KB-12-08, KB-12-09, KB-12-10, KB-12-11, KB-12-12, KB-12-13, KB-12-14 and KB-12-15) were crossed to three testers (KRCB-1, KRCB-2 and KRCB-3) during March, 2012. The F1 seedlings along with their parents were planted in randomized block design with two replications at Department of Vegetable Science, Kittur Rani Channamma College of Horticulture, Arabhavi, Belgaum district (Karnataka) during September 2012. Each entry was represented by two rows of 16 plants with spacing of 75 X 60 cm. Five competitive plants from each entry were selected randomly and data recorded for all the growth, earliness, yield and quality parameters. The heterosis over better parent, the best parent and the commercial check (Super 10) in percentage was calculated for these characters.

The sum of squares due to genotypes was highly significant for diversity among the genotypes (Table 1). Mean sum of squares due to genotypes, parents as well as crosses were also highly significant for all the traits and indicating presence of variability among parents and genotypes. Hence, results obtained were in desirable direction. The standard heterosis (CC-Commercial check) for plant height ranged from 8.80 to 13.47. Similarly, 13.92 to -7.59 for days to first flowering, 20.72 to -7.21 for days to fifty per cent flowering, -66.67 to 25.00 for per cent fruit set, -32.25 to 49.61 for average fruit weight, -23.85 to 39.55 for fruit length, -12.74

Table 1. Analysis of variance (mean sum of squares) of line x tester analysis for ten parameters in brinjal

Sr. No	Character	Replication	Genotypes	Parents	Parents vs Crosses	Crosses	Lines	Testers	Line x Tester	Error
		1	62	17	1	44	14	2	28	62
1.	Plant height q	0.57	36.49**	44.70 **	57.15 **	32.84**	44.66NS	32.49 NS	26.99 **	1.36
2.	Days to first flowering	0.03	18.05**	19.20 **	221.25 **	13.29 **	14.20 NS	8.84 NS	13.16 **	1.59
3.	Days to 50 per cent flowering	0.06	50.23**	30.89**	934.29**	38.05**	59.01NS	16.58 NS	29.07 **	1.61
4.	Per cent fruit set (%)	0.08	630.10 **	159.64**	2956.26**	762.72**	1632.85**	463.33NS	349.04 **	1.61
5.	Average fruit weight (g)	3.49	536.98**	245.38**	3499.93**	594.48 **	510.92 NS	328.01 NS	655.29**	2.22
6.	Fruit length (cm)	1.58	2.03**	2.30 **	0.81 NS	1.99 **	2.25NS	1.79 NS	1.87 **	0.36
7.	Fruit diameter (cm)	0.25	0.67**	0.37 **	1.77 **	0.77 **	1.26 *	0.01 NS	0.58 **	0.08
8.	Number of fruits per plant	1.78	17.63**	9.80 **	28.34 **	19.37 **	23.13 NS	10.54 NS	18.12 **	0.81
9.	Yield per plant (kg)	0.011	0.19**	1.59**	0.83**	0.21**	0.12NS	0.18 NS	0.26**	0.065
10.	Yield per hectare (t ha^{-1})	7.11	62.29**	776.54**	103.23**	68.24 **	109.65*	87.67 NS	46.15**	2.77

*and** indicate significance of values at p=0.05 and p=0.01, respectively. NS: Not significant, DAT: Days after transplanting

Table 2. Magnitude of heterosis, *per se* performances and best hybrids for ten characters

