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Efficient Alternate Cropping Systems of India

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Abstract: In order to achieve 4 per cent growth rate in agriculture as envisaged by the Planning Commission, Govt. of India, top priority need to be given to highly productive and profitable cropping systems, which can meet the food demand of burgeoning population and adequate attention has to be paid to remove bottleneck in achieving the growth rate. Cropping system research plays crucial role in crop diversification and intensification by selecting alternative crops, inclusion of catch and cash crops and making best use of leftover of each crop in synergistic manner. The cropping systems vary from region to region as they are designated on the basis of climate, soil type, irrigation facilities, market demand, input supply, labour availability and farmers' perception to adopt the systems. Therefore, all efforts are being made to develop production and protection technologies in all the agro-climatic regions of the country.

***Key Words*:** Cropping Systems, Crop Diversification, Issues Related to Cropping Systems, Sustainability

Undoubtedly, India got self-sufficiency in food grain production the ushering in the green revolution. Four fold increase in foodgrain production was registered, mainly because of evolution of high yielding nutrient responsive varieties of rice and wheat, development of irrigation infrastructure, use of fertilizers and development of production and protection technologies. Agricultural growth could not keep race with the population growth rate. The productivity of most of the cereals is declining or plateauing and the resources are showing the symptoms of fatigue. The fatigue in the post-green revolution ear is now a matter of serious concern. For achieving the required crop production targets to feed more than 1.5 billion in 2050, it is imperative to develop strategies that can sustain higher level of production without an adverse affect on the environment. To maximize the production from available resources and prevailing climatic conditions, need based, location specific technologies needs to be generated.

The self-sufficiency in foodgrain production was achieved at the cost of degradation (physically, chemically and biologically), diminishing biodiversity, depletion of ground water table, increase in environmental pollution, elimination of useful birds on account of high pesticide use and contamination in foods, ultimately affecting the human health. These emerging threats in the irrigated agriculture system have put greater challenge before agricultural scientists to maintain the balance between production and consumption to fulfill the food and nutritional security across the regions and sustainability of resources. The recommendation with regard to important production factors like fertilizer management, water management, weed control, disease and pest management has been formulated for component crops need to be integrated into cropping system mode. Substantial saving in input resources is accrued, when recommendations on cropping system basis are adopted. The main focus should be on to develop technologies, which are cost effective, increase use efficiency of inputs and highly suits to the agro-climatic regions based on soil, water, temperature, rainfall etc. is the first step towards productivity enhancement per unit area.

FAO defined an agro-climatic zone as a land unit delineated in terms of major climate and growing period, which is climatically suitable for certain range of crops/cropping systems and cultivars. Planning commission had identified fifteen resource development regions in the country with fourteen regions in the main land and remaining one in the islands of Bay of Bengal and the Arabian Sea (Gangwar and Singh, 2011). The main objective was to integrate plans of the agro-climatic regions with the state and national plans to enable policy development based on techno-agro-climatic considerations. In the agro-climatic regional planning, further sub-regionalization was possible based on agro-ecological parameters. An agro-ecological zone is a major area of land that is broadly homogeneous in climatic and edaphic factors, but not necessarily contiguous, where a specific crop exhibits roughly the same biological expression. For initiating research in the agro-climatic zones of the country, ICAR launched the National Agricultural Research Project (NARP). In NARP, the country was divided into 126 agro-climatic zones. The description of agro-climatic parameters is needed to determine the potential cropping system within a cropping pattern in a particular area (Table 1).

Table 1. Important agro-climatic features, soil type and predominant cropping systems of India

S.N.	Agro-climatic region/zone	Rainfall (mm)	Climate	Soils	Predominant cropping systems
1.	Western Himalayan Region	1650-2000	Cold arid to humid and sub-humid	Hills soils, sub-mountain, meadow sheletal	Rice-wheat, maize-wheat and rice-potato-potato
2.	Eastern Himalayan Region	1840-3528	Per humid to humid	Brown hills, acidic soils, alluvial, tarai soils, red sandy, laterite soils	Rice-fallow, rice-rice and rice-pulses/oilseeds
3.	Lower Gangetic Plains	1302-1607	Moist sub-humid to dry sub-humid	Recent alluvial, red, yellow loamy soils	Rice-rice, rice-wheat, rice-potato-jute and rice-potato-vegetable
4.	Middle Gangetic Plains	1211-1470	Moist sub-humid to dry sub-humid	Alluvial, calcareous, tarai soils	Rice-wheat, rice-maize and rice-potato-sunflower
5.	Upper Gangetic Plains	721-979	Dry sub-humid to semi-arid	Alluvial, tarai soils	Rice-wheat, sugarcane-ratoon-wheat, pearl millet-mustard
6.	Trans Gangetic Plains	360-890	Semi-arid to dry sub-humid and arid	Alluvial, calcareous soils	Rice-wheat, cotton-wheat and pearl millet-wheat
7.	Eastern Plateau and Hills	1296-1436	Dry sub-humid to moist sub-humid	Red, yellow, sandy loam to laterite	Rice-black gram/niger/linseed, rice-groundnut and rice- vegetable
8.	Central Plateau and Hills	490-1570	Semi-arid and dry sub-humid	Mixed red and black, medium black , grey, brown and alluvial soils	Maize/sorghum+ soybean-wheat, sorghum+ pigeon pea-Bengal gram/linseed, maize+ soybean-wheat and sorghum-wheat
9.	Western Plateau and Hills	602-1040	Semi-arid to dry sub-humid	Medium to deep black, shallow red loamy soils	Cotton-wheat, sorghum+ soybean-Bengal gram/ durum wheat, pearl millet+ black gram/green gram-safflower
10.	Southern Plateau and Hills	677-1001	Arid, semi-arid to dry sub-humid	Medium to deep black, red sandy to loamy coastal and deltaic alluvium	Sorghum-cotton-groundnut, rice- Bengal gram/green gram, rice-rice, rice-*rabi* maize-fodder
11.	East Cost Plains and Hills	780-1287	Moist sub-humid to semi-arid	Delta coastal alluvial, laterite red and medium black soils	Rice-groundnut-green gram, rice-green gram/ black gram and rice-rice
12.	West Cost Plains and Hills	2226-3640	Per humid to dry humid	Lateritic and coastal alluvium, red loamy soils	Soybean-wheat, cowpea/ groundnut/rice-green gram, cotton+ foxtail millet-green gram, rice-rice
13.	Gujarat Plains and Hills	340-1793	Semi-arid to dry sub-humid	Deep black, coastal alluvium, medium black and brown soils	Castor-chillies-fallow, pearl millet - mustard/ isabgol/cumin, cotton-wheat, pearl millet+ moth/guar-barley-fallow
14.	Western Dry	55-395	Arid to extremely arid	Desert, grey brown soils	Pearl millet+ black gram- mustard, maize+ soybean- durum wheat, groundnut- durum wheat- summer bajra, rice –*rabi* maize/ groundnut- summer moong, cotton-durum wheat
15.	Andaman & Nicobar Islands	1600-3000	Hot per humid	Medium to very deep, red loamy and sandy soils	Rice-fallow

(Source: Gill *et al.,* 2008)

Wide divergence has been noticed with respect to rainfall and soil types in the country and accordingly various cropping systems exist in different agro-climatic zones (Table 1). The constraints in the agricultural production in different agro-climatic regions and their possible ways to overcome have been given in Table 2.

Site-Specific Crop Diversification: Crop diversification in area, where continuous cropping of cereals-cereal systems is in vogue, has been advocated as one of the effective tools for minimizing the second-generation problems and to make a breakthrough in the productivity and profitability. The crop diversification can deliver many agronomic and ecological benefits simultaneously, while maintaining or enhancing the scale of efficiency of production. In this regard, besides adoption of proper input management technologies, diversification of the system through introduction of crops of diverse nature may be a good preposition to break the monotony of the predominant cereal based systems and to sustain productivity over a period of time. For diversification of rice-wheat system, several options are available different zones (Table 3).

Rice, maize, and wheat are major cereals

Table 2. Constraints limiting the system productivity and future thrust for enhancing yield of various cropping systems in different agro-climatic regions of India

S.N.	Agro-climatic regions/zones	Constraints	Future thrust
1.	Western Himalayan Region	Fragile ecosystem prone to soil erosion Low land productivity	Encourage watershed management concept Emphasis on temperate fruits and vegetable crops Promotion of micro-irrigation system under undulated topography of economic value plants/ for providing effective soil cover Need for selection of acid tolerant/ cold resistance crops/ varieties
2.	Eastern Himalayan Region	Fragile ecology prone to soil erosion with low level of irrigation and recurrent floods Low productivity	Need to promote integrated watershed management concept Develop pasture based farming system To provide effective soil cover through economic value plants or grasses Rice culture with fishery Discourage jhum cultivation to prove its alternative
3.	Lower Gangetic Plains	Low productivity level with high population pressure Poor soil quality Multi micronutrients deficiency	Development of heat/salinity cultivars for high yield realization Emphasis on rabi maize, boro rice and hybrid rice cultivation Improvement of drainage system Adoption of IPNS
4.	Middle Gangetic Plains	Low productivity level due to rice - rice monoculture Poor soil quality Drainage problem forced maturity of wheat due to high temperature	Crop diversification with emphasis on maize, fruits and vegetable crops Development of heat tolerant short duration wheat cultivars Management of diara and tal areas Amelioration of boron and iron deficiency
5.	Upper Gangetic Plains	Medium productivity level due to salinity/alkalinity Unscientific irrigation water use Availability of inputs Deteriorating environment with respect to land quality	Selection of salt tolerant crops and varieties Use of amendments which are cost effective Rational use of irrigation water using scientific approach Ensure availability of quality inputs Adoption of new tillage practices for effective crop residue management
6.	Trans Gangetic Plains	Decline in water table and scarcity of irrigation water Burning of crop residue Patches of salinity and alkalinity Deterioration in soil quality Poor water quality	Growing crops as per land capability classification Extensive use of zero tillage/ strip till drill Adoption of furrow irrigated raised bed technology in rice -wheat cropping system Crop diversification and intensification Delineation and mapping of multi-nutrient deficiency Promotion of integrated nutrient management for taking care of soil health
7.	Eastern Plateau and Hills	Low productivity Soil, water erosion and ruoff Depending on rainfall	Watershed management concept need to encouraged Need to follow integrated farming system with goatry, cattle, piggery and poultry Enhancing cropping intensity with vegetable crops
8.	Central Plateau and Hills	Lack of irrigation facilities Very low productivity with subsistence farming Excessive runoff Under utilize potential of horticulture and livestock Natural stress like drought, etc are very common	*In situ* water harvesting and recycling Development of abiotic tolerant varieties of rice, wheat, pulses and oilseeds Use of mulches for water conservation Promotion of agro-forestry, silvi-pastoral and agri-horti system Diversification of small millets with high values crops in different cropping systems
9.	Western Plateau and Hills	Growing low value cereal crops Poor irrigation facility Runoff and soil erosion Soils with high clay content with low drainability	Inclusion of high value crops (medicinal and aromatic crops) in different cropping systems Promotion of agri-horti-pastoral farming system Development of water shed
10.	Southern Plateau and Hills	Large rainfed area Tank led irrigation Large scale cultivation of low value cereals Poor quality water	Water harvesting and recycling Selection of crops, which can tolerate abiotic stress particularly water stress Selection of crops/varieties tolerant/semi tolerant to salts
11.	East Cost Plains and Hills	Fragile ecology due to water logging, salinity/acidity and soil erosion Rainfed area led with tank irrigation	Develop technology for Makhana/Sanghar cultivation Development of prawn/fishery based cropping system Need to develop agronomic manipulation to counteract flooding conditions

Cont....

12.	West Cost Plains and Hills	Excessive runoff/soil salinity/ acidity/irregular stretches of back water Inadequate drainage Poor quality water	Development of salt tolerant varieties of rice, sugarcane, foxmillet Reclamation of degraded land Develop for prawn based farming system in brackish water Preference to low water requiring crops during non-rainy season
13.	Gujarat Plains and Hills	Dependent on rainfall with frequent weather aberration Depletion of ground water Reducing forest cover Water logging in canal areas	Developing abiotic stress resistant varieties of rice Water harvesting and recycling Developing early hybrids of bajra Encouraging intercropping with groundnut and cotton
14.	Western Dry	Hot climate arid conditions Fragile ecosystem Poor land quality	*In situ* water harvesting/ conservation through adoption of cultural practices like ridge furrow planting, intercropping/mixed cropping with legume, soil mulch Development of extra short hybrids of bajra Integrated farming system with a component of crops, livestock, silvi-pastoral system, agri -horti system, agri -horti-silvi-culture to sustain arid ecosystem

(Source: Gill *et al.,* 2008)

Table 3. Efficient crop diversification options for rice-wheat farmers

Cropping system K – R – S	REY (t/ha/yr)	Productivity (kg/day/ha)	Profitability (Rs./ha/day)	NUP (kg grain/kg nutrient use)
South Alluvial Plain zone of Bihar				
Rice-Wheat	7.7	21.1	38.6	21.4
Rice-Garlic-Maize	11.2	30.6	76.4	23.7
Mid high altitude intermediate zone of J&K				
Rice-Wheat	9.2	25.3	87.4	26.4
Rice-Cauliflower-French bean	11.0	30.1	93.8	53.2
Central plain zone of Punjab				
Rice-Wheat	11.0	30.0	33.0	25.1
Maize-Potato-Onion	18.2	50.0	84.2	45.1
Central plain zone of U.P.				
Rice-Wheat	8.8	240.	36.4	28.1
Maize-Potato-Sunflower	15.3	41.9	56.4	20.5
Vindhyan plain zone of U.P.				
Rice-Wheat	8.5	23.2	32.3	17.7
Rice-Potato-Green gram	14.3	39.2	58.2	22.2
Bhabar and Tarai zone of Uttarakhand				
Rice-Wheat	11.9	32.7	91.5	23.9
Rice-Rapeseed-Sunflower	12.6	34.5	93.1	23.1
Plain zone of Chattisgarh				
Rice-Wheat	8.6	23.7	90.2	32.0
Rice-Brinjal-Green manure	10.7	29.4	112.4	54.0
Plateau and Satpura hill zone of M.P.				
Rice-Wheat	6.7	18.4	53.7	16.7
Rice-Berseem(f)-Berseem (S)	10.5	28.7	103.3	47.7
South Gujarat heavy rainfall zone				
Rice-Wheat	6.9	18.9	48.3	20.9
Rice-Onion-Veg. cowpea	8.6	23.5	52.2	22.0
Vindhyan Plateau zone of M.P.				
Rice-Wheat	5.4	14.6	33.4	14.1
Rice-Berseem(f)-Berseem (S)	7.2	19.6	62.4	23.8
Eastern plain zone of U.P.				
Rice-Wheat	7.1	19.4	37.0	15.9
Rice-Potato-Green gram	15.5	42.3	97.9	11.5

(Source: Gangwa *et al.,* 2011) K= *Kharif,* R= *Rabi,* S=summer, REY = rice equivalent yield; NUP= nutrient use productivity contributing to food security and income in South Asia. These crops are grown either as a monoculture or in rotations in tropical and sub-tropical environments of South Asia (Ttable 4). In the irrigated and favorable rainfed lowland areas, rice-rice, rice-wheat, and rice-maize are the predominant cropping systems. Rice-rice is common in tropical climate with distinct dry and wet seasons such as in South India, and in sub-tropical areas with mild cool winter climate such as in Bangladesh, Eastern India, and Eastern Nepal. Rice-wheat systems are extensive in the sub-tropical areas of the Indo-Gangetic Plains (IGP) of Bangladesh, India, Nepal, and Pakistan, while Rice-Maize systems exist in all climate ranging from tropical to sub tropical to warm temperates (Timsina *et al*., 2010). Rice-maize systems, however, are less extensive as compared to Rice-Wheat or Rice-Rice if total area under these cereal systems is considered.

Rice-wheat is the most predominant cropping system of Punjab. The wide adoption of rice-wheat system is mainly due to its high productivity,stability and less risk. Although the system has sustained over years but the yield shows stagnation since early 1990's. This stagnation may be due to appearance of new biotypes (hardy weeds), deterioration of physical properties of soil, formation of hard pan beneath plough layer, development of hardy and reisitant weeds, increase in insect-pest and diseasea, exhaustive nature of both the crops. For diversification of rice-wheat system, several options are available (Yadav *et al.,* 1998, Gangwar and Ram 2003, Katyal *et al.* 2002). The inclusion of crops like oilseeds, pulse and vegetable will improve the economic condition of the farmers owing to higher price and higher volume of their main and by- products. The legumes has also shown the favourable effect on the soil health. The maize-potato-wheat; summer groundnut-potato-pearl millet (f) and maize-potato-summer moong bean produced significantly higher rice equivalent yield as 22.5, 15.8 and 15.8 t/ha/year against 14.2 t/ha/year in rice-wheat system which cleary elucidated the superiority of these system over rice-wheat system (Walia *et al.,* 2010). Mandal *et al.* (2011) conducted an experiment for economic analysis of different diversified rotational cropping systems under Farmers' package/practices and improved package/practices in Birbhum district, West Bengal, located in the red and lateritic belt of lower Gangetic plainof eastern India. The results thus revealed that diversified cropping systems (peanut-brinjal-brinjal, rice-potato-pumpkin, and cucumber-cabbage-basella) required higher cost for cultivation, but also produced higher rice equivalent yield, higher net return and higher return per rupee invested in both management practices. Considering the resource-ability and risk-bearing capacity, and net return and return rupee^{-1} (RPR) invested, these cropping systems can be recommended for resource-rich farmers. Rice-rapeseed-cowpea, rice-wheat-green gram and radish-tomato-amaranthus systems required less inputs for cultivation, were less risky, and economically viable and profitable. These cropping systems can be recommended for resource-poor farmers. Peanut-brinjal + brinjal-okra-chilli + chilli-cucumber-cabbage-basella system was the best among all the 3-year rotational systems in respect to RPR (return rupee^{-1}) in both management practices.

Singh *et al.* (2003) reported that clusterbean-wheat is more economical than cowpea-wheat and pearl millet-wh eat crop sequences in parts of Rajasthan. With assured availability of irrigation, cottton-groundnut for Vidarbha and central Maharashtra plateau zones, and sugarcane-based cropping systems for western Maharashtra scarcity zone were found to be more productive, profitable and efficient (Gangwar *et al.,* 2003). Gangwar *et al.* (2004) reported that under limited irrigation water situations of Vindhyan plateau zone of Madhya Pradesh, soybean-based systems *viz.* soybean-wheat and soybean-chickpea systems were identified to be more efficient only in term of production (5128 and 4990 kg/ha/year as wheat grain-equivalent yield), productivity (14.50 and 13.67 kg/ha/year) and stability (0.56 and 0.62), but, in terms of economic viability, blackgram-linseed and maize-linseed were more viable in terms of net

Table 4. Area (Mha) under major cropping system in four South Asian countries

Cropping system	Area (Mha)			
	Bagladesh	India	Nepal	Pakistan
Rice-Rice	4.50	4.70	0.30	
Rice-Rice-Rice	0.30	0.04		
Rice-Wheat	0.40	9.20	0.57	2.20
Rice-Maize	0.35	0.53	0.43	
Maize-Wheat		1.80	0.04	1.00
Rice-Pulses		3.50		
Rice-Vegetable		1.40		
Millet-Wheat		2.44		

(Source: Timsina *et al.,* 2010)

return and benefit: cost ratioon. In mid high altitude of Jammu rice-wheat-sorghum + cowpea fodder system was identified be most productive with rice equivalent yield of 11835 kg/ha/year and yield stability of 0.45 (Gangwar *et al.,* 2006). The next best seuence was rice-mustard-greengram with 11221 kg/ha/year rice-equivalent yield and yield stability of 0.42. these systems were distinctly better than existing rice-wheat offering an opportunity to diversify the existing system.

Effective nutrient management is essential to sustain any cropping system over years. To check or reverse the present declining trend in factor productivity, it is essential to follow system-based integrated nutrient management approach. In fact site specific nutrient management approachb to achieve targeted yield is being focussed in recent years (Shukla *et al.,* 2004). Nutrient management based on system basis, rather than to indivisual crop, leads to higher efficiency and economics besides system sustainability (Hegde and Babu, 2002). Recent studies on loamy sand soils at Ludhiana have shown that the best approach for P management in rice-wheat system is to apply recommended doses of phosphorus to both the crrops (Singh *et al.,* 2002). Ali *et al.* (2012) compared the Seven cropping patterns *viz;* rice-berseem, rice-lentil, rice-canola, rice-wheat-mungbean, rice-wheat-cowpeas, rice-sunflower and rice-wheat-sesbania (rostrata) with commonly practiced rice-wheat cropping pattern. The cropping systems were evaluated for their productivity & to assess their effect on the soil organic carbon contents and available soil NPK. The results revealed that the green manuring and leguminous cropping patterns gave higher paddy yield as compared to commonly practiced rice-wheat cropping pattern. The maximum paddy yield of rice (3.73 t/ha) was obtained from rice-wheat-sesbania cropping pattern where sesbania was sown and incorporated in the soil as green manuring crop just before rice transplanting. This increase in paddy yield was statistically at par with the paddy yields received from rice-wheat-mungbean (3.57 t/ha) and rice-berseem (3.52 t/ha) cropping pattern. The yield of succeeding wheat crop was also higher in case of green manuring (sesbania) and leguminous crops (mungbean and cowpeas) which yielded 2.81, 2.69 and 2.63 t/ha respectively. The yield in case of rice-wheat cropping pattern was only 2.59 t/ha. As regards cost benefit ratio, the highest ratio was received in case of rice-lentil (1:2.38) cropping system followed by rice-canola (1:1.96) and rice-wheat-mungbean (1:1.78) as against the existing cropping pattern (rice-wheat) which gave the ratio (1:1.56). The results further indicated that introduction of green manuring or leguminous crops in the existing rice -wheat system not only increased grain yields but also improved the physio-chemical properties, organic matter contents and nutrients availability in the soil. Increase of NPK over initial soil fertility was N (0.12 %), P (2.8 ppm), and K (52 ppm). Soil pH lowered from 8.2 to 7.8 and organic carbon increased from 0.67 % to 0.72 %. Gangwar and Ram (2005) revealed that the population of *Phalaris minor* in wheat could be reduced through inclusion of vegetable pea as catch crop before wheat and interruptive cropping of mustard instead of wheat (once in 3 years). The soil fertility (Organic carbon, N, P, K and S) in general could be maintained or enhanced in cropping sequences involving vegetable pea, greengram or interruption of wheat through mustard and rice through maize and pigeon pea once in three years.

Specific Issues Relating to Some Important Cropping Systems

Rice-Wheat

Rice-Wheat system is the most widely adopted cropping system in the country and has become mainstay of cereal production. The states of Uttar Pradesh, Punjab,Haryana, Bihar, West Bengal and Madhya Pradesh are now the heart land of rice-wheat cropping system with an estimated area of 10.5 million hectares. Despite enormous growth of this cropping system in the country during the past few years, reports of stagnation in the productivity of these crops, with possible decline in production in future, have raised doubts on its sustainability. Important issues emerging as a threat to the sustainability of rice-wheat system are:

- Over mining of nutrients from soil,
- Disturbed soil aggregates due to puddling in rice
- Decreasing response to nutrients
- Declining ground water table
- Build up of diseases/pests
- Build up of *Phalaris minor*
- Low input use efficiency in north western plains
- Low use of fertilizer in eastern and central India
- Lack of appropriate varietal combination
- Shortage of labour during optimum period for transplanting paddy.

Rice-Rice

Rice-rice is the popular cropping system in irrigated lands in humid and coastal ecosystems of Orissa, Tamil Nadu, Andhra Pradesh, Karnataka and Kerala and it is spread over an area of six million hectares. The major issues in sustaining productivity of rice-rice system are:

i. Deterioration in soil physical conditions.
ii. Micronutrient deficiency.

iii. Poor efficiency of nitrogen use.
iv. Imbalance in use of nutrients.
v. Non-availability of appropriate transplanter to mitigate labour shortage during critical period of transplanting.
vi. Build up of obnoxious weeds such as *Echinochloa crusgalli* and non-availability of suitable control measures.

In Kerala, reduction in area is mainly attributable to the conversion of paddy lands to more profitable and less labour intensive plantation estates. In Assam, low productivity under prevailing soil and climatic situations, poor drainage in submerged areas, low nutrient use and iron toxicity are some of the issues of concern. The other general issues of low productivity are build up of pests, diseases and weeds year after year and deterioration of soil health to a large extent.

Cotton-Wheat

Cotton is widely grown in alluvial soils of north India (Punjab, Haryana, Rajasthan and Western Uttar Pradesh) and black cotton soils of central India (Andhra Pradesh, Tamil Nadu and Karnataka). With the availability of short duration varieties of cotton, cotton-wheat cropping system has become dominant in North. About 70-80 per cent area of cotton is covered under this system. In Central region also, wherever irrigation is available, cotton-wheat is practiced. The major issues of concern in cotton-wheat cropping system are:

i. Delayed planting of succeeding wheat after harvest of cotton.
ii. Stubbles of cotton create problem of tillage operations and poor tilth for wheat.
iii. Susceptibility of high yielding varieties of cotton to boll worm and white fly and consequently high cost on their control leading to unsustainability.
iv. Poor nitrogen use efficiency in cotton results in low productivity of the system.
v. Appropriate technology for intercropping in widely spaced cotton is needed to be developed.

Sugarcane-Wheat

Sugarcane is grown in about 3.4 million hectare. In north India (Uttar Pradesh, Punjab, Haryana and Bihar), which account for 68 per cent of the total area under sugarcane, sugarcane-ratoon-wheat is the most important crop sequence. The system is also gaining importance in Jorhat, Sibsagar and Sonitpur districts of Assam; Ahmedanagar and Kolhapur district of Maharashtra and Belgaum district of Karnataka. The other states where the system covers considerable area under sugarcane-wheat are Haryana, Punjab, Madhya Pradesh and Rajasthan. Problems in sugarcane-wheat system are:

i. Late planting of sugarcane as well as wheat.
ii. Imbalance and inadequate use of nutrients. Since majority of farmers apply only N in sugar cane and the use of P and K is limited. The emerging deficiencies of P, K, S and micro-nutrients are limiting system productivity directly and through interactions with other nutrients.
iii. Poor nitrogen use efficiency in sugarcane.
iv. Low productivity of ratoon due to poor sprouting of winter harvested sugarcane in north India.
v. Build up of *Trianthema partulacastrum* and *Cyprus rotundus* in sugarcane.
vi. Stubble of sugarcane pose tillage problem for succeeding crops and need to be managed properly.

Maize-Wheat

Among maize-wheat growing areas, maize is the principal crop of *Kharif* season in northern hills of the country but plains of northern states like Uttar Pradesh, Rajasthan, Madhya Pradesh and Bihar also have sizeable acreage under this crop. Results of national demonstrations and lab to land demonstrations clearly revealed that this system has a potential to produce 8-10 t/ha per year. However, experimental findings from various research stations revealed that a productivity of more than 10.5 t/ha per year (6.0 t+ 4.5t) may be realized under sub-montane conditions of Jammu. Likewise, a productivity of 7-8 t/ha per year at Palampur, 6.28 t/ha per year (2.00 + 4.28 t) at Indore and more than 7 t/ha per year at Ludhiana has been recorded in maize-wheat system. Maximum yield research in maize-wheat sequence at Palampur has shown a potential of 14.21 t/ha per year by optimization of various resources like plant population, manures and fertilizers.

Poor maize-wheat yield has been reported from Andhra Pradesh, Assam, Gujarat, Madhya Pradesh, Maharashtra, Rajasthan,Tripura, Eastern Uttar Pradesh and Tamil Nadu. There are number of reasons for poor but the most significant are:

1. Sowing time
2. Poor plant population
3. Poor weed management
4. Poor use of organic and inorganic fertilizers.
5. Large area under rain fed.

Declining yield trends in maize-wheat system under long term experiments have indicated that the system suffers due to emerging deficiencies of multiple nutrients. Continuously over-mining of nutrients from soil and imbalance on use of fertilizers in maize-wheat system are some of the many reasons for such decline.

Soybean – Wheat

Soybean-wheat cropping system has emerged as an important cropping system only after 1980 with the introduction of soybean as a *Kharif* crop in wheat growing areas of the country particularly under irrigated ecosystem.

Constraints limiting the soybean production and productivity *viz*. a relatively recent introduction of soybean as a crop, limited genetic diversity, short growing period available in Indian latitudes, hindered agronomy/availability of inputs at farm level, rain fed nature of crop and water scarcity at critical stage of plant growth, insect pests and diseases, quality improvement problems, inadequate mechanization and partial adoption of technology by farmers have been identified.

The realized and realizable yield potential have shown that the nation-wide average realized yield obtained by adopting improved technology is about 2 t/ha in soybean as against one t/ha obtained under farmers' practices. It is, however, to be noted that yield level of 3 to 3.5 t/ha in individual farmer's fields is not so uncommon in southern Maharashtra, Malwa plateau and some areas of Rajasthan.

Legume Based Cropping Systems

Legume crops (pulses and oilseeds) are popular for their suitability in different cropping systems. Recent advances in the development of large number of varieties of pulse and oilseed crops, varying largely for maturity duration, have made it possible to include them in irrigated crop sequences. The popular cropping systems are pigeon pea-wheat in Madhya Pradesh and groundnut-wheat in Gujarat, Maharashtra and Madhya Pradesh and groundnut-sorghum in Andhra Pradesh and Karnataka.

The major issues in legume based cropping systems are:

i. No technological breakthrough has been achieved so far in respect of yield barriers, particularly in legumes.

ii. Susceptibility of the pulses to aberrant weather conditions especially water logging and adverse soils making them highly unstable in performance.

iii. High susceptibility to diseases and pests.

iv. Low harvest index, flower drop, indeterminate growth habit and very poor response to fertilizers and water in most of the grain legumes.

v. Nutrient needs of the system have to be worked out considering N-fixation capacity of legume crops.

Future thrust

i. Water will be a scarce resource in future. Therefore, most efficient cropping systems for quantified water availability conditions need to be identified.

ii. Inputs becoming more costly every year resulting increase in cost of crop production. Therefore, *in situ* supplementation of inputs would be helpful. As such, bio-intensive complementary cropping systems need to be identified for partial *in situ* management of nutrients and pests.

iii. Diversification effects through inclusion of spices, medicinal and aromatic and horticultural crops with reference to productivity, profitability, stability and soil health in rice-wheat systems need to be quantified at different locations.

iv. Both short and long-term strategies need to be worked out considering the present trends and future perspectives of globalization of economy with new trade opportunities.

v. Development of synthesized sustainable cropping system models need to be attempted to achieve desirable change in the existing systems.

vi. Location specific resource management strategies need to be worked out for different crops and cropping systems so as to achieve quantum jumps in crop production.

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On-Farm Evaluation of Various Rice (*Oryza sativa*) Based Cropping Systems to Improve Profitability and Resource Use Efficiency in Coastal Saline Zone of West Bengal

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Abstract: A farmers' participatory field experiment with four different rice-based cropping systems was conducted during 2011-12 and 2012-13 in coastal saline zone of West Bengal. Due to low land agro-ecosystem, conventionally farmers grow long duration high yielding varieties of rice during wet season and keep their land either fallow or marginally growing some low water requiring crops in dry season (*rabi* and summer) using residual moisture or life saving irrigation. This study was aimed to evaluated profitability and resource use efficiency of rice-greengram, rice – sunflower, rice – sunflower + greengram and rice – lady's finger cropping systems. Rice – lady's finger cropping system recorded significantly higher yield of rice grain (4,617.04 kg ha^{-1}) and straw (6,605.11 kg ha^{-1}), system equivalent yield (28,080.17 kg ha^{-1}) and productivity (78.01 kg ha^{-1} day^{-1}). The highest net return (₹1,44,600 ha^{-1}) and B:C ratio (2:24) were also obtained in rice – lady's finger cropping system, followed by rice – sunflower. Rice – sunflower cropping system recorded significantly higher phosphate and potash uptake, however, regarding nitrogen uptake the same was at par with rice – lady's finger system. Higher land use efficiency, irrigation water use efficiency, energy output and employment generation were registered with rice – lady's finger system followed by rice – sunflower.

Key Words: Cropping System, Coastal Saline Zone, Employment Generation, Energy Output

There are mainly six agro-climatic sub-regions in West Bengal state, namely: i) the Northern hilly zone, ii) the Terai-Teesta flood plain, iii) the Gangetic flood plain, iv) the Coastal flood plain, v) the Vindhya old flood plain and v) the undulating Lateritic sub-regions of the Eastern Plateau Region (Sengupta, 2001). Out of these six agro-climatic regions, the Coastal flood plain is one of the most constrained zone, comprising of whole south 24 Parganas district and part of north 24 Parganas, Howrah and East Midnapore districts. This area represents low land agro-ecosystem with heavy textured saline soils, limited availability of irrigation water and very low cropping intensity (134%) as compared to state average of 185%. Conventionally, farmers grow high yielding rice varieties during wet season and use to keep their land fallow in dry season (*rabi* and summer) except marginally growing some low water requiring crops like greengram, lathyrus etc. using residual moisture or life saving irrigation. Water harvested in small tanks is the only source of irrigation during dry period. Though most of the farmers are resource poor, but this area is well connected by rail and road facility, favouring better marketing of their produce. Diversification of cropping system with food crops like potato, oilseed and vegetables is necessary for obtaining higher yield and return, maintenance of soil health, protection of environment and meeting up daily requirement of human and livestock (Samui *et al*., 2004). Inclusion of legumes in the cropping system increases soil fertility status (Ghosh, 1987; Upadhyay *et al.*, 2011). By and large a number of soil and climatic parameters decide cropping system of a region, which determine overall agro-ecological setting for nourishment and appropriateness of a crop or set of crops for cultivation. Choice of crop or cropping system is further narrowed down by several forces regarding infrastructure facilities, socio-economic factors and technological development which are operating interactively at micro-level. Potential productivity and monetary benefit act as guiding principles for a particular crop / cropping system, at farmers' level.

Mostly the scientists and extension workers simply do not have definite answers to the problems faced problems by the stakeholders (farmers) in an uncertain and ever-changing environment. This condition provides the opportunity for a new era in agricultural research and development, where scientists, extension workers and farmers can learn together how to best manage the agriculture in a sustainable manner. In general, in the process of technology assessment farmers' concern like their resources, social and economic aspect as well as their perception were often ignored, particularly in case of the resource poor farmers. As a result the potential yield and profitability of a crop/cropping system remains far behind from that of actual. Farmers' participatory research (FPR) emphasizes the process that enables a local farmer to evolve and promote improved agricultural technologies to the field. It values scientists and farmers knowledge equally and underlines the complementary nature of both pools of knowledge in generating and using technologies. Considering this fact, a participatory research was conducted to evaluate the productivity, profitability and resource efficiency at farmer field representing coastal flood plains of West Bengal. The objectives of the present study were to assess productivity, profitability, resource efficiency and energy efficiency of different rice-based cropping systems at farmers' level through farmers' participatory approach.

MATERIAL AND METHODS

A field experiment was conducted at farmers' field in two blocks (Mandirbazar and Kakdwip) of 24 Paraganas (South) district of West Bengal adopted by AICRP on Integrated Farming Systems, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia during two consecutive years 2011-12 and 2012-13 with four rice-based cropping systems. In each block, there were three villages and in each village there were four farmers' field *i.e.* in total there were twenty four numbers of farmers' field. These farmers' fields lie between 21°50.068'N to 22°06.975' N latitude and 88°11.858' E to 88°19.653' E longitude with an average altitude of 8.18 m above mean sea level in coastal saline flood plain of West Bengal. The cropping systems of the experiment were: Rice – Greengram; Rice – Sunflower; Rice – Sunflower + Greengram (2 : 4) and Rice – Lady's finger. Crop sowing window period, harvesting window period, recommended fertilizer dose and variety of different crops under all cropping systems are given in Table 1. Recommended doses of N, P and K were applied to different crops through urea, single super phosphate and muriate of potash, respectively. Irrigation water is the most scare and limited resource during dry period for crop cultivation in this area. *Kharif* rice was grown under rain fed condition. Limited amount of irrigation water at critical growth stage was given to all the dry period crops and total depth of irrigation was calculated for each of the crop, in turn for all the cropping systems. The need based intercultural and plant protection measures were adopted for different crops. The average values of soil properties as well as ranges of experimental fields were: pH 5.43 (4.45-6.99), EC 0.58 (0.15-1.95) dS m^{-1}, organic carbon 0.71 (0.58-0.82)%, available N 140.46 (111.09-186.55) kg ha^{-1}, P 48.07 (39.88-59.82) kg ha^{-1} and

Table 1. Date of sowing, date of harvesting, fertilizer dose and variety of the different crops of the crop sequences

Cropping sequence	Parameters	2011-12		2012 -13	
		Kharif	Summer	*Kharif*	Summer
Rice-Greengram	Sowing window	Last week of June	2nd fortnight of January	Last week of June	2nd fortnight of January
	Harvesting window	Last week of November	2nd fortnight of April	Last week of November	2nd fortnight of April
	Fertilizer dose	80:40:40	20:40:40	80:40:40	20:40:40
	Variety	IET-5656	Local	IET-5656	Local
Rice-Sunflower	Sowing window	Last week of June	1st fortnight of January	Last week of June	1st fortnight of January
	Harvesting window	Last week of November	1st fortnight of May	Last week of November	1st fortnight of May
	Fertilizer dose	80:40:40	80:40:40	80:40:40	80:40:40
	Variety	IET-5656	GK-2002	IET-5656	GK-2002
Rice-Sunflower+Greengrm (2:4)	Sowing window	Last week of June	1st fortnight of January	Last week of June	1st fortnight of January
	Harvesting window	Last week of November	1st fortnight of May	Last week of November	1st fortnight of May
	Fertilizer dose	80:40:40	80:40:40	80:40:40	80:40:40
	Variety	IET-5656	Local/ GK-2002	IET-5656	Local/ GK-2002
Rice-Lady's finger	Sowing window	Last week of June	1st fortnight of January	Last week of June	1st fortnight of January
	Harvesting window	Last week of November	2nd fortnight of May	Last week of November	2nd fortnight of May
	Fertilizer dose	80:40:40	80:40:40	80:40:40	80:40:40
	Variety	IET-5656	Pankaj	IET-5656	Pankaj

available K 305.84 (281.45-324.67) kg ha^{-1}. The area received an annual rainfall of 1626 cm and 1667 cm in the year 2010-11 and 2012-13, respectively.

All the four cropping systems were allotted in each of the farmer's field taking a block of 100 m^2 area i.e. the area of each cropping system at every farmer's plot was 25 m^2. The experiments were conducted at same site during the entire period of study and each farmer's field was treated as one replication. The observations on yield and other parameters were taken and analysed following Gomez and Gomez (1984). The cost of cultivation was calculated on the basis of prevailing market price of different inputs used for each cropping system. The prevailing farm gate price at the time of harvest were used for rice grain and straw, sunflower seed, greengram and lady's finger. The monetary return for the cropping systems was calculated on yearly basis. To compare among the cropping systems, the economic yield of component crops was taken into account over the year and converted into rice equivalent yield (REY) on price basis for each cropping system (Verma and Mudgal, 1983). The land use efficiency (LUE) was calculated from total duration of crops in the cropping system divided by 365. The total economic yield in terms of REY of a cropping system was divided by 365, to get the system productivity (kg $ha^{-1}day^{-1}$) (Devasenapathy *et al*., 2008). Net return was worked out by the difference of gross returns and total cost of cultivation of a system. B:C ratio (Returns per rupee invested) of a system was expressed as net returns (₹) per ₹ spent. Economic efficiency in terms of ₹ ha^{-1} day^{-1} was worked out by dividing the net returns of the system by total duration of crops in a system in an agricultural year (Patil *et al*., 1995). The irrigation water use efficiency of a system refers to the economic yield obtained, in terms of REY, due to use of per unit of irrigation water. The energy output of different systems was calculated on the basis of economic yield as given by Mittal and Dhawan (1988) and expressed as the total energy (MJ/ha).

RESULTS AND DISCUSSION

Productivity: The yield of *kharif* season rice crop was higher at second block (Kakdwip) (4627.52 kg ha^{-1}) as compared to first block (Mandirbazar) (4473.98 kg ha^{-1}). The same block also recorded significantly higher straw yield (6546.02 kg ha^{-1}).This may because of better soil fertility of second block. The pooled analysis revealed that rice crop registered highest yield in terms of grain (4617.04 kg ha^{-1}) as well as straw (6605.11 kg ha^{-1}) in rice-lady's finger cropping system, which was significantly higher than the other crop sequence and was followed by rice-greengram+sunflower, rice-sunflower and rice-green gram. In rice-lady's finger sequence rice yield was 2.8%, 1.9% and 1.1% more than rice-greengram, rice-sunflower and rice-sunflower+greengram respectively. Maximum rice equivalent yield (REY) (15,937.28 kg ha^{-1}) and system productivity (44.45 kg ha^{-1} day^{-1}) were recorded with second block, which showed 15.82% and 18% higher REY and productivity respectively over second block. Rice-lady's finger crop sequence was found most productive in terms of REY (28,080.17 kg ha^{-1}) and productivity (78.01 kg ha^{-1} day^{-1}), followed by rice-sunflower, rice-greengram+sunflower and rice-greengram. Rice-lady's finger sequence recorded 220.7, 163.28 and 190.61 percent higher REY than rice-greengram**,** rice-sunflower and rice-greengram+sunflower sequence, respectively. Regarding productivity rice-lady's finger sequence registered 224.37, 164.62 and 192.83 percent higher values than rice-greengram**,** rice-sunflower and rice-greengram+sunflower sequence, respectively (Table 2). The system containing lady's finger, rice yield was significantly higher due to residual effects of high doses of fertilizer and organic manure applied to lady's finger may have caused benefits for rice, as has also been observed in other studies with potato and lady's finger (Ray *et al.,* 2009 and Samui *et al.,* 2004).

Profitability: Both production cost and annual net return must be considered for choosing suitable cropping systems for the coastal saline flood plain of West Bengal because those varied widely among individual cropping systems. Production cost for rice-lady's finger cropping system was observed highest (₹1,17,780 ha^{-1}), followed by rice-sunflower (₹59,440 ha^{-1}), rice-greengram+sunflower (₹56,280 ha^{-1}) and rice-greengram (₹53,120 ha^{-1}). Inclusion of lady's finger in cropping system resulted in significantly higher production cost than any other crops, primarily due to high cost of labour, fertilizers, plant protection chemicals and irrigation (Table 3). Singh *et al.*(2013) reported that the rice-lentil and rice-pea crop sequence required less cost of cultivation in comparison to rice-frenchbean or rice-mustard sequence. Marginally higher cost of production was recorded in Mandirbazar block (₹70,880 ha^{-1}) than Kakdwip block (₹70,780 ha^{-1}) due to comparatively higher labour cost (Table 3).

Net returns were directly related to the price that the producer received for the produce and inversely related to the production cost. Though growing lady's finger was associated with highest production cost, it was also the most profitable crop. Both net return and B:C ratio were highest for lady's finger as well as for lady's finger containing cropping system (₹1,44,600/- and 2.24), followed by sunflower and

Table 2. Rice grain and straw yield, system rice equivalent yield and system productivity

Treatment	Rice grain yield (kg ha^{-1})			Rice straw yield (kg ha^{-1})			System rice equivalent yield (kg ha^{-1})			System productivity (kg ha^{-1} day^{-1})		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
Block 1	4553.05	4394.92	4473.98	6623.71	6315.55	6469.63	49391.04	12363.58	12643.90	35.41	33.87	34.64
Block 2	4645.11	4609.92	4627.52	6559.95	6532.09	6546.02	79585.44	14122.73	15937.28	50.21	38.69	44.45
SEm (±)	15.23	16.06	11.06	23.83	24.93	17.24	1627.21	88.23	161.62	0.55	0.24	0.30
CD(0.05)	42.99	45.34	30.66	67.29	70.40	47.79	4594.83	249.15	447.93	1.54	0.68	0.83
Cropping Systems												
R-G	4541.57	4439.55	4490.56	6512.29	6339.27	6425.78	9048.04	8460.79	8754.42	24.92	23.18	24.05
R-S	4583.58	4476.38	4529.98	6566.26	6388.76	6477.51	11375.71	9954.96	10665.33	31.69	27.27	29.48
R-S+G	4612.73	4518.10	4565.41	6610.35	6435.44	6522.90	10017.00	9307.88	9662.44	27.78	25.50	26.64
R-L	4658.42	4575.65	4617.04	6678.41	6531.81	6605.11	30911.33	25249.00	28080.17	86.85	69.18	78.01
SEm (±)	21.53	22.71	15.65	33.70	35.26	24.39	439.78	124.78	228.57	0.77	0.34	0.42
CD(0.05)	60.80	64.12	43.36	95.16	99.56	67.59	1241.84	352.35	633.47	2.18	0.97	1.17

R-G: Rice-Greengram, R-S: Rice-Sunflower, R-S+G: Rice-Sunflower+Greengrm (2:4), R-L: Rice-Lady's finger

greengram containing system respectively (Table 3). This is mainly due to higher yield of lady's finger. Rice-lady's finger system recorded 400, 258 and 322 per cent higher net returns than rice-greengram, rice-sunflower and rice-greengram+sunflower systems, respectively. Rice-lady's finger system also recorded 44.52, 31.76 and 38.27 per cent higher B:C ratio than rice-greengram, rice-sunflower and rice- greengram+sunflower systems, respectively. The results of this experiment confirm the findings of Ray *et al.,* 2009 and Samui *et al.,* 2004. Among the two blocks, significantly higher net return (₹75,010/-) and B:C (1.91) were recorded in Kakdwip block than Mandirbazar mainly due to higher yield and less cost of production.

Nutrient Uptake: Among the different cropping systems, rice-lady's finger registered the highest N uptake (₹324.93 kg ha^{-1}) followed by rice-sunflower (₹320.89 kg ha^{-1}) and rice-greengram+sunflower (₹316.28 kg ha^{-1}) and those were found statistically at par, whereas rice-sunflower system recorded the highest P (₹66.62 kg ha^{-1}) and K (₹310.45 kg ha^{-1}) uptake and was observed at par with rice-greengram+sunflower. The lowest N, P, K uptake was found in rice – greengram sequence (Table 3). Lady's finger and sunflower are heavy feeder of nutrients, so inclusion of these two crops in the system resulted in more uptake of N, P, K than that of greengram crop. Moreover, greengram uptakes less amount of nutrients from the soil due to its low yield. This result is in inconformity with the findings of Upadhyay *et al.,* 2011, Yadav *et al.,* 2013 and Prasad *et al.,* 2013.

Maximum P uptake was found in Kakdwip block (₹51.44 kg ha^{-1}), which was slightly higher than that of Mandirbazar block. No significant difference for N and K uptake was observed between these two blocks.

Resource Use Efficiency: The highest land use efficiency (LUE) was observed in rice-lady's finger (79.32%), followed by rice-sunflower (74.47%) and rice-greengram+sunflower (74.47%) and found statistically at par. The lowest LUE was recorded in rice-greengram system (69.13%) (Table 4). As rice is the common *kharif* crop in all the systems, the LUE is governed by the duration of summer crops. Among the summer crops lady's finger remained in the field for longer duration than any other crops, followed by sunflower and greengram. The highest irrigation water use was recorded in rice-lady's finger sequence (13.47 cm), then in rice-sunflower (10.83 cm), rice-greengram+sunflower (9.48 cm) and rice-greengram (4.11 cm) (Table 4). The highest irrigation water use in rice-lady's finger system was mainly due to longer duration of lady's finger crop as well as higher amount of irrigation water requirement. Irrigation water use efficiency is one of the most important factors to be considered for choosing suitable cropping system in

Table 3. Effect of different cropping sequence on economics and nutrient uptake

Treatment	Cost of production ('000 ₹ha^{-1})	Net return ('000 ₹ha^{-1})	B:C ratio	Nutrient uptake (kg ha^{-1})		
				N	P_2O_5	K_2O
Block 1	70.88	49.06	1.64	309.157	47.81	266.37
Block 2	70.78	75.01	1.91	306.491	51.44	267.52
SEm (±)	-	0.94	0.01	8.255	1.26	6.12
CD(0.05)	-	2.61	0.03	NS	3.48	NS
Cropping System						
R-G	53.12	28.91	1.55	269.21	36.40	206.88
R-S	59.44	40.36	1.70	320.89	66.62	310.45
R-S+G	56.28	34.28	1.62	316.28	53.76	295.37
R-L	117.78	144.60	2.24	324.93	41.73	255.07
SEm (±)	-	1.33	0.01	11.67	1.78	8.65
CD (0.05)	-	3.68	0.04	32.36	4.92	23.97

R-G: Rice-Greengram, R-S: Rice-Sunflower, R-S+G: Rice-Sunflower+Greengrm (2:4), R-L: Rice-Lady's finger

Table 4. Resource use efficiency (pooled over two years)

Treatments	Land use efficiency (LUE) (%)	Economic efficiency (₹ha^{-1}day^{-1})	Irrigation (cm)	Irrigation water use efficiency (kg ha-cm^{-1})	Employment generation (Man days ha^{-1})	Energy output ('000MJ/ha)
Block 1	71.48	134.42	10.84	1222.86	352	174.62
Block 2	77.53	205.52	8.10	2546.58	351	174.67
SEm (±)	-	-	-	-	-	0.45
CD(0.05)	-	-	-	-	-	NS
Cropping System						
R-G	69.13	79.22	4.11	3159.60	303	159.35
R-S	74.47	110.58	10.83	1081.24	320	179.79
R-S+G	74.47	93.93	9.48	1078.36	311	175.18
R-L	79.32	396.15	13.47	2219.69	475	184.26
SEm (±)	-	-	-	-	-	0.63
CD (0.05)	-	-	-	-	-	1.75

R-G: Rice-Greengram, R-S: Rice-Sunflower, R-S+G: Rice-Sunflower+Greengrm (2:4), R-L: Rice-Lady's finger

irrigation water scared area like coastal saline flood plain of West Bengal. It is directly related to the yield of component crops and inversely related to the amount of irrigation water used for growing crops. Rice crop was grown fully under rainfed condition, so yield of summer crops and amount of water used for raising those crops made difference among the cropping systems. Maximum irrigation water efficiency was observed with rice-greengram system (₹3159.60 kg ha-cm^{-1}), followed by rice-lady's finger system (₹2219.69 kg ha-cm^{-1}) and rice-sunflower (₹1081.24 kg ha-cm^{-1}). The lowest water productivity was recorded in rice-greengram+sunflower (₹1078.64 kg ha-cm^{-1}) system. Among the two blocks better irrigation water use efficiency was recorded in second block (₹2546.58 kg ha-cm^{-1}) (Table 4). The highest irrigation water use efficiency was observed in rice-greengram sequence due to very negligible irrigation water was utilized for successful growing of the crops.

Though the requirement of irrigation for lady's finger was the highest among all summer crops but the second highest water productivity of a system containing lady's finger was mainly due to significant higher yield of lady's finger than other crops. Chitale *et al.,* (2011) also reported that higher irrigation water use efficiency with rice-brinjal-green manuring and rice-onion-green manuring. Higher irrigation water efficiency was observed in second block due to higher REY and less irrigation water application. Employment generation was also found highest in rice-lady's finger system (₹475 man days ha^{-1}) due to more involvement of labour in harvesting, irrigation and management of lady's finger. The lowest employment generation was found with rice-greengram system (303 man days ha^{-1}) as greengram required less labour than other crops. Economic efficiency refers to per day net return of a cropping system. The rice-lady's finger had the highest economic efficiency (396.15 ha^{-1} day^{-1}), followed by rice-sunflower system (110.58 ha^{-1} day^{-1}), rice-greengram+sunflower (93.93 ha^{-1} day^{-1}) and rice-greengram (79.22 ha^{-1} day^{-1}). Like other resources the higher economic efficiency was found in second block (Table 4).

Energetics: The highest energy output was found in rice-lady's finger system (1,84,260 MJ ha^{-1}), followed by rice-sunflower (1,79,790 MJ/ha), rice-greengram + sunflower (1,75,180 MJ/ha) against lowest value of 1,59,350 MJ ha^{-1} found with rice-greengram sequence (Table 4). This is because of lower productivity of greengram crop as compared to other summer crops. Regarding energy output no significant difference was recorded between the two blocks (Table 4). Mishra *et al.,* (2013) also reported higher output energy with rice-vegetable cropping system.

Thus, rice-lady's finger is the most efficient, resource conservative, highly profitable cropping system under coastal flood plain, which has the potential to serve as a viable and better alternative cropping system with limited irrigation facility to the existing rice-fallow and rice-greengram system. However, farmers still has the reservation to take this cropping system mainly due to its high cost of cultivation and labour crisis.

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Evaluation of Production Potential for Rice-Based Cropping Sequences on Cultivators' Fields in Sub-Tropical Low Hills Zone of Himachal Pradesh

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***Abstract*:** Five rice-based cropping sequences *viz.* rice-wheat, rice-radish- potato, rice-potato-French bean, rice-potato-onion and rice-berseem + oats were evaluated on cultivators' fields for their production potential and economic feasibility in the low hills of Una and Kangra districts of Himachal Pradesh. Five year's (2007-08 to 2011-12) results revealed that rice-potato-onion, cropping sequence recorded significantly higher rice equivalent yield (14705 kg ha^{-1}) and net return (Rs 149597 Rs ha^{-1}), which was at par with rice-potato - French bean (12858 kg ha^{-1} and 117761 Rs ha^{-1}, respectively) and rice-radish-potato (11701 kg ha^{-1} and 109548 Rs ha^{-1}, respectively) cropping sequence. The extent of rice equivalent yield and net returns increase under rice-potato-onion, rice-potato-French bean and rice – radish – potato sequences was 177.8 & 102.0, 142.9 & 59.0 and 121.0 & 47.9%, respectively, over the conventional rice-wheat cropping sequence. In terms of total calories, only rice - potato - onion and rice-radish-potato cropping sequences could excel over the rice-wheat sequence. Total calories in rice-berseem+oats sequence were 81.4% of that realized under the rice-wheat cropping sequence. Conventional rice – wheat cropping system was superior over all the tried cropping systems in terms of physical energy intensity as well as economic energy intensity terms. Land use efficiency ranged between 76.5 to 97.9 % under different cropping systems.

Key Words: Cropping Sequences, Economics, Production Efficiency, Rice

Rice-wheat is the most important cropping system in India (Prasad, 2005). It occupies 10.5 m ha productive lands in Indo-Gangetic plains and contributes about 25% of the national food production. This system has sustained over the years and brings together conflicting and complementary practices. Because of high productivity, stability, low risk, and assured marketing the wide adoption of this system will also play a major role in future planning to sustain self sufficiency of food grains (Singh *et al.*, 2012). But now the productivity of both the crops has stagnated and factor productivity is declining year after year. In Himachal Pradesh, this system covers more than 80 thousand hectares with average productivity of 3.07 t ha^{-1} (Anonymous, 2013) as against the national average of 5.70 t ha^{-1}. The farmers realize much of their food security from this cropping system and the low production level need immediate attention for the efforts to be geared in strengthening it. Besides food security, the low production levels jeopardize farmers' economic security to a considerable extent. To strengthen the economic security, it is imperative to intensify and diversify the existing rice-wheat system. Therefore, it is essential to diversify the system with rice as the base crop with more productive and profitable crops in place of wheat on cultivators' fields on participatory mode.

MATERIAL AND METHOD

Field investigation to evaluate the production potential of rice- based cropping sequences was taken under the On-Farm Research Programme of 'All India Coordinated Research Project on Integrated Farming Systems', Project Directorate of Farming System Research, Modipuram (ICAR) for five years (2007-08 to 2011-12).

During the years 2007-08 to 2008-09 experimental trials were conducted at 3 centres viz; Nandpur and Kalruhi in district Una and Khabli in district Kangra, whereas during the subsequent three years (2009-10 to 2011-12) trials were conducted within at four centres viz; Jawali, Rehan Tripal and Fatehpur in district Kangra. During 2009-10,there were three centres (excluding Fatehpur) with four locations per centre, whereas during subsequent years, trials were conducted at all the four centres with three locations per centre.

Five rice-based cropping sequences *viz.* rice-wheat, rice-radish-potato, rice-potato-French bean, rice-potato-onion and rice-berseem + oats were evaluated at farmers' fields. The crops in each cropping sequence were raised in accordance with the recommended package of practices (Table 1).

The soils of the zone were inceptisols, texture varying from loamy sand to silty clay loam, with pH 5.6-8.2.

Table 1. Varieties, fertilizer dose (kg/ha), sowing and harvesting time of different crops

Crop	Variety	Fertilizer dose (kg/ha)			Sowing Time	Harvesting Time
		N	P_2O_5	K_2O		
Rice	Kasturi / HPR 1068	90	40	40	16 May - 3 June	9-30 Oct.
Wheat	HPW-184/ HPW 236	120	60	30	2-19 Nov.	10-30 April
Radish	Japanese white	100	50	40	15 Oct. - 5 Nov.	15 Jan. - 15 Feb.
Potato (spring)	Kufri Jyoti	120	80	60	21 Jan. - 19 Feb.	29 April - 28 May
Potato (autumn)	Pukhraj	120	80	60	8 Oct. - 6 Nov.	9 Jan. - 13 Feb.
French bean	Contender	50	80	60	5 Feb. - 1 April	26 April - 10 June
Onion	N-53/ AFDR	125	75	60	25 Dec. - 10 Jan.	25 April - 15 May
Berseem + oats	Local	25	60	-	25 Oct. - 14 Nov.	18 April - 12 June

Organic carbon was in the range of low to high in both the farming situations. It ranged from 0.3 to 0.85% in FS I (Farming situation I, Una & Kangra) and from 0.31 to 0.91% in FS II (Farming situation II, Kangra) with mean of 0.53 and 0.59%, respectively. Available N content was low to medium in both the farming situations ranging from 128.0 - 273.1 kg/ha in FSI and from 199.3 -337.9 kg/ha in FSII. Available P was medium to very high in FS I (13- 63.3 kg/ha) and low to very high in FS II (6.0 - 65.7 kg/ha). Available K content was low to high in both FS I (107.2-425.6 kg/ha) and FS II (60.8-399.2 kg/ha) (Table 2). The variation in the content of available P and K as determined in terms of coefficient of variation (CV %), was large in both the farming situations followed by OC, N and pH. The average annual precipitation recorded was 795 mm, 1479 mm, 1141 mm, 1841 mm and 1623 mm during 2007-08, 08-09, 09-10, 10-11 and 2011-12, respectively, whereas, mean maximum and minimum temperature of the test sites varied from 27.2 to 29.1 °C and 14.3 to 16.9 °C, respectively throughout the period of study.

Economics of the crop sequences was computed, based upon the farm gate prices. Area equivalent ratio (AER), relative profit, additional profit and profit equivalent ratio (PER) were determined according to studies conducted by Rana *et al*. (2010) i.e.,

AER = Cost of cultivation of conventional cropping sequence divided by cost of cultivation of alternative cropping sequence

Relative profit (Rs ha^{-1}) = AER multiplied by net returns (Rs ha^{-1})

Additional profit (Rs ha^{-1}) = Relative profit of alternative cropping sequence minus net returns of conventional cropping sequence

PER = Relative profit (Rs ha^{-1}) divided by net returns of conventional cropping sequence

Land utilization efficiency was worked out by summation of duration of each crop under individual crop sequence divided by 365. System productivity (kg $ha^{-1}day^{-1}$) was obtained by dividing total production in terms of rice equivalent in a sequence by the total duration of year (365), while system profitability (Rs $ha^{-1}day^{-1}$) was obtained by dividing net monetary return by 365. Energy intensity was worked out as follow. Energy intensity (physical terms) = energy output/equivalent yield, Energy intensity (economic terms) = energy output/cost of cultivation.

For comparison among crop sequences, the economic yield of crops were converted into rice equivalent on price basis. Homogeneity of error variances was tested by using Bartlett x^2 – test; which were found to be homogeneous. Therefore, the data were pooled and analyzed in randomized block design.

RESULTS AND DISCUSSION

Crop yields: During the experimental period, the yields of rice, wheat, radish, onion, potato, French bean, and berseem + oats ranged between 2684-3274, 3498-3828, 13579-18643, 11253-17350, 8542-19774, 4554-8018 and 40702-54415 kg ha^{-1}, respectively (Table 4). Mean yield of rice, wheat, autumn potato and spring potato was, 97.4, 100.0, 5.9, and 18% higher than the average yield (rice 1550 kg,wheat 1530 kg & potato 14000 kg ha^{-1}) of these crops in Himachal Pradesh, respectively (Anonymous, 2013 and Baba, 2007). The mean yield of onion, radish and French bean was lower by about 13.2, 15.2 and 35%, respectively

Table 2. Soil fertility status of the farmers' fields before sowing of the crops

Centre	pH	OC (%)	Available nutrients (kg ha^{-1})		
			N	P	K
		Farming Situation I (Una & Kangra)			
		(2007-08)			
Nandpur	8.0	0.85	273.1	48.5	298.7
Kalruhi	7.5	0.30	128.0	25.4	171.7
Khabli	7.2	0.49	217.6	13.0	130.7
		(2008-09)			
Nandpur	8.2	0.66	236.0	57.3	161.7
Kalruhi	7.7	0.32	165.6	42.7	107.2
Khabli	7.7	0.58	144.9	63.3	425.6
		Farming Situation II (Kangra)			
		(2009-10)			
Jawali	6.0	0.50	238.3	24.2	159.6
Rehan	5.8	0.67	284.2	46.3	240.1
Tripal	5.8	0.31	199.3	6.0	60.8
		2010-11			
Jawali	7.0	0.91	250.9	65.7	399.2
Rehan	5.9	0.60	284.3	28.4	248.6
Tripal	6.3	0.53	213.2	31.4	146.7
Fatehpur	5.8	0.57	271.8	25.4	297.6
		2011-12			
Jawali	6.9	0.69	316.9	30.1	205.1
Rehan	5.6	0.68	337.9	23.4	173.2
Tripal	6.0	0.44	209.1	11.9	70.0
Fatehpur	5.6	0.61	323.2	21.4	165.4

than the state average yield (onion 175 qt, radish 225 qt and French bean 87 qt ha^{-1}) of these crops indicating their comparatively less productive after rice. This may probably be owing to disturbance in the structure of soil after pudding and its after effects. Yearly variations in crop yields were small during the study period. The CV values were < 10% for rice and wheat and about 10-20% for radish, onion and berseem + oats. The yearly variation in yield indicated by CV was 20-25% for rest of the crops.

Rice equivalent yields: Rice equivalent yield of the newly introduced cropping sequences viz. rice-potato-onion, rice-potato-French bean and rice-radish-potato was superior to prevalent rice - wheat sequence. However, rice-potato-onion cropping sequence was significantly superior in terms of rice equivalent yield (14705 kg ha^{-1}), The second best cropping sequence was rice-potato-French bean (12858 kg ha^{-1}) followed by rice-radish-potato (11701 kg ha^{-1}). The higher rice equivalent yield in these cropping systems was owing to replacement of wheat with high volume/high priced vegetable crops like potato, onion and French bean. Results are in conformity with number of findings suggesting inclusion of oilseeds, vegetables, ornamental or fodder crops to diversify the existing rice-wheat system for achieving higher rice equivalent yield (Kumar *et al*., 2008; Sharma *et al*., 2008; Tripathi and Singh, 2008). The rice-berseem + oats cropping sequence was also superior to rice-wheat in terms of rice equivalent yield. Rice-potato-onion, rice-potato-French bean and rice-radish-potato cropping sequences resulted in 177.8, 142.9 and 121.0%, higher rice equivalent yield, respectively, over the rice-wheat cropping sequence (Table 3).

Total calories of the main product: Rice - potato-onion, rice-radish-potato and rice-potato-French bean cropping sequences had excelled over the rice-wheat sequence in terms of production of total calories of the main product. Total calories under these cropping systems were higher about 26.4, 18.7 and 10.3%, respectively, than under the rice-wheat system. This indicated that these systems had high value of quality produce. Sharma *et al.* (2008) also documented higher energy output of cropping sequences in which, potato crop was included. In spite of significant increase in rice equivalent yield, total calories under rice-berseem + oats sequence were 75.7% of that realized under rice - wheat cropping sequence. It is pertinent to mention that

Table 3. Crop yield, rice equivalent yield and return under rice based cropping sequences

Sequence	Yield (kg ha^{-1})			Rice equivalent (kg ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})
	Kharif	*Rabi* I	*Rabi* II			
FSI (average of 9 locations/replications) (2007-08)						
Rice-wheat	3114	3828	-	5666	100801	70236
Rice-Radish-Potato	3084	18643	17307	12004	185239	104870
Rice-Potato-French bean	3178	14092	7845	11590	182275	93565
Rice-Potato-Onion	3198	14591	16973	13232	203815	116064
Rice-Berseem + Oats	3199	47222	-	6977	110012	80048
LSD (P=0.05)				1009	15055	15055
FSI (average of 9 locations/replications) (2008-09)						
Rice-wheat	3070	3791	-	5597	100226	69661
Rice-Radish-Potato	3139	15474	19774	12166	187667	107298
Rice-Potato-French bean	3186	17566	7565	12491	194959	106249
Rice-Potato-Onion	3218	17391	17350	14219	218636	130885
Rice-Berseem + Oats	3221	54415	-	7574	119033	89069
LSD (P=0.05)				1135	16571	16571
FSII (average of 12 locations/replications) (2009-10)						
Rice-wheat	3177	3751	-	5261	115833	78877
Rice-Radish-Potato	3203	13579	15015	12814	237053	146570
Rice-Potato-French bean	3230	14658	8018	13385	253880	155511
Rice-Potato-Onion	3274	14306	13771	14958	275494	176684
Rice-Berseem + Oats	3261	47880	-	7251	137546	100932
LSD (P=0.05)				1358	24567	24567
FSII (average of 12 locations/replications) (2010-11)						
Rice-wheat	2684	3786	-	4577	112413	75457
Rice-Radish-Potato	2805	15411	9837	8560	178125	87642
Rice-Potato-French bean	2828	8542	4554	9233	171110	72741
Rice-Potato-Onion	2789	8542	11253	11405	235020	136210
Rice-Berseem + Oats	2823	50824	-	6635	139172	102558
LSD (P=0.05)				801	15589	15589
FSII (average of 12 locations/replications) (2011-12)						
Rice-wheat	2805	3498	-	5538	117102	74002
Rice-Radish-Potato	2831	14215	14328	13155	203129	99629
Rice-Potato-French bean	2795	13544	5273	17183	260162	151812
Rice-Potato-Onion	2864	13114	13501	19222	283781	175081
Rice-Berseem + Oats	3011	40702	-	8724	138402	90777
LSD (P=0.05)				2193	23635	22366
(Average of 54 locations/replications) (Pooled 2007-08 to 2011-12)						
Rice-wheat	2956	3722	-	5294	110249	74058
Rice-Radish-Potato	3001	15287	14887	11701	199553	109548
Rice-Potato-French bean	3028	13442	6534	12858	215128	117761
Rice-Potato-Onion	3053	13322	14282	14705	246919	149597
Rice-Berseem + Oats	3091	40048	-	7450	130423	93579
LSD (P=0.05)				1324	19447	19165

Rice (Basmati) Rs 15.0-18.0 kg^{-1}; Wheat Rs 10.0-11.0 kg^{-1}; Onion Rs 5.00-10.00 kg^{-1}; Potato Rs 4.50-7.00 kg^{-1}; French bean Rs 8.00-20.00 kg^{-1}; Berseem + Oats (green fodder) Rs 1.20-1.50 kg^{-1}

in spite of higher total energy output of the main product; all the new cropping systems were inferior to the conventional rice – wheat cropping system in terms of energy intensity both in physical as well as economic terms (Table 4). It is therefore, evident that the system has not to be given up completely.

Economics: Rice -potato - onion sequence fetched higher net returns (Rs 149597 ha^{-1}) than other cropping sequences (Table 4), which was followed by rice-potato-French bean rice-radish-potato and rice-berseem+oats sequences. The increase in net profit might be due to higher yields of crops under crop sequences. Chaudhary *et al* (2001) have also reported higher net income by diversification of the existing rice-wheat cropping system. Rice-potato-onion, rice-potato-French bean, rice-radish-potato and rice-berseem+oats cropping sequences, resulted in 102.0, 59.0, 47.9 and 26.4% higher net returns, respectively, over the rice - wheat cropping sequence. Rice - berseem + oats registered higher B: C ratio than other cropping sequences. In spite of higher yields and net returns, rice - potato – onion, rice - potato - French bean and rice-radish-potato resulted in lower B: C ratio than rice-wheat cropping sequence due to higher cost of cultivation of potato and onion.

Land use efficiency: The land use efficiency ranged between 76.5 to 97.9% under different cropping systems (Table 5). All the new cropping sequences occupied the land for longer period of time and thus registered higher land utilization indices than rice-wheat cropping sequence. Rice-potato-onion registered highest land utilization efficiency (97.9%) followed by rice- berseem + oat (84.0 %) and rice- potato- French bean cropping sequence (82.4%). The field remained idle for about three months under rice-wheat cropping sequence. From the LUE of rice- wheat crop sequence, there was possibility to include some other short duration crop to maximize returns.

Production efficiency: As the indication of AER (0.372-0.402), a farmer cultivating 'rice-wheat' in one ha with cultivation cost of Rs 36191, when switches to alternative rice-vegetable-vegetable cropping sequence ('rice-potato-onion', 'rice-radish-potato' and 'rice-potato-French bean') can cultivate 37-40% of the area with the same amount (Table 7). Consequently relative profit from these alternative cropping sequences is also reduced to 37-40% of that obtained from one ha .

This was 59% under 'rice-radish-potato' and 'rice-potato-French bean', and 75% under rice-potato-onion of what was under rice-wheat. The further analysis indicated that to obtain the same return as under 'rice-wheat', the new cropping systems viz 'rice-potato-onion', 'rice-radish-potato', 'rice-potato-French bean' and rice-berseem+oats have to be sown in 49.5, 67.5, 62.9 and 79.1% of the entire area. By switching to cultivation of these alternative copping systems ('rice-potato-onion', 'rice-radish-potato' and 'rice-potato-French bean'), to get equivalent return as under one ha rice-wheat, a farmer would require Rs 12004, 24638, and 25092 more. However, the farmer can spare 20-50% of his land resource for some other economic activity.

Table 4. Total calories of the main product and energy intensity under different cropping systems

Cropping sequence	Total calories (10^6 K cal ha^{-1})				Energy intensity	
	Kharif	*Rabi* I	*Rabi* II	Total	Physical terms (k cal ha^{-1})	Economics (k cal ha^{-1})
Rice-wheat	10.1	12.9		23.0	4348.1	636.0
Rice-radish-potato	10.3	2.6	14.4	27.3	2335.9	303.7
Rice-potato-French bean	10.4	13.0	2.0	25.4	1974.2	260.7
Rice-potato-onion	10.5	12.9	5.7	29.1	1979.4	299.1
Rice-berseem+oats	10.6	8.1		18.7	2516.7	508.9
LSD				1.1		

Table 5. Duration and land use efficiency under different cropping systems

Treatment	Duration (days)				LUE (%)
	Kharif	*Rabi* I	*Rabi* II	Total	
Rice-wheat	119.7	159.5		279.2	76.5
Rice-radish-potato	119.7	80.8	91.7	292.2	80.0
Rice-potato-French bean	119.7	89.8	91.3	300.8	82.4
Rice-potato-onion	119.7	89.5	148.0	357.2	97.9
Rice-berseem+oats	119.7	187.0		306.7	84.0

Table 6. Economics, productivity and profitability of different crop sequences

Treatment	B:C ratio	COC System (Rs. ha^{-1})	AER	Relative profit (Rs)	Additional profit	PER	Productivity (Kg $ha^{-1}day^{-1}$)	Profitability (Rs. $ha^{-1}day^{-1}$)
Rice-wheat	2.05	36191	-				14.5	202.9
Rice-radish-potato	1.22	90004	0.402	44050	-30008	0.595	32.1	300.1
Rice-potato-French bean	1.21	97367	0.372	43771	-30286	0.591	35.2	322.6
Rice-potato-onion	1.54	97321	0.372	55631	-18427	0.751	40.3	409.9
Rice-berseem+oats	2.54	36844	0.982	91920	17862	1.241	20.4	256.4
LSD		282					3.6	25.5

All the cropping sequences resulted in higher production efficiency in terms of system productivity (kg $ha^{-1}day^{-1}$) and system profitability (Rs $ha^{-1}day^{-1}$) over the rice-wheat cropping sequence. Rice-potato-onion cropping sequence recorded the highest system productivity (40.3 kg ha^{-1} day^{-1}) and system profitability (Rs 409.9 ha^{-1} day^{-1}) than the other cropping sequences, which was followed by rice-potato-French bean and rice-radish-potato cropping sequences (Table 6). System productivity (kg ha^{-1} day^{-1}) under rice-potato-onion, rice-potato-French bean and rice-radish-potato was, 2.8, 2.4 and 2.2, times higher than conventional rice-wheat cropping system. These crop sequences were also higher in case profitability by 2.0, 1.6 and 1.5 times, respectively, over the rice-wheat system. The system productivity and system profitability scenario clearly depicted that there is sufficient availability of food and cash for an average marginal family having one ha of land.

It is concluded that farmers of low hills of HP can adopt rice-potato-onion, rice-potato-French bean and rice-radish-potato cropping sequences for higher net income as an alternative to rice-wheat cropping system. However, complete replacement is not advisable.

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Effect of Cropping Systems on Crop Productivity and Profitability Under South Gujarat Condition

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Abstract: A field experiment was carried out during 2009-10 to 2011-12 at Farming System Research Farm, Navsari Agricultural University, Navsari (Gujarat) to study the effects of cropping systems on crop productivity and profitability in south Gujarat regjon. Compared to minimum tillage, paddy equivalent yield (PEY) and net profit under conventional tillage were 5.9 and 9.9 % higher, respectively. In pooled result, paddy - sorghum – summer green gram (159.33 q ha^{-1}) recorded significantly higher PEY, which was at par with paddy –green manuring -summer groundnut (142.01 q ha^{-1}). Paddy - sorghum – summer green gram recorded significantly higher net profit of ₹117669 ha^{-1}, which was at par with paddy –green manuring -summer groundnut (₹94163 ha^{-1}). Mulch has no significant effect on paddy equivalent yield during individual years but in pooled result, mulching with crop residue recorded significantly highest PEY (135.15 q ha^{-1}) and net profit (₹140342 ha^{-1}) over no mulch treatment. Significant effect of 25 % higher RDF on PEY (138.55 q ha^{-1}) and net profit ₹93144 ha^{-1} over RDF was observed during all individual years and in pooled result.

Key Words: Cropping System, Mulch, Paddy Equivalent Yield, Profitability, Productivity

Soil organic matter (SOM) is a useful indicator of soil quality since it determines the fertility, productivity and sustainability in agricultural systems where nutrient poor and highly weathered soils are managed with little external input (Feller and Beare, 1997). The dynamics of SOM are influenced by practices such as tillage, mulching, removal of crop residues and application of organic and mineral fertilizers. Removal of crop residue from the fields is known to hasten soil organic carbon (SOC) decline especially when coupled with conventional tillage. This is a common practice in most smallholder farms. Carbon sequestration in agricultural soils can be enhanced by addition of carbon inputs from crop residues. Locally available organic nutrient sources are often used in the form of farmyard manure, crop residues and green manure.

Tillage plays an important role in the nutrient storage and release from SOM, with conventional tillage (CT) soil disturbance through tillage is a major cause of reduction in the number and stability of soil aggregates and subsequently organic matter depletion (Six *et al.,* 2000). Cropping systems play an important role in determining soil physical characteristics and in nutrient cycling mechanisms. Present investigation was undertaken to assess the effects of conventional tillage, crop residue and cropping systems on yields between different cropping systems.

MATERIAL AND METHODS

An experiment was initiated during 2009-12 at Farming System Research Farm, Navsari Agricultural University, Navsari (Gujarat) to study the effects of cropping systems on crop productivity and profitability under heavy rainfall zone of south Gujarat condition. Climate is characterized by fairly hot summer, moderately cold winter, humid and warm monsoon with heavy rain. Average rainfall during the experimental years recorded about 1600 mm in 62 rainy days with highest evaporation rate of 7.2 (mm/day) in the month of May. Minimum bright sunshine hours observed during month of July (1.2 BSSH), while clear atmosphere with maximum bright sunshine hours in the month of April (11.0 BSSH). The soil of the experimental site was clayey with 0.59 % organic carbon, 1.46 g cc^{-1} bulk density, 256 kg/ha available nitrogen, 21.4 kg ha^{-1} available phosphorus and 260 kg ha^{-1} available potassium. The experiment was conducted in split-split plot design with three replications. There were two tillage practices as main plots, T_1: Minimum tillage, T_2: Conventional tillage (Puddling). Three cropping systems i.e., C_1: Paddy-green manuring-summer Groundnut, C_2: Paddy-*rabi* castor-green manuring, C_3: Paddy-sorghum-summer green gram, the two levels of mulch i.e., M_1: No mulch and M_2: Mulch with wheat reside incorporation. The recommended dose of fertilizers were 100-30-0,120-25-0, 80-40-0, 25-50-0 and 20-40-0 (NPK kg ha^{-1}) for paddy, castor, sorghum, groundnut and green gram, respectively. There were two levels of fertilizer F_1: RDF, F_2: 25% of RDF (recommended dose of fertilizer). Paddy equivalent yield (PET) was calculated on the basis of farm gate prices for each crop. no sever pests and diseases were found during the crop seasons.

RESULTS AND DISCUSSION

Tillage: The results revealed that tillage had not effect in respect of paddy equivalent yield, gross profit and net profit of sequences during individual years but showed significant effect on pooling the data. Conventional tillage recorded significantly highest paddy equivalent yield (136.01 q ha^{-1}) to the tune of 5.9 % over minimum tillage (128.01 q ha^{-1}). Same trend was observed in case of gross return and net profit. Increase in net profit of conventional tillage (₹91918 ha^{-1}) over minimum tillage (₹83621 ha^{-1}) to the tune of 9.9 % (Table 1). Reduced mineralization of plant residues have often been considered responsible for the low yields obtained with minimum tillage systems. These results are similar to the findings of Małecka and Blecharczyk (2008).

Cropping systems: The perusal of data indicated that the effect of cropping systems during individual year was significant among the treatments. Significantly highest paddy equivalent yield (135.98 q ha^{-1}) was recorded under C_3 during 2009-10 and 2011-12, while in 2010-11, C_3 was as par with C_1 (129.39 q ha^{-1}). In pooled data, C_3 (159.33 q ha^{-1}) recorded significantly higher PEY, which was at par with C_1 (142.01 q ha^{-1}). The cropping sequence paddy-*rabi* castor secured significantly lowest PEY (94.62 q/ha) over C_1 and C_3 (Table 1).