Character	Magnitude of heterosis			Range of *perse* performance	No. of hybrids having significant heterosis (over CC)		Best hybrids over commercial check
	BP	BTP	CC		+ ve	-ve	
Plant height	-12.71 to 17.57	-15.48 to 5.16	-8.80 to 13.47	80.90 to 100.64	24	5	KB-12-08 × KRCB-3, KB-12-07 × KRCB-2 and KB-12-01 × KRCB-1
Days to first flowering	13.92 to -22.22	13.92 to -7.59	13.92 to -7.59	36.50 to 45.06	20	20	KB-12-05 × KRCB-1, KB-12-06 × KRCB-3 and KB-12-12 × KRCB-1
Days to fifty per cent	13.91 to -21.21	21.82 to -6.36	20.72 to -7.21	51.50 to 67.00	14	10	KB-12-09 × KRCB-1, KB-12-05 × KRCB-1 flowering and KB-12-05 × KRCB-2
per cent fruit set	-60.00 to 133.33	-60.00 to 50.00	-66.67 to 25.00	20.00 to 75.00	15	28	KB-12-11 × KRCB-2, KB-12-09 × KRCB-3 and KB-12-06 × KRCB-2
Fruit length	-37.00 to 35.32	-44.92 to 0.94	-23.85 to 39.55	7.24 to 11.45	32	7	KB-12-14 × KRCB-2, KB-12-03 × KRCB-2 and KB-12-01 × KRCB-1
Fruit diameter	-23.22 to 22.70	-29.74 to 22.84	-12.74 to 52.56	4.90 to 8.55	24	18	KB-12-09 × KRCB-3, KB-12-05 × KRCB-1 and KB-12-12 × KRCB-1
Average fruit weight	-34.73 to 75.89	-37.13 to 38.92	-32.25 to 49.61	52.61 to 116.00	21	19	KB-12-06 × KRCB-3, KB-12-07 × KRCB-1 and KB-12-05 × KRCB-2
Number of fruits plant^{-1}	-42.55 to 13.95	-42.55 to 4.25	-35.70 to 16.70	13.50 to 24.50	13	32	KB-12-03 × KRCB-1, KB-12-07 × KRCB-3 and KB-12-10 × KRCB-1
Yield plant^{-1}	-40.66 to 74.72	-51.46 to 23.31	-47.81 to 31.77	.85 to 1.77	15	25	KB-12-06× KRCB-2, KB-12-11 × KRCB-2 and KB-12-01 × KRCB-3
Yield hectare^{-1}	-40.70 to 41.38	-51.43 to 1.87	-47.76 to 9.57	18.85 to 39.60	10	24	KB-12-11 × KRCB-2, KB-12-06 × KRCB-2 and KB-12-01 × KRCB-3

BP-Better parent heterosis, BTP- Best parent heterosis and CC- Commercial check.

to 52.56 for fruit diameter, -35.70 to 16.70 for number of fruits per plant, -47.81 to 31.77 for yield per plant and -47.76 to 9.57 for yield per hectare. These results are little higher compared to earlier studies reported by Chowdhary *et al*. (2011) for plant height and days to fifty per cent flowering, Nalini *et al*. (2011) for days to first flowering, Bavage (2002) for per cent fruit set, Bulgundi (2000) for average fruit weight, Prakash *et al*. (2008) for fruit length and diameter, Abhinav and Nandan (2010) for number of fruits per plant, whereas, Sharma (2010) reported little higher heterosis for yield per hectare. Kamani and Monpara (2009) reported the heterosis for yield per plant, which was lower than present study. The best hybrids for yield per hectare were KB-12-11 X KRCB-2, KB-12-01 X KRCB-3, KB-12-12 X KRCB-3 and KB-12-03 X KRCB-3. These hybrids also exhibited specific combining ability for yield per hectare hence the heterosis was associated with sca. This indicates the presence of non-additive gene action. These heterotic hybrids were obtained from H x L, H x H, L x L and H x A. However, higher proportion of heterotic hybrids were obtained from H x L type of combination. This information will be further useful in the precise selection of parents to get the highly heterotic hybrids.

Ten hybrids showed the standard heterosis for yield per hectare and also yield attributing traits in positive direction. Hence results were associated with non- additive gene action. This indicates that parents have the specific combining ability for these traits.

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Biology of Banana Pseudostem Weevil, *Odoiporus longicollis* Olivier

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Banana is an important plantation crop but its production is constrained by a number of insect pests. Amongst pseudostem weevil, *Odoiporus longicollis* Oliver (Coleoptera: Curculionidae) is a major one. It is estimated that banana pseudostem borer causes 10-90 per cent yield loss depending on the growth stage of the crop and management efficiency. Attempts have been made by different workers to study the biology of this pest. As this pest has been reported only recently from Karnataka. Present study was undertaken to generate detail information on biology of insect.

Studies on the biology of the banana pseudostem borer; *O. longicollis* were conducted in the laboratory for one season during October to January, 2013 at Department of Horticulture Entomology, College of Horticulture, Mudigere, Chikmagalur, Karnataka, India. The population was raised from a field strain of *O. longicollis*. Freshly emerged individual pairs of weevils were released in plastic boxes (7 x 14 cm) with strip of pseudostem (4-8 cm) and replicated 10 times. The strips of pseudostem were replaced on every third day. Egg containing pseudostems were kept in separate plastic boxes having moist filter paper to record incubation period on hatching, the grubs were transferred to fresh pseudostems having artificial holes. For recording the number and duration of instars, the grubs were taken out of pseudostem and tunnels were examined for moulting skin. The same procedure was adopted for recording pre-pupal and pupal duration. The same set explained above was used for determining pre-oviposition, oviposition and post- oviposition periods, fecundity and longevity of the adults.

The pre-oviposition period lasted for 18 to 27 days with an average of 23.90 ± 2.85 days. Oviposition occurred both during day and night hours. The oviposition period varied from 20 to 25 days with an average of 23.30 ± 1.70 days. The post oviposition period varied from 15 to 18 days with an average of 16.90 ± 1.20 days. These observations are in agreement with the findings of Padmanaban and Sathiamoorthy (2001).

Incubation period : The egg was laid singly inside the air chamber; freshly laid egg was translucent and yellowish in colour. The incubation period varied from 3.50-6.00 days (Av. 4.80 ± 0.90) during October to January. Mean fecundity was 16.90 ± 2.42.

Larva: The grub passed through five instars to complete the larval period. Before moulting, the grub stopped feeding and boring. Freshly moulted grubs were white in colour except mandibles, which were light brown coloured. Freshly emerged larva was yellowish white, apodus, soft, wrinkled, bulged in the middle and pointed towards both ends. Later on, as the cuticle colour changed to creamy white and the head capsule became light reddish brown. The first instar lasted for 3.00 to 4.00 (Av. 3.60 ± 0.46) days. Morphometrically second instar was similar to that of first instar except the size, and segments, which were clearly visible. The second instar occupied 4.00 to 5.00 (Av. 4.60 ± 0.52) days.

Head was yellowish brown with anterior margin of cranium reddish brown. The body appeared whitish in colour. Other characters were similar to first and second instars. The abdomen gradually broadened posteriorly. This instar occupied 5.50 to 6.50 (Av. 5.95 ± 0.44) days. Similar to third instar grub in all respect except for the increase in size and rounded posteriorly. The instar occupied 7.50 to 8.50 (Av. 8.10 ± 0.39) days.

Fifth instar was yellowish white, stout, fleshly and head free, reddish brown in colour and rounded abdominal tip. Mandibles stout, more or less triangular with bluntly pointed three apical denticles. Small circular shiny areas and minute setae were sparsely distributed all over the body. Dorsal segments were wrinkled and indistinct and ventrally segmentation appeared clearer. The sloping of the truncate abdominal tip starts from 8th abdominal segment. There were nine pairs of spiracles situated laterally. This instar occupied 13.50 to 16.00 (Av. 15.15 ± 0.88) days. The total larval period varied from 33.50 to 40.00 (Av. 37.40 ± 2.69) days during October to January.

Pre-pupa and pupa: Matured larva constructed the cocoon and the size of the pre-pupa was about $^{2}/_{3}$rd of larva. The pre-pupa was characterized by change in colour to pale yellow. The pre-pupal period lasted for 3.50 to 6 (Av. 4.52 ±

0.82) days during October to January. These observations are in agreement with the findings of Kung (1964). The pupa was exarate type; yellowish in colour with setae on the head and base of the rostrum and a tuft of hairs on the anal region. The pupal period lasted for 19.50 to 23 (Av. 21.13 ± 1.31) days during October to January. Similar observations were reported by Dutt and Maiti (1972).

Total life cycle: The total life cycle of *O. longicollis* from egg to adult emergence varied from 60 to 75 (Av. 67.85 ± 5.72) days during October to January. Similar observations were reported by Padmanaban and Sathiamoorthy (2001). The adult individuals reared in the laboratory survived for 71 to 98 days with an average of 84.10 ± 10.02 days during October to January. These findings are more or less in agreement with the findings of Visalakshi *et al*. (1989).