In case of net profit, C_3 recorded significantly highest net profit during individual years. In pooled data cropping system C_3 recorded significantly higher net profit of ₹117669 ha^{-1}, which was at par with C_1 (₹94163 ha^{-1}) due to higher land use efficiency of this cropping sequence. Cropping system C_2 recorded significantly lowest net profit over C_1 and C_3. (Table 1)

Mulch: Mulch has no significant effect on paddy equivalent yield during initial years 2009-10 and 2010-11; while residue incorporation recorded significantly highest PEY (139.58 q ha^{-1}) over no mulch during 2011-12. In pooled data, mulching (135.15 q ha^{-1}) recorded significantly highest PEY over no mulch (Table 1), which will be due to gradual addition of large amount of easily decomposable mulch material. Gross and net profits were not affected due to use of mulch in experimentation, but in pooled results, mulching recorded significantly highest gross profit of ₹147118 ha^{-1} over no mulch (₹140342 ha^{-1}), but net profit ha^{-1} was not significant (Table 1). These results are in accordance with the findings of Jat *et al* (2012)

Fertilizer: PEY was significantly highest with additional fertilizer during 2009-10 (149.05 q ha^{-1}), 2010-11

Table 1. Effect of management of cropping systems for resource conservation on paddy equivalent yield and economics of crop sequence

Treatment		Paddy equivalent yield (q/ha)				Gross profit (Rs./ha)	Net profit (Rs./ha)
		2009-10	2010-11	2011-12	Pooled	Pooled	Pooled
A. Main plot:- Tillage x Cropping systems							
Tillage	T_1 : Minimum tillage	135.63	116.94	131.53	128.01	139402	83621
	T_2 : Conventional tillage	146.24	122.23	139.47	136.01	148117	91918
CD at 5 %		NS	NS	NS	57.77	6292	6292
Cropping systems	C_1 : Paddy –Summer Groundnut	153.47	129.39	143.19	142.01	154654	94163
	C_2 : Paddy – *Rabi* Castor	93.93	93.39	96.68	94.67	103092	51476
	C_3 : Paddy - Sorghum – Summer green gram	175.39	135.98	166.68	159.33	173533	117669
CD at 5 %		13.33	8.62	17.58	23.14	25196	25196
B. Sub Plot :- Mulch x Fertilizer							
Mulch	M_1 : No mulch	138.25	116.39	131.46	128.87	140342	85809
	M_2 : Mulch/Residue Incorporation	143.09	122.79	139.58	135.15	147178	89730
CD at 5 %		NS	NS	5.86	3.67	3993	NS
Fertilizer	F_1 : RDF	132.81	114.36	129.25	125.47	136639	82394
	F_2 : 25% higher of RDF	149.05	124.82	141.78	138.55	150881	93144
CD at 5 %		6.34	7.32	5.86	3.68	4011	4011

Table 2. Effect of management of cropping systems for Resource Conservation on grain and straw yield of crop sequence

Treatment		Grain and Straw yield (q ha^{-1})																	
		2009-10						2010-11						2011-12					
		Kharif		*Rabi*		Summer		*Kharif*		*Rabi*		Summer		*Kharif*		*Rabi*		Summer	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A. Main plot:- Tillage x Cropping systems																			
Tillage	T_1	39.3	40.1	16.6	16.6	10.8	38.2	25.9	41.2	17.1	18.2	8.9	35.5	30.7	60.4	17.3	62.2	8.3	33.4
	T_2	42.1	42.9	18.6	18.6	11.5	41.2	28.4	43.8	17.3	18.6	9.26	37.7	31.8	63.7	17.2	54.7	9.97	39.4
Cropping	C_1	40.1	40.6	0.0	0.0	20.3	52.9	25.5	38.6	0.0	0.0	18.5	48.9	29.3	60.4	0.0	0.0	19.8	54.2
systems	C_2	40.6	41.5	20.3	0.0	0.0	0.0	27.1	42.7	26.3	0.0	0.0	0.0	32.9	62.5	24.1	0.0	0.0	0.0
	C_3	41.4	42.4	32.5	32.5	13.2	66.2	28.9	46.1	25.3	55.1	8.6	60.8	31.8	63.3	27.6	63.7	7.7	54.9
B. Sub Plot :- Mulch x Fertilizer																			
Mulch	M_1	40.1	40.8	17.2	17.2	11.0	38.8	26.6	40.4	16.6	17.9	8.8	35.6	30.3	61.4	16.6	58.0	8.8	35.0
	M_2	41.2	42.2	0.0	17.9	11.3	40.4	27.7	44.5	17.7	18.8	9.2	37.5	32.1	63.6	17.8	58.81	9.4	37.7
Fertilizer	F_1	38.2	39.3	16.5	16.5	10.5	38.5	26.0	40.4	16.0	18.1	8.79	35.5	29.7	60.6	15.7	56.2	8.95	35.5
	F_2	43.2	43.7	18.7	19.7	11.8	41.0	28.3	44.6	18.3	18.6	9.3	37.6	32.7	63.5	18.7	60.6	9.3	37.2

Table 3. Soil fertility status at end of crop sequence after three years (2011-12)

Treatment		Available nutrients (kg ha^{-1})			Organic carbon (%)
		N	P	K	
A. Main plot:- Tillage x Cropping systems					
Tillage	T_1	264.67	23.97	155.94	0.587
	T_2	265.19	24.02	158.70	0.584
Cropping systems	C_1	264.93	22.12	158.36	0.583
	C_2	265.53	25.37	156.80	0.581
	C_3	264.35	24.50	156.80	0.592
B. Sub Plot :- Mulch x Fertilizer					
Mulch	M_1	263.11	23.50	155.94	0.573
	M_2	266.77	24.49	158.70	0.598
Fertilizer	F_1	261.54	23.00	156.63	0.576
	F_2	268.34	24.99	158.01	0.595
Initial status		256.00	21.40	160.00	0.590

(124.82 q ha^{-1}) and 2011-12 (141.78 q ha^{-1}) over recommended dose, while in pooled results, dose 125 % RDF recorded significantly highest PEY (138.55 q ha^{-1}) over recommended (125.47 q ha^{-1}) (Table 1). Similar findings were observed by Parvez *et al.* (2009).

Significant effect of 125 % RDF on net profit over RDF was observed during all individual years except 2010-11. Significantly highest net profit of ₹93144 ha^{-1} was recorded under enhanced over normal fertilizer (₹82394 ha^{-1}) in pooled data.

From the experimental results, it can be concluded that after three years, paddy- sorghum-green gram cropping system was beneficial for getting higher PEY, net profit by adopting conventional method with 25 % higher fertilizer recommended dose and crop residue mulch.

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Probability of Wet Spells, Expected Amount and Long-Term Trends of Rainfall for Crop Planning in Bihar

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***Abstract*:** Rainfall analysis for Pusa, Purnia, Sabour and Patna representing North west alluvial plains (Zone I), North East alluvial plains (Zone II), and South Bihar alluvial plains (Zone III A and III B), respectively using annual and weekly rainfall data was carried out for Bihar state. The overall mean annual rainfall was lowest (1031 mm) for zone III B and highest (1466.7 mm) for zone II. But coefficient of variation was highest (30.8%) for Pusa (zone I) and lowest (23.7%) for Patna (zone III B). A long term significant decreasing trend in annual rainfall was observed in Patna (zone III B). At Pusa and Purnea, 25^{th} to 34^{th} SMW are favorable weeks for field preparation/sowing and transplanting of rice crop due to more than 75 per cent probability of rainfall of 10-30 mm. At Sabour, probability of rainfall more than 20 mm is 75 per cent during 25^{th}-33^{rd} week while for Patna; it is during 27^{th}-34^{th} SMW. So, sowing and field operations may be delayed by two weeks in Patna region. The study reveals that crops and varieties could be selected through the analysis of wet spell durations with the onset of monsoon in the given region. When monsoon is late or dry spell is encountered, practice direct seeded rice or intercropping of green gram or black gram. Under stress situations, less water requirement crops like sorghum, ragi, finger millet, etc. can be adopted in the region.

Key Words: Wet Spells, Rainfall Trend Analysis, Rainfall Probability, Crop Planning

Rainfall is the single most important factor in crop production planning in rainfed ecology. The information on annual, seasonal and weekly rainfall of a region is useful to design water harvesting structure for agricultural operations, field preparation, sowing, irrigation, fertilizer application and overall in field crop planning (Singh *et al*., 2008). Historically in Bihar, zone I and zone II are receiving too much rainfall to cause flood in the region, whereas, zone III B is characterized as rainfed region with low, erratic and uncertain rainfall pattern with frequent dry spells during the monsoon season. Hence monsoon cropping is tricky operation in the region as well as sudden crop failures during the *kharif* season is a common phenomenon due to early withdrawal of monsoon. Rainfall probability pattern has been studied by many scientists in India (Pradeep *et al*., 2012; Suchit *et al*., 2012) and concluded that rainfall occurrence is certain at greater than or equal to 80 per cent probability, while 50 per cent probability is the medium limit of certainty and may involve dry spell risk. Taking into account these climatic and probability factors, the study was conducted for four different locations situated in different agro-climatic zones of Bihar for interlinking the rainfall probability with the crop planning pattern in the region.

MATERIAL AND METHODS

Weekly rainfall data for the period 1955 to 2012 i.e. 58 years pertaining to Pusa (25° 98' N, 85° 13' E, 47 m msl), Purnea (25° 98' N, 87° 80' E, 37 m msl), Sabour (25° 23' N, 87° 70' E, 37 m msl) and Patna (25° 36' N, 85° 9' E, 58 m msl) representing North west alluvial plains (Zone I), North East alluvial plains (Zone II) and South Bihar alluvial plains (Zone III A and III B) of Bihar, respectively was used for analysis. Weekly, annual and seasonal rainfall distribution patterns were critically examined and analyzed. Trends were examined by Mann-Kendall rank statistics as described by Sneyers (1990). This test was used by several researchers to detect trends in hydrological time series data (Luo *et al*., 2008). An initial and conditional probability of weekly rainfall at different threshold limits (10, 20 and 30 mm) were computed using first order Markov chain process (Robertson, 1976). Expected amount of rainfall at a given probability level was computed for 24-39 SMW during monsoon season using Weibull's distribution (Chow, 1964).

RESULTS AND DISCUSSION

Variability in annual and seasonal rainfall: The average annual rainfall of Pusa (zone I) is 1246.9 mm with coefficient of variation (CV) of 30.8% (Table 1). About 83.8 per cent of annual rainfall is received from south west monsoon. The winter, pre monsoon and post monsoon season rainfall contribute 2.4, 7.9 and 5.9 per cent rainfall to the annual rainfall, respectively. For Purnea (zone II), the average annual rainfall is 1466.7 mm with CV 25.8 per cent. The contribution of monsoon, post monsoon, winter and pre monsoon season rainfall to the annual rainfall is 80.1, 6.5, 1.4 and 12 per cent, respectively. The average annual rainfall of Sabour (zone III A) is 1231.4 mm with CV of 24.5 per cent and monsoon season rainfall contribution is 78.7 per cent. The winter, pre monsoon and post monsoon rainfall contribution is 2.8, 10.4 and 8.1 per cent, respectively. The average annual rainfall of Patna (zone III B) is 1031.0 mm with CV of 23.7 per cent and monsoon season rainfall contribution is 85.9 per cent. The winter, pre monsoon and post monsoon rainfall contribution is 3.3, 4.5 and 6.3 per cent, respectively.

Trend analysis: The long-term annual rainfall of Patna (zone III B) shows significant decreasing trend (Table 1). In Pusa (zone I), it also shows decreasing trend but statistically non significant. In Purnea (zone II) and Sabour (zone III A), there is increasing trend but statistically not significant.

There is a decreasing trend of winter rainfall in all the zones though it is statistically not significant. There is significant increasing trend of pre monsoon rainfall in Patna (zone III B). In pre monsoon season, there is increasing trend of rainfall for all the zones except zone II, though it is statistically not significant. But there is decreasing trend of monsoon and post monsoon rainfall, in Pusa (zone I) and Patna (zone III B) though it is statistically not significant.

Initial and conditional rainfall probability analysis: An amount of 10 mm rainfall per week can be taken as the minimum requirement for seedbed preparation/sowing of rainfed *kharif* crops (Ahmed *et al.*, 2009). The long term rainfall data analysis revealed that at Pusa (zone I), initial {P (W)} and conditional {P (W/W) i.e. wet week followed by wet week} probabilities of getting 10 mm rainfall per week was 77-89 per cent from 25th to 34th standard meteorological week (SMW), in which, seed bed preparation/sowing can be done. Probability of receiving more than 20 mm rainfall per week was more than 75 per cent from 28th to 30th week and again during 32nd to 34th week, which would be an ideal time for transplanting or fertilizer application in the region. P (W/W) of getting 20 mm rainfall was 61-86 per cent from 25th to 33rd week and probability of getting 30 mm rainfall was 66-79 per cent during the same period (Fig. 1). In Purnea (zone II), probability of getting 10 mm rainfall per week was more than 80 per cent during 25th week and again from 28th to 30th SMW, which would be the ideal time for nursery bed preparation and again for transplanting of rice in 29th week. In 34th week rainfall pattern was again repeated, in which fertilizer application may be done. P (W/W) of getting 20 mm rainfall was 70-96 per cent during 25th-34th week and getting 30 mm rainfall was 59-93 per cent during the same period (Fig 1). Probability of 10 mm rainfall in Sabour region (zone III A) was 75-86 per cent during 25th to 33rd week, which would be ideal time for sowing and other cultural operations in the area (Fig 1). In Patna region (zone III B), from 25th to 34th week would be the ideal time of bed preparation/sowing of the crop due to probability of getting 10 mm rainfall was 70-88 per cent. Probability of getting 20 mm rainfall was 68-86 per cent from 27th to 34th week. P (W/W) of getting 20 mm rainfall was 70-91 per cent during 26th-34th week and of getting 30 mm rainfall was 64-84 per cent during the same period (Fig 1). Therefore these weeks are ideal for integrated field operations like sowing, fertilizer application etc. in these regions.

Expected rainfall amount and crop planning: As discussed above, rainfall at 75 per cent and 90 per cent probability is assured rainfall and at 50 per cent probability is the median limit for taking risk. At Pusa, the probability of

Table 1. Variation, percentage contribution (% C) and long term trends of seasonal and annual rainfall in four districts representing different zones of Bihar

Season	Pusa (zone I)				Purnia (zone II)			
	Rainfall (mm)	CV (%)	% C	Trend (mm/year)	Rainfall (mm)	CV (%)	% C	Trend (mm/year)
Annual	1246.9	30.8	-	-1.57	1466.7	25.8	-	0.81
Winter	30.3	75.8	2.4	-0.48	20.6	97.5	1.4	-0.10
Pre-monsoon	98.6	59.3	7.9	1.10	175.5	54.4	12.0	-0.14
Monsoon	1044.7	34.3	83.8	-1.20	1175.3	28.3	80.1	2.26
Post- monsoon	73.3	93.5	5.9	-0.99	95.4	99.0	6.5	-1.20
	Sabour (zone III A)				Patna (zone III B)			
Annual	1231.4	24.5	-	2.08	1031.0	23.7	-	-7.04*
Winter	34.8	89.3	2.8	-0.39	34.0	79.2	3.3	-0.51
Pre-monsoon	127.8	66.3	10.4	0.54	46.4	68.2	4.5	0.43*
Monsoon	969.7	25.0	78.7	2.39	886.1	25.1	85.9	-5.74
Post- monsoon	99.1	91.2	8.1	-0.46	64.5	94.5	6.3	-1.23

*Significant at 5 %

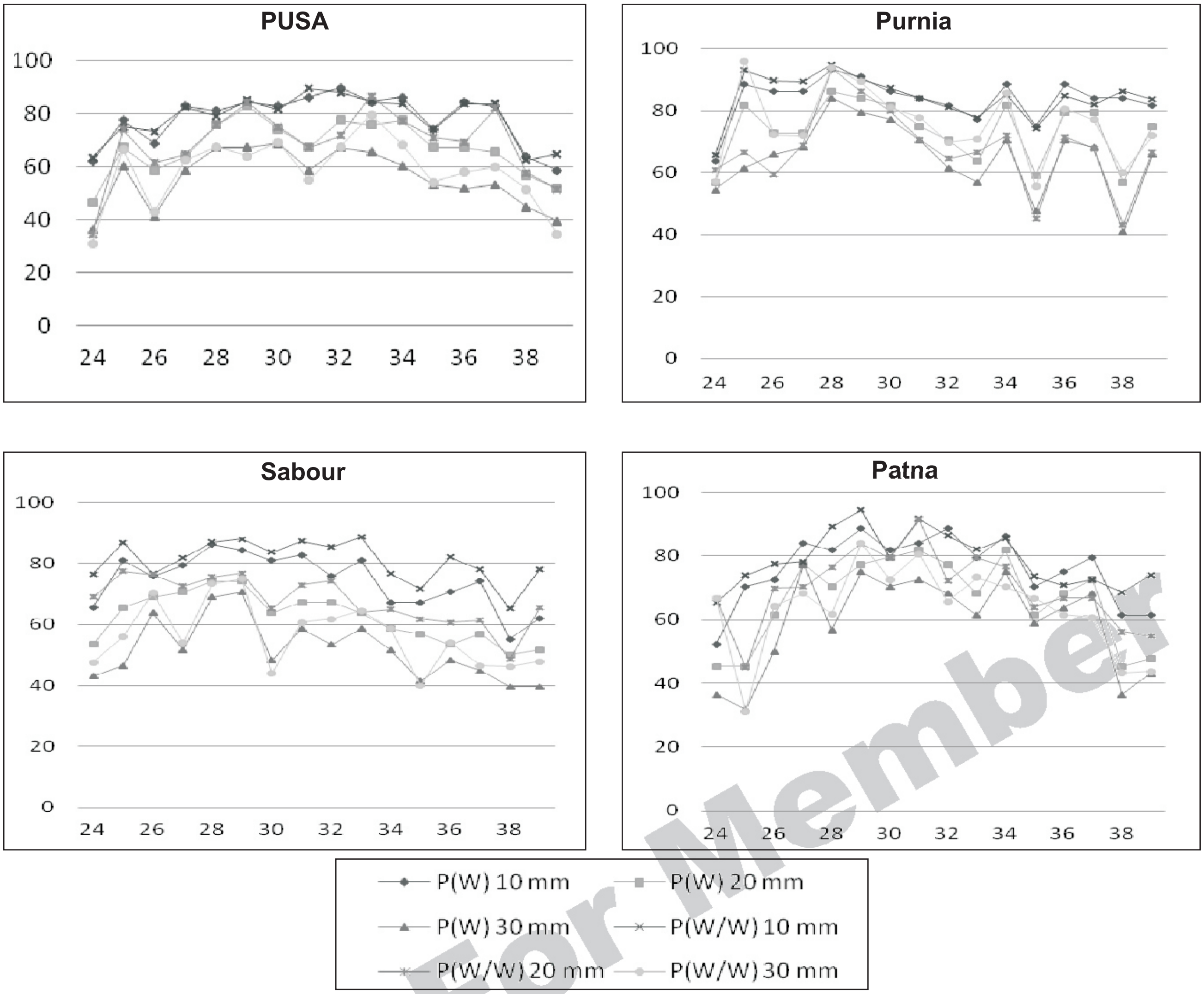

Fig.1. Initial P(W) and conditional probabilities P(W/W) of weekly rainfall at different threshold limit at Pusa, Purnia, Sabour & Patna

more than 30 mm rainfall from SMW 25th is above 50 per cent, but there is some risk. From 27th SMW, there is probability of more than 75 per cent of getting rainfall of more than 15 mm and farmers can initiate their field preparation operations and from 28th week expected rain becomes more than 20 mm, 27th and 28th week are an ideal time for sowing/transplanting of *kharif* crop and also for the crop fertilization based upon the rainfall pattern and intensity. In Purnea, the probability of more than 20 mm rainfall from SMW 25th is above 75 per cent and more than 10 mm rainfall is above 90 per cent (Table 2). From SMW 25th, sowing of kharif crop can be initiated in the region. In 28th and 29th week probability of receiving more than 30 mm rainfall is more than 75 per cent which is sufficient amount of rainfall for transplanting of rice in the region. In Sabour and Patna region, the probability of more than 10 mm rainfall is above 75 per cent from 25th and 26th SMW respectively. The probability of receiving more than 20 mm rainfall in the regions are from 28th and 29th week, respectively in which transplanting of rice can be completed.

Major crop of the region is rice, which is highly dependent on monsoon rainfall for nursery bed preparation, transplanting and maintenance of water in the field. Analysis indicates the need for selection of crops according to the probability of getting wet weeks preceded by wet weeks with the onset of southwest monsoon in the region. Timely monsoon will favour selection of long duration and high water requiring crops like rice. Late monsoon will lead to selection of crops with medium duration and moisture stress tolerant crops like ragi, finger millet and sorghum, in the moderate rainfall districts, where erratic monsoon behavior is observed. Pulses like green gram and black gram need to be selected often as intercropping based on varied rainfall

Table 2. Expected weekly rainfall amount (mm) at different probability level (%) in Pusa and Purnea

SMW	Pusa				Purnea				Sabour				Patna			
	50 %	75 %	90%	Total	50 %	75 %	90 %	Total	50 %	75 %	90 %	Total	50 %	75 %	90 %	Total
24	18.4	5.4	1.2	32.3	32	9.6	2.2	56.5	22.6	7	1.7	38.4	14.7	3.6	0.6	29.6
25	34.4	10.8	2.7	58.9	47.5	24.2	11.6	59.5	31.5	12.8	4.6	45.1	24	8.2	2.3	38.3
26	32.0	9.3	2.1	57.4	53.8	24.8	10.4	71.6	39.9	16.8	6.2	56.2	31.2	10.3	2.8	51.2
27	42.9	16.1	5.1	65.2	52.8	21.8	7.9	75.4	34.9	12.8	4	53.6	50.3	20.8	7.6	71.8
28	56.2	22.6	7.9	81.8	85.4	41.3	18.5	111.1	54.2	22.3	8	77.7	47.6	17.6	5.5	73.1
29	50.9	20.3	7.1	74.2	82.6	39.8	17.8	107.5	45.8	19.1	7	64.9	72.3	33.4	14.1	96.5
30	46.5	19.8	7.5	65.0	50.6	25.7	12.2	63.6	33.1	12.5	4	49.7	49.5	18.2	5.6	76.2
31	42.2	17.8	6.6	59.3	53.5	23.0	8.8	74.5	40.4	16.1	5.6	58.8	47.1	22.5	9.9	61.3
32	49.7	21.0	7.8	70.0	37.7	17.3	7.2	50.1	35.9	13.1	4	55.3	49.6	22.8	9.6	66
33	47.5	19.1	6.7	69.0	42.1	14.4	4.1	67.8	42.9	15.6	4.8	66.4	40.6	15.7	5.2	60.5
34	47.2	19.1	6.8	68.3	45.2	20.9	8.8	60.0	26.8	8.8	2.3	44.1	55.3	26.2	11.4	72.5
35	33.3	12.6	4.0	50.0	34.9	13.0	4.1	53.3	23.4	7.8	2.1	38	33.7	13.8	5	48
36	38.8	16.0	5.8	55.3	48.1	24.1	11.3	60.8	25.4	8	2	43.2	36.9	15.8	6	51.3
37	39.4	15.4	5.2	58.2	51.2	22.6	9.0	69.9	23.4	8.5	2.6	36	44.6	17.7	6.1	65.2
38	23.8	8.1	2.2	38.1	29.8	11.5	3.8	43.9	20.4	5	0.9	41.4	16	5.5	1.5	25.3
39	26.1	6.5	1.2	51.9	46.7	17.0	5.2	72.4	24	5.3	0.8	52.1	25.6	7.7	1.8	44.9

situation. Direct seeded rice can be adopted in that situation. Analysis reveals that past rainfall record may be handy tool for future rainfall probability projections.

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Thermal Energy Requirement and Heat Use Efficiency of Barley Varieties Under Different Dates of Sowing

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Abstract: Field studies with three barley varieties (PL l72, PL 426 and PL 807) under three dates of sowing (D_1-16[th] October, D_2-15[th] November and D_3-15[th] December) were conducted during the rabi 20012-13 at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana to study the variation in the efficiency of varieties to utilise solar radiation under different dates of sowing. Crop sown on 16[th] October took more number of days from sowing to heading than other dates of sowing, thus it availed longest vegetative phase. All the varieties took almost same number of days for completion of emergence. Variety PL 807 availed more number of days for attainment of all phenological stages. Variety PL 807 consumed the highest (477 °C day) number of GDD up to tillering and PL 426 consumed the lowest (367 °C day) under first date of sowing and this differential behaviour of the varieties continued till harvest. All the three varieties behaved alike in the subsequent dates of sowing. Similar pattern was fallowed for PTU and HTU. Variety PL 426 was more efficient in terms of HUE up to 90 days of crop growth. Heat use efficiency of PL 807 for production of grain, straw and total dry matter (grain + straw) was the highest in all the three date of sowing and that of variety PL 426 was the lowest. The linear regression models indicated that GDD, PTU and HTU accounted for more than 97 per cent variation in the onset of different phenophases for barley varieties. Periodic dry matter accumulation and periodic HUE accounted for more than 94 per cent variation in the onset of different phenophases for barley varieties.

Key Words: Barley, Dates of Sowing, Phenology, Thermal Energy Utilization, Varieties

Barley (*Hordeum vulgare* L.) is the fourth most important cereal crop of the world after wheat, rice and maize. Barley can be grown under wide range of climatic conditions (Prasad 2002). The yield of a crop is a result of complex set of interactions occurring during the growth period of the crop. Genotype and optimum time of sowing are primary inputs for higher yields. These factors viz. genotype and date of sowing assumes importance in view of the photo and thermal requirements of the crop plant. Rates of most biological processes are affected markedly by temperature. Growth and development of any organism shows a significant response to temperature, which results from the integrated effect of temperature on many physiological processes involved (Reddy 2001). Plants require a specific amount of heat to complete their lifecycle i.e. from sowing to the maturity.

Barley is a long day plant. Every crop requires accumulation of a definite amount of heat energy to complete its life cycle. Growing degree days (GDD) are a simple means of relating plant growth, development and maturity to air temperature. The heat units or growing degree days concept assumes that the growth of plant is dependent on the total amount of heat to which it is subjected during its life cycle. Heat accumulated in terms of GDD in association with solar radiation determines the yield of a crop, which can be measured in terms of heat use efficiency (Nelson,1963). Such studies are gaining more importance under the changing climatic conditions as crop varieties and agronomic management options with higher heat use efficiency need to be explored under global warming scenarios. Keeping this in view, an investigation was carried out on three barley varieties under three dates of sowing to evaluate the photo and thermal requirements of barley crop and to correlate these temperature based indices with yield and phenology of the crop.

MATERIAL AND METHODS

Field studies with three barley varieties (PL l72, PL 426 and PL 807) under three dates of sowings (D_1-16[th] October, D_2-15[th] November and D_3-15[th] December) were conducted during *rabi* 20012-13 at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (30°54'N; 74°48'E and 247 meter above the mean sea level). The soil of the experimental farm was loamy sand in texture, low in available N, organic carbon, medium in available P and high in available K. The crop was sown at 22.5 cm row spacing using 87.5 kg seed per hectare. Three nitrogen levels (75, 100 and 125 % of recommended dose of nitrogen, 62.5 kg/ha) were included in the sub-sub plot and 30 kg P_2O_5 per hectare was drilled uniformly at the time of sowing. Nitrogen levels did not cause much variation in the phenological calendar of the crop. Hence results were averaged over nitrogen levels The phenological stages of the crop were recorded when 50 per cent of the tagged plants showed occurrence of particular phenophase (complete emergence, tillering, jointing, booting, heading and maturity). Agroclimatic indices namely growing degree days, heliothermal units, photothermal units and heat use efficiency were computed as per the following formulae suggested by Nuttonson (1955):

$$\text{Growing degree days (°C days)} = \frac{(T_{max} + T_{min})}{2} - T_b$$

Where, T_{max} = Daily maximum temperature (°C)

T_{min} = Daily minimum temperature (°C)

T_b = Base temperature (4.4°C)

The heliothermal units (HTU), the product of GDD and corresponding actual sunshine hours for that day were computed on daily basis and summed up:

$$\text{Accumulated HTU} = \sum_{i=1}^{n} \text{GDD x Actual sunshine hours}$$

The photothermal units (PTU), the product of GDD and corresponding day length for the day were computed on daily basis and summed up:

Where day length refers to maximum possible sunshine hours.

Accumulated PTU = GDD x Day length

Growing degree day, heliothermal units and photothermal units were accumulated from the date of sowing to each date of sampling and a particular date of phenophase to give accumulated indices.

The heat use efficiency (HUE) for total dry matter was obtained as under:

$$\text{Heat Use Efficiency (kg/ha/°C days)} = \frac{\text{Seed or dry matter yield (kg/ha)}}{\text{AGDD (°C day)}}$$

AGDD = Accumulated growing degree days (°C days)

Phenophasic models are the linear regression models between days taken to attain different phenological stages and heat units consumed by the crop derived for predicting the onset of any particular phenophase based on growing degree days or photothermal units or heliothermal units. Similar regression models were developed in the present investigation for predicting phenology of barley varieties under different dates of sowing as were developed by Hundal and Kingra (2000) for soybean crop.

RESULTS AND DISCUSSION

Phenological Behaviour: Time taken for completion of crop emergence was greatly influenced by date of sowing. Crop sown on 16th October took eight days for completion of emergence. Likewise, time taken for completion of emergence followed the same pattern in other dates of sowing. Subsequently the crop growth and development was also slowed down due to low temperature. Duration of October sown crop ranged from 162 to 168 days which was reduced to 140 to 145 day in November sown and 115 to 120 days in December sown. It was observed that the delay in sowing caused reduction in the vegetative phase and reproductive phase but proportionate reduction in reproductive phase was more than vegetative phase. Similar results were reported by Hundal and Sandhu (1992).Variety PL 807 sown on 16th October, took maximum number of days (44) between jointing and boot stage whereas, variety PL 426 took minimum 26 days. Duration between jointing to booting stage was reduced in all the varieties with delay in sowing. The effect was more pronounced on the crop sown in 15th December. The interval between heading stage to maturity stage was from 64 and 82 days for variety PL 807 and PL 426 days respectively in October sown crop which was reduced to 53 and 58 days for the these variety in November sown crop and 34 and 39 days in December sown crop, which clearly indicates that delayed sowing caused relatively more reduction in the reproductive phase. Varieties differ in their genetic makeup from one another. Hence, there reaction towards the growth factors such as nutrients and biotic factors also varies. Varietal differences for attainment of various phenophases were also reported by (Sardana and Zhang, 2004; Kingra and Kaur, 2013 & Kingra *et al*., 2011)

Growing Degree Days (GDD): All the varieties consumed same number of degree days for emergence (Fig.1). The GDD consumption for emergence increased progressively with delay in sowing from 15th November to 15th December. The three varieties exhibited differential response to GDD after emergence. Variety PL 807 consumed the highest (477°C day) number of GDD up to tillering and PL 426 consumed minimum (367°C day) under first date of sowing. This differential behaviour of the varieties continues till harvest. All the three varieties behaved like in the subsequent date of sowing. Similar results were reported by Kingra and Kaur (2012a).

Photo Thermal Units (PTU): All the varieties consumed same number of degree days for emergence (Fig. 1). The PTU consumption for emergence increased progressively with delay in sowing from 15th November to 15th December. The three varieties exhibited differential response to PTU after emergence. Variety PL 807 consumed the highest PTU up to tillering and PL 426 consumed minimum under first date of sowing this differential behaviour of the varieties continues till harvest. All the three varieties

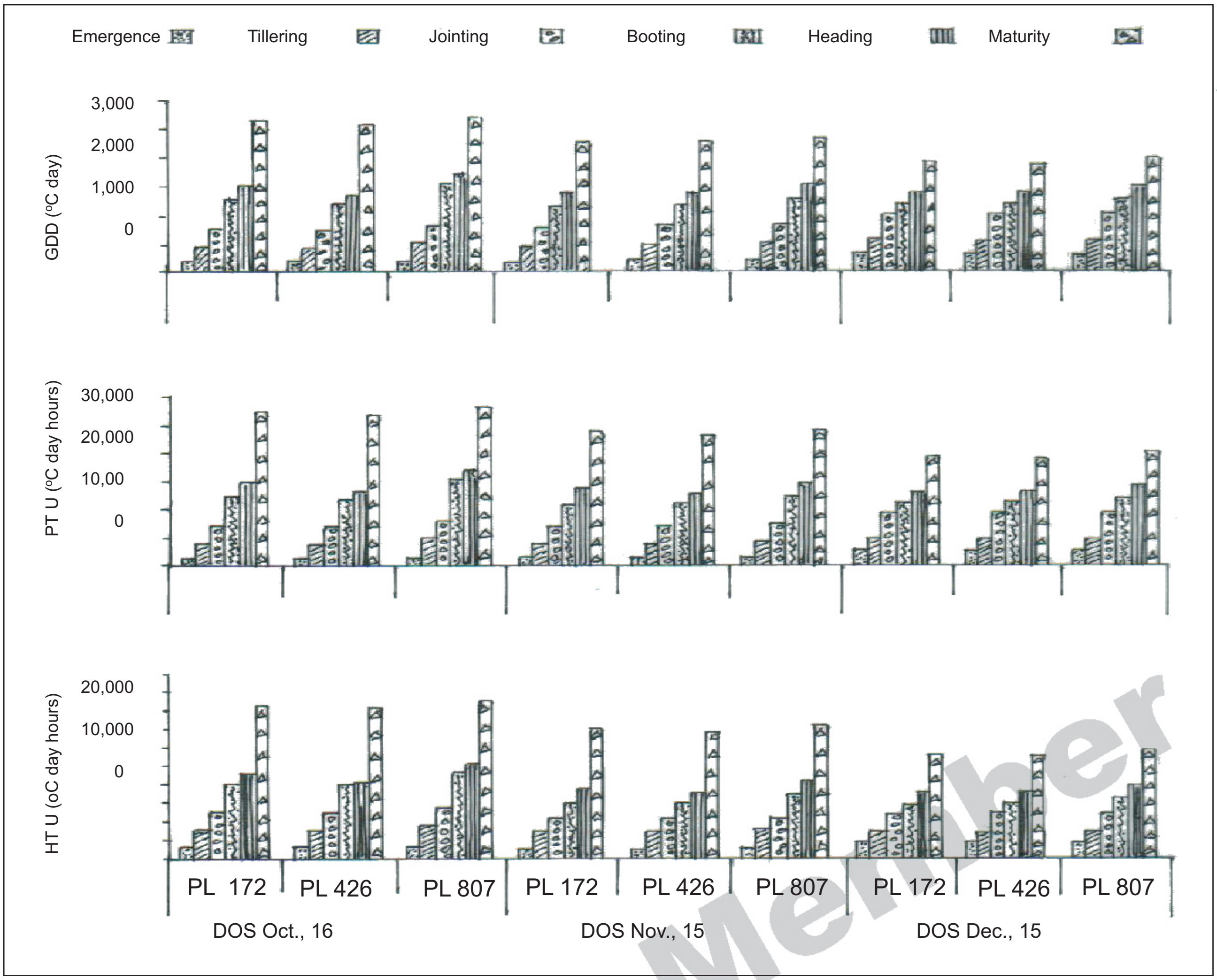

Fig.1. Growing degree days (GDD), photo-thermal (PTU) and helio-thermal units (HTU) accumulated by barley varieties as influenced by dates of sowing (DOS)

behaved like in the subsequent two (D_1 and D_2) date of sowing. However, variety 426 consumed the highest PTU in tillering stage and PL 172 consumed minimum under third date of sowing.

Helio Thermal Units (HTU): All the varieties consumed same number of degree days for emergence. The HTU consumption for emergence increased progressively with delay in sowing from 15th November to 15th December. The three varieties exhibited differential response to HTU after emergence which is evident from Fig. 1. Variety PL 807 consumed the highest HTU up to tillering and PL 426 consumed minimum under first date of sowing this differential behaviour of the varieties continues till harvest. All the three varieties behaved like in the subsequent date of sowing. Kingra and Kaur (2012a) also reported varietal differences in accumulating HTU and PTU by groundnut cultivars.

Heat Use Efficiency (HUE): The HUE kept on increasing from 30 DAS till harvest, maturity of the crop for all the varieties and dates of sowing (Table 2). Variety PL 426 was found more efficient in terms of HUE up to 90 days of crop growth whereas after that PL 807 was found more efficient. Heat use efficiency of PL 807 for production of grain, straw and total dry matter (grain + straw) was the highest in all the three date of sowing and that of variety PL 426 was the lowest.

Development of Phenophasic Models: Two linear regression models taking the phenophasic data, of three dates of sowing for three varieties (separate) derived for predicting the onset of any particular phenophase based on growing degree days, helio thermal units and photo

Table 1. Phenological calendar of barley varieties as influenced by sowing dates

Date of sowing	16^{th} October			15^{th} November			15^{th} December		
Variety	PL 172	PL 426	PL 807	PL 172	PL 426	PL 807	PL 172	PL 426	PL 807
Phenological stage	Number of days taken for commencement (DAS)								
Sowing to emergence	8	8	8	11	11	11	14	14	14
Sowing to tillering	23	21	28	26	26	28	29	28	28
Sowing to jointing	45	44	48	47	46	48	57	58	58
Sowing to booting	76	70	92	70	70	79	68	68	72
Sowing to heading	90	80	104	86	82	92	78	79	86
Sowing to maturity	165	162	168	142	140	145	117	115	120

Table 2. Heat use efficiency (HUE) of barley varieties as influenced by sowing dates

Date of sowing	16^{th} October			15^{th} November			15^{th} December		
Variety	PL 172	PL 426	PL 807	PL 172	PL 426	PL 807	PL 172	PL 426	PL 807
Treatment	Heat use efficiency (kg/ha/°C day)								
30 DAS	0.12	0.12	0.12	0.14	0.14	0.14	0.15	0.15	0.15
60 DAS	0.88	0.92	0.83	1.06	1.10	1.00	1.19	1.24	1.10
90 DAS	1.39	1.47	1.37	1.80	1.88	1.77	2.31	2.43	2.26
At harvest	4.40	4.13	4.53	5.11	4.76	5.26	5.45	5.04	5.60
Grain yield	1.48	1.42	1.59	1.76	1.69	1.88	1.74	1.65	1.88
Straw yield	2.92	2.70	2.95	3.35	3.07	3.37	3.72	3.39	3.73

thermal units is shown below.

Growing Degree Days (GDD)

Pl 172- $Y = 15.467 X_1 + 22.041$ ($R^2 = 0.9987$, n=18)

PL 426- $Y = 15.406 X_1 + 24.264$ ($R^2 = 0.9986$, n=18)

PL 807-$Y = 15.511 X_1 + 19.437$ ($R^2 = 0.9986$, n=18)

Photothermal Units (PTU)

Pl 172-$Y = 167.3 X_2 + 17.254$ ($R^2 = 0.998$, n=18)

PL 426-$Y = 166.22 X_2 + 32.22$ ($R^2 = 0.9979$, n=18)

PL 807-$Y = 167.98 X_2 + 56.441$ ($R^2 = 0.9977$, n=18)

Heliothermal Units (HTU)

Pl 172-$Y = 96.316 X_3 + 154.85$ ($R^2 = 0.9809$, n=18)

PL 426-$Y = 95.372 X_3 + 232.75$ ($R^2 = 0.9768$, n=18)

PL 807-$Y = 97.387 X_3 + 107.83$ ($R^2 = 0.9849$, n=18)

Where,

Y is number of days predicted for attainment of particular stage.

X_1, X_2 and X_3 are AGDD, APTU and AHTU, respectively.

The model indicated that GDD, PTU and HTU accounted for more than 97 per cent variation in the onset of different phenophases for three barley varieties under investigation. Hundal and Kingra (2000) also reported AGDD as the best index to predict various phenophase for soybean crop under Ludhiana conditions.

Heat use efficiency (HUE) and periodic dry matter accumulation (kg/ha):

Pl 172-$Y = 0.0005 X_4 + 0.0325$ ($R^2 = 0.9597$, n=12)

PL 426-$Y = 0.0005 X_4 + 0.0343$ ($R^2 = 0.9576$, n=12)

PL 807-$Y = 0.0004 X_4 + 0.0294$ ($R^2 = 0.963$, n=12)

Where,

Y is periodic dry matter accumulation for attainment of particular stage.

X_1, X_2 and X_3 are periodic AHUE, respectively.

The model indicated that periodic AHUE accounted for more than 94 per cent variation in the onset of different periodic dry matter accumulation for three barley varieties under investigation. Kingra and Kaur (2011) also reported significant linear relationship ($R^2 = 0.968$) between HTU and dry matter accumulation of groundnut crop. By using such models, the dates of occurrence of various phenophases, growth and yield of crops can be predicted by accumulating real time temperature.

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Estimation of Groundwater Recharge Using Well Recharging Unit in Parasai- Sindh Watershed of SAT Region of India

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Abstract: Field study was undertaken in Parasai – Sindh watershed to investigate the ground water recharge possibilities of shallow dug well by well recharging unit. Water table rise of about 14.87 per cent was recorded as compared to control well after getting rainfall of 100 mm of cumulative rainfall. At 270 mm cumulative rainfall, the water column of treated well was recorded 32 per cent higher as compared to control. When cumulative rainfall of watershed was 506 mm, the water column of treated well was found 21 per cent higher than control well and at 700 mm of cumulative rainfall the difference in water level of both treated and control well was found very less. The change in ground water storage volume of watershed during pre and post monsoon by treated and control well was observed 1143 and 1023 m^3.

Key Words: Rainfall, Shallow Dug Well, Well Recharging Unit, Ground Water Recharge

Groundwater has now become a major natural resource contributing the water supply system in the country like India but groundwater is actually under strong human pressures in many countries. Groundwater fulfils about 60% irrigation and 80% drinking water requirements of India (CWC, 2007). Though groundwater has played a vital role in stabilizing Indian agriculture but indiscriminate use has resulted in fast depletion and degradation of this key natural resource. Water table is declining at an alarming rate in about 15% of India's geographical area (Kamra and Sharma, 2011).

Due to over-reliance and rapid development of irrigation using ground water, the unsustainable and over-exploitation of ground water has been observed in several parts of the country especially in the North-Western States of Punjab, Haryana and Rajasthan, and in the hard-rock regions of Peninsular India. Artificial groundwater recharge involves regulated movement of excess surface water through a constructed recharge structure into an aquifer. The recharge structures must be combined with an efficient filtering unit to prevent entry of physical impurities of the run-off water into the recharge system.The filtration unit must perform effectively to get potential benefits from the installed recharge structures it depends on hydraulic efficiency and the filtration effectiveness (Martinson and Thomas, 2005).