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Effect of Different Cooking Methods on Total Phenolic Content of Selected Vegetables

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Phenolic compounds, commonly found in plants, been associated with flavour and colour characteristics of fruits/ vegetables have multiple biological effects, including antioxidant activity and play a preventive role in the development of cancer/heart diseases by slowing the progression of atherosclerosis by acting as anti-oxidants towards low-density lipo-proteins (Kahkonen *et al.,* 1999). The anti-oxidant activity of phenolics is mainly because of their redox properties which allow them to act as reducing agents, hydrogen donors, singlet oxygen quenchers and metal chelators (Rice-Evans *et al.,* 1997). Vegetables are one of the most valued components for their colour, flavour, therapeutic and nutritional value in the Indian culinary as majority of Indian population is vegetarian. Many Brassicaeae crops (e.g. broccoli, brussels sprouts, cabbage and cauliflower) commonly known as crucifers have been associated with inhibition of chemically induced carcinogenesis. Broccoli is high in polyphenols. Capsicum are rich sources and green leafy vegetables contain an immense variety of bioactive non-nutritive health enhancing factors such as antioxidants, phytochemicals, essential fatty acids and dietary fiber.

Processing, particularly cooking is a crucial factor that has an impact on total antioxidant activity of any food material, especially for vegetables, since most of them are commonly eaten in cooked form. The present study is conducted to evaluate the effect of different cooking methods on the phenolic content of the selected vegetables.

Five commonly consumed vegetables viz. spinach, fenugreek leaves, broccoli, cabbage and capsicum were procured from the local market during the peak season (January 2012) and were randomly sampled from the shelf. Vegetables were washed with tap water after removing inedible parts manually with knife and then were cut into almost equal pieces and mixed well. Four hundred grams of each vegetable were taken and divided into four portions of hundred grams each. One portion was retained raw; others were cooked by three most common methods to cook vegetables viz. cover lid cooking (CLC), microwaving (MW) and stir frying (SF). Cover lid cooking: One hundred gram of each vegetable was cooked with added water at 5, 10 and 15 min interval in a pan covered with a lid. Microwaving: One hundred gram of each vegetable was cooked in a microwave safe glass container and cooked in domestic microwave (Samsung CE2933) with added water at 5, 10 and 15 min interval. The content of added water during CLC and MW was determined with a preliminary experiment for each vegetable and cooked for the three time periods. Stir frying: One hundred gram of each vegetable was stir fried in a pan with ten grams of refined soyabean oil per vegetable sample. The vegetables were stir fried for 5, 10 and 15 min interval while stirring the sample frequently and without putting the lid on. All the samples were then cooled rapidly under the fan and sealed in air tight pouches for further analysis. Fresh: One hundred gram of fresh uncooked and almost equally and evenly cut vegetables were taken and used for analysis.

The selected vegetables cooked by above mentioned methods for three time periods i.e. 5, 10 and 15 min were evaluated for the sensory characteristics namely colour, appearance, texture, flavor, taste to assess the overall acceptability by the panel of 10 judges using a nine point hedonic scale (Ranganna, 1986). The method of Singleton *et al.* (1999) was followed to estimate total phenols by using Folin–Ciocalteau reagent. The methanolic extracts for the samples of raw and cooked vegetables were prepared by keeping overnight in methanol.

The results of the sensory evaluation revealed that maximum overall acceptability of vegetables i.e. spinach, fenugreek, broccoli, cabbage and capsicum was at 15, 10, 5, 10 and 10 min. during cover lid cooking and microwave cooking, while it was at 10, 15, 5, 10 and 10 min during stir frying (Table 1). Total phenolic content (TPC) of analyzed vegetables ranged between 117.2 to 396.6 mg/ 100 g fresh weight, the minimum value was observed for spinach while maximum was noted for fenugreek leaves. The values for broccoli, cabbage and capsicum were 200.0, 158.6 and 263.8 mg. The available literature reported that vegetables are rich sources of total phenols, which possess strong antioxidant

Table 1. Overall acceptability of vegetables cooked by three methods for three time periods

Vegetables	Cooking Time (min)	Spinach	Fenugreek	Broccoli	Cabbage	Capsicum
Covered Lid	5 min	5.9	5.25	7.7	3.8	3.7
Cooking (CLC)	10 min	5.7	7.2	6.2	6.5	6.6
	15 min	7.6	6.1	5.5	.4	6.0
Microwaving (MW)	5 min	3.9	6.0	7.4	1.9	3.4
	10 min	5.6	7.7	6.4	5.9	6
	15 min	6.9	6.5	5.8	5.2	4.8
Stir Frying (SF)	5 min	4.6	4.6	7.3	4.2	3.7
	10 min	7.9	6.9	5.9	7.0	7.4
	15 min	7.3	8.0	5.0	6.0	6.7
CD (0.05)		0.9	0.7	0.9	1.1	1.0