The objective of this paper is to investigate the possibilities and prospects of ground water recharge and to identify the potentiality of rainwater for recharging shallow dug well in semi arid tropics of India.

MATERIAL AND METHODS

The study was conducted at Parasai - Sindh watershed area of 1246 hectares. Study area Consitituted three villages namely Parasai, Chhatpur and Bachhauni which is located in Babina block of Jhansi District, Bundelkhand region (part of Uttar Pradesh), Semi-arid tropics (SAT) of Central India.The watershed located between 25 ° 23' 47.6" - 25 ° 27' 05.1" latitude and 78º 20' 06.5" - 78º 22' 33.0" longitude (Fig. 1). Watershed has a semi-arid tropical climate and is characterized by dry and hot summer, warm and moist rainy season and cool winter with occasional rain showers. The annual rainfall of the watershed region varies from 800 to 1300 mm. The landscape is rugged, featuring undulating terrain with low rocky outcrops, narrow valleys and plains. Surface rocks are predominantly granite of the Lower Pre Cambrian/Archaen period. Some Dharwarian and Vindhayan rocks present in the region contain minerals of economic value. Sandstone, shales and limestone of high quality, along with Dyhes, Sills and the famous pink Archaean gneiss rocks, are also found in places.

Study is dependent upon several factors including local hydrogeology, topography, daily rainfall data during monsoon season and also types of facilities available for artificial recharge of groundwater through rainwater harvesting. Daily rainfall data was recorded withtwo automatic rain gauges, which was installed in upper ridge and middle ridge of watershed. Based on the land use, drainage network, slope, geomorphology and lithology of the area, twenty three dug wells were identified and proposed for recharging the ground water in whole watershed (Fig. 2). Two open shallow dug wells were selected for the comparative study for recharging. These wells were either gone dry, or the water levels have declined considerably during summer months. The field observation was carried out by monitoring water level in these wells during monsoon season. One well was used for treatment (installing well recharging unit) and other one used for control. Both wells were situated at upper reach of watershed at equal distances from drain where slope was high and water availability was very less for drinking and irrigation during summer months. The depth and diameter of both selected wells was equal i.e., 10.5 and 6 m, respectively. The recharging unit was designed for artificial recharge. It consist sediment trap pit and recharging filter (Fig.3). Recharging filter having six layer of fine sand, coarse sand, small concrete grit, concrete grit, pebble and stone of 0.2 mm, 2 mm, 2 cm, 5 cm, 10 cm and 20 cm, respectively. Recharge filter was installed at 3m away from the well. Rain water was allowed to pass through plug and water stored in sediment pit. Sediment settled in sediment pit and water passes through filter unit. Filtered water was guided through a pipe to the bottom of well, below the water level to avoid scouring of bottom and entrapment of air bubbles in the aquifer.

The water level of selected wells was monitored on daily basis during whole monsoon for groundwater recharge estimation. Ground water recharge in selected well of watershed during monsoon season is estimated by water level fluctuation during before and after monsoon and specific yield method by well accepted technique (GREC, 1997).

Ground water level fluctuation and specific yield method:

S=Area x Average water table fluctuation x Specific yield

Where, S = change in ground water storage volume during pre and post monsoon period

RESULTS AND DISCUSSION

Digital Elevation Model (DEM) and slope gives an idea about the topography and level of inclination of the study

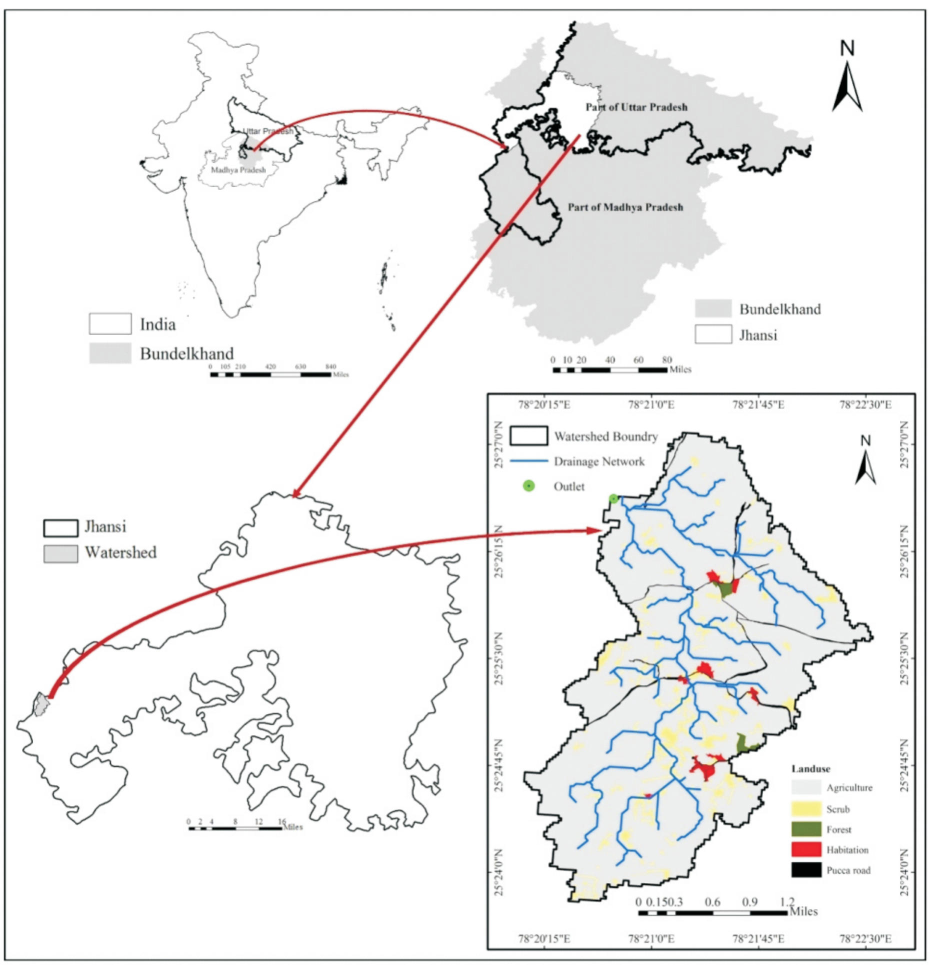

Fig. 1. Location map of Parasai - Sindh watershed

area. Land use of Parasai-Sindh watershed was categorized in six types. Maximum area is under agricultural land (88.7%) followed by scrub land (5.29%), drainage network (3.6%), road (1.15%), habitat (0.89%) and very small area covered by forest (0.45%).

Based on DEM and slope, the different types of artificial recharge structures were proposed in watershed area. In alluvial as well as hard rock areas, where the dug wells have gone either dry or the water level have declined can be used as an artificial recharge structure, by diverting groundwater reservoir, tank water, canal water, etc. to the dried aquifer. Existing wells of the study area were recharged by dug well method. Well recharging priority was based on the wells, which are situated at upper ridge of watershed. In study area, there are 200 wells present out of these 25% of the wells were dried up and this dried well has given the first priority. Since these wells already exist, this method can be easily adopted without much expenditure. The artificial recharge of ground water was done by using well recharging unit (WRU) in the watershed. The data was collected on daily basis during monsoon season (June to Oct.).

The water level of both treated and control wells were recorded initially 3.7 m and 3.5 m, respectively. The recharging of well was negligible when cumulative rainfall was below 50 mm. Water table rise of about 14.87 per cent was recorded as compared to control well after getting rainfall of 100 mm. It was observed that, recharge was very fast as compared to control one after getting cumulative rainfall more than 100 mm. At, 270 mm cumulative rainfall, the water column of treated well was recorded 1.46 m higher than control and it was 32 per cent higher compared to control. In general, groundwater recharge increased with increasing rainfall amount. When cumulative rainfall of watershed was 506 mm, the water column of treated well (7.25 m) was found 21 per cent higher than control well. Up to 700 mm rainfall, the difference in water column between treated and control was recorded 0.98 m (Fig. 4). Above 700 mm rainfall, the fluctuation of water level of both wells were very low and recharging efficiency of WRU decreased because the area around well was saturated and percolation rate of surface and sub-surface water was higher. The percolated water increased ground water and contributed to recharging the open dug well.

The regression coefficient of treated and control well were analyzed between water level of both well with cumulative rainfall upto 700 mm. The water level of wells was separated at each approximate 50 mm cumulative rainfall. The regression coefficient at 700 mm rainfall was 0.984 (98.40%) for treated well and 0.981 (98.10 %) control (Fig. 5). Groundwater recharge increased linearly in control well whereas, groundwater recharge in treated well reached to its saturation (7.93 m) with 855 mm cumulative rainfall. Storage capacity of groundwater aquifer is limited therefore, additional rainfall could not help in further groundwater recharge. Above 700 mm rainfall, the fluctuation of water level of both wells was very low and recharging efficiency of WRU was decreased because the area around both the wells was saturated. It was observed that after 1100 mm of cumulative rainfall difference in water column of both selected well was negligible. At the end of rainy season (31st October) when cumulative rainfall was 1421.30 mm, water level of both wells coincided (Fig. 6). Thus the artificial groundwater recharge through WRU was effective up to 1100 mm rainfall and artificial groundwater recharge through WRU was very useful for semi-arid regions which receive low rainfall. It is also effective in upper reaches of high rainfall region where slope is higher and soil depth is less.

The results of this study indicate that in pre-monsoon, water level of treated wells was 3.70 m, whereas, 3.50 m was recorded in control well.The water level of treated and control well were recorded 7.51 and 6.91m, in post-monsoon season. Water availability at the end of monsoon was dependent on groundwater recharge in current year. The hydraulic head (difference in water level) of treated and control well was recorded 3.81 m and 3.41 m, respectively before and after monsoon (Table 1). Singh *et al.* (2014) recorded on an average 4.0 m difference in hydraulic head in open wells before and after monsoon period for Garhkundar watershed of Bundelkhand region. Garg and Wani (2013) also reported 4.5 m difference in hydraulic head (difference in water label) in open wells before and after monsoon period in Kothapalli watershed of semi-arid tropics. The change in ground water storage volume during pre and post-monsoon period was estimated by ground water level fluctuation method. The change in ground water storage volume of watershed during pre and post-monsoon by treated and control well was observed 1143 and 1023 m^3. Approximately 11.73 per cent of the ground water recharge was estimated during treated over the control well. After the treatment of selected well for artificial groundwater recharge in watershed, the ground water recharge will be increased by 28575 m^3.

It can be concluded that this study provided a vital quantitative description of the impact of ground water recharge induced by WRU on the water supply and quality of wells in semi-arid region of India. Water table of dug well was utilized to investigate the surface to groundwater interaction between WRU and control wells.The artificial ground water recharge through WRU was suitable where, annual rainfall is up to 1100 mm thus, WRU was very useful for semi arid

Table 1. Different parameters of water potentiality

S. No.	Water potentiality parameters	Treated	Control
1.	Water level (m) well Pre-monsoon	3.70	3.50
2.	Water level (m) well Post-monsoon	7.51	6.91
3.	Difference in water level (m)	3.81	3.41
4.	Change in ground water storage volume during pre and post - monsoon period by water table fluctuation method (m^3 $year^{-1}$)	1143.00	1023.00
5.	Increasing ground water storage volume in wells (per cent) through treatment	11.73	-

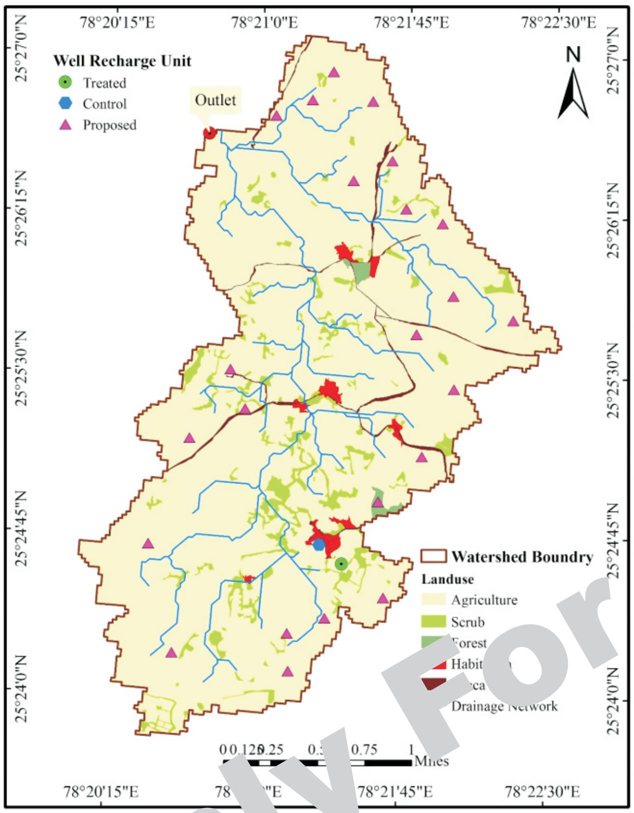

Fig. 2. Location of [illegible] for [illegible]ificial recharging in watershed

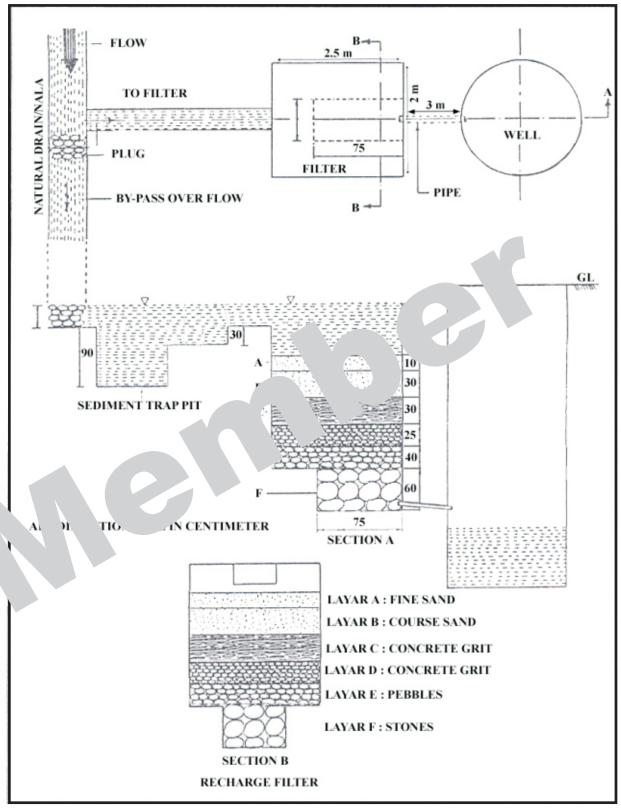

Fig. 3. Artificial recharging of shallow dug well with recharge filter

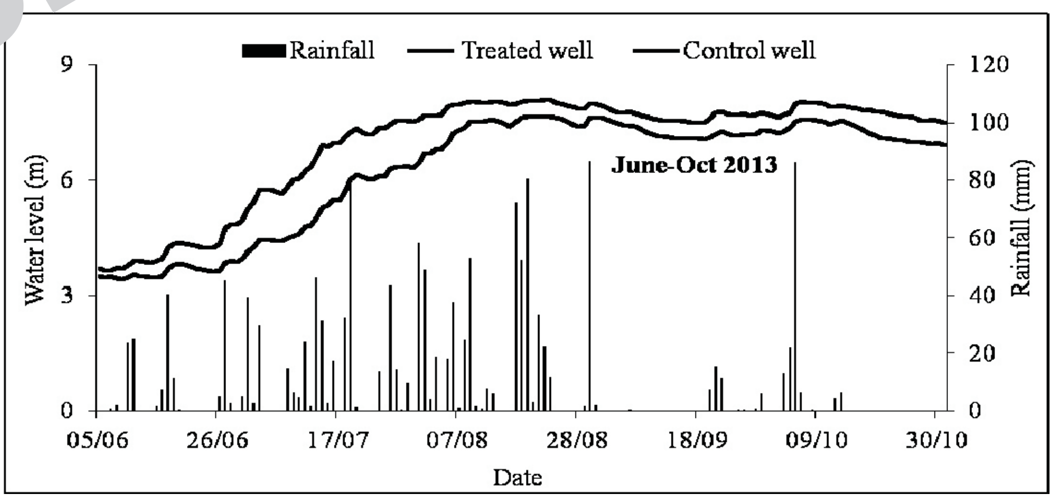

Fig. 4. Water level situation in treated well as compare to control well with rainfall

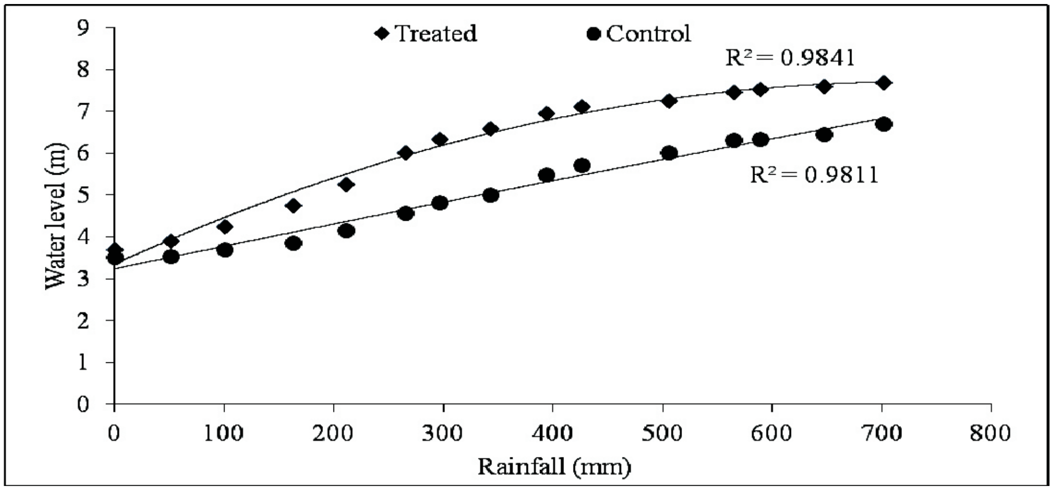

Fig. 5. The regression coefficient of treated and control well of study area

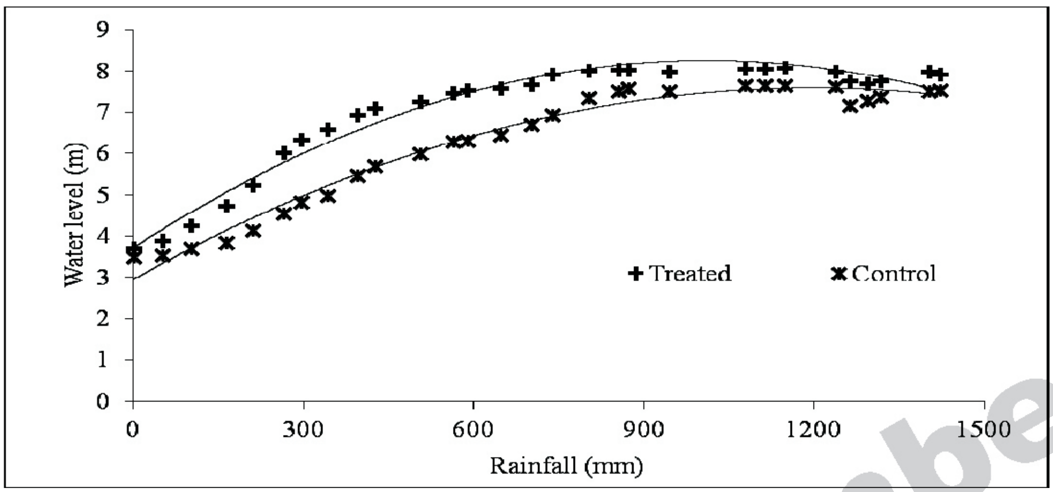

Fig. 6. Cumulative rainfall (mm) effect on water level (m) of treated and control well

regions which receive low rainfall. It is also effective in upper reaches of high rainfall region where slope is higher and soil depth is less. Results of this study indicated that the change in ground water storage volume during pre and post-monsoon period was increased after the installation of WRU in the watershed. Increase in ground water storage volume in treated well was recorded as 11.73 per cent.

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Meteorological Model for Rice Yield Forecasting in Ludhiana Region

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Abstract: An attempt was made to predict rice (*Oryza sativa* L.) yield by regression models. Three statistical models were developed for forecasting the yield of the rice in Ludhiana district by using the rice yield as well as meteorological data (1972-2012). The weekly weather variables used for this study were maximum and minimum temperature, relative humidity (morning and evening), sunshine hours, rainfall and number of rainy days. In the first basic model, sensitive period for rice yield with respect to weather parameters was identified for different weather parameters for selected windows and correlations were developed. The selected sensitive weekly parameters were taken for further regression analysis. In the second model (modified model), time trend was taken as one of the extra variable in multiple regressions. In the third model, multiple regression analysis was done using Statistical Package for the Social Sciences (SPSS) software. Regression equations were developed separately for all the three models and were used to predict the rice yield. The data for a period of (1972-2009) was used to develop the forecast model. The three year meteorological data (2010-2012) was used to validate the models. Among all the three models, basic model explained up to 64 per cent variation, modified model explained 67 per cent and SPSS model predicted highest i.e. 88 per cent variation in rice yield due to weather parameters. The results revealed that SPSS accurately predicted the rice yield as compared to other models and it had strong relation with rice crop yield.

***Key Words*:** Rice, Correlation, Multiple Regression, SPSS, Technology Trend, Yield Forecasting

Rice (*Oryza sativa*), as staple food crop, plays an important role in the Indian economy. In Punjab, it ranks second after wheat in terms of area, production and productivity. Rice is indigenous to the humid areas of the tropical and subtropical regions and has vide adaptability. On an average, Indians consume 83 kg rice year^{-1}. According to Agricultural Policy Vision 2020 of ICAR, India will need 112.4 million tonnes of rice in the year 2020. Meteorological variables such as rainfall, temperature, etc. predominantly affect the rice yield (Ji *et al.,* 2007). Weather affects crop growth at different phenological phases. Therefore, large variation in yields from year to year and place to place is attributed to the weather. These parameters may vary yearly and intra and inter seasonal temperature, relative humidity and sunshine hour deviation from normal are very important as these variations play a pivotal role in determining the final crop yields (Prabhjyot-Kaur and Hundal, 2009). A number of statistical techniques such as multiple regression, empirical linear regression models (Qian *et al*., 2009), CERES- Maize model for maize (Lobell and Burke, 2010), regression and probability models in sugarcane (Aggarwal and Jain, 1996), Ceres-Rice and ORYZA1N for rice (Aggarwal and Mall, 2002) and agro-meteorological models (Walker, 1989; Mukherjee *et al.,* 2011) have been used to quantify the response of crops to weather.

Development of good forecasting techniques requires accommodation of variability such as agricultural inputs or technological changes, meteorological variability and random noise into the model. Crop productivity is projected to decrease for the increase of local temperature at the rate of 0.6°C per year in the region and the crop models are useful tools for considering the complex interactions between a range of factors that affect crop performance, including weather and crop management (Shamim *et al*., 2012). Pre-harvest estimates of rice yield are of immense help to the policy makers and the planners for making advance planning for food and other relief measures in areas of impending crop failure, planning food imports and exports in case of an anticipated deficit and surplus, respectively. With the help of the satellites it has become easier to know the acreage, stand of the crop, disease incidence, irrigation and weather condition instantaneously. Keeping these points in view, an attempt was made to develop a regression models to forecast the yield of rice taking into account the weather variables for Ludhiana district of Punjab.

MATERIALS AND METHODS

Rice Yield Data: In the present study, the yearly production (q) and area (ha) under rice crop for the period 1972 to 2012 in respect of Ludhiana district were collected from Statistical Abstract of Punjab. For each year, the total production of the district was divided by the total acreage to calculate the rice productivity.

Weather Data: Weather parameters influence the crop growth and yield. Series weekly data of different weather elements (maximum temperature, minimum temperature, rainfall, sunshine hour, number of rainy days, morning and evening relative humidity) for the years 1972 to 2012 were collected from the meteorological observatory installed at School of Climate Change and Agricultural Meteorology, PAU, Ludhiana. The data were collected for the months covering life cycle of the crop, except the harvesting period (23^{rd} week to 39^{th} standard meteorological week), since the forecast is to be given before harvesting.

Yield Forecast Models: The correlation analysis was carried out using Pearson correlation technique and the statistical model was developed using multi-regression method. All the three models were developed from a data series of 37 years (1972 to 2009) and the model was verified with independent data for the years from 2010 to 2012, outside their sampling series. The performance of the model was examined critically by computing percentage deviations of estimates and forecast yield figures.

Basic Model (Model 1): A basic model was developed using weather parameters without including technological trend. The average reported crop-yield was taken as dependent variable with weather parameters as independent variables. In the correlation and regression technique, significant correlation between yield and the meteorological parameters was identified. The critical periods when weather parameters exert significant influence on yield were located by analyzing the correlation coefficients for statistical and phenological significance. Out of all the periods, the sensitive periods of statistical and phenological significance were selected in terms of standard meteorological weeks (SMWs) for regression analysis.

Modified Model (Model 2): Secondly, a modified model was obtained by introducing an assumed technological trend in the basic model keeping other independent variables constant. The development of modified model was intended to improve the accuracy of forecast of rice yield by superimposing the impact of agricultural technology in the form of linear time scale dummy variable.

SPSS Model (Model 3): The third model was based on analyzing regression using SPSS (Statistical Product and Service Solutions) software. Pearson's correlations between observed rice yield and weather parameters and with combinations of weather parameters were computed. Sum of weather parameters and sum product of different weather parameters and correlation coefficient was derived. Multiple regressions between dependent variable (yield) and independent variables (time, sum and sum products for different weather parameters) were worked out using SPSS software. Regression equation was written using the regression formula for all the three models as follows:

$$Y_e = a_0 + \sum_{i=1}^{n} a_i x_i + \sum a_j x_j$$

Where,

Y_e = Estimated yield (kg/ha)

a_0 = Regression constant

a_i = Regression coefficients for meteorological predictor variables

x_i = i^{th} meteorological predictor variable i = 1, 2, ……n

a_j = Regression coefficients for technological trend variables.

x_j = j^{th} technological trend variable

RESULTS AND DISCUSSION

The three different yield forecast models were developed based on different weather variables affecting crop yield, then correlated with rice crop yield on weekly basis and the sensitive windows for further processing were worked out. The normal weather conditions required for rice crop at Ludhiana are presented in Fig 1 (a & b).

Out of all the periods, the sensitive periods of statistical and phenological significance were selected in terms of standard meteorological weeks (SMWs) for regression analysis (Table 1). The sensitive periods for rice crop represented maximum tillering, panicle initiation, heading and anthesis. The maximum and minimum temperature, sunshine hours and morning and evening relative humidity showed positive effect on the rice yield

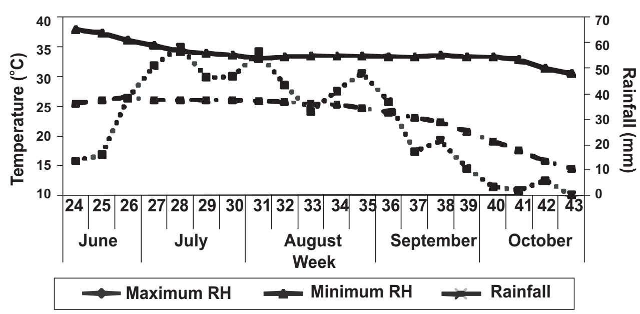

Fig 1(a). Normal weather conditions for rice season in Ludhiana

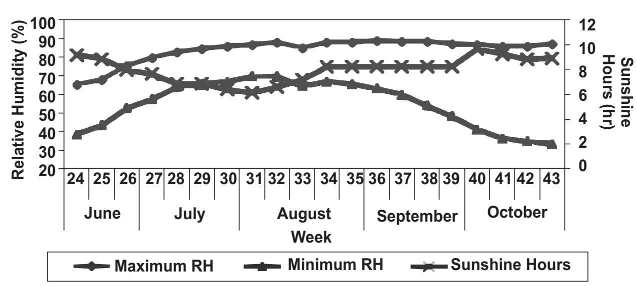

Fig 1(b). Normal weather conditions for rice season in Ludhiana during the crop growth season, whereas, total rainfall and number of rainy days showed negative effect on the rice yield during late vegetative and early reproductive stages.

The correlation coefficients were worked out for the rice crop season by taking into account the meteorological data on weekly basis. It was found that sunshine hours were positively and significantly (p=0.05) correlated with grain yield (Table 2). The other meteorological parameters like maximum temperature and minimum temperature also exhibited a similar trend during vegetative and reproductive stages. The rest of the weather parameters like relative humidity, rainfall and number of rainy days were significantly and negatively correlated with grain yield.

The final yield forecast models constructed by using important weather variables have been presented as below.

Model 1: In the basic model, the weekly weather data at critical periods were correlated with the yield and then the sensitive periods were taken for further analysis to develop regression equation and the regression expression is as follows:

Yield = (-5082.78) + Tmax32 *115.14 + Tmin27 * 75.37 + Rain27 *(-2.27) + rainy days 33 * 219.73 + RH max 30 * 34.22 + RH min 37 and 38 * 5.74 + SSH 37 *(-55.03)

$R^2 = 64\%$

This model explains 64 per cent of variation in the rice yield due to weather variables. The per cent error ranged between minimum -29.3 per cent to 12.5 per cent. The forecasted yield and per cent error of 37 years based on above regression equation is given in Table 3.

Model 2: In second model (Modified model), the weather parameters in critical periods along with technology trend variable were used through multiple regression analysis to obtain forecast equations. Improved agricultural technology necessitated the need to modify the basic model by introducing technological trend as an independent linear time scale dummy variable. The regression expression is as follows:

Yield = (-1480.32)+ Tmax 32 *85.19 + Tmin 27*13.38 + Rain 27 *(-2.03)+ Rainy days 33 *184.74 + Rmax * 32.48+ Rmain (37+38) *(-9.59) +SSH*(-87.87)+ Technology* 0.23

$R^2 = 67\%$

Upon incorporating technology trend in the equation, the R^2 value increased to 67 per cent. The error per cent for modified model ranged between -29.2 per cent to 10.9 per cent during the study period.

Model 3 (Regression using SPSS software): The multi-regression analysis using SPSS was employed for the estimation of rice yield. The regression expression is as follows:

Regression equation = 9627.789 + Z10 * (-11.424) + Z 71 * 117.779 + Z 350 * (-0.011) + Z 370 * (-0.250) + Z 461 * 2.556 + Time * 21.544

$R^2 = 88\%$

Here,

Z10 is sum of Tmax, Z71 is sum product of sunshine hours, Z350 is sum of rain, *Relative humidity (morning), Z370 is rain, *sunshine hours and Z461 is rainy days, * Relative

Table 1. Sensitive periods for rice crop and effect of weather variables on rice yield

Meteorological parameters	Sensitive period (SMWs)	Stage of rice crop	Effect on rice yield
Maximum temperature	32	Early reproductive stage	+ve
Minimum temperature	27	Late vegetative stage	+ve
Rainfall	27	Late vegetative stage	-ve
Number of rainy days	33	Early reproductive stage	-ve
Sunshine hours	37	Late reproductive stage	+ve
Maximum relative humidity	30	Early reproductive stage	+ve
Minimum relative humidity	37,38	Late reproductive stage	+ve

Table 2: Correlation coefficients of rice yield with weekly meteorological parameters at Ludhiana (*Kharif* 1972 to 2012)

Crop growth phase	Temperature (°C)		Sunshine Hour (hr)	Relative humidity (%)		Rainfall (mm)	Rainy Day
	Tmax	Tmin		RH max	RH min		
Vegetative phase	0.45	0.04	0.45	-0.50	-0.34	-0.46	-0.42
Reproductive phase	0.24	0.10	0.30	-0.44	-0.29	-0.11	-0.50

Table 3. Validation of statistical models for yield prediction of rice crop

Year	Actual yield (Kg/ha)	Forecasted yield (Kg/ha)	% deviation
Model 1 (Basic model)			
2010	4409	4025	8.7
2011	4257	4613	-8.4
2012	4548	4640	-2.0
Model 2 (Modified model)			
2010	4409	4066	7.8
2011	4257	4583	-7.7
2012	4548	4506	0.9
Model 3 (SPSS model)			
2010	4409	4100	7.0
2011	4257	4446	-4.4
2012	4548	4075	10.4

humidity (evening)

Results were consistent with previous work by Huang *et al.* (2013) and Prabhakaran *et al.* (2013) where, the regression equation showed that maximum temperature, sunshine hours, combination of rain and relative humidity (morning), combination of rain and sunshine hours, combination of rainy days and relative humidity (evening) played an important role on rice yield in Ludhiana region. The per cent error ranged between minimum -12.4% in year 1998 and maximum 8.4% in year 1984. The forecasted yield and per cent error based on above regression equation is given in Table 4. The forecasted yield of rice for year 2012 is 4075 kg/ha and actual yield is 4548 kg/ha. R^2 value is 88% indicates that weather variables are able to explain 88% of

Table 4. Forecasted yield and error per cent of three different models from year 1972 to 2009

Year	Actual yield (kg /ha)	Model 1		Model 2		Model 3	
		Forecasted yield (kg /ha)	% Error	Forecasted yield (kg /ha)	% Error	Forecasted yield (kg /ha)	% Error
1972	2342	2262	3.4	2288	2.3	2339	0.1
1973	3123	3256	-4.3	3179	-1.8	2978	4.7
1974	2979	3419	-14.8	3394	-13.9	3212	-7.8
1975	3383	3590	-6.1	3503	-3.6	3315	2
1976	3614	3385	6.3	3296	8.8	3671	-1.6
1977	3720	3771	-1.4	3567	4.1	3761	-1.1
1978	3776	3668	2.9	3485	7.7	3542	6.2
1979	3443	3556	-3.3	3519	-2.2	3827	-11.2
1980	3790	3661	3.4	3523	7.0	3597	5.1
1981	4130	3931	4.8	3815	7.6	4069	1.5
1982	3941	3605	8.5	3647	7.5	3924	0.4
1983	3677	3747	-1.9	3666	0.3	3493	5
1984	3568	3501	1.9	3470	2.7	3266	8.5
1985	3812	3471	8.9	3454	9.4	3699	3
1986	4274	3784	11.5	3862	9.6	4096	4.2
1987	3927	3910	0.4	3942	-0.4	3751	4.5
1988	3242	3390	-4.6	3570	-10.1	3138	3.2
1989	4146	3825	7.7	4006	3.4	4130	0.4
1990	3673	3554	3.2	3653	0.6	3463	5.7
1991	3579	3765	-5.2	3817	-6.7	3756	-4.9
1992	4257	4004	5.9	4105	3.6	4128	3
1993	3900	3869	0.8	3863	0.9	4047	-3.8
1994	3557	4088	-14.9	4152	-16.7	3668	-3.1
1995	3231	4177	-29.3	4174	-29.2	3310	-2.4
1996	3604	3518	2.4	3685	-2.2	3362	6.7
1997	3841	3583	6.7	3734	2.8	3935	-2.4
1998	3273	3911	-19.5	3907	-19.4	3679	-12.4
1999	3611	3559	1.4	3591	0.5	3547	1.8
2000	3947	4261	-8	4229	-7.1	4265	-8.1
2001	3897	3705	4.9	3873	0.6	3886	0.3
2002	4322	4113	4.8	4103	5.1	4173	3.5
2003	4342	4573	-5.3	4506	-3.8	4197	3.3
2004	4633	4701	-1.5	4661	-0.6	4651	-0.4
2005	4521	3954	12.5	4112	9.0	4468	1.2
2006	4371	4548	-4	4482	-2.5	4589	-5
2007	4532	4073	10.1	4039	10.9	4508	0.5
2008	4469	4225	5.4	4156	7.0	4555	-1.9
2009	4693	4449	5.2	4510	3.9	4551	3

variation in the rice yield in Ludhiana region.

Validation of the models: Three years (2010, 2011 & 2012) weather data was used for the validation of model for the prediction of rice yield for Ludhiana region. The results showed a close proximity between predicted and observed values during the validation period. The forecasted yield of three years was compared with actual yield of that particular year to calculate the error percentage. The results showed that in year 2010, all the three models predicted the yield less than the actual yield with a deviation ranges from 7 to 8.7%, but the trend was reverse in the year 2011, where all the three models showed positive deviation ranging from 4.4 to 8.4% and predicted more yield than the actual yield. Again in 2012, a different trend was noticed, where Model 1 predicted yield more than the actual, but the other two models i.e. Model 2 and Model 3 predicted lower yield than the actual yield of rice crop and higher range of deviation was found, which ranged from -2.0 to 10.4% (Table 2).

On the other hand, the error percentage for model within the model for validation period, ranged from -2.0 to 8.7 %, 0.9 to -7.7 % and -4.4 to 10.4 % for basic model, modified model and SPSS model, respectively. The error per cent of Model 2 was less than the basic model for all the three years and it was 7.8, -7.7 and 0.9 per cent for the year 2010, 2011 and 2012, respectively. The error per cent for Model 3 was 7.0, -4.4 and 10.4 per cent for year 2010, 2011 and 2012, respectively, which was quite high during 2012 since during the year 2012, the weather was quite different as compared to earlier years.

The models developed in this study provide the possibility of predicting pre-harvest estimates of rice yield for Ludhiana district and could be computed successfully in advance before the actual harvest. The predictability of the model within 10% accuracy is considered to be reliable by any crop-modelling standard. The actual output can be compared with simulated output under normal weather conditions to assess stress on the crop and thereby, could help in formulating suitable agroadvisory for the management of the crop to decrease the yield loss. Moreover, the model also computes the potential production of the crop under optimal conditions which will help in identifying regions suitable for optimal crop production in the state. The district government authorities also can make use of the forecast model developed using weather indices for obtaining accurate pre-harvest estimates of rice crop. The main beneficiaries are farmers, traders, exporters and importers.

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Fertilization Unsuitability Index for Assessing Fertilizer Induced Contamination Risk in Soils of Cotton-Wheat System of South Punjab Districts

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Abstract: In this study the fertilization unsuitability index (FUI) has been proposed for estimating soil contamination and nutrient imbalance resulting from fertilizer application at farm source. The fertilizer use data was collected directly from the selected farmers in the study area and interpolated environmental risk resulting from over fertilization was represented in spatial format using Arc GIS software. The results reported that urea was applied more than double the amount recommended for cotton and wheat cultivation where as the diammonium phosphate was applied at recommended levels in wheat and 50% above recommended dose in cotton in majority of villages in the study area. The average value of FUI was higher in cotton (527.205) in comparison to wheat (491.35) when nitrogen and phosphorus requirement of crops was met by application of urea and diammonium phosphate. Whereas the maximum FUI was reported in Muktsar district (544.52) for fertilization in wheat crop and it was reported to be 536.82 in cotton fertilization. The average soil contamination (SC) risk was higher in cotton fertilization (2.79) than in wheat fertilization (2.47) and the maximum value was reported in Muktsar district for cotton fertilization (3.11). The wheat fertilization practice in the study area threats only nitrate pollution whereas the fertilization in cotton has associated risks of both nitrate and phosphate pollution in the study area.

Key Words: Fertilization Unsuitability Index, Soil Contamination, Nutrient Imbalance, GIS

The crop productivity is dependent on the availability of sufficient nutrients and this nutritional demand is met by means of mineral fertilizers which are applied to soil at different stages of plant growth. The recommendation level of fertilizers is crop and region specific based on the crop variety and inherent nutrient supplying capacity of the soil in which crop is being produced. According to Fertiliser Association of India, six crops *viz*. rice, wheat, cotton, sugar cane, rapeseed-mustard, and potato consume more than two-thirds of the fertilizer. According to one estimate, 14 million tons of nitrogen is added annually to Indian soils in the form of mineral fertilizers. The fertilizer consumption in Indian agriculture increased from 0.13 Mt in 1955-56 to 14.3 Mt in 1996-97 (Rao and Srivastava, 1998).The under dosage of fertilizer, will trigger the heath and vigour of plants and on the other hand the overdose will lead to nutrient leaching and environmental pollution and definitely affecting the economy of agriculture business. The uncontrolled manner of fertilization to crops exhibit a great environmental threat as excess amounts of nutrients is flowed down into water bodies and triggers growth of unwanted plants and algae. With inefficient use of fertilizers, significant amounts of nutrients escape into the air, or seep into the soil and underground water, which in turn result in a host of environmental and human health problems, from climate change and dead zones in the oceans to cancer and reproductive risks (Galloway *et al*., 2008). The over fertilization with nitrogenous fertilizers poses risk of methemoglobinemia, or blue baby syndrome associated with nitrate pollution and on the other hand over fertilization with phosphate fertilizer poses the risk of eutrophication i.e. the growth of unwanted algae in water bodies increasing biological oxygen demand (BOD). According to a review by the Food and Agricultural Organization (FAO) in the 1990s, about half of the cultivable soils in India were degraded, which is the highest percentage in the Asian-Pacific region (Scherr, 1999). The judicious use of fertilizers keeping in mind application timing, weather conditions, proximity to crop growth etc., will not only reduce the amount of N required but also thereby the loss of N to air, soil and water from the current 60 per cent (possibly as high as 80 per cent) to an average of 30 per cent as in much of Europe and North America (Ju *et al*., 2009). Therefore, it is necessary to have a check on the fertilization at field level to eliminate the chances of environmental contamination on later stages. Developments in information and communication technology have given rise to frontier technologies like remote sensing, geographic information systems (GIS) and global positioning system (GPS) and are indispensable tool for natural resource management. In this study the fertilisation trend to meet the requirement of primary nutrients is studied in cotton growing belt of Punjab and results are represented in thematic maps using GIS.

MATERIAL AND METHODS

The cotton producing districts of Punjab namely Bathinda and Muktsar situated between 29.78° N to 30.67° 'N of Latitude and 74.25° E to 75.38° E of Longitude and with total geographical area 5,946.00 km was selected for studying fertilizer usage trends. The farmers in the study area produce two main crops in a cropping year predominantly cotton (*Gossypium hirsutum* L) in summer and wheat (*Triticum aestivum*) during winter. The nutritional demand of crops is met by application of urea and diammonium phosphate for the supply of nitrogen and phosphorus, respectively and murate of potash (Potassium chloride) for the potassium supply.

A sample size of 138 villages from two districts namely Bathinda and Muktsar of Punjab state in India was randomly selected from the cotton growing region of study area and survey questionnaire was distributed through the channel of village scouts for the collection fertilization data from the farmers. The queries regarding various farming activities including fertilizer usage were made directly with the farmers of the study area during the cotton cropping season of 2010. The data collected was converted to geospatial format using Arc GIS v9.1 and digital maps were generated to study fertilization pattern in cotton and successive wheat crop in the study area. The village boundaries obtained from Survey of India were used to display the results in geo-spatial format. The statistical interpolation was performed in Arc GIS v9.1 software using Inverse distance weighted technique for spatial analysis. The descriptive statistical analysis was performed using data analysis add-in in Excel module of Microsoft Office 2010.

The recommended doses of fertilisers have also been defined for all crops by PAU, Ludhiana based on crop varieties, soil properties and weather conditions (Table 1). The overuse of applied fertilisers was calculated based on recommended fertiliser dose (RDF) for the study area (Anonymous, 2010) and studied for urea and DAP application in both cotton and wheat crops.

The overuse of fertilizer application was calculated as percentage of urea and DAP application above recommended level.

$$\%\ \text{Overdose of fertilizer} = \frac{[(\text{Applied dose(kg/acre)} - \text{Recommended fertilizer dose (kg/acre)}]}{\text{Recommended fertilizer dose (kg/acre)}} \times 100$$

RESULTS AND DISCUSSION

General Fertilization Pattern

The spatial representation of fertilization trend showed that the majority of villages in the study area were comparatively over fertilized with the nitrogen in both cotton and wheat (Fig 1 and 2). Also phosphorus over fertilization was reported in cotton cultivation but in wheat recommendation DAP at the rate of 55kg per acre was followed by the majority of farmers in the study area. Further the incidence of over fertilization was comparatively higher in Bathinda as comparison to the Muktsar district and the extent of over fertilization was higher for urea application than DAP application for both the crops in the study area. The study of urea application pattern showed that majority of farmers had applied more than 100% of excess urea in their fields in both Bathinda and Muktsar districts and most farmers have applied 50 per cent excess DAP in cotton crop. The availability of DAP fertilizer in Punjab in the 50kg bags may be reason of DAP over fertilization in cotton which requires it at the rate of 27 kg per acre.

The over fertilization in both crops with urea may be attributed to higher subsidies on nitrogen fertilizers in India thus shifting the balance of fertilizer use in favour of N and against P and K (Chand and Pandey, 2008). In India the use of urea is a common practice, the soil degradation associated with this practice gives an early warning about the unsustainability of the current system (Masto *et al.,* 2008). Apart from nutrient imbalances, it also negatively affects the physical and biological properties of the soils as microbial biomass, enzymatic activity and water-holding capacity are all drastically reduced under nitrogen fertilizer practices (Masto *et al*., 2008; Kang *et al*., 2005). Another common detrimental effect of the excess use of nitrogen fertiliser on soil health is acidification, and microorganisms which are crucial for natural nutrient cycling (Darilek *et al.,* 2009; Kibblewhite *et al*., 2008).

Table 1. Recommended fertilizer dose of major fertilizers in cotton and wheat in Punjab

Crop/variety	Urea (kg/acre)	Diammonium Phosphate (kg/acre)	Muriate of Potash (kg/acre)
Cotton-Bt and Hybrids	120	27	20
Wheat-PBW 343,502, 550	90	55	20

Source: Anonymous, 2010

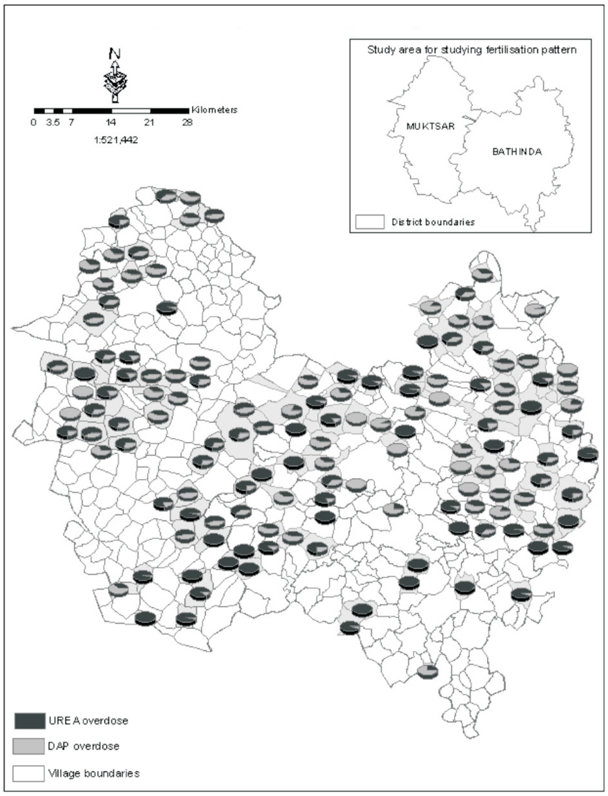

Fig. 1. Fertilization pattern of cotton crop in the study area

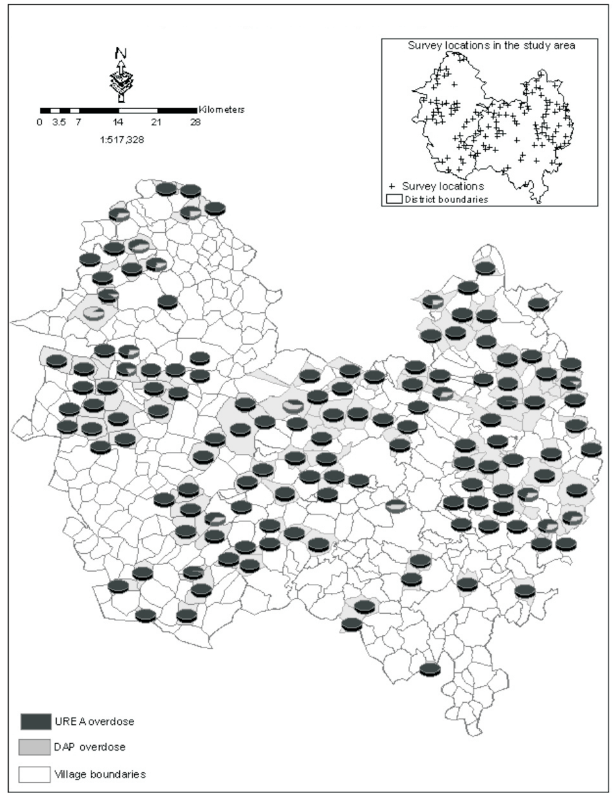

Fig. 2. Fertilization pattern of wheat crop in the study area

In addition to widespread environmental damage, studies carried out under different cropping systems have categorically shown that stretching of synthetic fertilizer application to 150 per cent of recommended rate does not result in significant increments in crop yields (Mandal 2006).On contrast addition of organic matter, commonly in the form of farm-yard manure, is very effective in improving soil quality and yields (Yadav *et al*., 2000; Dwivedi *et al*., 2003; Singh *et al*., 2005; Mandal *et al*., 2006; 2007).

Development of Fertilization Unsuitability Index

It was found that the urea and DAP were the frequently over used fertilisers and muriate of potash (potassium chloride) was used at recommended levels and not considered for derivation of fertiliser unsuitability index (FUI). Moreover, unlike nitrogen and phosphate, potash has no known role in soil and ground water contamination (Syers, 1997).A index defining the magnitude of variation of applied fertilizers over the basal recommended fertilizer dose was derived based on the following hypothesis:

I. Fertilization unsuitability index for fertilization at recommended dose is zero and it represents perfect fertilization for a particular crop and soil type.

II. It is combined measure of adverse affects it exert on surrounding environment and crop nutrition in the form of soilcontamination and nutrition imbalance respectively. For mathematical convenience it is expressed as quadratic mean of Soilcontamination factor (SC) and Nutritional imbalance (NI) factor.

III. The excess of mineral nutrients (nitrogen & phosphorus) released to the soil depends on fertilizer composition and are the potential pollutants and are ultimate risk to the environment in every possible way.

Based on above assumption, the Fertilization Unsuitability Index (FUI) for combination of fertilizer applications in a crop originating at source per unit area is given as:

$$FUI = \pm F \sqrt{[(SC)^2 + (NI)^2]/2} \text{ (kg/acre)}$$

$$SC = \sum x_i/X_i - n \text{ and } NI = \sum x_i/x_{i+1} - C$$

where x_i is amount of fertilizer applied in kg/acre against recommended dose of X_i, n is total number of fertilizers applied in a crop,F is fertilizer specific factor (based on nutrient composition), C is crop specific factor (equal to summation of ratios of recommended doses of successive fertilizers).

The value of FUI is positive for over fertilization and negative for under fertilization (Fig 3).

The above formula is simplified for dual fertilization which is common practice in the study area where urea (46% N) and diammonium phosphate (46% P_2O_5 and 18%N) fertilizersare applied in cotton and wheat crops and FUI index is expressed as:

$FUI_c = \pm (0.46x + 0.64y) \sqrt{[(x/120 + y/27 - 2)^2 + (x/y - 4.4)^2]/2}$

$FUI_w = \pm (0.46x + 0.64y) \sqrt{[(x/90 + y/55 - 2)^2 + (x/y - 1.64)^2]/2}$

Where FUI_c , FUI_w are fertilization unsuitability indices for cotton and wheat crops and x, y are the actual amounts of urea and diammonium phosphate applications by the farmers in the fields.

The calculated value soil contamination reflects the relative degree of over fertilization and resulting threat in the form of soil contamination owing to the excess of nutrients released to the surface waters. The positive values of SC represents over fertilization whereas negative value shows fertilizer is applied at lower levels than recommended for a crop. The calculated value of NI indicates which fertilizer is playing dominant role in soil contamination, if it is positive it designates nitrogen pollution and if it is negative it shows phosphate pollution is in action (Fig 3).The calculated values of SC with proportional increment in the applied urea and DAP in a crop for sake of reference scale is given in Table 2.

Spatial Representation of Fertilization Indices for the Study Area

The study of the fertilization trends in the study area,

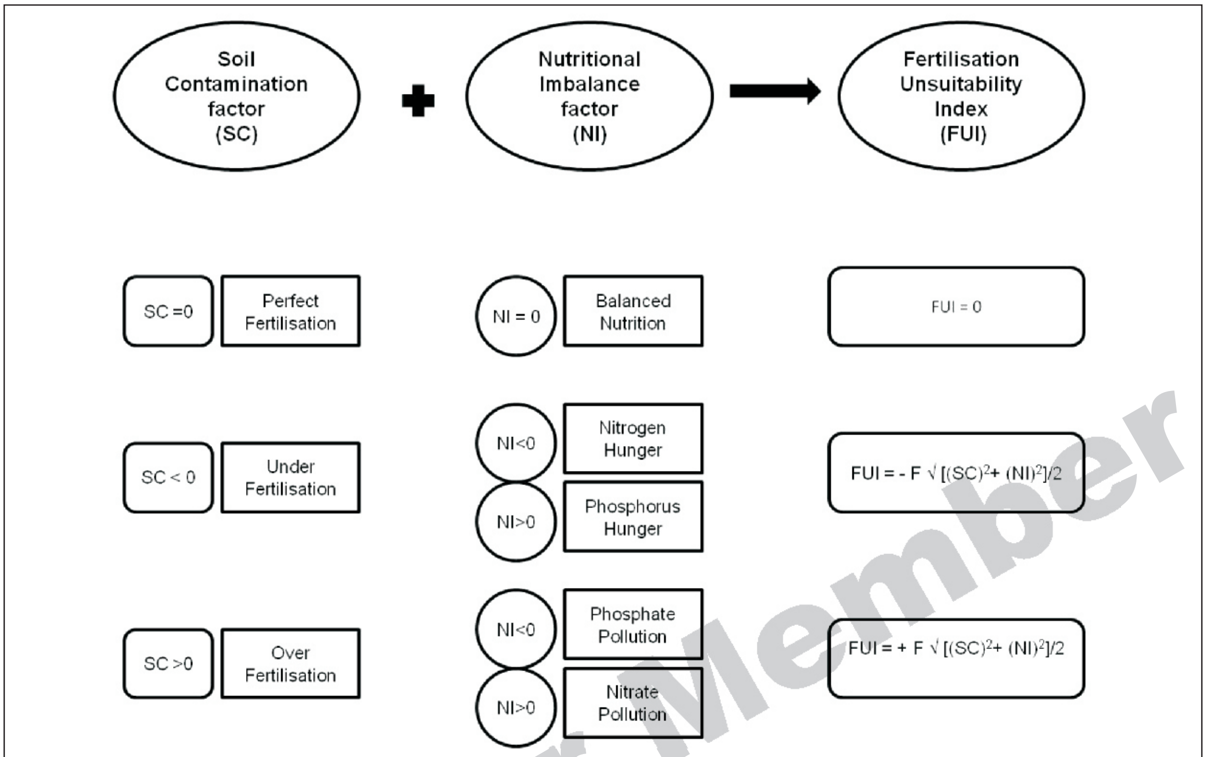

Fig. 3. Inference of Fertilization Unsuitability Index for fertilizer (urea and diammonium phosphate) application in a crop

Table 2. Calculated values of soil contamination factor (SC) for incremental doses of urea and DAP fertilization

	Percentage of higher dose of Urea over recommended basal dose									
	5	10	25	50	75	100	150	250	350	500
5	0.1	0.2	0.3	0.6	0.8	1.1	1.6	2.6	3.6	5.1
10	0.2	0.2	0.4	0.6	0.9	1.1	1.6	2.6	3.6	5.1
25	0.3	0.4	0.5	0.8	1.0	1.3	1.8	2.8	3.8	5.3
50	0.6	0.6	0.8	1.0	1.3	1.5	2.0	3.0	4.0	5.5
75	0.8	0.9	1.0	1.3	1.5	1.8	2.3	3.3	4.3	5.8
100	1.1	1.1	1.3	1.5	1.8	2.0	2.5	3.5	4.5	6.0
150	1.6	1.6	1.8	2.0	2.3	2.5	3.0	4.0	5.0	6.5
250	2.6	2.6	2.8	3.0	3.3	3.5	4.0	5.0	6.0	7.5
350	3.6	3.6	3.8	4.0	4.3	4.5	5.0	6.0	7.0	8.5
500	5.1	5.1	5.3	5.5	5.8	6.0	6.5	7.5	8.5	10.0

the calculated values of soil contamination at selected locations is interpolated using Arc GIS platform to present a whole picture of the study area. This approach helped in the identification of spatial location of the problem area where the problem of over fertilization is more intense. The results showed that in cotton fertilization, the SC values generally ranged between 1-2 in Bathinda district and 2-4 in Muktsar district which means combined adverse affect of urea and DAP on soil is more pronounced in Muktsar district (Fig 3) . Similarly for wheat fertilization in the study area, the values of SC ranged between 1-2 for most area of Bathinda and 2-4 for maximum geographical area falling under Muktsar district (Fig 4). In wheat fertilization, the value of NI is positive for whole study area which means there is only associated risk of nitrate pollution in the wheat growing season. But in cotton fertilization in the study area, there are some patches where phosphate pollution is occurring in greater magnitude (Fig 5).

The mean value of soil contamination (SC) was highest (3.11) for the cotton fertilization in Muktsar and lowest (2.19) for wheat fertilization in Bathinda district (Table 3). Whereas the individual maximum value of SC was found to be highest in village of Bathinda for cotton fertilization and individual minimum value was found for the village of Bathinda reported for wheat fertilization (Table 2). Calculated values of soil contamination factor (SC) for incremental doses of urea and DAP fertilization above RFD percentage higher dose of diammonium phosphate over recommended basal dose.

The calculated values of fertilization unsuitability index (FUI) showed the maximum range and magnitude for cotton festination in Bathinda followed by wheat fertilization in Muktsar. While the minimum FUI was reported for wheat fertilization in Bathinda district in the study area. The mean value of FUI was highest (544.52) for wheat cultivation in Muktsar and lowest (438.18) for wheat cultivation in Bathinda (Table 3). The above results demonstrates a high degree of over fertilization in the study area and need to check on the fertilization practice to further damage to the environment because over fertilization and imbalanced use of mineral fertilizers triggers soil degradation (Scherr, 1999). Also, soil degradation, resulting from the decline in soil organic matter, is one of the major reasons linked to stagnation and decline in yields in India (Yadav *et al*., 2000; Dawe *et al*., 2003; Ladha *et al*., 2003). The decline in soil organic matter is related to the improper use of mineral fertilizers and lack of organic fertilization (e.g. addition of fertilizers rich in organic matter, like compost, manure or green manure), practices that are now widespread in the most intensive agriculture areas in

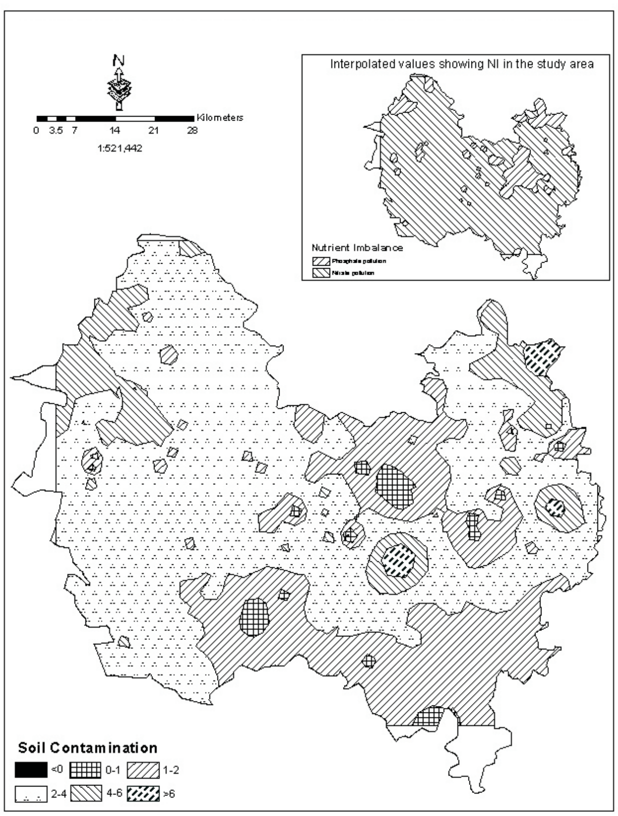

Fig. 4. Interpolation of SC and NI values for the fertilization data collected for cotton crop in the study area

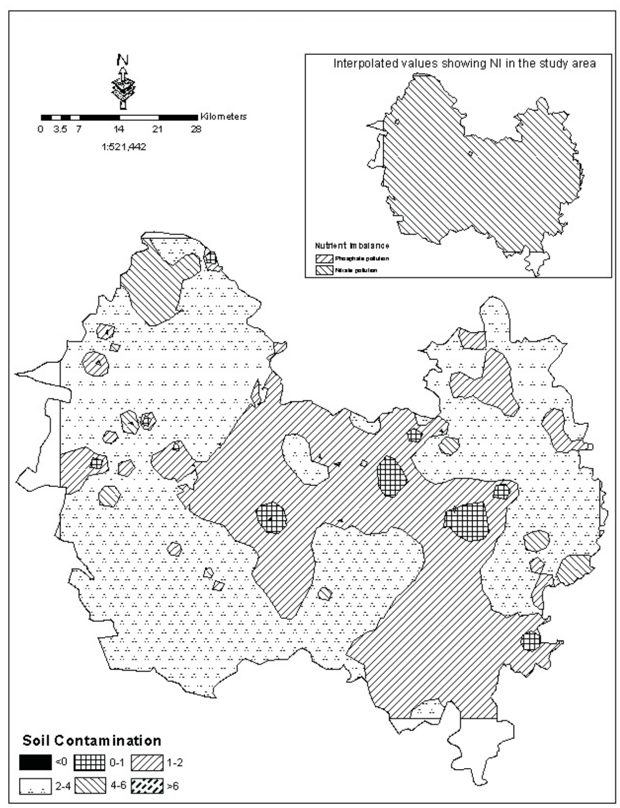

Fig. 5. Interpolation of SC and NI values for the fertilization data collected for wheat crop in the study area

Table 3. Descriptive statistical measures calculated for the fertilization based indices for cotton and wheat fertilization in the study area

Statistical measure	Cotton crop fertilization						Wheat crop fertilization					
	Bathinda district			Muktsar district			Bathinda district			Muktsar district		
	SC	NI	FUI	SC	NI	FUI	SC	NI	FUI	SC	NI	FUI
Minimum	-0.06	-3.77	-36.12	0.69	-2.44	98.02	0.02	-0.39	14.06	0.02	-0.64	14.06
Maximum	10.78	15.56	3439.72	6.70	11.16	1383.38	5.73	9.61	1241.55	7.21	10.36	1811.83
Mean	2.47	2.49	517.59	3.11	2.57	536.82	2.19	3.80	438.18	2.75	4.04	544.52
Median	1.70	1.56	324.55	2.95	1.56	448.79	1.98	3.36	331.31	2.58	3.92	513.62
Range	10.83	19.33	3475.85	6.02	13.60	1285.36	5.71	10.00	1227.49	7.19	11.00	1797.77
Sample Variance	4.35	20.95	357093.47	2.02	13.38	118749.76	2.03	5.28	115201.89	2.51	5.60	140587.16
Standard Deviation	2.08	4.58	597.57	1.42	3.66	344.60	1.43	2.30	339.41	1.58	2.37	374.95
Kurtosis	5.31	0.25	7.57	-0.37	-0.45	-0.13	-0.13	-0.69	-0.72	0.44	-0.44	1.16
Skewness	2.05	0.87	2.53	0.53	0.72	0.69	0.67	0.43	0.77	0.66	0.27	0.90
Standard Error	0.23	0.50	65.20	0.19	0.50	46.89	0.16	0.25	37.03	0.22	0.32	51.02
Confidence Level (95.0%)	0.45	0.99	129.68	0.39	1.00	94.06	0.31	0.50	73.66	0.43	0.65	102.34

SC: Soil Contamination Factor
FUI: Fertilization Unsuitability Index
NI: Nutrient Imbalance Index

India (Masto *et al*., 2008; Singh *et al*., 2005).

The overuse of mineral fertilisers has also been linked to soil degradation problems such as soil acidification and alkalization, as well as deterioration of the soil's physical properties, such as infiltration, soil aeration, soil structure and bulk density. However, since much of this N is used inefficiently, significant amounts escape into the air, or seep into the soil and underground water, which in turn result in a host of environmental and human health problems, from climate change and dead zones in the oceans to cancer and reproductive risks (Galloway *et al*., 2008).

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Potassium Fixation Isotherms and Factors Affecting Potassium Fixation in Rainfed Soils of District Ganderbal, J&K

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Abstract: K fixation (KF) isotherms and factors affecting KF were studied in rainfed maize growing soils of North Kashmir for understanding and measuring the inherent potential of soils to deliver K to crops and factors determining K availability. KF isotherms were constructed by equilibrating 5g soil samples with eight levels (0-200µg mL^{-1}) of K contained in 10ml of KCl solution. Factors affecting soil KF were then extracted by factor analysis and stepwise regression. At K addition treatments of 1 and 200µg K mL^{-1} contained in 10ml of KCl solution, the fixed amounts of K varied from 130 to 210 per cent and 16.35 to 36.3 per cent of added K respectively. The fixation data were fitted to Freundlich, Langmuir and Temkin fixation equations. Freundlich equation explained K fixation behavior better than the either two equations as evidenced by higher R^2 (0.90-0.99). Magnitude of soil KF capacity was found highest in Silty clay (S7) and lowest in Sandy loam (S6). K fixation capacity was significantly correlated with CEC and clay content. KF capacity of soils was affected by two components extracted by the method of PCA: the first including soil available K (Av. K), exchangeable K (Ex. K), OC and EC and the second including CEC and clay contents. KF rate was mainly affected by CEC and Av. K with lower added K concentration (from 1-20µg mL^{-1}) and by clay and OC with higher added K concentration (from 60-200µg mL^{-1}).

***Key words*:** Potassium Fixation Rate, Potassium Fixation Capacity, Freundlich, Langmuir, Temkin Equation

Potassium (K) is one of the three major nutrients required for plant growth and reproduction and a significant quantity of K is removed by maize crop (White, 2003). The availability of K is influenced by soil physico-chemical and biological properties (HuiMin *et al.,* 2009). Transformation of available K forms into unavailable ones (K-fixation) influences the K availability and the degree of fertilizer K uptake by plants. Consequently, understanding the mechanism that involve fixation of K in soil is of particular agronomic and practical interest (Simonsson *et al*., 2009). A rapid method for measuring K fixation could help clarify relationship with other soil properties (Murashkina *et al*., 2007).

The K fixation in soil is quite complex and may not be explained by simple and single reactions. To visualize the K fixation in soil several equations or fixation isotherms have been developed. Their use allows summarizing results, reducing the sorption data to comparable values. Among isotherm adsorption equations, Langmuir, Freundlich and Temkin equations are the most used for soil characterization and research purposes however the conformity of the equations and their constants still remains in discussion (Taylor *et al*., 1996). Langmuir and Freundlich fixation isotherms are mostly employed for understanding the relationship between the quantities of K fixed per unit soil weight and the concentration of K in solution. The Freundlich equation is the oldest fixation equation in the literature on soils, first used by Russell and Prescott in 1916. It is an empirical equation and corresponds to an equation of fixation in which the affinity term decreases exponentially as the amount of fixation increases. Over a limited range of concentration, Freundlich equation often describes the K fixation well (Hannan *et al*., 2011). According to the Freundlich equation, energy of fixation decreases as the amount of fixation increases.

The K fixation in North Kashmir soils specifically in rainfed Karewas (Lacustrine deposits) where wetting and drying play a predominant role in K fixation having soil depth ranging from 10-30cm with slope in the range of 8-15% is not well documented as intensive investigations in this regard had not been undertaken so far. The present study was therefore, conducted to elucidate the K fixation in rainfed soils.

MATERIAL AND METHODS

Soil Sampling and Experimental Site: The study area is in the North of Kashmir valley, Ganderbal District, India. The cultivated area falls in the rainfed zone dominated by maize cropping. Ten surface soil samples (0-20cm) in triplicate of low (Babaweyl, Satran, Doon and Mamar), mid (Chatergul, Wangat and Sumbal) and high (Ghund, Kulan and Gagangir) altitude zones with altitude range of <1600, 1700-1800 and >1900m masl respectively were collected. The samples inherit wider range of soil characteristics like texture, pH, clay contents, $CaCO_3$ and organic matter (Table 1). The soil samples were air-dried and ground to pass through 2mm sieve before use.

Measurement

Soil Analysis: The pH was determined by 1:2.5 soil-water suspension by a glass electrode, EC with the help of solu bridge conductivity meter at 25° C (Jackson, 1967) and CEC by ammonium acetate or ammonium chloride-ammonium acetate method (Lu, 1999). Particle size distribution was determined by the sedimentation procedure using the pipette method after dispersing the soil with sodium hexametaphosphate (Gee and Bauder 1986). The total $CaCO_3$ in soil expressed as the calcium carbonate equivalent was determined by a rapid titration method (Rayment and Higginson 1992). Organic matter was determined by wet digestion (Nelson and Sommers 1996). Available potassium was extracted with normal neutral ammonium acetate (Pratt, 1982). Equilibrium K concentration with distilled water (Jackson, 1967) and Exchangeable potassium was obtained from the difference between available potassium and water soluble potassium (Dhillon *et al*., 1985).

Potassium Fixation: The K fixation capacity was calculated by using Huang and Jin (1996) procedure. Surface samples (5g) were taken and equilibrated in 50mL plastic bottles for 72 hours at 25±1°C after adding eight rates of 0, 1, 5, 10, 20, 60, 100 and 200 μg K mL^{-1} in 10ml of KCl solution and then analyzed for K in 1mol/L NH_4OAc extract (pH 7) with a flame photometer.

The assessment of K fixation capacity was calculated as follows (Huang and Jin, 1996):

K fixation capacity (μg g^{-1}) = added K - (NH_4OAc extractable K- original soil K)

K fixation rate (%) = (K fixation capacity × 100)/ added K

The K fixation data were fitted into following fixation equations:

Langmuir Fixation Equation:

$$C/(x/m) = 1/kb + C/b$$

Where C is the equilibrium solution K concentration (μg g^{-1}), x/m is the mass of K adsorbed per unit mass of soil (μg g^{-1}), *k* is a constant related to bonding energy of K to the soil, and 'b' is the maximum K fixation capacity of the soil.

Freundlich Fixation Equation:

$$x/m = a\,C^{1/n}$$

By rearranging

$$\log (x/m) = \log a + 1/n \log C = \log a + b \log C$$

Where x/m is the mass of K adsorbed per unit mass of soil (μg g^{-1}), C is the equilibrium solution K concentration (μg g^{-1}), 'a' and 'b' are constants. The values of 'a' and 'b' are obtained from the intercept and slope, respectively.

Temkin Fixation Equation:

$$x/m = a + b \ln C$$

Where x/m is the mass of K adsorbed per unit mass of soil (μg g^{-1}), C is equilibrium solution K concentration (μg g^{-1}), 'a' and 'b' are constants. The values of 'a' and 'b' are obtained from the intercept (a) and the slope (b), respectively. The K buffering capacity (PBC^K) was interpolated from the K sorption isotherms by determining the slope of the lower linear portion of the curve. The necessary statistical analysis of the data were done using MS Excel and Xlstat software programme.

RESULTS AND DISCUSSION

Potassium Fixation: The soils differed in their K

Table 1. Physico-chemical properties of maize growing soils of District Ganderbal

Site	Location	Altitude (masl)	pH (1:2.5)	EC (dSm^{-1})	Organic carbon	$CaCO_3$	C E C cmol (P^+) Kg^{-1}	Coarse sand	Fine sand	Silt	Clay	Av. K [$cmol_c$ Kg^{-1}]	Ex. K [$cmol_c$ Kg^{-1}]	PBC^K ($cmol_c$ kg^{-1})/(mol L^{-1})^{½}
					Per cent			Per cent						
S_1	Babaweyl	1700	7.1	0.35	2.08	0.50	15.50	5.69	45.24	21.33	26.30	0.519	0.408	31.36
S_2	Satran	1780	7.1	0.38	2.45	0.50	16.23	10.53	43.21	31.32	13.93	0.532	0.376	29.63
S_3	Doon	1800	7.7	0.29	1.07	0.63	17.50	0.63	1.31	60.12	37.00	0.237	0.216	34.72
S_4	Mamar	1820	7.8	0.44	0.90	0.55	15.36	23.43	27.25	18.23	30.93	0.132	0.119	31.08
S_5	Chatergul	1900	7.4	0.20	1.18	0.10	17.70	11.25	39.08	16.21	32.21	0.207	0.190	26.36
S_6	Wangat	1920	6.8	0.43	2.06	0.14	17.70	20.43	47.49	12.33	18.92	0.427	0.389	33.69
S_7	Sumbal	1940	6.2	0.45	3.00	0.64	17.96	9.65	13.55	26.25	50.30	0.895	0.818	37.62
S_8	Ghund	2020	6.4	0.40	2.75	0.53	17.85	6.00	14.32	40.20	38.40	0.701	0.523	35.01
S_9	Kulan	2100	7.6	0.42	2.85	0.21	17.95	1.42	18.20	40.33	39.92	0.846	0.750	36.79
S_{10}	Gagangir	2270	7.5	0.21	1.98	0.38	17.40	22.84	40.52	18.23	18.12	0.250	0.233	21.95
	Mean		7.2	0.37	2.03	0.35	17.11	11.19	29.02	28.46	30.60	0.464	0.412	31.82

fixation behavior (Table 2). Irrespective of soil type and clay content the amount of K fixed increased with the increasing K additions (Figure 1). Jafari and Baghernejad (2007) and Srinivasarao *et al*. (2007) also reported that fixation of potassium increased with increasing concentration of added K in solution. For the initial added solution concentration of K (1 µg mL^{-1}), K fixed ranged from 130 to 210% and for the highest added solution concentration of K (200 µ g mL^{-1}) 16.3 to 36.3%. The NH_4AOc extractable K [C] ranged from 0.25 to 0.70 µg mL^{-1} for 1 µg mL^{-1} of added K and from 164 to 184 g mL^{-1} for 200 µg mL^{-1} of added K (Table 2). The highest mean K fixation capacity (KFC) of 26.4µg g^{-1} soil was observed in Silty clay (S_7) soil and lowest value of 13.4µg g^{-1} soil was observed in Sandy loam (S_6) soil. The mean K fixation rate (KFR) ranged from 51.56% to 84.60% which accounts for Loam (S_4) soil and Silty clay (S_7) soil respectively (Table 2). The maximum K fixation rate of 210% at lowest concentration of treated K (1µg mL^{-1}) and 36.3% at highest concentration of added K (200g mL^{-1}) with a mean value of 28.04 was observed for Silty clay (S_7) soil. Overall the KFC and KFR of soils ranged from 1.48µg g^{-1} and 157.4% at 1g mL^{-1} of added K to 62.49µg g^{-1} and 28.04% at 200g mL^{-1} of added K respectively (Table 2).

The K buffering capacity (PBC^K) ranged from 21.95 to 37.62 ($cmol_c$ Kg^{-1})/(mol L^{-1})$^{1/2}$. In general, the higher PBC^K are for the soils containing large amounts of clay and indicative of the continuing availability of adequate K over a long period of cropping where as low buffering indicates the need for frequent fertilization (Pal *et al*., 1999).

Applicability of Different Kinetic Equationsto Describe Potassium Fixation

The data on potassium fixation obtained for different soils at different concentrations of treated K were fitted to various kinetic equations viz., Langmuir, Freundlich and Temkin equation for testing their applicability using least square regression analysis. The values of coefficient of determination (R^2) for different potassium kinetic equations (Table 3) indicate that potassium sorption isotherms (Figure 2) were well described by the Freundlich equation used in this study for all the soils based on the highest value of R^2. The equation gave a better fit as it assumes unlimited fixation sites having heterogeneous surfaces which correlate better with the physico-chemical factors of the soils.

The values of the Freundlich constants 'a' and 'b' were determined from the plots between logx/m and logC. The Freundlich constant 'a' was obtained from the intercept at zero equilibrium concentration and 'b' from the slope of the plot. 'a' and 'b' provide the estimates of fixation capacity and intensity of fixation respectively. The values of 'b' also

Table 2. Amount of K fixed (µg g^{-1}) in different soils treated with different concentrations of K

Location	Added Potassium (µg mL^{-1})																							
	1			5			10			20			60			100			200			Mean		
	[C]*	[x/m]**	(%)***	[C]	[x/m]	(%)	[C]	[x/m]	(%)	[C]	[x/m]	(%)	[C]	[x/m]	(%)	[C]	[x/m]	(%)	[C]	[x/m]	(%)	[C]	[x/m]	(%)
S_1	0.60	1.3	130.0	3.0	4.5	90.0	7.6	5.3	53.0	16	8.5	42.5	48	24.5	40.8	80	40.5	40.3	167	66.5	33.3	46.0	21.6	61.4
S_2	0.25	1.7	174.0	2.5	5.2	104.8	5.6	9.0	90.4	15.5	9.2	46.2	48	24.2	40.3	81	38.2	38.2	167	40.24	20.1	47.5	18.3	73.5
S_3	0.50	1.4	140.0	2.5	5.4	108.0	6.5	7.4	74.0	14	12.4	62.0	45	30.4	50.4	78	44.4	44.3	165	70.4	35.2	44.5	24.5	73.5
S_4	0.55	1.3	130.0	4.0	2.4	48.0	8.0	4.4	44.0	16	8.4	42.0	49	22.4	37.2	84	32.4	32.3	173	54.4	27.2	47.8	18.0	51.6
S_5	0.45	1.7	170.0	3.0	4.6	92.0	8.5	3.6	36.0	17	6.6	33.0	52	16.6	27.5	88	24.6	24.5	182	36.6	18.3	50.1	13.6	57.4
S_6	0.70	1.3	130.0	2.8	5.1	102.0	6.0	8.7	87.0	17	6.7	33.5	52	16.7	27.7	89	22.7	22.6	184	32.7	16.3	50.2	13.4	60.0
S_7	0.25	2.1	210.0	3.0	4.6	92.0	6.5	7.6	76.0	13	14.6	73.0	44	32.6	54.3	75	50.6	50.6	164	72.6	36.3	43.7	26.4	84.6
S_8	0.50	1.4	140.0	2.3	5.8	116.0	7.0	6.4	64.0	14	12.4	62.0	43	34.4	57.3	77	46.4	46.3	164	72.4	36.2	44.0	25.6	74.6
S_9	0.50	1.8	180.0	3.5	3.8	76.0	7.0	6.8	68.0	14	12.8	64.0	43	34.8	58.0	73	54.8	54.0	152	64.8	32.4	41.8	25.6	76.2
S_{10}	0.30	1.7	170.0	2.2	5.9	118.0	8.0	4.3	43.0	16	8.3	41.5	46	28.3	47.2	84	32.3	32.3	172	50.3	25.2	47.0	18.7	68.2
Mean	0.46	1.6	157.4	2.8	4.7	92.7	7.1	6.4	63.5	15.3	9.9	49.9	47.0	26.5	44.1	80.9	38.7	38.5	169.0	62.5	28.0	46.8	20.6	68.1

*Equilibrium concentration (µg mL^{-1}); **Amount of added K fixed or K fixation capacity (µg g^{-1}) and ***Per cent of added K fixed or K fixation rate

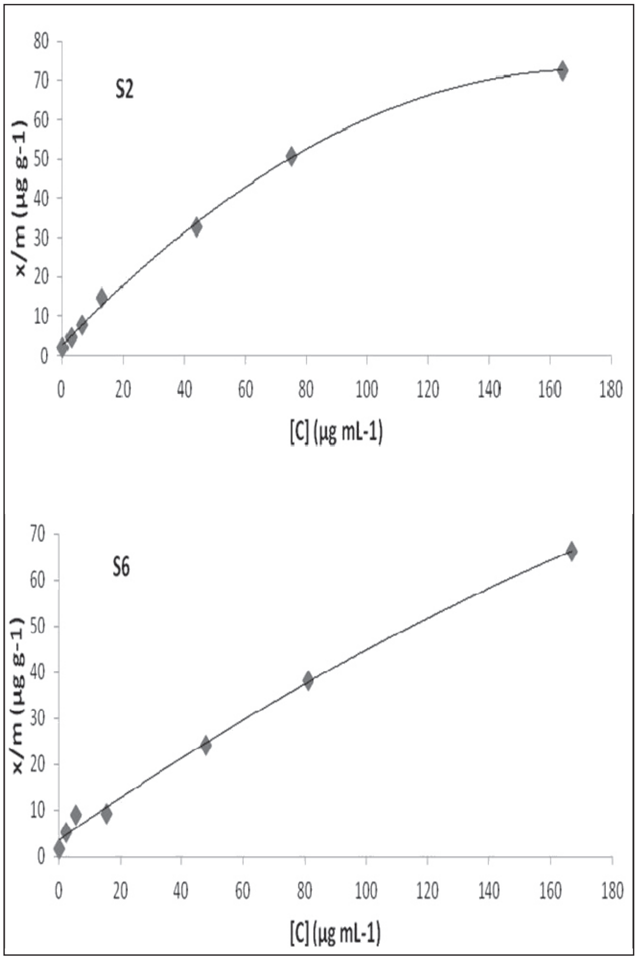

Fig. 1. Representative Fixation isotherms of S_2 and S_6 soils of maize growing soils of North Kashmir

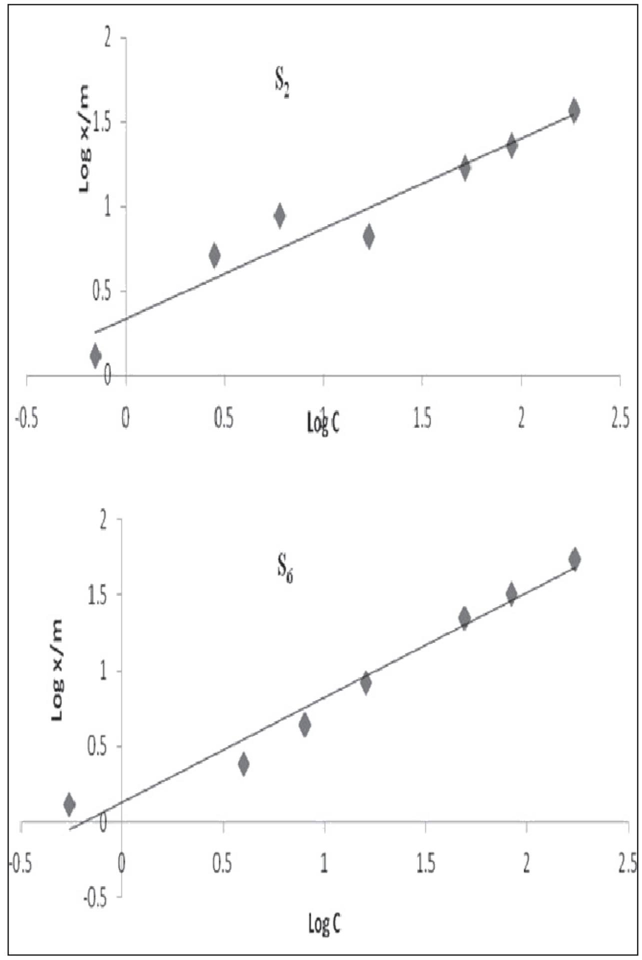

Fig. 2. Representative Freundlich fixation isotherms for K fixation by maize growing (S_2 and S_6) soils of North Kashmir

indicate the degree of non-linearity between solution concentration and fixation.