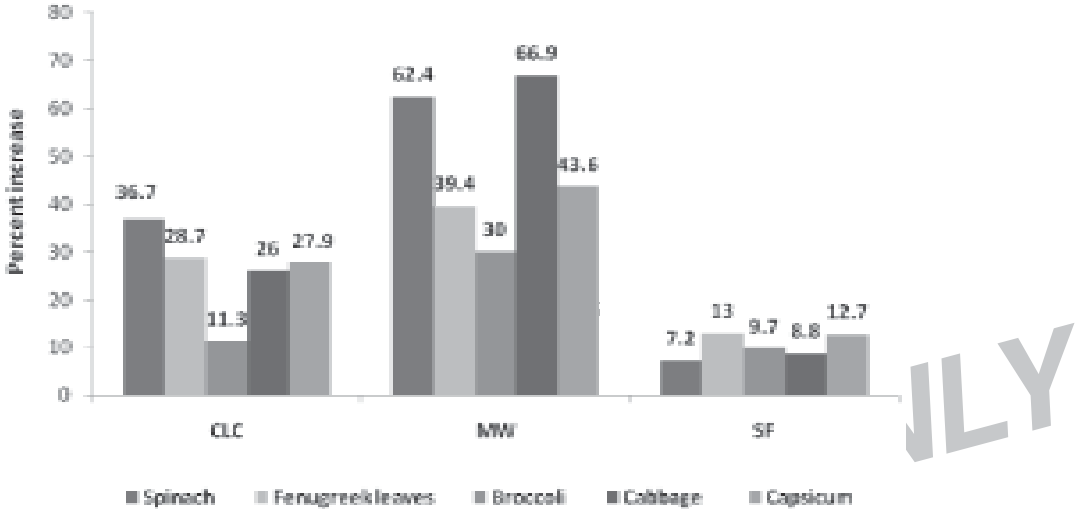

Fig. 1. Per cent increase in total phenol content in selected vegetables cooked by coverlid cooking (CLC), microwave cooking (MW) and stir frying (SF)

activity (Kaur and Kapoor, 2002). Cooking of selected vegetables by three common methods i.e. CLC, MW and SF resulted in an increase of total phenolics (TPC) in case of all the vegetables when the results were expressed on dry matter basis (Fig. 1). MW resulted in maximum increase in TPC (30.0-66.9%) as compared to CLC and SF, while the minimum increase in TPC was during SF in all five vegetables, the range being 7.2 to 13.0%. The maximum increase of TPC during MW was observed in cabbage (66.9%) closely followed by spinach (62.4%) while the least increase was during MW cooking of broccoli (30%). The CLC resulted in maximum and minimum increase of TPC in spinach (36.7%) and broccoli (11.3%), respectively. Other analyzed vegetables also showed lesser increase of TPC during CLC, when compared to SF and MW, the percentage values being 36.7, 28.7, 26.0 and 27.9% for spinach, fenugreek leaves, cabbage and capsicum, respectively.

On comparison of 5 vegetables, CLC resulted in maximum increase of total phenol content (TPC) in spinach (36.7%) while least increase was observed in broccoli (11.3%). During MW, maximum increase was observed in cabbage followed by spinach (62.4%) while least increase was in broccoli (30.0%). Stir frying had least increase, the range being 7.2 to 13.0%, the highest value was for fenugreek leaves while the least was for spinach (Fig. 1). Zhang and Hamauzu (2004) reported that raw broccoli floret contained 34.5 mg/100 g fresh weight of total phenolics and the florets cooked for 5 min by boiling or microwave cooking retained 28.1 and 28.4% of total phenolics, respectively. The results of the present study were in line with those Adefegha and Oboh (2011), who found that the total phenol content of the uncooked leafy vegetables ranged from 146.9 mg/100g to 693.8 mg/100g, while total phenol content of the cooked vegetables ranged from 272.8 mg/100 g to 1037.5 mg/100g. Pellegrini *et al.* (2010) also observed that there was an increase in polyphenols after cooking of vegetables. The

study concluded that though all methods resulted in an increase in phenolic content but the maximum increase was observed during microwave cooking followed by covered lid cooking, while, the least increase was during stir frying in all the analyzed vegetables. The results indicated that cooked vegetables are an important source of phenolic compounds, hence they are noteworthy contributors of these antioxidant compounds with proven health benefits.

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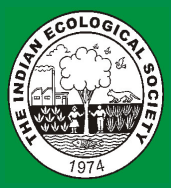

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