A plot of potassium fixed against equilibrium potassium concentration on a log scale gave linear relationship in all soils (Fig. 2). The Freundlich 'a' values ranged widely among the soils. The value was maximum of 3.38µg g^{-1} was found Silty Clay (S_7) soil which may be due to high organic carbon, CEC, clay content and Av. K. The maximum value of 'b' (2.02) was obtained in Silty loam (S_2) soil and minimum value (1.44) was obtained in Clay loam (S_1) soil and Loam (S_4) soil.

Effect of Soil Properties on Potassium Fixation: Factor Analysis

The potassium fixation capacity differences among soils or treatments are related to the differences in soil available K (Av. K), exchangeable potassium (Ex. K), CEC, clay content, organic matter and electrical conductivity (EC) (Table 1). The data was further analyzed by the Varimax with Kaiser Normalization method to know how these factors affect K fixation capacity (Table 5). By the method of principle component analysis two components were extracted. Four factors, including Av. K, Ex. K, OC and EC, had a large positive loading (0.702-0.922) on the first component, and a small positive loading (0.313-0.409) or negative loading (-0.156) on the second component. The other two factors, including CEC and Clay, in contrast, had a small positive loading (0.072-0.352) on the first component, and a large positive loading (0.757-0.997) on the second component. The two components had great communalities (0.688—0.982) for all the six factors. Therefore, the first component included soil Av. K, Ex. K, OC and EC, and the second component included CEC and clay contents.

Stepwise Regression Analysis: Relationships between K Fixation Rate and Factors Affecting K Fixation

` The data between K fixation rates of rainfed maize growing soils and factors affecting K fixation capacity showed a significant correlation upon stepwise regression analysis (Table 5). The K fixation rate was significantly correlated with Av. K only, but not with soil Ex. K, CEC, Clay contents, OC and EC with the addition of 1μg mL^{-1} K, which account for 62% of K fixation rate variability. With the addition of 5μg mL^{-1} K, K fixation rate was correlated significantly with CEC which account for 72% of K fixation rate variability. The K fixation rate was correlated significantly with EC and Ex. K with the addition of 10μg mL^{-1} K, which account for 68% of K fixation rate variability. The K fixation rate was significantly correlated with Ex. K and OC with the addition of 20μg mL^{-1} K, which account for 67% of K fixation rate variability When the addition of K ranged from 60-200μg mL^{-1} K, the K fixation rate was correlated significantly with clay content and OC, which accounts for 59% to 66% of K fixation rate variability. In general, when the concentration of added K was lower (1-20μg mL^{-1} K), the CEC in the first component and Av. K in the second component were the main factors affecting the K

Table 3. Comparison of coefficients of determination (R^2) for the Freundlich, Langmuir and Temkin equations to the fixation data of the soils of District Ganderbal

Site	Equation		R^2	K fixation parameters of the Fruendlich equation	
				Fixation capacity 'a' (g g^{-1})	Intensity of fixation 'b'
S_1	Freundlich	Y= 0.665x + 0.374	0.993	2.35	1.50
	Langmuir	Y= 0.006x + 0.821	0.860		
	Temkin	Y= 34.98x – 9.322	0.793		
S_2	Freundlich	Y= 0.532x + 0.335	0.926	2.16	1.88
	Langmuir	Y= 0.009x + 1.110	0.881		
	Temkin	Y= 24.26x – 6.654	0.805		
S_3	Freundlich	Y= 0.674x + 0.374	0.978	2.36	1.48
	Langmuir	Y= 0.027x + 1.051	0.828		
	Temkin	Y= 12.77x – 1.040	0.797		
S_4	Freundlich	Y= 0.514x + 0.317	0.925	2.07	1.94
	Langmuir	Y= 0.010x + 0.713	0.764		
	Temkin	Y= 26.70x – 4.103	0.744		
S_5	Freundlich	Y= 0.694x + 0.225	0.978	1.67	1.44
	Langmuir	Y= 0.021x + 1.421	0.613		
	Temkin	Y= 12.47x – 1.165	0.736		
S_6	Freundlich	Y= 0.694x + 0.127	0.965	1.33	1.44
	Langmuir	Y= 0.011x + 1.426	0.690		
	Temkin	Y= 19.93x – 5.689	0.746		
S_7	Freundlich	Y= 0.583x + 0.530	0.966	3.38	1.71
	Langmuir	Y= 0.010x + 0.620	0.864		
	Temkin	Y= 24.31x + 0.210	0.753		
S_8	Freundlich	Y= 0.496x + 0.527	0.972	3.36	2.02
	Langmuir	Y= 0.011x + 0.711	0.924		
	Temkin	Y= 25.51x – 3.955	0.804		
S_9	Freundlich	Y= 0.533x + 0.440	0.908	2.75	1.87
	Langmuir	Y= 0.012x + 0.786	0.636		
	Temkin	Y= 19.71x + 0.743	0.739		
S_{10}	Freundlich	Y= 0.685x + 0.344	0.970	2.21	1.45
	Langmuir	Y= 0.013x + 1.025	0.874		
	Temkin	Y= 16.51x + 0.446	0.812		

Table 4. Factor analysis for the effect of factors on the soil K fixation rate*

Effect factor	Component matrix		Rotated component	
	Component 1	Component 2	Component 1	Component 2
Av. K	0.995	0.102	0.922	0.388
Ex. K	0.997	0.080	0.912	0.409
CEC	0.543	-0.840	0.072	0.997
Clay	0.480	-0.144	0.352	0.757
OC	0.852	0.109	0.800	0.313
EC	0.541	0.474	0.702	-0.156

*Extraction method: Principal Component Analysis and Rotational method: Varimax with Kaiser Normalization

Table 5. Regression equations and correlation coefficients of the linear relationship between K fixation rate and soil factors for the seven potassium additions

Added K concentration (μg mL^{-1})	Linear regression equation*	R^2
1	KFR= 13.14 (t=8.41, p<0.001) + 5.63 (t=1.91, p<0.001) Av. K	0.624
5	KFR= 17.46 (t=6.52, p<0.002) + 9.94 (t=2.53, p<0.001) CEC	0.723
10	KFR= 22.88 (t=4.28, p<0.002) + 11.38 (t= 2.91, p<0.003) CEC + 1.56 (t=4.52, p<0.003) Ex.K	0.676
20	KFR=20.66 (t=2.31, p<0.004) + 0.958 (t=3.47, p<0.002) Ex. K + 0.852 (t=5.53, p<0.014) CEC	0.665
60	KFR=31.85 (t=5.37, p<0.001) + 26.41 (t=2.37, P<0.004) Clay + 1.42 (t=4.41, p<0.003) OC	0.661
100	KFR= 25.24 (t=4.06, p<0.001) + 28.94 (t=3.08, p<0.005) Clay + 2.53 (t=4.02, p<0.001) OC	0.644
200	KFR=12.87 (t=2.43, p<0.004) + 0.496 (t=3.041, p<0.003) Clay + 2.23 (t=3.67, p<0.001) OC	0.593

*The value in parentheses refer to the t value and p value of the significant level of the constant or the regression equation

fixation rate. When the concentration of added K was higher (60-200μg mL^{-1} K), the clay in the first component and OC in the second component were the main factors affecting the K fixation rate. Those results are consistent with the results of other studies (Huang and Jin 1996 and Pannu *et al*., 2003). Conti *et al* (2001) suggested that K fixation rate was correlated significantly (P<0.01) with the contents of soil organic carbon and exchangeable K. Shaimukhametov and Petrofanov (2008) reported that the loamy soil fixed more K than the sandy loamy soil irrespective of the rate of K fertilizer (0-2.5 cmol/kg).

The K-fixation was found maximum in Sumbal (S_7) soil having significant correlation clay content and CEC of the soil. Wangat (S_6) soil has the least fixation capacity which is likely due to its coarse texture and low CEC. For these results, it could be concluded that fixation of K was mainly governed by the clay content and CEC of the soil. HuiMin *et al.* (2009) and Zhang *et al*., (2009) also found the black soils (high clay content and CEC) fixed more K as compared to the red soils (low clay content and CEC).

There might be an interaction between or among those main factors that affect the K fixation. There were relationships among the four factors (i.e., Av. K, Ex. K, OC and EC) in the first component. Shaimukhametov and Petrofanov (2008) implied that the fixation of K in the unexchangeable form could be regarded as the buffering capacity of soil exchangeable K and that recently fixed K had higher availability for crops than K fixed earlier. Similarly, there were also relationships among the two factors (i.e., CEC and clay) in the second component. It was reported that soil CEC was correlated significantly with SOM and <0.002 mm clay contents (Gao and Chang 1996).

From evaluation and comparison of the Langmuir, Freundlich, and Temkin isotherm equations, it was concluded that the Freundlich isotherm equation explain the sorption phenomenon more accurately.

Our results also showed that the K fixation capacity was greater in the following sequence in the seven tested soils: Silty caly (S_7) > Silty clay loam (S_9) > Silty clay loam (S_8) > Silty clay loam (S_3) > Clay loam (S_1) > Sandy loam (S_{10}) > Silty loam (S_2) > Loam (S_4) > Clay loam (S_5) > Sandy loam (S_6) and was significantly correlated with CEC and clay content. Potassium fixation rate was mainly affected by CEC and Av. K with lower added K concentration and by clay and OC with higher added K concentration.

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Effect of Integrated Nutrient Management on Physico-Chemical Properties of Soil, Growth, Yield and Quality of Rice Under Irrigated Ecosystem of Uttar Pradesh

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Abstract: Higher organic carbon, electrical conductivity, bulk density and growth attributes *viz*. plant height, tiller and dry matter were recorded in 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S $ha^{-1}$and this treatment was significantly higher over all other treatments but which was at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} at all stages of crop. Higher pH was recorded at 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S $ha^{-1}$and minimum pH was recorded at control treatment. Maximum grain and straw yield were recorded (4.6 and 6.4 t ha^{-1}) with 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S $ha^{-1}$and which was significantly superior to all others treatment. Nutrient uptake and nutrient available in soil were found in 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S $ha^{-1}$and this treatment was significantly to all others treatment but which was at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} at all stages of crop.

Key Words: INM, Organic Matter, Nutrient Uptake, Rice Yield, Soil Health

Rice is grown over on area of 148.36 million hectares with annual production of about 678 million tonnes. Rice contributes 43% of total grain production and 46% of the total cereal production of India (FAO, 2010). Among the rice growing countries India has largest area (44 million hectare) followed by China. Rice produced in India accounted for 21.60% of all world rice production (Ministry of Agriculture, 2010). The India's rice production reached to a record high of 104.32 million tonnes and productivity of rice 21.3 q/ha in 2011-2012. The average rice yield per hectare is highest in state of Punjab. To improve the production efficiency of rice, it is necessary to apply required dose of N, P, K and organic matter (Wani *et al*., 2012 and Upadhyay *et al*., 2011). Intensive cultivation and growing of exhaustive crops, accompanied by restricted use of organic manures and biofertilizers have made the soils not only deficient in the nutrients but also deteriorated the health resulting in decline in crop response to the recommended dose of N-fertilizer in the region. Non-Judicious enhancement of the N-fertilization further worsens the situation. Under such a situation, integrated plant nutrient system (IPNS) has assumed a great importance and has vital significance for the maintenance of soil productivity. Use of chemical fertilizers in combination with the organic manures is essential to improve soil health (Bajpai *et al*., 2006). Continuous recycling of the green manures with organic amendments enhances the organic matter and also supplements the nutrient pool of the soil (Kumar *et al.,* 2008). Biofertilizers carried out in different part of country indicated the high production with maintaining the soil fertility. As compared to the chemical fertilizers, biofertilizers are cheaper, pollution free and renewable source of nutrient supply. Extensive use of chemical fertilizers caused environmental pollution and ecological damage and increased production cost (Mitsh and Day, 2006). Under these circumstances, integrated use of organic manures, inorganic fertilizers and biofertilizers has assumed great importance for sustainable production and maintaining soil health. The objective of this study was to find out the evaluation of integrated nutrient management practices under irrigated ecosystem of Uttar Pradesh.

MATERIAL AND METHODS

Crop Management and Experimental Design: The field experiment was conducted during *Kharif* season of 2011-2012 on Research Farm of Department of Agricultural Chemistry and Soil Science, Udai Pratap Autonomous College, Varanasi (U.P.). The Research Farm is located at 25° 32' N latitude and 82° 97' E longitude with an elevation of 128.93 m above mean sea level. The soils of Varanasi formed on alluvial, deposited by river Ganga have predominance of illite, quartz, feldspars and illite minerals are partly inherited from micas which are predominant in the sand and silt fractions. There were six treatment combinations (Table 2) in randomized block design with 3 replications. Selection of 'Mansuri' rice varieties were sown on 15th July, 2011 and harvesting was done on 26th November, 2011, respectively. Rice crop was fertilized as per treatments.

Soil and Plant Sampling: The soil samples were taken each treatment and air dried, crusted with wooden roller and removed by passing through 2 mm round hole sieve. Soil samples collected were analyzed for various chemical properties such as organic carbon (Walkley and Black, 1934), available nitrogen (Subbiah and Asija, 1956), 0.5 M $NaHCO_3$ (pH 8.5) extractable phosphorus (Olsen *et al*., 1954), 1 N NH_4 OAC extractable potassium and available sulphur (Chesnin and Yien, 1951).

Growth attributes *viz*. plant height (cm), number of tillers (per meter row length) and dry matter (g) was determining on five tagged plants and averaging them. The grain yield of net plot after cleaning and proper drying was recorded in gram and converted to t ha^{-1} by multiplying with appropriate conversion factor. After threshing stem and chaff weight per plot were recorded and added treatment wise. Then, these were converted to t ha^{-1} by multiplying with appropriate conversion factor. Harvest index was calculated by dividing economic yield, *i.e.*, grain yield with biological yield (grain and straw) and expressed as percentage.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}}$$

Effect on Physico-Chemical Properties of Soil: Data of the soil pH slightly increased from transplanting of the seedling to the harvest of the crop. Significant effect of integrated use of inorganic fertilizers, organic manures and biofertilizer was recorded at all growth stages . Highest pH was recorded with addition of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1}. In respect of soil pH, various treatments could be arranged in the order $T_1>T_3>T_4>T_6>T_2>T_5$ with soil pH varied from 7.70 to 7.74, 7.71 to 7.76, 7.73 to 7.78, 7.74 to 7.79, 7.77 to 7.81 and 7.80 to 7.89 at 30 60 DAT and at harvest, respectively (Table 2). The release of organic acid during decomposition of organic manures might have resulted in decline in soil pH. Significantly higher organic carbon content was recorded in 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} (T_5) as compared to other treatments. The organic carbon content of soil under different treatments was found in the order $T_5>T_3>T_6>T_4>T_2>T_1$ with values were 0.60, 0.58, 0.55, 0.53, 0.50 and 0.44 at 30 DAT; 0.57, 0.55, 0.53, 0.50, 0.44 and 0.42 at 60 DAT and 0.52, 0.51, 0.49, 0.47, 0.42 and 0.38% at harvesting under respective treatments (Table 2). Higher organic carbon content in plots received higher amount of FYM and carpet waste may be attributed to higher amount of organic carbon content in the FYM and carpet waste. The increase in organic carbon content in the manurial treatment combination is attributed to the direct incorporation of organic matter in the soil on the subsequent decomposition of these materials might have resulted in the

Table 1. Nutrient contents of Farm yard manure (FYM), Carpet waste and Phosphate solublizing bacteria

Parameters	Organic sources		
	Farm yard manure (FYM)	Carpet waste	Phosphate solublizing bacteria (100 g)
Nitrogen (%)	0.5	12.0	0.5
Phosphorus (%)	0.4	0.05	3.2
Potassium (%)	0.9	0.05	0.2

Table 2. Effect of integrated nutrient management on physio-chemical properties of soil

Treatment	pH	OC (%)	EC	Bulk density	pH	OC (%)	EC	Bulk density	pH	OC (%)	EC	Bulk density
	30 DAT (Days after transplanting)				60 DAT (Days after transplanting)				At harvest			
T_1	7.70	0.44	0.30	1.22	7.72	0.42	0.28	1.24	7.74	0.38	0.28	1.27
T_2	7.77	0.50	0.33	1.28	7.79	0.44	0.34	1.30	7.81	0.42	0.36	1.33
T_3	7.71	0.58	0.28	1.24	7.74	0.55	0.29	1.25	7.76	0.51	0.30	1.28
T_4	7.73	0.53	0.27	1.27	7.76	0.50	0.31	1.29	7.78	0.47	0.32	1.30
T_5	7.80	0.60	0.35	1.30	7.81	0.57	0.37	1.32	7.89	0.52	0.38	1.35
T_6	7.74	0.55	0.31	1.27	7.77	0.53	0.32	1.28	7.79	0.49	0.33	1.29
LSD (P=0.05)	NS	0.03	0.02	0.03	NS	0.03	0.02	0.03	NS	0.03	0.02	0.03

T_1- Control, T_2 - 100 % N through urea + PSB + 20 kg S ha^{-1}, T_3 - 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1}, T_4 - 25 % N through FYM + 75% N through urea + PSB + 20 kg S ha^{-1}, T_5 - 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1}, T_6 - 25 % N through carpet waste +75% N through urea + PSB + 20 kg S ha^{-1}

enhanced organic carbon content of soil (Basker, 2003 and Tolanur and Badanur, 2003).

Maximum EC was recorded in (T_5) 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} followed by T_2 , T_6 , T_1, T_3 and T_4 at all stages of crop growth and difference in values of EC among various treatments was found to be statistically significant (Table 2). The bulk density of soil increased with advancement in growth stages and maximum bulk density was recorded at harvesting of crop under all treatments. Significantly higher bulk density was recorded in 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1}. The effect of various treatment of bulk density of soil was found in order $T_5>T_2>T_4>T_6>T_3>T_1$ with varied from 1.35 to 1.30, 1.33 to 1.28, 1.30 to 1.27, 1.29 to 1.27, 128 to 1.24 and 1.27 to 1.22 g m^{-1} at 30, 60 DAT and at harvest, respectively (Table 2). Addition of organic manures decreased the bulk density of soil might be due to the fact that better aggregation, high porosity and low bulk density of organic matter. It was also observed that the bulk density of rice plot increased with time might be due to natural compaction and consolidation (Roy *et al.,* 2013).

Effect on Growth Attributes: The effect of different treatments of organic manures, bio-fertilizer and inorganic fertilizers on plant height, tiller per meter row length and plant dry matter was found significantly under respective treatments. Highest plant height, tiller per meter row length and plant dry matter was recorded with 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} and this treatment was significantly increased the plant height, tiller per meter row length and plant dry matter over other treatments at different growth stages, respectively (Table 3). This could be attributed to higher and continuous supply of nutrients in organic manures treated plots which was significantly increased the growth characteristics of rice (Hasanuzzaman *et al.*, 2010).

Effect on Yield: Significantly higher grain yield was obtained with the application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} (4.6 t ha^{-1}) over T_6, T_4, T_2 and T_1 (3.1 t ha^{-1}) but which was statistically at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} (T_3). Application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} was 6.9, 17.9, 24.3, 31.4 and 48.4 % grain yield increased over T_3, T_6, T_4, T_2 and T_1, respectively (Table 4). In case of straw yield was obtained with the application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} (6.4 t ha^{-1}) and this treatment was significantly higher straw yield over T_6, T_4, T_2 and T_1 (4.2 t ha^{-1}) but which was statistically at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} (T_3). Application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} was 6.7, 18.5, 23.1, 36.2 and 52.3 % straw yield increased over T_3, T_6, T_4, T_2 and T_1, respectively (Table 4). The combined application of inorganic and organic sources produced higher grain and straw yield than inorganic alone might be attributed to higher and continuous supply of nutrient and improvement in physical environment of soil which increased significantly the yield characteristics of the rice. This is in agreement with findings of Selvakumari *et al.* (2000), Kumar *et al.*, (2013) and Roy *et al.* (2013) also obtained significantly higher grain and straw yield of rice crop by integrated of organic and inorganic sources of nitrogen.

Effect on Nutrients Uptake: Data revealed that the significant effect of integrated use of inorganic fertilizers, organic manures and biofertilizer on nitrogen uptake. Application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} was recorded maximum NPK uptake of rice and this treatment was significantly higher NPK uptake than other treatment combinations. The minimum NPK uptake of rice was observed in control (Table 4). Application of N through organic sources may be ascribed to the release of K from the K-bearing minerals by complexing ascent or organic acids produced during decomposition of organic manure (Kumari *et al.*, 2010, Nath *et al.*, 2010 and Roy *et al.*, 2013). This might be due to the improved physical properties of soil with better N availability to the crop. Sulphur uptake was maximum with 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} due to chelating action of organic compounds which prevents these cations from fixation, precipitation, oxidation and leaching (Gogoi *et al.*, 2010, Kumar *et al.*, 2013 and Roy *et al.,* 2013).

Effect on Available Nitrogen: The available nitrogen status of soil decreased continuous with advancement in growth stage (Table 4). Various treatments of inorganic fertilizers, organic manures and biofertilizer in respect of available nitrogen content could be arranged in order $T_5>T_3>T_6>T_4>T_2>T_1$. Available nitrogen content of surface soil increased appreciably with the application of manures along with fertilizers as compared to sole application of NPK fertilizers. Application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} significantly increased available N content over different treatments, but which was at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1}treatment at all growth stages. Increase in available N might be due to the direct addition of N through FYM and improved microbial activities, which might have converted organically bound N to inorganic forms (Singh and Dhar, 2011, Kumar *et al.*, 2013 and Roy *et al.,* 2013).

Table 3. Effect of integrated nutrient management on growth attributes of rice

Treatment	Plant height (cm)	Tillers (m^{-1} row length)	Dry matter (g)	Plant height (cm)	Tillers (m^{-1} row length)	Dry matter (g)	Plant height (cm)	Tillers (m^{-1} row length)	Dry matter (g)
	30 DAT (Days after transplanting)			60 DAT (Days after transplanting)			at harvest		
T_1	55.0	25	17.0	64.3	48	39.0	70.7	44	47.2
T_2	56.6	29	24.0	67.3	50	43.3	71.9	47	52.4
T_3	65.7	35	44.0	80.4	62	65.0	86.4	55	78.6
T_4	59.6	30	32.0	68.0	53	45.6	75.3	49	55.2
T_5	67.5	38	58.0	83.5	68	81.3	90.1	60	98.4
T_6	61.4	31	39.0	78.2	56	61.6	80.2	50	74.5
LSD (P=0.05)	1.8	0.9	2.7	2.2	1.5	3.8	2.3	1.5	4.6

Table 4. Effect of integrated nutrient management on grain yield, straw yield and nutrient uptake of rice

Treatment	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest index (%)	Nutrient uptake ($kg\ ha^{-1}$)			
				N	P	K	S
T_1	3.1	4.2	42.5	12.6	7.4	60.6	4.5
T_2	3.5	4.7	42.7	16.4	9.4	71.4	7.7
T_3	4.3	6.0	41.7	21.0	13.6	114.0	10.2
T_4	3.7	5.2	41.6	18.3	10.4	81.0	8.1
T_5	4.6	6.4	41.8	22.7	14.2	132.0	12.2
T_6	3.9	5.4	41.9	19.6	12.7	102.5	9.8
LSD (P=0.05)	0.3	0.4	NS	0.6	0.4	3.0	0.3

Table 5. Effect of integrated nutrient management on available soil nutrient content of rice

Treatment	Available nutrient content ($kg\ ha^{-1}$)											
	N	P	K	S	N	P	K	S	N	P	K	S
	30 days after transplanting				60 days after transplanting				At harvest			
T_1	235.5	16.2	218.2	10.0	225.1	13.5	211.3	8.6	216.6	10.0	197.3	6.8
T_2	251.6	16.8	225.6	10.6	246.0	14.7	222.0	9.2	230.6	10.6	203.2	8.0
T_3	270.2	21.8	246.4	15.7	259.5	18.9	237.0	12.8	246.3	14.7	224.1	11.6
T_4	257.4	17.6	231.1	12.0	254.1	15.2	226.0	10.3	238.2	11.5	212.5	8.9
T_5	276.3	22.4	253.1	16.0	263.2	19.3	243.0	13.1	250.1	15.0	229.6	11.7
T_6	261.1	19.0	236.7	13.0	255.7	16.0	230.0	11.2	241.3	12.1	216.0	10.0
LSD (P=0.05)	7.3	0.6	6.7	0.4	7.1	0.5	6.4	0.3	4.7	0.4	6.1	0.3

Effect on Available Phosphorus: In general, available phosphorus content of soil gradually decreased with age of crop. Significant effect of integrated use of mineral fertilizer with organic manures was recorded. The effect of addition of organic of soil was found in the order $T_5 > T_3 > T_6 > T_4 > T_2 > T_1$. Maximum available phosphorus was recorded with 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} application and this treatment was statistically at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} and which was significantly superior over all other treatments at 30, 60 DAT and at harvest. Increase in P availability might be due to the fact that organic materials form a cover on sesquioxides and thus reduce the phosphate fixing capacity of the soil and increased phosphorus solubilization for the native soil pool. The benefit of using organic manure like FYM was due to release of aliphatic and aromatic hydroxy acids and humates that leads to higher availability of nutrients (Kumar *et al.*, 2013). Available P enhanced due to CO_2 released and organic acid produced during decomposition, which helps in solubilizing native P. The organic matter (humus) may also reduce the fixation of phosphate by providing protective cover on sesqueoxides and chelating cations, which in turn enhanced the availability of P (Singh *et al.,* 2008 and Roy *et al.,* 2013).

Effect on Available Potassium: The result showed that the available potassium status of soil decreased with days after transplanting and effect of various treatment of organic manures, biofertilizer and inorganic fertilizers on available potassium were found in the order $T_5 > T_3 > T_6 > T_4 > T_2 > T_1$. The available K content of the recording data was significantly higher in application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} (T_5) as compared to rest of treatments at 30, 60 DAT and at harvest stage except, application of 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} (T_3). Increase in available K due to organic manures application may be attributed to direct addition of potassium to the available pool of the soil. Beneficial effect of organic manures and biofertilizer on available K due to reduction of K-fixation, solubilization and release of K due to the interaction of organic matter with clay, besides the direct potassium addition to the potassium pool of the soil (Singh *et al,* 2008, Roy *et al.,* 2013 and Kumar *et al.*, 2013).

Effect on Available Sulphur: The result indicated that the available sulphur status of soil decreased with days after transplanting whereas the effect of various treatments of organic manures, biofertilizer and inorganic fertilizers on available sulphur was found in the order $T_5>T_3>T_6>T_4>T_2>T_1$. Maximum available phosphorus was recorded with 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} (T_5) application and this treatment was statistically at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} (T_3) and which was significantly superior over all other treatments at 30, 60 DAT and at harvest. Increase in available sulphur due to organic manures and biofertilizer application may be attributed to direct addition of sulphur to the available pool of the soil and reduction in losses and fixation of S through various mechanisms. Similar results were also report by Tiwari *et al.* (2002), Yadav and Kumar (2009) and Roy *et al.* (2013).

In conclusions, it could be recommended that application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} treatment showed the highest growth attributes, yield, nutrient uptake and available nutrients among all other treatments. However, 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} was applied the next best treatment in these respects under irrigated ecosystem of Eastern Uttar Pradesh.

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Fertilizer Prescription for Targeted Yield of Rice (*Oryaza sativa* L var. Saryu-52) in an Inceptisol of Varanasi

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Abstract: The development of prescription based fertilization recommendations for a given soil crop fertilizer situation takes into account the soil fertility status as well as crop needs and is thus based on balanced nutrition of crops. So, the target yield concept involves fertilizer recommendation based on yield targets to be achieved taking into consideration the contribution of soil available nutrients and fertilizer nutrients for total uptake. Three field experiments were conducted at farmers fields to check the validity of the fertilizer adjustment equation for rice crop (cv. Saryu-52) by comparing control, farmers practice, general recommended doses of fertilizers and fertilizer doses based on soil test crop response (STCR) for 45 q ha^{-1} for ascertaining the economics of each practice. Results of the study showed the superiority of the target yield concept over the other practices as it gave higher yield and optimal economics returns. The yield targets were achieved within reasonable limits when the fertilizer was applied on soil test basis in rice thus establishing the utility of the adjustment equations for recommending soil test based fertilizer application to the farmers.

Key Words: Benefit Cost Ratio, Target Yield, Fertilizer, Farmer Practice, Soil Test.

Rice (*Oryza sativa L.*) is the major crop in Uttar Pradesh and occupies 5.86 mha of land, which comprises of 13.82% of total area under rice in India. Uttar Pradesh is the leading producer (14.41 Mt) of rice and rank 2^{nd} in the country (Anonymous, 2013). Fertilizer is a costly input and, therefore, its economics before use should be evaluated from the yield production per unit of nutrient applied. The efficiency of added fertilizer depends upon many factors like nature of the soil, availability of the nutrient status of the soil, the climate, crop and its variety, management practices, etc. Soil testing enables to evaluate the nutrient supplying capacity of the soil and being widely used to work out nutrient requirement of the crops. Fertilizer requirements of different crops vary due to their differential production potential and ability to mine nutrients from native and fertilizer sources. Therefore, the quantity of fertilizers to be applied to crops depends upon the initial nutrient status of the soil and thereby, soil test value need considerable attention. The fertilizer requirements of crops also depend upon yield targets to be achieved. For achieving a definite target yield of a crop, a definite quantity of nutrients must be applied to the crop and this requirement of nutrients can be calculated by taking in to consideration the contribution of soil available nutrients and fertilizer nutrients for total uptake. This forms the basis for fertilizer recommendations for targeted yield of crops. Farmers are using excess chemical fertilizers to achieve higher yield but the decision on fertilizer use requires knowledge of the expected crop yield and response to nutrient application (1.214, 0.418 and 0.074 Mt per ha fertilizer consumption in the district in terms of NPK). Field-specific balanced amounts of primary nutrients (N, P and K) were prescribed based on crop based estimates of the supply of N,P and K and by modelling the expected yield response as a function of nutrient interaction (Ramamurthy *et al.,* 2009). These equations were developed after establishing significant relationship between soil test values and the added fertilizer. This study was conducted keeping the above facts in view and non-availability of STCR data for rice in eastern Uttar Pradesh.

The objective of this study was to evolve a sound basis of fertilizer prescriptions for rice crop in alluvial soil (Inceptions) at different soil fertility levels under the conditions of fertilizer scarcity and to ensure maximum fertilizer use efficiency. The present study was, therefore, conducted at farmer's fields on rice crop for comparing control, farmers practice, soil test based general recommendation dose of fertilizer and yield target concept for ascertaining the economics of fertilizer application of each practice.

MATERIAL AND METHODS

Field experiments were conducted at farmer's fields in three villages viz., Khewashipur (location I), Bhatshar (location II) and Loharpur (location III) of Varanasi district, Uttar Pradesh, India during year *kharif* 2013 (15.06.2013 to 10.10.2013) on alluvial soil (Inceptions). Before sowing of crop, surface soil samples (0-15 cm) were collected from the experimental fields, processed for analysis and analyzed for various physico-chemical properties. Available nitrogen was determined by the alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus by Olsen method (Olsen *et al*., 1954) and available potassium by the ammonium acetate method (Hanway and Heidal, 1952) as described by Jackson (1973). Four treatments viz., control, farmers practice, general recommended dose of fertilizer and fertilizer doses based on soil test crop response (STCR) for target yield 45 q ha^{-1} of rice (cv. Saryu-52) were evaluated. The targeted yield of crop was decided as per yield potential of varieties. Soil resource inventory of the study area in given in the Table 1. The fertilizer adjustment equations are derived by the All India Coordinated Research Project, Institute of Agricultural Science, B.H.U., Varanasi centre. Doses of nitrogen, phosphorus and potassium were calculated with the help of fertilizer adjustment equations as follow:

With FYM:

$FN = 4.74\,T – 0.49\,SN – 0.34\,ON$

$FP_2O_5 = 1.53\,T – 1.41\,SP - 0.09\,OP$

$FK_2O = 2.92\,T – 0.35\,SK - 0.11\,OK$

Where - T = Yield target (t ha^{-1})

FN = Fertilizer N (kg ha^{-1})

FP_2O_5 = Fertilizer P (kg ha^{-1})

FK_2O = Fertilizer K (kg ha^{-1})

SN = Soil available nitrogen (kg ha^{-1})

SP = Soil available phosphorus (kg ha^{-1})

SK = Soil available potassium (kg ha^{-1})

ON = Amount of N applied through FYM (kg ha^{-1})

OP = Amount of P applied through FYM (kg ha^{-1})

OK = Amount of K applied through FYM (kg ha^{-1})

One third dose of N and full dose of P_2O_5 and K_2O were applied as basal application at transplanting time and rest amount of N was applied in two equal splits at 25 and 50 days after transplanting of the crop. Nitrogen, phosphorus and potassium were supplied through urea, single super phosphate and muriate of potash, respectively.

The pH varied from 7.2 - 8.4, organic carbon 0.28 - 0.56 % (Table 1). The soils were low in available nitrogen (160-180 kg ha^{-1}), low in available phosphorus (10-15 kg ha^{-1}) and medium in available potassium (160-180 kg ha^{-1}).

RESULTS AND DISCUSSION

From the field experiment, the basic data on nutrient requirement (NR) for producing one quintal grain yield of rice, per cent contribution of nutrients from soil (%CS), fertilizer (%CF) and farm yard manure (%CFYM) were evaluated. These basic parameters were used for developing the fertilizer prescription equations under NPK with farm yard manure. The nutrient requirement of N, P_2O_5 and K_2O were 2.56, 0.56 and 2.21 kg q^{-1} of grain yield, respectively. The per cent contribution of nutrients from soil, fertilizers and farm yard manure were found to be 26.35, 54.03 and 18.59 for N, 51.17, 36.35 and 3.10 for P_2O_5 and 26.14, 75.68 and 8.56 for K_2O, respectively. It was noted that contribution of potassium from fertilizer for rice was higher in comparison to soil. This high value of potassium could be due to the interaction effect of higher doses of N, P coupled with priming effect of starter K doses in the treated plots, which might have caused the release of soil potassium form, resulting in the higher uptake from the native soil sources by the crop (Basavaraja *et al.,* 2011). Similar type of higher efficiency of potassic fertilizer was also reported for rice by Ahmed *et al*. (2002) in alluvial soils and for finger millet by Kadu and Bulbule (2007). Contribution of available nutrient from FYM is low, which might be due to lower mineralization rate of FYM (Sachan *et al*., 1981). However, in the case of P_2O_5, the contribution was more from soil than fertilizer.

In all the cases, yield of 45 q ha^{-1} for rice (variety–Saryu-52) was achieved with in ± 10 per cent of the target yield (Table 2). At third location, the benefit cost ratio 2.03 was higher comparison to first and second locations. Generally, the rice yield was higher when fertilizer was applied on target basis as compared to that obtained through the farmers practice and general recommended dose of fertilizers. At all sites, grain yields of rice through general recommendation (GRD) of fertilizers lagged behind the yield obtained at 45 q ha^{-1} fixed target. These results find the support of Basavaraja *et al*. (2011), Deshmukh *et al.* (2012) and Avtari *et al.* (2010).

Target yield of 45 q ha^{-1} has been achieved with comparatively lower application of N and P_2O_5 fertilizers but higher application of K_2O, in comparison to doses applied in farmer's practice and soil based recommendations. Although, the fertilizer application based on this concept is more balanced, profitable and helps in long term maintenance of soil fertility, but due to inadequacies in managerial skills and aberrant weather conditions, actual yield obtained deviates from the target fixed in some of the cases. By taking into consideration the cost of fertilizer applied to the crops and value of additional produce over farmer's, the benefit of other approaches of fertilizer application over farmer's practice was calculated (Table 2). Several studies carried out at experimental farms and under

Table 1. Physico-chemical properties of the experimental fields

Locations	Physico-chemical properties			Available nutrients (kg ha^{-1})		
	pH	EC (dSm^{-1})	OC (%)	N	P	K
Location-I	7.2-8.2	0.30-0.42	0.28-0.36	160.0	10.0	180.0
Location-II	7.3-8.4	0.40-0.58	0.38-0.56	180.0	10.0	160.0
Location-III	7.5-8.4	0.58-0.70	0.40-0.55	160.0	15.0	180.0

Table 2. Economics of verification trails for rice crop

Treatments	Doses NPK (kg/ha) and FYM (t/ha)	Mean yield (kg/ha)	Additional yield over control (kg/ha)	Value of additional yield (Rs/ha)	Cost of fertilizer and FYM (Rs/ha)	Net benefit (Rs/ha)	B/C ratio
Location - I : Village-Khewashipur							
Control	0-0-0-0	2166	-	-	-	-	-
FP	110-35-35-0	2966	800	8800	4800.75	3999.25	0.83
GRD	120-60-60-0	3780	1614	17754	7037.40	10716.60	1.52
TY 45 q ha^{-1}	119-52-64-5	4560	2394	26334	9675.05	16658.95	1.72
Location - II : Village- Bhatshar							
Control	0-0-0-0	2000	-	-	-	-	-
FP	110-35-35-0	3000	1000	11000	4800.75	6199.25	1.29
GRD	120-60-60-0	3800	1800	19800	7037.40	12762.60	1.81
TY 45 q ha^{-1}	119-52-64-5	4550	2550	28050	9675.05	18374.95	1.90
Location - III: Village-Loharapur							
Control	0-0-0-0	2000	-	-	-	-	-
FP	110-35-35-0	2866	866	9526	4800.75	4725.25	0.98
GRD	120-60-60-0	3833	1833	20163	7037.40	13125.60	1.87
TY 45 q ha^{-1}	119-52-64-5	4666	2666	29326	9675.05	19650.95	2.03

Note: Paddy @ Rs.11.00/kg, N @ Rs.17.39/kg, P_2O_5 @ Rs.56.25/kg, K_2O @ Rs.26.66/kg, FYM @ Rs. 0.60/kg. FP: Farmers practice, GRD: General recommendation dose, TY: Target yield, B C ratio: Benefit cost ratios.

farmer's field conditions have established the validity of target yield concept for different crops under variable soil type and agro climate conditions (Dhillon *et al*., 2006). The benefit cost ratio of rice crop at all locations (Table 2) suggests that target yield concept gives higher yields and hence better economic returns than farmer practice and general recommendation. Also, the target yield treatment recorded higher percentage of target and BC over other treatments. The favourable complementary influence of organic and inorganic on chemical, physical and biological properties of soil under target yield treatment would have resulted in higher yields of rice crop.

The results of the study have clearly brought out the superiority of fertilization based on target yield concept over traditional approaches as reflected through higher yields and optimal economic returns. The farmers practice was poor yielder in all the locations. The results showed a very close correspondence between targeted yields and the yield obtained and are an evidence of the usefulness of soil testing within limits of variation under field conditions. The equation generated can be used for making fertilizer recommendations for targeted yields of rice in Inceptisol of eastern Uttar Pradesh.

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Performance of Fodder Maize Under Zero Tillage, Bed Planting and Nitrogen in Comparison to Conventional Tillage for Seed Production

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Abstract: The experiment was conducted to find out the planting method and nitrogen level for enhancing the seed yield of fodder maize (*Zea mays* L.). The treatment comprised of three planting methods as zero tillage (ZT), conventional tillage (CT) and bed planting (BP) and four nitrogen levels (0, 100, 125 and 150 kg N/ha). Results revealed that maize fodder (variety J 1006) seed yield did not vary with ZT, CT and BP because biometrical parameters like plant height, leaf area, dry matter accumulation, stover yield, shelling percentage, 1000 grain-weight were also not varied with methods of planting. Nitrogen application of 150 kg N/ha produced the significantly higher seed yield than 0, 100 and 125 kg N/ha.

Key Words: Bed planting, Conventional Tillage, Fodder Maize, Nitrogen, Seed Production, Zero Tillage.

Maize (*Zea mays* L.) is the third most important cereal crop next to rice and wheat and has the highest production potential among the cereals. In Punjab, maize was grown on 133 thousand hectares with total production of 491 thousand tonnes during 2011-12 (Anonymous, 2012). However, the average yield of maize is 27.3 q/ha which is rather low as compared to yield of developed countries. So, there is scope to increase its productivity through agronomic interventions and it can also be an attractive alternative to rice for diversification by the farmers of the state. Maize production can be enhanced by adoption of proper planting method and use of essential nutrients. For raising the crop yield fertilizer impact is one of the major factors and it contributes about 50% to yield performance. The planting of maize in *kharif* also experiences high rainfall during monsoon season which often results in temporary flooding on flat planted crop. Thus there is a need to try various planting methods in order to reduce its water requirement when sown during end of May and also to save it from temporary flooding damage caused due to monsoon rains. Zero tillage, ridge or bed sowing also gave higher yield than the flat sowing method. Freeman *et al.* (2007) reported that planting of maize on bed provides a good option for managing water, nutrients and weeds. The bed planting system have number of advantages like better irrigation management, increased availability of nutrients to crop roots, better crop establishment, better weed management through inter bed cultivation and less soil compaction and also helps to increase aeration in root zone and ensure good plant stand by increasing emergence particularly in crusting type soil. Singh and Singh (2012) observed ridge method to be better than flat and raised used planting in winter maize. The main objective of the study is to find out the suitable planting method and nitrogen requirement for enhancing the seed yield of fodder maize.

MATERIAL AND METHODS

Field experiment was carried out at the students' Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (36^{o} 54' North latitude and 75^{o} 48' East longitudes; 247 meters above mean sea level). The treatment consisted of three planting methods zero tillage (ZT), conventional tillage (CT) and bed planting (BP) and four nitrogen (N) levels (0,100,125 and 150 kg N/ha) with planting methods in vertical strip and nitrogen levels in horizontal strip. The treatment was replicated three times in strip plot design. The soil of experimental field was sandy loam in texture and normal in pH, EC and organic carbon, medium in available N (125 kg N/ha), P (12.3 kg P_2O_5/ha) and K (115.0 kg K_2^{o}/ha). Nitrogen was applied in the form of urea in three splits as per treatment. One third at sowing and other one third at knee high stage near the plant base and remaining one third at pre tasseling stage. The row-to-row spacing was 50 cm and plant-to-plant spacing was 20 cm. The crop husbandry was as per recommended package of practices. Five plants were randomly selected from the each plot and tagged. The plant height from the base of the stem to the base of the topmost unfolded leaf was recorded periodically at 10 days interval starting from the day of sowing. The mean plant height of five tagged plants was computed. The periodic dry matter accumulation and leaf area index was determined by randomly selecting three plants per plot. Five cobs were selected at random from each plot for measuring cob length, 1000- grain weight; stover yield and shelling percentage were determined by randomly selecting a sample from the pool of harvested seeds from each plot. Grain yield (q/ha) was determined by recording the seed yield after shelling. The shelling percentage (SP) was calculated by dividing the grain weight of five cobs by the total weight of five cobs and multiplying it by 100.

RESULTS AND DISCUSSION

Growth Parameters: The plant height increased slowly between 20 and 40 DAS, increase more pronounced between 40 to 60 DAS and increase was very slow between 80 DAS and at harvest under different planting methods and N levels (Table 1). It shows that increase in plant height from 40 to 60 DAS is the grand growth period of the maize crop. Plant height increased with increase in N from 0 to 150 kg/ ha at all the stages of the crop growth. At 60 DAS and at harvest, application of 150 kg N/ha produced significantly taller plant over the control and 100 kg N/ha, but at par with 125 kg N/ ha. Whereas, at 80 DAS, 150 kg N/ha was at par with 125 and 100 kg N/ha, but significantly higher than control (147.9 cm). The improvement in plant height with each successive increment of nitrogen might be attributed to the fact that nitrogen is an integral part of protein, the building blocks of plant and it also helps in maintaining higher auxin level, which might have resulted in better plant height (Kumar, 2009). These results are in close association with Rizwan *et al.* (2003) and Harikrishna *et al.* (2005) who reported a non-significant effect of nitrogen application on maize plant height. Increasing nitrogen level from 120 kg /ha to 200 kg /ha also increased the plant height of hybrid maize varieties. Higher N applications increase the cell division, cell elongation, nucleus formation as well as green foliage. It also encourages the shoot growth. Higher doses of nitrogen increased the chlorophyll content, which increased the rate of photosynthesis and extension of stem resulting increased plant height (Thakur *et al.,* 1997).

Leaf area varied significantly at 20, 40 and 80 DAS due to different planting methods. It was increased progressively up to 80 DAS and at harvest decreased substantially as compared to 80 DAS under different planting methods and N levels (Table 1). The bed planted method recorded significantly better leaf area than other two methods at 20, 40 and 80 DAS. It could be due to better water and nutrient absorption by the crop resulted in better leaf growth. However, at 60 DAS and at harvest, leaf area was higher under bed planting method but the differences were non-significant among the different planting methods. Leaf area with 150 kg N/ha was significantly at par with 125 kg N/ha and both these levels were significantly better than 100 and 0 kg N/ha at 20, 40 and 60 DAS. However, application of 150 kg N/ha gave significantly better leaf area over the rest of the N levels at 80 DAS and harvest. The increase in leaf area with increasing nitrogen levels might be due to better crop growth with higher N availability (Vedivel *et al.,* 2001).

The dry matter accumulation (DMA) increased progressively with advancement of age and the maximum values were recorded at harvest. Among the planting methods, BP showed significantly more DMA as compared to CT and ZT at 30 DAS (Table 2). At other growth stages, BP recorded comparatively more DMA as compared to other planting methods. High DMA in bed planted crop was due to better growth owing to better water and nutrient utilization.

DMA increased with the increment of N levels up to the highest level tried at all the growth stages. However, 150

Table 1. Effect of planting methods and nitrogen levels on plant height and leaf area at different stages of Fodder maize

Treatment	Plant height (cm)					Leaf area (cm^2)				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Planting method										
ZT	22.1	75.5	158.6	176.7	194.4	77.8	107.3	212.6	247.8	223.2
CT	23.0	83.7	160.1	185.9	201.4	86.1	121.2	218.8	258.3	227.3
BP	23.1	89.6	160.8	187.4	207.9	90.1	124.5	241.4	275.8	227.8
CD(p=0.05)	NS	4.2	NS	NS	NS	2.2	2.3	NS	16.5	NS
Nitrogen level (kg/ha)										
0	21.5	79.1	140.0	147.9	169.6	59.0	75.3	151.5	180.8	148.6
100	22.7	80.5	159.3	192.2	208.3	90.2	117.3	225.5	276.2	243.2
125	23.2	81.9	165.8	199.4	210.5	94.2	139.0	254.2	277.8	250.1
150	23.3	90.2	168.8	201.4	216.5	95.3	140.9	266.2	307.7	262.4
CD(p=0.05)	NS	NS	5.3	16.3	7.0	2.7	2.1	14.7	24.6	9.5

DAS –Days after Sowing

Table 2. Effect of planting methods and nitrogen levels on dry matter accumulation, yield and yield attributes

Treatment	Dry matter accumulation per plant (g)				Cob length (cm)	Grain yield (q/ha)	Stover yield (q/ha)	Shelling (%)	1000-grain weight (g)
	30 DAS	50 DAS	70 DAS	80 DAS					
Planting method									
ZT	37.4	62.5	144.0	157.6	8.7	44.4	177.1	50.1	168.1
CT	39.9	62.5	144.9	158.5	11.1	44.6	178.7	50.4	178.9
BP	45.8	63.0	147.2	159.9	12.7	48.0	197.6	50.8	182.5
CD (p=0.05)	0.6	NS	NS	NS	0.7	NS	NS	NS	NS
Nitrogen level (kg/ha)									
0	34.5	48.2	124.6	140.8	6.0	21.0	144.9	36.8	132.5
100	36.5	59.1	135.8	147.7	9.8	45.3	171.8	46.7	183.9
125	42.4	65.7	153.6	166.2	13.5	53.0	207.4	57.2	193.0
150	50.8	77.0	167.4	180.0	14.0	63.3	213.7	61.0	196.7
CD (p=0.05)	1.2	2.5	4.2	4.9	1.2	3.0	20.0	3.4	21.7

DAS –Days after Sowing

kg N/ha showed significantly better DMA than other N levels at all stages of growth. Significant increase in DMA at each increment of N level has also been reported by Singh *et al.* (2003).

Yield and Yield attributes: BP showed significant more cob length than CT and ZT. Among all the methods of planting, zero tillage showed the minimum cob length. The cob length was statistically comparable under 125 kg N/ha and 150 kg N/ha, but differed significantly under control and 100 kg N /ha. Paradkar and Sharma (1993) reported a positive effect of N application on cob length of maize. Costa *et al.* (2002) reported that cob length increased when N level was increased from 0 to 85 kg /ha. Bakht *et al.* (2007) reported that maximum cob length (15.67cm) was produced in plots receiving 200 Kg N/ha followed by plots treated with 160 and 120 Kg N/ha.

The data presented in Table 2 showed that method of planting had no significant effect on the 1000-grain weight. Bed planted crop recorded the maximum 1000-grain weight followed by CT and ZT. Maximum 1000-grain weight was recorded at 150 kg N/ha (196.7 g), which was at par with 100 kg N/ha and 125 kg N/ha but significantly differed with control level of nitrogen. Maqsood *et al* (2001) reported that high levels of N markedly increased 1000-grain weight. The maximum SP was recorded from the BP plots (50.8 %), which was comparatively high as compared to CT and least in ZT. Higher value of SP was showed by 150 kg N/ha, which was significantly high as compared to 125, 100 kg N/ha and control, which was 3.8, 14.3 and 24.2 % more shelling as compared to other N levels. The results are in close agreement with the findings of Hussaini *et al.* (2001).

Grain and Stover yield: Seed yield was not significantly affected by the planting methods (Table 2). Seed yield of fodder maize was maximum at 150 kg N/ha (63.3 q/ha), which was significantly higher than 125 kg N/ha, 100 kg N/ha and control (21.0 q/ha) which was 16.3, 28.4 and 66.8 per cent higher as compared to 125, 100 kg N/ha and control, respectively. Singh *et al.* (2003) also observed a significant increase in grain yield at high N levels. Planting methods had no significant influence on stover yield. BP showed fairly better stover yield than CT and ZT. It produced 9.5 and 10.3 per cent higher stover yield as compared to CT and ZT. Bed planted crop had better growth and more dry matter accumulation resulting in higher stover yield than the other methods of sowing. Maximum stover yield was recorded under 150 kg N/ha which was significantly better than 100 kg N/ha and control, but at par with 125 kg N/ha. Chaudry and Jamil (1998) revealed that stover yield increases with increasing nitrogen rate. The reduction of stover yield might be associated with lower plant height and lower internodes growth.

Maize fodder gave the similar seed yield with the ZT, CT and BP. CT and BP requires intensive tillage for sowing of crop and it will enhance the cost of cultivation but not seed yield and also delay the sowing due to the seed bed preparation. The application of 150 kg N/ha gave the significantly higher seed yield than all other N levels. Therefore, fodder maize can be sown with ZT for higher seed yield at low cost by skipping the tillage operation at the time of sowing.

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Variability in Limonoid and Oil Content of Neem in Different Eco-Climatic Regions of Rajasthan

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Abstract: The present study deals primarily with oil and limonoids, tree structural features, seed characters among selected 53 plus trees (PTs) of neem Azadirachta *indica* A. Juss) distributed in extreme arid, arid, semi arid and dry sub-humid regions. Due to better rainfall and other favourable environmental conditions, the growth and development of tree structural traits were best in dry sub-humid region. However, it was not same for seed characters, and oil and limonoid content. The progressive increase in seed diameter from dry sub-humid region to extreme arid region indicated presence of bold and better quality seeds as diameter was found to be one of the best seed characteristic for quick selection of better seeds to raise quality seedling for future tree crops having high oil and limonoid contents. Further presence of high concentration of azadirachtin-A (AA), azadirachtin-(AB), nimbin (N) and salinin (S), and as well as oil content in PTs of extreme arid region indicated that adaptability of trees of the spices in a very high thermal environment coupled with very low moisture conditions. Probably such situation influence better synthesis of these compounds. Moreover, production of seeds in high quantum does not necessarily mean that they contain high amount of limonoids.

Key Words: Azadirachtin, Limonoid, Neem, Nimbin, Oil Plus Tree, Salanin

Neem (*Azadirachita indica* A. Juss is an ever green tree that can grow upto 20 m tall. Its spreading branches forms rounded crowns, sometimes up to 10 m in diameter. Neem is rarely leafless and is usually in full foliage even during months of prolonged drought. There are acknowledged to be two varieties of neem; *A. Indica* (Indian neem) and *A. indica* var. siamensis (Thai neem). Indian neem is spread throughout the Indian sub- continent, while Thai neem has a wide natural distribution in Thailand and adjoining countries in south east Asia (Willan *et al.,* 1990). In Indian sub-continent, Indian neem is a highly esteemed tree for the people of the region.

Organic pesticides extracted from neem have attracted the attention of whole world in recent years. The pesticidal properties of neem based formulations are due to the presence of bioactive limonoids such as azadirachtins, nimbin, salinin etc. (Kaushish *et al*., 2006; Azam *et al.,* 2009). Wide variations are found in reproductive phenology of neem in regional scale (Gupta *et al.*, 2010). It appears that the reproductive phenology have some role in formation of limonoids in neem seeds, the source of oil and limonoids. It is important to understand the regional and habitat variations in limonoid content in neem seeds so that it could be established that limonoid content especially AA, AB, N and S is influenced by eco-climatic conditions. The present paper discusses the vaiations in oil and limonoids (AA, AB, N, S) contents in seeds of PTs of neem in different eco-climatic regions of Rajasthan, the area wise largest state of India.

MATERIAL AND METHODS

Primarily based on rainfall patterns, Rajasthan state has four distinct eco-climatic regions. The extreme western part which receives less than average annual rainfall of 200 mm is categorized as extreme arid. A large region which receives rainfall between 200 mm and 350 mm is categorized as arid. Between arid and dry sub-humid region lies a tract which is categorized as semi- arid region (average annual rainfall between 350 mm and 675 mm). Eastern and south eastern part, which receives more than 675 mm rainfall is categorized as dry sub-humid region. Arid Intensive survey was conducted during 2000-2001 under national network on integrated development of neem project in four regions to identify the PTs following the method given by Tewari *et al.* (2001) in which tree height, straight bole length and diameter at breast height (DBH) i.e. 1.37 m above the ground were taken as criteria for selection. In this way 100 candidate plus trees (CPTs) were identified (extreme arid = 14, arid = 38, semi arid = 29, dry sub humid = 19). The CPTs which produced more than 17 kg of seeds were selected as PTs. In this way total 53 PTs were selected of which extreme arid had 8, arid 20, semi arid 15 and dry sub humid 10 (Table 1). All the PTs were registered with National

Table 1. Details of Plus Trees (PT's) identified from natural stands of *A. indica*

CPT's	IC. No.	Place of collection	Latitude (N)-Longitude(E)
		Extreme arid	
JS-1	268494	15 km NE of Pokaran, Phalodi road, Jaisalmer	26°55′-71°58′
JS-4	268498	2 km NE of Chandan, RRS, CAZRI	do-do
JS-7	268500	-do-	do-do
JS-10	268502	RRS,CAZRI campus, Jaisalmer	do- 70°57′
BR-1	251592	BSF campus, Barmer	25°45′-71°25′
BR-2	251593	-do-	do-do
BR-4	268524	5 km NE of Balotra, Barmer district	25°49′-72°21′
BR-9	251596	Near Nakoda Temple, Balotra, Barmer district	do-do
		Arid	
JD-7	251544	Silva nursery, CAZRI campus, Jodhpur	26°18′-73°04′
JD-8	268485	-do-	do-do
JD-10	268486	Agrostology Block, CAZRI campus, Jodhpur	do-do
JD-11	251548	-do-	do-do
JD-12	251549	-do-	do-do
JD-13	251550	Botanical garden, CAZRI campus, Jodhpur	do-do
JD-15	251552	-do-	do-do
JD-16	251553	-do-	do-do
JD-18	251555	Silva nursery, CAZRI campus, Jodhpur	do-do
JD-20	268493	-do-	do-do
BL-1	251597	5 km NW of Pipad city, Jodhpur district	26°11′-73°42′
BL-2	251598	3 km NW of Bilara town, Jodhpur district	do-do
BL-3	251599	-do-	do-do
MN-1	268512	Forest nursery, Mandore Garden, Jodhpur	26°23′-73°04′
MN-2	251639	-do-	-do-do
MN-3	268514	-do-	do- do
MN-4	268515	Mandore Garden, Jodhpur	26°23′-73°04′
MN-5	251642	Mandore Garden, Jodhpur	do-do
MN-6	251643	Crematory entrance, Mandore Garden, Jodhpur	do-do
MN-7	251644	-do-	do-do
		Semi arid	
JP-3	251652	2 Km SW from Sanganer, Tonk road, Jaipur	26°55′-75°52′
JP-9	251657	-do-	do-do
JP-17	251987	10 km NW of Jaipur, Sikar road, Jaipur	do- 75°50′
UD-1	268541	Gulab Bagh, Udaipur	24°38′-73°33′
UD-4	268545	RCA campus, Udaipur	do-do
UD-9	251584	Eklingji, Udaipur	24°44′ -do-
UD-10	251585	Jang ki Bari, Sukhadia University, Udaipur	24°38′ -do-
CT-1	251568	Near Vijay Stambh, Chittorgarh	24°54′-74°42′
CT-4	268517	Dam side, Chittorgarh	do-do
CT-7	268524	7 km. SE of Nimbahera, Chittorgarh road, Chittorgarh	24°37′-74°45′
CT-8	268525	15 km SE of Kapasan, Chittorgarh road, Chittorgarh	24°46′-74°43′
RJ-1	268546	10 km NW of Kankroli, Rajsamand district	25°02′-73°59′
RJ-5	251589	Near Rajsamand lake, Rajsamand	-do-do
RJ-7	251590	Kumbhalgarh forest range, Desuri, Pali district	25°11′-73°35′
RJ-8	251591	-do-	do-do
		Dry Sub humid	
DG-1	251623	5 km SW of Aspur	23°58′-74°05′
DG-2	251624	10 km SW of Aspur	23°58′-74°06′
DG-6	251625	6 km NW from Dungarpur, Dungarpur	23°50′-73°50′
DG-7	251626	15 km SW of Sagwara, Banswara road, Dungarpur	23°31′-74°05′
DG-9	251628	-do-	-do-do
BW-2	251607	ARS, Banswara	23°30′-74°24′
BW-3	251608	-do-	do-do
BW-5	251609	-do-	do-do
BW-8	251610	-do-	do-do
BW-10	268554	8 km NE of Banswara	do-do

Bureau of Plant Genetic Resources (NBPGR), New Delhi, where they were given specific IC numbers. These PTs were marked with permanent iron plates having both locally given and as well as IC numbers.

During last week of June and first week July, 2010 when trees were laden with fruits, selected PTs were revisited and 2.5-3.0 kg fruits were collected from individual PTs. The collected fruits were brought to the laboratory. There they were depulped and washed to obtain the pure seed. These seeds of individual PT were dried in shade. From each PT a sample of 250 g dried seeds were taken for further study. First seed characterization viz., 100-seed weight, seed length and seed diameter were measured randomly by standard procedure. After recording said observations, sample seeds of individual PT were broken very carefully by a wooden hammer to obtain kernels. The kernels obtained so were used to determine number of kernels/100 seeds and weight of 100-kernels separately for individual plus tree (PT). Known quantity (10 g) of kernels was ground in an electric mixture for individual PT to determine oil and limonoid viz., AA, AB, N and S.

Seed characters viz.100- seed weight, seed length, seed diameter, number of kernel/100 seeds and weight of 100-kernels were determined following standard procedure. Seed samples of individual PT were packed with an local identity tag in muslin bags. Oil content from seed kernels were extracted through soxhlet method (%v/w) and limonoids i.e. AA, AB, N and S were analyzed using standard HPLC procedure with known operating conditions (Rengasamy *et al.*, 1993). For computing region wise oil and limonoids content values obtained were averaged across all PTs in each eco-climatic region.

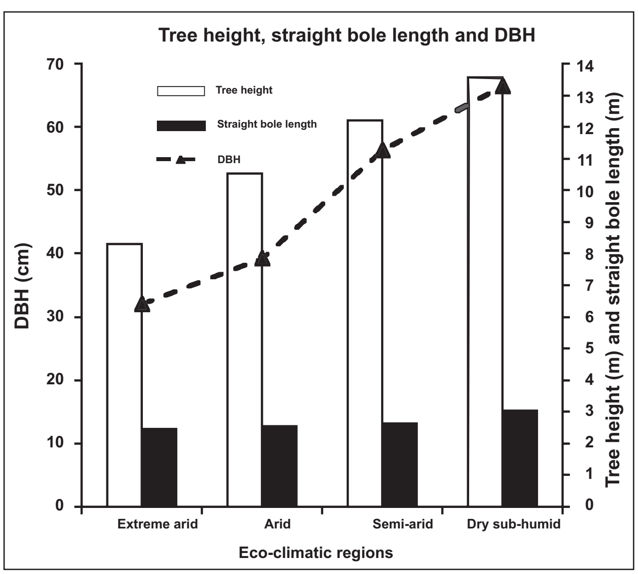

Fig. 1. Tree structural features

RESULTS AND DISCUSSION

Structural features and seed characteristics: Wide variations were recorded in tree structural features. Among individual PT in entire study region, the tree height was maximum for PT, UD-1 and minimum in PT, JD-1. Similarly, straight bole length exhibited marked variation with maximum being observed for PT, BW-10 and minimum for UD-10. Wide variations were observed in seed related characteristics. Seed yield was maximum in PT, UD-1 and minimum in PT, JS-7. 100-seed weight was maximum in PT, DG-7 and minimum in PT, JS-1. Seed length was found to be maximum in PT, JD-10 and minimum in PT, JP-17. Seed diameter was highest in PT, BR-9 and lowest in PT, RJ-8. Number of kernel/100 seeds was maximum in PT, JS-10 and minimum in PT, MN-7. Weight of 100-kernels was highest in PT, DG-7 and lowest in PT, DG-6. On an average across each region tree height, straight bole length and DBH exhibited a progressive increase from extreme arid to dry sub-humid region (Fig. 1), However, no such trend was observed for seed related characters.

On an average across all the PTs in a particular region, total seed yield exhibited a progressive increase (Table 2) from extreme arid to dry sub-humid region. However, mean 100-seeds weight was found to be maximum for PTs of semi arid region and minimum for PTs of extreme arid region.

On an average across the PTs of particular region though no trend was found for average seed length, interestingly seed diameter exhibited a progressive increase from extreme arid to dry sub-humid region. There was not much difference in average number of kernel/100 seeds in different eco-climatic regions. More or less similar trend was observed for weight of 100-kernels (Fig.2).

Oil and limonoid contents: Oil and limonoid contents exhibited wide variations from individual to individual PTs when the entire study region was considered. Oil content was minimum in PT, CT-4 and maximum in MN-2. AA was found to be minimum in BW-8 and maximum in BR-9. Similarly for AB, lowest value was found in PT, DG-6 and highest in BR-1. DG-6 had lowest N content and BR-2 had highest. S was found to be minimum in BW-5 and maximum in JS-10.When the value of all said parameters were averaged across individuals in a particular eco-climatic region, it was observed that oil content progressively increased from dry sub- humid to extreme arid region. It was very interesting that on an average across the individual PTs, values of limonoid contents (AA, AB, N and S) also exhibited a systematic increase from dry sub-humid to extreme arid region. Data indicated that average oil content was 5.2 percent higher in extreme arid region as compared to dry

Table 2. Summary of structural features, seed characteristics and oil and limonoid contents of PTs in different eco-climatic regions of Rajasthan

Particular	Extreme arid			Arid			Semi arid			Dry sub-humid		
	Range	Mean	CV(%)	Range	Mean	CV(%)	Range	Mean	CV(%)	Range	Mean	CV(%)
Tree characters												
Tree height (m)	7.25(BR 9)-10.20 (JS4)	8.30	10.79	7.20(JD 11)-12.43(JD 10)	10.53	13.89	7.53(RJ 5)-16.92(UD1)	12.22	19.77	8.00(DG 9)-16.8(DG 1)	13.57	18.89
Straight bole length (m)	1.90(BR1)-3.37(BR9)	2.46	20.17	1.90(JD 20)-3.73 (JD 10)	2.54	18.45	1.80(UD 10)-4.07(JP 3)	2.63	21.70	2.00(DG 9)-4.40 (BW 10)	3.03	20.38
DBH (cm)	25.60(BR2)-37.00(BR9)	32.01	12.98	22.61(JD 11)-53.46(JD10)	39.21	21.28	2.6(UD 10)-107.00(JP 3)	56.40	41.02	40.81(DG9)-101.43(BW (10)	66.52	36.68
Seed characters												
Seed yield (kg tree^{-1})	16.0(JS 7)-27.0 (BR 9)	21.00	17.26	16.0(JD 11)-41.0 (MN 1)	25.4	13.51	16.0(CT 7)-49.0 (UD 1)	28.07	37.28	20.0(DG 9)-39.0 (DG 7)	29.37	20.12
100- seed wt (g)	11.67 (JS 1)-14.53 (JS 10)	12.90	9.29	14.15(JD 7)-22.01(MN 3)	17.56	11.48	14.36(RJ 1)-20.19 (JP 3)	18.57	7.93	12.41(BW 8)-23.73 (DG 7)	16.39	22.83
Seed length (cm)	0.93(BR 9)-1.20 (JS10)	1.03	9.29	0.95(MN 7)-1.42 (JD 10)	1.17	11.48	0.91(JP 9)-1.29 (UD 1)	1.12	10.60	0.94(BW 8)-1.28(DG 7)	1.07	11.11
Seed diameter (cm)	0.59(JS 1)-0.78 (BR 9)	0.66	9.31	0.55 (JD 10)-0.66 (MN 3)	0.60	5.54	0.49(RJ 8)-0.62(JP 3)	0.56	7.21	0.49(DG 6)-0.61(DG7)	0.55	7.23
No. of kernel/100 seeds	102 (JS 7)-115 (JS 10)	109	4.66	79(MN 7)-112 (JD 7)	103	7.73	90(JP 9)-109(CT 4)	100	5.18	96(DG 1)-108(BW 5)	102	3.97
Wt. of 100 kernels (g)	8.38(BR 9)-10.36 (JS 10)	9.08	6.92	7.73(MN 1)-9.74 (BL 2)	8.82	6.90	7.65(RJ 1)-10.24 (RJ 5)	8.62	8.19	6.94(DG 6)-10.94 (DG 7)	9.01	11.96
Oil and limonoids												
Oil percent (%v/w)	38.95 (BR9)-41.38 (BR 20	40.1	2.26	36.62(JD 8)-45.14 (MN 2)	41.87	5.71	34.79(CT 4)-43.90 (JP 9)	40.88	5.92	36.38(BW 5)-42.35 (BW 10)	38.10	4.38
Azadirachtin A (mg kg^{-1})	1210(JS 1)-1377 (BR 9)	1312.25	4.42	1190(BL 3)-1321 (MN 4)	1246.55	3.42	1107(RJ 5, UD 10)-1272(JP 17)	1175.13	4.34	1020 (BW 8)-1201(BW 3)	1092.2	5.39
Azadirachtin B (mg kg^{-1})	402(JS 1)-482 (BR 9)	444.13	7.25	357(MN7)-410 (JD 20)	389.8	3.83	297(RJ 7)-384(JP 9)	327.93	8.84	271(DG 6)-319 (BW 2)	296.8	5.05
Nimbin (mg kg^{-1})	1181 (BR 9) -1261(BR 2)	1213	2.30	1070(JD 10) -1201 (JD 8)	1112.9	3.47	1020 (RJ 7,8)-1121 (UD 1)	1070	3.23	972(DG 6)-1072 (DG 9)	1014	2.91
Salinin (mg kg^{-1})	1207(JS 1)-1272(JS 10)	1226.63	2.04	1102 (JD 13)-1222 (JD 7)	1163.25	3.70	1067 (CT 1)-1178(JP 17)	1090	2.90	957(BW 5)-1101(DG 7)	1034.7	5.12

sub-humid region. Among the limonoids, AB was 49.63 percent higher in extreme arid region in comparison to dry sub-humid region. In the rest of the limonoids, this systematic progressive increase ranged from 18.54 percent in case of S to 20.15 per cent in case of AA (Fig.3).

The low coefficient of variation for oil and limonoids content in different eco-climatic region of Rajasthan state, India indicated that oil and limonoid content in particular eco-climatic region has very higher degree of uniformity. From the observations it can be safely concluded that concentration of limonoid contents in neem seeds had great impact of environmental conditions of different eco-climatic region. Rengasamy and Parmer (1995) reported that eco-type belonging to arid ecosystem had high AA than those from sub-humid regions.

Interrelationship among tree structural feature, seed characteristics and, oil and limonoid contents: Through considering group of PTs of different eco-climatic region certain set of ranking of characters were observed, however when all individual PTs irrespective of eco-climatic regions were considered, no one had very clear cut ranking as far as tree structural traits and seed characteristics are concerned. Oil and limonoid content in PTs definitely showed clear cut trends in different eco-climatic regions. These observations demanded to study of the interrelationships among various characters studied. As would be expected auto correlations were found for within the group of tree structural characters, seed characters, and oil and limonoid contents in the seed kernel.

Of the possible 81 characters combinations 33 found to be significantly positively correlated and 19 were observed to be significantly negatively correlated. Tree height was found to be significantly positively correlated with straight bole length, DBH and 100-seed weight and total seed yield. DBH was found to be significantly positively correlated with straight bole length, 100-seed weight as well as total seed yield. Straight bole length didn't show any relation with total seed yield, and seed characters, and oil and limonoid content.

Seed diameter was found to be positively and significantly correlated with number of kernels/100 seeds, weight of 100-kernels, AA, AB, N and S. Oil percent was found to be positively correlated with seed length but no significant correlation could be found with other seed characters, except in case of N, where oil percent was significantly and positively correlated. Number of kernels/100 seeds was found to be positively and significantly correlated with weight of 100-kernels, AA, AB, N and S. As expected AA, AB, N and S exhibited significantly positive correlation among themselves. There are many tree structural characters showed some kind of relationship with oil and limonoid content but such relationship do not have any practical value.

Most interesting feature of this correlation matrix was that total seed yield was significantly negative with AA, AB, N and S contents (Table 3). Even oil content was negatively correlated with total seed yield though not significant. With exception of seed length, other important seed related characters exhibited negative correlation though not significant. This indicated that high seed yield does not necessarily mean better quality of seeds.

In general, oil was found in higher quantum in drier eco-climatic conditions, as quantity of oil extracted from seeds of arid and extreme and eco-climatic region was

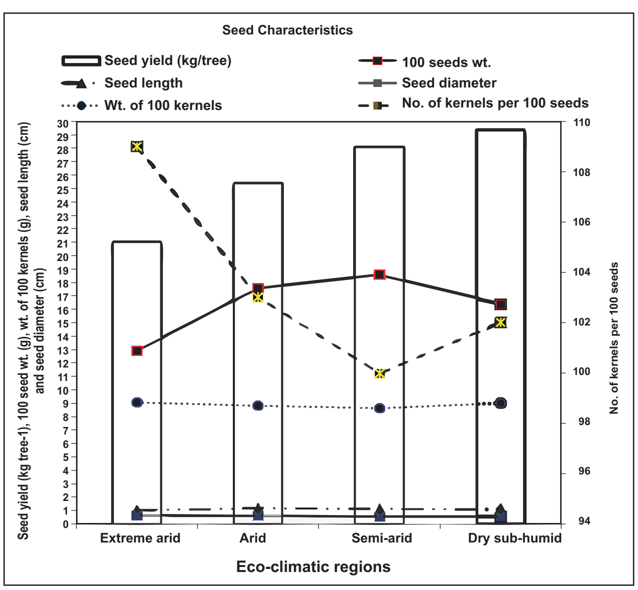

Fig. 2. Seed characteristics

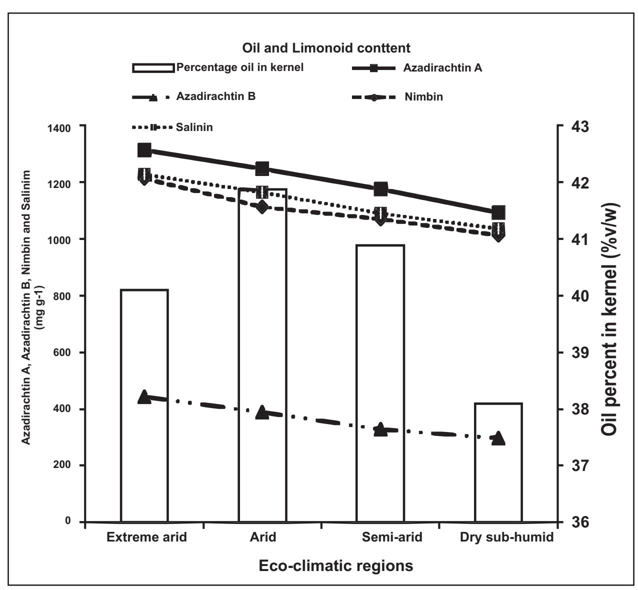

Fig. 3. Oil and limonoid content

Table 3. Interrelationship among tree structural feature, seed characteristics and, oil and limonoid content in entire study area

Character	Tree height	Straight bole length	DBH	100 - seed wt.	Seed length	Seed diameter	No. of kernel/ 100 seed	Wt. of 100 kernels	Oil percent	AA	AB	N	S	Seed yield
Tree height	1	0.503**	0.770**	0.466**	0.098	-0.440**	-0.343*	0.007	-0.124	-0.556**	-0.529**	-0.566**	-0.534**	0.531**
Straight bole length		1	0.648**	0.196	0.088	-0.072	0.139	0.191	0.021	-0.124	-0.136	-0.224	-0.270*	0.255
DBH			1	0.342*	0.065	-0.316*	-0.285*	0.055	-0.006	-0.413**	-0.410**	-0.459**	-0.446**	0.417**
100- seed wt.				1	0.404**	-0.117	-0.108	0.161	-0.126	-0.271*	-0.266	-0.400**	-0.296*	0.317*
Seed length					1	0.094	0.159	0.100	0.250**	0.017	0.064	-.054	0.088	0.426**
Seed diameter						1	0.562**	0.298*	0.070	0.528**	0.678**	0.626**	0.553**	-0.154
No. of kernel/ 100 seed							1	0.349*	-0.072	0.311*	0.408**	0.416**	0.325*	-0.134
Wt. of 100 kernels								1	-0.194	-0.065	0.097	0.094	0.016	-0.021
Oil per cent									1	0.364**	0.292*	0.136	0.285*	-0.027
AA										1	0.785**	0.733**	0.776**	-0.325*
AB											1	0.814**	0.794**	-0.258
N												1	0.799**	-.0306*
S													1	-0.385**
Seed yield														1

relatively higher than oil found in seeds of dry sub-humid and semi-arid eco-climatic region. Our findings in conformity the results obtained by Tewari *et al*. (2007) who ascribed it to site x environment interaction.

Production of secondary metabolite is governed by both genetic and environmental factors (Kamarainen *et al*., 2003). In a region specific study, large variations in azadirachtin content (7525-2895 mg kg^{-1}) has been reported in neem kernels of different ecotypes in Tamil Nadu (Kumar *et. al.,* 1995).

Rajasthan the largest state of India is spread over an area of 3,42,239 km^2. The state has four different eco-climatic regions with a total annual average rainfall gradient extending from 200 to 900 mm. Neem grows profusely in entire state except hilly tract (altitude > 350m). In present investigation, tree structure, seed characteristics and major limonoids of 53 PTs were studied precisely, as the work on erstwhile 'National Network on Integrated Development of Neem' project ended with selection, location, positioning, marking and description of identified PTs on the basis of tree architecture and fruit/seed production potential. Analysis of limonoids was done at some centres but that too very unsystematically. Present study clearly indicated that on an average across the PTs total seed yield/PT of dry sub-humid region was 29.37 kg which was 4.4 %, 13.7 %; and 28.5 % higher than that of semi arid, arid and extreme arid region, respectively. Contrary to this, quantity of AA, AB, S and N showed a just a reverse trend. The progressive increase in seed diameter from dry sub-humid region to extreme arid region indicated presence of bold and better quality of seed as seed diameter (on an average across individual PT of particular region) was found to be one of the best seed characteristics for selection of seeds to raise large scale nursery for having quality seedling for future tree crops having high azadirachtin content (Kaushish, 2006).

Neem seeds having higher quantity of limonoids must be given preference for nursery raising so the future plantations of neem in any form yield seeds of high limonoids contents. The presence of higher concentration of AA, AB, N and as well as oil content in PTs of extreme arid region indicated that adaptability of trees of the species in a very high thermal environment coupled with very low moisture regime should have some influence of reproductive phenophases at some point (Azam *et al*., 2009) which in turn perhaps enhance the synthesis of these compounds. Infact, this is one probability, but to establish the facts presented in the study require more precise eco-physiological investigations. However, present study clearly proved that production of high quantity of seed does not necessarily mean the production of quality seed material especially, in context of limonoids.

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Integrated Pest Management Strategies for Sustainable Transgenic Cotton Pest Management in Punjab

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Abstract: Integrated pest management (IPM) strategies for the management of sucking insect pests were disseminated in 12 villages of three districts of Punjab during 2010. Three non-IPM villages adjoining to IPM villages were kept as check for comparing the impact. The impact of adoption of IPM strategies led to reduction in the population of mealybug in IPM villages as compared to non-IPM villages. The mean population of jassid per three leaves varied from 0.21 to 1.23 in IPM villages and 0.91 to 2.35 in non-IPM villages. Whitefly population per three leaves varied from 0.38 to 3.05 in IPM villages and 1.58 to 7.30 in non-IPM villages. Population of natural enemies including spiders, predatory bugs, ladybird beetle varied from 0.11 to 1.61 per plant in IPM villages. The impact of dissemination of IPM strategies resulted in the reduction in number of spray in IPM villages (39.73%) over non-IPM villages. The reduction in cost of spray in IPM villages was 32.98 per cent over non-IPM. The average cost of cultivation was Rs. 26112 ha^{-1} in IPM villages, which was comparatively low as compared to non-IPM villages. Average seed cotton yield in IPM villages was 2241 kg ha^{-1} in comparison to non-IPM villages (1864 kg ha^{-1}). The average net return in IPM villages was Rs. 68005 ha^{-1}, which was Rs. 16697 more than non-IPM villages.

Key Words: Bt cotton, Sucking insect-pests, IPM, Non-IPM, Economics

Cotton (*Gossypium* sp.) is a major field crop in many countries, constituting a valuable cash crop for many smallholders in developing countries. Cotton, being the most important commercial crop plays a vital role in social and monetary affairs of India. Besides other causes, major in cotton cultivation are biotic stresses due to attack of insect-pests and diseases, which play a significant role in achieving optimum yield potential. At world level, 1326 species of insects harbour cotton plants (Hargreaves, 1948) and in India, 162 insect species have been reported of which nine are of utmost importance inflicting significant losses in yield (Dhaliwal *et al.,* 2004). In Punjab, there has been a change in pest scenario in the last decades. Besides increasing cost of production and environmental problems, the excessive and indiscriminate use of insecticides for the control of these insect-pests has resulted in development of insecticidal resistance, decline in natural enemies population and resurgence of the insect pests like whitefly, *Bemisia tabaci* (Gennadiaus) and jassid, *Amrasca biguttula biguttula* (Ishida). Besides, these, other sucking pests like thrips, *Thrips tabaci* (Lindemann) hitherto occurring during May-June and aphids, *Aphis gossypii* (Glover) at fag end of the crop season are also gaining importance. During 2006, a new sucking pest, mealy bug, *Phenacoccus solenopsis* (Tinsley) appeared in few pockets of Bathinda, Ferozepur and Muktsar districts and caused economic loss (Dhawan *et al*., 2007). Mealy bug, a minor pest, which was earlier supposed to be suppressed with the use of insecticides attained the pest status. In 2007, this pest wide spread to other parts of the state and became a menace of great challenge for cotton production. Mealybug because of its high reproductive potential, wide host range, powdery/waxy surface of its body and specific feeding behaviour on the apical and lower stem portion of plant is very difficult to control with insecticides only and there is a need of integrated pest management (IPM). Looking into the potential of these insect pests to cause economic losses and sustainability of cotton production it becomes necessary to develop and disseminate management strategies. Keeping in view the above facts, our main emphasis was to disseminate IPM technologies for the management of sucking pests on cotton.

MATERIAL AND METHODS

Twelve villages were adopted for dissemination of IPM strategies for the management of sucking insect pests in three districts viz. Muktsar, Bathinda and Ferozepur in cotton belt of Punjab state during 2010. In each of the three districts, four villages were selected for dissemination of IPM strategies. From Muktsar district villages adopted were Kothemannawala, Bharu, Husner and Butter. In Bathinda district villages adopted were Shekhpura, Bhagwanpura, Lalewala and Nawanpind and in Ferozepur district villages adopted were Dharangwala, Roorianwali, Khatwan and Cholara. Three villages adjoining to IPM villages were kept as check and these constituted the non-IPM villages. Bt cotton crop was grown as per recommendation by Punjab Agricultural University, Ludhana (Anonymous, 2009). All the selected villages were regularly visited twice a week from time of sowing till harvesting to disseminate the IPM strategies and to up scale the knowledge of farmers. Awareness campaign on weed eradication, removal of stacks from fields, sowing of barrier crops and other cultural practices were carried out in these villages. Farmers trainings were conducted to aware the farmers about the recommended varieties, fertilizer application and right use of insecticides. Farmers were given knowledge about spray techniques, judicious use of pesticides, ill effects of tank mixtures of pesticides. Farmers were guided about the benefits of recommended pesticides and harmful effects of unrecommended pesticides on cotton crop. Almost 100 per cent farmers adopted spot treatment technology and use of recommended insecticides for the control of mealy bug in adopted villages. At least 50 farmers from each village were selected as a target group for dissemination of IPM strategies.

RESULTS AND DISCUSSION

Impact of IPM Technology

Variety Selection: IPM technology was disseminated in adopted villages in which approximately 3094 ha area was covered under cotton and about 970 farmers followed IPM strategies and impact of technology was seen on sowing time and variety selection and all other agronomic practices. The area under timely sown crop (15th April to 15th May) varied from 74 to 85 per cent and under recommended varieties varied from 65 to 80 per cent (Table 1). There was about 72.50 per cent area under recommended varieties in adopted villages. Maximum area was under recommended varieties like MRC 7031, MRC 7017 and F 6488. Among different villages, maximum area under recommended varieties i.e. 85 per cent was in Cholara village of Ferozepur district.

Incidence of Sucking Insect pests: The population of jassid on cotton in different IPM and non-IPM villages remained below the economic threshold level. The average population of jassid during different meteorological weeks (MW) varied from 0.21 to 1.23 per three leaves in different IPM villages. In non-IPM villages also, the mean population of jassid nymphs was 0.91 to 2.99 per three leaves. However, it was slightly higher than IPM villages in corresponding MW. The mean population of jassid per three leaves was 0.72 in IPM villages as compared to 2.00 in the non-IPM villages. The population of whitefly adults per three leaves varied from 0.38 to 3.05 during different MW in IPM villages. While in non-IPM villages, it varied from 1.58 to 7.30 per three leaves. Higher population of whitefly was recorded during 37th MW in non-IPM villages. The mean population of whitefly per three leaves was 1.83 in IPM villages as compared to 3.46 in non-IPM villages. In case of IPM villages mealybug varied from zero to 0.16 per 2.5 cm of central shoot during different MW. In non-IPM villages, the average population of mealy bug varied from 0.03 to 0.60 per 2.5 cm during different MW. Maximum population was recorded in

Table 1. Area under cotton, number of IPM farmers and sowing pattern in IPM villages

District	Village	Total Area under cotton (ha)	No. of farmers followed IPM	Per cent area under			
				Timely sown (%)	Delayed sown (%)	Recommended varieties (PAU + GEAC*) (%)	Un-recommended varieties (%)
	Shekhpura	247.5	96	85	15	65	35
Bathinda	Bhagwanpura	250	102	79	21	72	28
	Lalewala	274	105	80	20	69	31
	Nawan pind	370	100	83	17	71	29
	Dharangwala	257	80	75	25	72	28
Ferozepur	Roorianwali	285	85	78	22	75	25
	Khatwan	364	68	80	20	79	21
	Cholara	415	61	85	15	70	30
	Kothemannawala	105	51	74	26	75	25
Muktsar	Bharu	167	70	82	18	80	20
	Husner	221	82	80	20	71	29
	Butter	139	70	84	16	71	29
Punjab		3094.00	970.00	80.42	19.58	72.50	27.50

*GEAC-Genetic Engineering Approval Committee non-IPM villages and it was found to be 0.60 per 2.5 cm in 31st MW. The average population of mealy bug was less in IPM (0.04) as compared to non-IPM villages (0.19). In case of IPM villages, population of thrips varied from zero to 1.60 per three leaves during different MW (Table 2). In non-IPM villages, the average population of thrips remained 0.17 to 1.65 per three leaves during different MW. The average population of thrips was more in non-IPM (1.00) as compared to IPM villages (0.63).

In Muktsar district, low population of mealybug was recorded in IPM villages throughout the season. However, higher population of mealybug per plant was recorded on weeds growing on wasteland as compared to weeds growing in or around the cotton field in all the villages (Fig. 1). Maximum population was recorded in Butter village on weed on wasteland (0.26) as compared to weed growing in or near the fields (0.14). Similarly, in district Ferozepur, higher population was recorded in Cholara village on weeds growing on wasteland (0.79) as compared to weeds growing in or near the fields (0.45) as shown in Fig 2. Among all the districts maximum population of mealybug was recorded in village Lalewala of district Bathinda (Fig 3) on weeds growing on wasteland (8.26) as compared to weeds growing in or near the fields (3.30).

Table 2. Incidence of Insect-pests and population of natural enemies in cotton (Punjab)

Village	Incidence of insect pest during different meteorological week													
	26th	27th	28th	29th	30th	31s	32nd	33rd	34th	35th	36th	37th	38th	Mean
							Jassid nymphs/ 3 leaves							
IPM	0.25	0.21	0.83	0.98	1.10	1.23	0.87	0.67	0.64	0.82	0.63	0.79	0.36	0.72
Non-IPM	1.27	2.35	0.91	1.65	1.62	2.04	2.20	2.35	2.24	2.07	2.71	2.99	1.62	2.00
							Whitefly adults/ 3 leaves							
IPM	0.52	0.38	1.42	2.33	1.80	2.94	1.73	3.05	1.93	2.85	1.75	2.11	1.03	1.83
Non-IPM	2.40	4.55	1.58	2.69	2.59	3.12	3.10	4.55	2.97	3.54	3.82	7.30	2.83	3.46
							Mealy bug/ 2.5 cm in infested plants							
IPM	0.00	0.01	0.10	0.16	0.01	0.00	0.14	0.00	0.00	0.00	0.02	0.01	0.07	0.04
Non-IPM	0.03	0.04	0.08	0.44	0.40	0.60	0.22	0.04	0.24	0.15	0.07	0.08	0.10	0.19
							Thrips/ 3 leaves							
IPM	0.10	0.10	0.00	0.44	1.60	0.55	1.14	0.55	0.71	1.29	0.39	0.86	0.44	0.63
Non-IPM	1.05	1.05	0.17	0.78	1.03	1.65	1.48	1.05	1.05	1.08	1.03	1.02	0.59	1.00
							Tobacco caterpillar/ plant							
IPM	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.16	0.37	0.10	0.05
Non-IPM	0.13	0.18	0.00	0.00	0.17	0.19	0.14	0.18	0.18	0.83	0.48	1.45	0.10	0.31
							Number of natural enemies/ plant							
IPM	0.17	0.11	0.41	0.50	0.51	0.75	0.99	0.70	0.97	1.01	1.16	1.61	1.12	0.77
Non-IPM	0.05	0.43	0.16	0.43	0.57	0.55	0.65	0.43	0.63	0.47	0.34	0.88	0.16	0.44

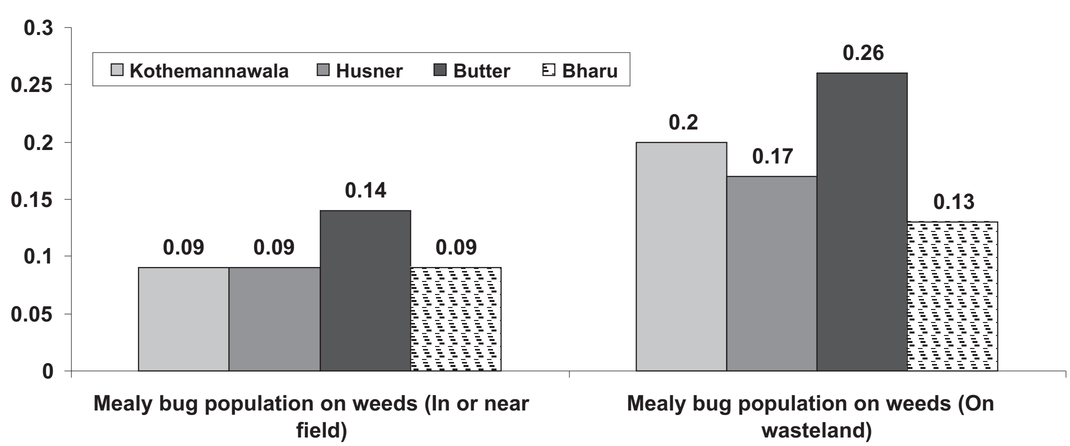

Fig. 1. Mean population of mealy bug in zero mealy bug villages in Muktsar district

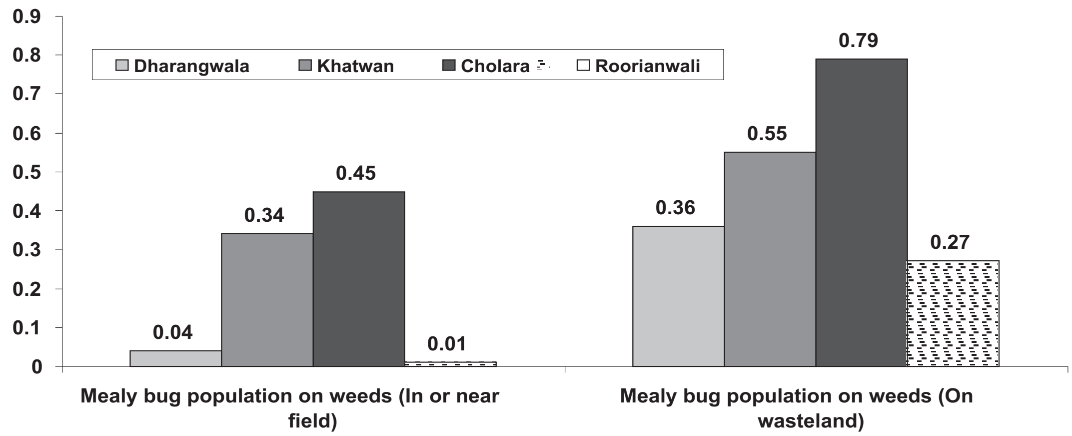

Fig. 2. Mean population of mealy bug in zero mealy bug villages in Ferozepur district

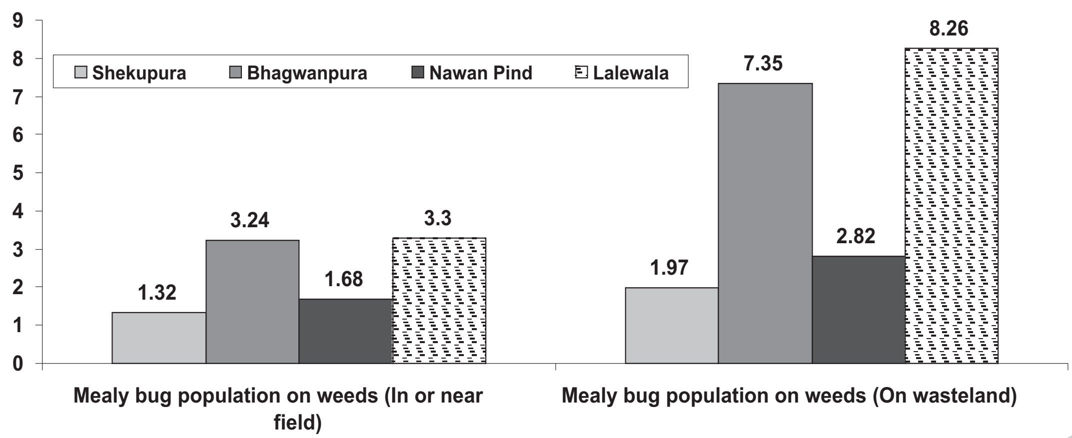

Fig. 3. Mean population of mealy bug in zero mealy bug villages in Bathinda district

Tobacco Caterpillar: Very low incidence of tobacco caterpillar was recorded during different MW. However, maximum incidence of tobacco caterpillar was observed during 37th MW (0.37) in IPM villages and it was 1.45 in non-IPM villages during same MW (Table 2).

Natural Enemies: The average number of natural enemies in different IPM villages varied from 0.11 to 1.61 per plant, which was relatively higher than the non-IPM villages (0.05 to 0.88 per plant). The population was maximum (1.61 per plant) during 37th MW in IPM villages. The average number of natural enemies in different IPM villages was 0.77 per plant as compared to 0.44 in non-IPM villages during different MW (Table 2).

Impact of Dissemination of IPM Strategies on Economics

Number of sprays: Mean number of insecticide sprays for sucking insect pests, foliage feeders and bollworms was higher in non-IPM villages than IPM villages. Among the 12 villages it was highest sprays (4.00 each) in Lalewala and Dharangwala village of Bathinda and Ferozepur, respectively followed by 3.95 sprays in Khatwan village of Ferozepur district under IPM villages. In non-IPM, village number of sprays was 5.91 in Tajjapatti village of Ferozepur district (Table 3). The per cent reduction in number of sprays was highest in IPM villages of Muktsar (42.38%) and lowest in Bathinda (37.73 %) over non-IPM villages. In Punjab, average number of sprays was 3.37 in IPM villages, however, it was 5.58 in non-IPM villages with per cent reduction of 39.73 (Table 4).

Spray Cost: Spray cost was also higher in non-IPM villages as compared to IPM villages (Table 3). Spray cost was highest in Butter village of Muktsar district i.e. Rs. 2233 and lowest in Nava Pind (Rs. 1993) of Bathinda district in IPM villages. However, it was Rs. 3267 in Shamkhera village of Muktsar district under non-IPM villages. District wise, per cent reduction in spray cost was highest in Muktsar (34.43%) and lowest in Bathinda (30.44%). In Punjab, average spray cost was Rs 2123 in IPM villages as compared to Rs 3162 in non-IPM. Per cent reduction of spray cost in IPM villages was

Table 3. Impact of cotton IPM technology on the economics and net returns

District	Village	Total area under cotton (ha)	No. of sprays/ha					Total no. of sprays	Cost of sprays (Rs/ha)	Cost of inputs (Rs//ha)	Cost of farm operations (Rs/ha)	Cost of cultivation (Rs/ha)	Seed cotton Yield (Kg/ha)	Net Profit (Rs/ha)
			W	J	TC	BW	MB							
IPM														
Bathinda	Bhagwanpura	247.5	1.88	1.20	0.10	0.00	0.00	3.10	2008	7488	18075	25563	2186	66232
	Lelewala	250	2.20	0.80	1.00	0.00	0.00	4.00	2079	8561	18041	26601	2229	67020
	Nava Pind	274	1.65	1.35	0.21	0.00	0.00	3.21	1993	8250	18106	26356	2160	64378
	Sekhpura	370	2.15	1.10	0.10	0.00	0.00	3.35	2139	8005	18057	26063	2246	68275
	Mean	1141	2.0	1.1	0.4	0.0	0.0	3.4	2055	8076	18069	26145	2205	66476
Ferozepur	Dharangwala	257	2.48	1.30	0.30	0.00	0.00	4.00	2107	8443	17923	26366	2262	68672
	Cholara	285	2.00	1.00	0.00	0.00	0.00	3.00	2111	9061	17663	26527	2189	65223
	Khatwan	364	2.48	1.42	0.15	0.00	0.00	3.95	2193	9166	19632	28798	2392	71697
	Ruharianwali	415	2.15	1.35	0.00	0.00	0.00	3.50	2277	9178	18619	27797	2476	76207
	Mean	1321	2.3	1.3	0.1	0.0	0.0	3.6	2172	8962	18459	27372	2329	70449
Muktsar	Bharu	105	2.00	1.00	0.12	0.00	0.00	3.12	2108	8521	16021	24542	2213	68422
	Butter	167	1.98	1.02	0.10	0.00	0.00	3.10	2233	8876	16976	25853	2165	64691
	Husnar	221	2.00	1.00	0.00	0.00	0.00	3.00	2093	8279	16057	24335	2225	69106
	Kothe Manawale	139	2.00	1.15	0.15	0.00	0.00	3.30	2133	8561	15907	24468	2157	66137
	Mean	632	2.0	1.0	0.1	0.0	0.0	3.1	2142	8559	16240	24799	2190	67089
	Total /Mean	3094	2.08	1.14	0.19	0	0	3.37	2123	8532	17590	26105	2242	68005
Non IPM														
Bathinda	Dyalpura	366	2.20	2.77	0.49	0.00	0.00	5.46	2953	10060	16895	26955	1866	51406
Ferozepur	Tajjapatti	449	2.22	3.31	0.38	0.00	0.00	5.91	3266	11264	16114	27377	1896	52273
Muktsar	Sham Khera	374	2.08	2.80	0.51	0.00	0.00	5.38	3267	10418	16227	26646	1831	50244
	Total /Mean	1191	2.17	2.96	0.46	0.00	0.00	5.58	3162	10580	16412	26992	1864	51307

W- Whitefly, J- Jassid, TC- Tobacco caterpillar, BW- Bollworms and MB- Mealybug

Table 4. Per cent reduction in sprays, spray cost, cost of cultivation, yield and net profit over non-IPM

District	Number of sprays			Spray cost (Rs/ha)			Cost of cultivation (Rs/ha)			Yield (kg/ha)			Net profit		Additional profit	Additional Profit (%)
	IPM	Non IPM	% reduction	IPM	Non IPM	% reduction	IPM	Non IPM	% reduction	IPM	Non IPM	% reduction	IPM	Non IPM		
Bathinda	3.4	5.46	37.73	2055	2953	30.44	26145	26955	3.05	2205	1866	15.37	66476	51406	15070	22.66
Ferozepur	3.6	5.91	39.09	2172	3266	33.49	27372	27377	0.01	2329	1896	18.59	70449	52273	18176	25.80
Muktsar	3.1	5.38	42.38	2142	3267	34.43	24799	26646	6.93	2190	1831	16.39	67089	50244	16845	25.10
Punjab	3.37	5.58	39.73	2123	3162	32.86	26105	26992	3.28	2241	1864	16.78	68004	41307	16697	24.52

32.98 over non-IPM villages (Table 4).

Cost of inputs: Average cost of inputs was higher in non-IPM villages (Rs/ha 10580) as compared to IPM villages (Rs/ha 8532). Village wise it was highest (Rs. 9178 ha^{-1}) in IPM village Ruhianwali of Ferozepur district as compared to Rs. 11264 ha^{-1} in non-IPM village, Tajjapatti of the same district (Table 3).

Cost of cultivation: The cost of cultivation was higher in non-IPM villages than IPM villages (Table 3). In Punjab, it was Rs 26105 ha^{-1} in IPM villages as compared to Rs. 26992 ha^{-1} in non-IPM. The per cent reduction in cost of cultivation was 3.28.

Seed cotton Yield: Seed cotton yield was higher in IPM villages than non-IPM villages. Among IPM villages, it was highest in Ruhianwali village (2476 kg ha^{-1}). However, it was 1896 kg ha^{-1} in Tajja patti village of Ferozepur district under non-IPM villages (Table 3). District wise, it was highest in Ferozepur district (2329 kg ha^{-1}) followed by Bathinda and Muktsar (2205 & 2190). Per cent increase in yield of IPM villages over non-IPM villages was highest in Ferozepur district (18.59). In Punjab, average yield of IPM farmers was 2241 kg ha^{-1} as compared to 1864 kg ha^{-1} of non-IPM farmers. Per cent increase in seed cotton yield in IPM farmer was 16.78.

Net profit: Net profit was higher in IPM villages than non-IPM villages (Table 3). It was highest in Ruharianwali village of Ferozepur district (Rs. 76207 ha^{-1}). In non-IPM villages, it was as low as Rs. 51406 ha^{-1} in Dyalpura village of Bathinda district. Per cent increase in net profit (Table 4) was highest in Ferozepur district (25.80%) and lowest in Bathinda district (22.66%). In Punjab, net profit was Rs 68005 ha^{-1} in IPM villages as compared to Rs 51307 ha^{-1} in non-IPM villages. Addition profit was Rs 16697 ha^{-1}. The per cent increase in additional profit in Punjab was 24.52.

The present findings corroborate with the results of Kranthi *et al.,* (2000), who reported that number of sprays for the control of sucking pests and bollworm complex varied from 8-17 in North India and there was 90 per cent reduction in sprays while seed cotton yield increased up to 59 per cent. Plant protection cost reduced by 25-60 per cent due to impact of the IPM strategies. Similarly, Dhawan *et al.* (2012) reported 40.79 per cent reduction in the number of sprays in IPM villages over non-IPM villages with an additional profit of Rs. 11422 per hectare. Suruli Velu *et al.* (2004) also reported 63 per cent reduction in number of sprays at Coimbatore and Theni districts of Tamil Nadu with the mean of 2.7 in project village as compared to 7.3 in the control villages. With the adoption of IPM strategies, there was less incidence of sucking pests and foliage feeders, higher number of natural enemies in IPM villages as compared to non-IPM villages. There was also reduction in number of sprays, spray cost and cost of cultivation and increase in yield and ultimately the net profit.

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Assessment of Economic Threshold Level for Blister Beetles (*Mylabris phalerata*) on Greengram

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Abstract: Blister beetle, *Mylabris phalerata* is a serious pest of short-duration crops like greengram and blackgram. The adult beetles feed gregariously and devours buds and flowers translating in heavy yield reduction. The data on blister beetles density and corresponding loss in pod bearing and grain yield in mungbean varied inversely. The blister beetle density of 1, 2, 3, 4 and 5 beetles per meter row length (mrl) registered decreasing yield trend of 1240, 1120, 950, 750 and 573 kg/ha with corresponding avoidable losses of 9.7, 18.4, 45.4, 58.3 and 68.4 per cent, respectively. The lowest yield was recorded at 8 beetles per mrl (136.7 kg/ha) with avoidable loss of 90.0 per cent, indicating immense damage potential of blister beetles. The economic threshold level of 0.4 blister beetles per mrl is reported for the first time on greengram. The linear regression equation of y = 11.75 – 1.208x and y =1398.0 - 158.6x was set for prediction of loss in pod bearing and yield loss, respectively. The estimated ETL predicted yield loss of 4.7 per cent and loss in pod bearing of 4.2 per cent which validated the established ETL.

Key Words: Blister Beetle, Economic Threshold Level, Greengram

Greengram (*Vigna radiata*: Wilczek), referred as 'Queen of pulses' is the third most important pulse crop of India after chickpea and pigeonpea. Blister beetles, *Mylabris* sp. (Coleoptera: Meloidae) are highly cosmopolitan and reported to occur on pulse crops from tropical Tamil Nadu to temperate regions of Uttar Pradesh (Garg, 1985; Patnaik *et al*., 1993). In Vidarbha region of Maharashtra, blister beetles were once considered as minor pest, but have assumed a major pest status in recent years, especially on short-duration crops like greengram and blackgram and can inflict huge losses on account of their association with flowering phase (Shende *et al*., 2013 and Pawar *et al*., 2014). *Mylabris phalerata* has a wide host range which includes major pulses viz., greengram, cowpea and blackgram. Immense damage potential of 16.8–19.4 flowers per adult per day signifies its economic importance (Dhavan, 2013). Boopathi *et al.* (2009) reported 80 per cent damage of flowers by blister beetles of and yield loss up to 25-30 per cent in greengram.

Adoption of plant protection measure is justified by pest density. The initiation of spray on appearance of pest is costly and may have an adverse effect on the environment. The economic threshold level (ETL) is the best known term and most widely used index in making pest management decisions. The information on crop losses and ETL of blister beetles in greengram is not available, thus, present study was framed to work out this crucial aspect on the basis of adult blister beetles density dependent yield loss.

MATERIAL AND METHODS

An experiment for estimation of ETL of adult blister beetles on greengram was conducted during *Kharif* 2011-12 at Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra). Greengram variety, PKV Green Gold was sown at 30 cm x 10 cm. The crop was raised as per recommended package of practices under pesticide free condition.

The ETL of *M. phalerata* on greengram was worked out on the basis of a cage experiment. The plots were covered with insect proof net of size 1.0 m x 1.8 m x 1.8 m before bud initiation to avoid natural infestation of blister beetles. The cages were set up in such a way that they did not interrupt ventilation and aeration to the growing plants inside. These nylon net cages were erected on iron sticks fixed in four corners. The bottom edges of the nylon nets were inserted into the soil from all sides to check the escape or entry of beetles.

Seven treatments, each comprising of six rows of one meter length, were sown per plot. Field collected assorted population of adult blister beetles were released inside the cage at initiation of flowering at various density differentials (Table 1). Yield of greengram was recorded for a range of beetle densities. The yield loss with every increment of blister beetles was worked out and fitted in linear regression equation. The assessment of losses inflicted by different beetle densities was worked out in terms of number of pods/plant and yield per mrl (g). The yield data was extrapolated to per hectare for statistical comparisons by subjecting it to randomized block design by GW Basic program.

The data generated was also utilized for regression equation based validation of blister beetle ETL on greengram. Regression equation between adult blister beetles per mrl and grain yield was worked out to determine the regression coefficient 'b' and the value of gain threshold (GT). Blister beetle density per mrl (X) and grain yield of greengram: q/ha (Y) formed the equation Y= a ± bx. Other approach for validation of ETL was through estimation of economic injury level (Pedigo, 1996). The EIL was enumerated as the ratio between GT and the value of the intercept which gave the incremental yield loss per unit insect.

$$\text{Grain threshold (GT)} = \frac{\text{Cost of plant protection measures (Rs./ha)}}{\text{Market price of the produce (Rs./q)}}$$

Eighty per cent of the yield loss was considered to be avoided with insecticidal treatment. Two applications of methyl parathion dusting @ 20 kg per ha was considered as the cost of plant protection. ETL was set at 75 per cent of EIL (Pedigo, 1996).

RESULTS AND DISCUSSION

I) Estimation of Losses due to Blister Beetle in Greengram:

a. Loss of Pod Bearing: The maximum pods per plant (11.8 pods) were recorded in the control plot where no beetles were released (Table 1). With every increment in the blister beetle count per mrl, reduction in pod bearing was observed. At density of one beetle per mrl, 10.6 pods per plant were recorded with avoidable loss of 10.6 per cent, whereas, two beetles per mrl had 9.6 pods per plant with per cent avoidable loss of 19.3 per cent. Similarly, with each increase in blister beetle density, significant reduction in the pod bearing of greengram was recorded. Pod bearing of 8.1, 6.6 and 5.4 pods per plant with corresponding avoidable loss of 31.5, 44.1 and 54.2 per cent was recorded at beetle densities of 3, 4, and 5 per mrl, respectively. The lowest count of pods was recorded in density of 8 beetles per mrl (2.4 pods) and the per cent avoidable loss of 79.9 per cent, indicating immense damage potential of blister beetles.

b. Prediction of Loss of Pod Bearing: Predicted loss in pod bearing of greengram at various blister beetle densities per mrl (Table 2) was based on regression equation of y = 11.75 – 1.208x with R^2 value of 0.995. The beetle density per mrl and yield per hectare were negatively correlated. From the regression equation, it was evident that one beetle per mrl could cause the apparent pod loss of 1.2 pods per plant. Though, ETL is not available for blister beetle on greengram, generally, review of literature suggests about 5 per cent damage level as ETL. Therefore, as per the derived equation, the established ETL of 0.4 beetles per mrl registered 4.2 per cent loss in pod bearing which is around 5 per cent mark. The next beetle density of 0.5 beetles per mrl translated in pod loss of 5.4 per cent higher than assumed yield loss level of 5 per cent. Thus, ETL of 0.4 beetles per mrl could be treated as an indicator for economic damage beyond which adoption of plant protection measure against blister beetles will be rational.

c. Loss of Grain Yield: The grain yield also varied inversely with beetle density (Table 1). The control plot where no beetles were released registered maximum yield of 1373.3 kg/ha. The higher blister beetle density of 1 and 2 beetles per mrl inflicted 9.7 and 18.4 per cent loss, respectively. Similar trend of decrease in yield due to increasing blister beetle counts was observed in blister beetle abundance of 3, 4 and 5 beetles per mrl with corresponding avoidable yield losses of 45.4, 58.3 and 68.4 per cent, respectively. The lowest grain yield (137 kg/ha) was recorded at 8 beetles per mrl with an avoidable loss of 90.0 per cent. Each of the blister beetle density resulted in statistically significant differences in yield over rest of the densities under evaluation.

Table 1. Effect of different blister beetle densities on pod bearing and yield of greengram

Beetles/mrl	Mean pods per 10 plants	Per cent reduction in pod bearing over control	Grain yield (kg/ha)	Per cent reduction in yield over control
0	118.4	0.0	1373	0.0
1	105.8	10.6	1240	9.7
2	95.5	19.3	1120	18.4
3	81.1	31.5	950	45.4
4	66.2	44.1	750	58.3
5	54.2	54.2	573	68.4
8	23.8	79.9	137	90.0
CD at 5%	2.55		118	
CV %	6.79		22	

Table 2. Regression equation based estimation of blister beetle density dependent reduction in pod bearing and yield of greengram

Beetles/mrl (x)	(b)	(a)	Pods/plant	Pod bearing loss (pods/plant)	Per cent loss in pod bearing	(b)	(a)	Grain yield (kg/ha)	Yield loss (kg/ha)	Per cent yield loss
0.0	-1.208	11.75	11.8	-	-	-158.6	1398	1398	-	-
0.1	-1.208	11.75	11.6	0.1	1.0	-158.6	1398	1382	15.9	1.1
0.2	-1.208	11.75	11.5	0.2	2.1	-158.6	1398	1366	31.7	2.3
0.3	-1.208	11.75	11.4	0.4	3.1	-158.6	1398	1350	47.6	3.5
0.4	-1.208	11.75	11.3	0.5	4.2	-158.6	1398	1334	63.4	4.7
0.5	-1.208	11.75	11.1	0.6	5.4	-158.6	1398	1318	79.3	5.9
0.6	-1.208	11.75	11.0	0.7	6.5	-158.6	1398	1302	95.2	7.2
0.7	-1.208	11.75	10.9	0.8	7.7	-158.6	1398	1287	111.0	8.5
0.8	-1.208	11.75	10.8	1.0	8.9	-158.6	1398	1271	126.9	9.9
0.9	-1.208	11.75	10.7	1.1	10.1	-158.6	1398	1255	142.7	11.2
1.0	-1.208	11.75	10.5	1.2	11.3	-158.6	1398	1239	158.6	12.6

d. Prediction of Yield Loss: Prediction of yield loss due to blister beetles in greengram was based on regression equation of y = 1398.0 - 158.6x (Table 2) with R^2 value of 0.996. Grain yield varied inversely with beetle density. Predicted grain yield at zero beetle density was 1398 kg/ha, whereas, at one beetle per mrl the predicted yield level was 1239 kg/ha with 12.6 per cent avoidable loss.

II) Assessment of Economic Threshold Level: Plant protection cost of Rs. 2480 for two dustings of methyl parathion (@ Rs. 1240 /dusting/ha) was considered for preventing 80 per cent avoidable loss.

Gain Threshold (GT) =2480/3000 = 0.82 q/ha.

Economic injury level (EIL) = 0.82/1.59 = 0.51 beetles per mrl

Once the population reaches the ETL, chances are good that it will grow to exceed the EIL.

ETL is 75 per cent of EIL = 0.51 x (75/100) = 0.38 beetles per mrl.

Thus, the ETL of blister beetle was established at 0.38 ≈ 0.4 blister beetles/mrl for greengram. Durairaj and Ganapathy (2000) reported that the yield loss was positively correlated with beetle numbers (r= 0.87) and an economic injury level (EIL) of 3 beetles per 10 plants was established at flowering in cowpea. Based on a constant Grain Threshold level, Economic injury level of 7.97 and 7.78 beetles per 50 pigeonpea plants at flowering were enumerated by Durairaj et al. (1998) on pigeonpea cultivars Vamban 1 and ICPL 86012, respectively.

Pawar *et al.* (2013) reported that for effective management of adult blister beetles on greengram, selection of insecticides, the application time and application interval are very crucial. Thus, present study will help to restrict the losses in greengram due to timely application in a cost effective manner.

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Spatial Distribution of Greenhouse Whitefly, *Trialeurodes vaporariorum* (Westwood) in Tomato Under Protected Environment in North-Western Indian Himalaya

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Abstract**:** Spatial distribution of greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) was determined in summer and autumn crop of tomato under naturally ventilated polyhouse. The population varied from 0.18 to 4.98 adults per leaf in summer crop and was relatively low in autumn crop (0.26 to 1.92 adults per leaf). The dispersion indices namely, variance to mean ratio, David and Moore index of clumping and Iwao's patchiness regression index revealed the population of *T. vaporariorum* in summer crop to have negative binomial distribution, whereas, in autumn crop it followed binomial series. Lewis index, index of dispersion and Morisita's coefficient of dispersion fitted to determine dispersion of greenhouse whitefly showed that in vegetative stage (pre-flowering) in both the cropping seasons, greenhouse whitefly was distributed randomly. However, in reproductive stage (flowering and fruiting stage), distribution was aggregated/ clumped in summer crop and regular/ uniform in autumn crop. Taylor's power law also proved the hypothesis of population dispersion to be aggregated in summer and regular/ uniform in autumn cropping season. The index of patchiness revealed the clumping in greenhouse whitefly being influenced by the environmental factors greatly.

Key Words**:** Spatial Distribution, *Trialeurodes vaporariorum,* Protected Cultivation, Tomato

The greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), is a serious pest in temperate regions under protected cultivation situations and in field crops where the summers are warm enough. In India, the pest was first recorded from Nilgiri hills of Tamil Nadu on potato and subsequently it has been reported to infest 102 host plants belonging to 36 plant families (Sood and David, 2012). *T. vaporariorum* remained a low density pest in north - western Indian Himalayan region and assumed significance only in late nineties when it posed a threat to the cultivation of some vegetable crops and ornamental plants under protected and field conditions. Presently, it is categorized as the key pest of tomato under protected environment with more incidence in summer crop (Sharma *et al.,* 2006). Understanding the dispersion parameters of pest population helps in devising sampling plan, determining sample size, population modeling for forecasting and pest management interventions. Information on spatial distribution of *T. vaporariorum* under protected environment is scanty. Therefore, present investigations were undertaken to generate information which would be beneficial in planning strategies for the management of *T. vaporariorum* under protected environment.

MATERIALS AND METHODS

The studies were carried out on spatial distribution of greenhouse whitefly during summer and autumn season crop of tomato under naturally ventilated modified quonset polyhouse (size: 250 m^2) at Palampur (1290 m ASL) representing the mid-hill zone of north-western Indian Himalaya. Tomato cultivar Avtar (F_1 hybrid) was raised following all agronomic practices as per the 'Package of Practices for the Vegetable Crops' (Anonymous, 2010) in insecticide free environment. Thirty day old seedlings were transplanted for raising the crop with plant to plant and row to row spacing of 30 x 60 cm, respectively. Tomato plants were trained on two stems by snapping side shoots at regular interval. The crop was artificially infested by releasing about 500 adults of greenhouse whitefly 10 days after transplanting inside the polyhouse nearby the entrance of the polyhouse. The mean temperature and relative humidity in the polyhouse varied between 23.5 - 28.1°C and 45.9 - 77.9 per cent, respectively, during summer crop, whereas, in autumn crop the corresponding values were 12.0 - 25.8°C and 64.5 – 80.3 per cent.

Visual *in-situ* observations were recorded on the number of greenhouse whitefly adults on all fully opened leaves starting from top to bottom on every fourth day between 0800-1000 hours. These observations were recorded from 90 randomly selected plants. Mean adult population per leaf was worked out for different dates of sampling. Various indices of dispersion given hereunder were used to work out the spatial distribution of greenhouse whitefly.

Variance to mean ratio (VMR): The simplest approach used for determining the insect distribution was used as:

$$VMR = S^2/\overline{X}$$

$$\text{where, } S^2: \frac{\sum_{i=1}^{n}(Xi-\overline{X})^2}{n-1} \; : \; \overline{X} = \frac{1}{n}\sum_{i=1}^{n} Xi$$

The value of VMR is one for 'Poisson' distribution, less than one for binomial and more than one for negative binomial distribution.

Index of clumping of David and Moore (I_{DM}): The index of clumping (I_{DM}) was also calculated to confirm the distribution as given hereunder:

$$I_{DM} = \frac{S^2}{\overline{X}} - 1$$

I_{DM} results in value of zero for Poisson, positive value for negative binomial and negative for binomial distribution.

Lewis index was worked out as per formula given hereunder to determine the dispersion of *T. vaporariorum:*

$$\sqrt{\frac{S^2}{\overline{X}}}$$

The value of this index revealed >1 contagious; <1: regular and =1 random distribution.

Index of dispersion **(I_D):** Distribution pattern was further confirmed by 'Index of Dispersion' which was calculated as follow:

$$I_D = (n-1)\ \frac{S^2}{\overline{X}}$$

where, I_D = index of dispersion; n = the number of samples

The Z-coefficient of I_D was also worked out to test its significance as

$$Z = \sqrt{2I_D} - \sqrt{2v-1}$$

where, v = degree of freedom (*n-1*)

If 1.96 = *Z* = -1.96, the spatial distribution be random, but in case of *Z* >1.96 and *Z* < -1.96 this parameter becomes aggregated and uniform, respectively.

Morisita's coefficient of dispersion (I_δ): The uneven distribution was calculated by working out the coefficient of dispersion (I_δ) using following equation:

$$I_\delta = \frac{n\sum Xi(Xi-1)}{N(N-1)}$$

where, n = the number of sample units; X_i = the number of individuals in each sample; *N* = total number of individuals in *n* samples

The following large sample test of significance was used to determine whether the sampled population significantly differed from random:

$$Z = \frac{(I_\delta - 1)}{\sqrt{\frac{2}{n\overline{X}^2}}}$$

If 1.96 = *Z* = -1.96, the spatial distribution be random, but in case of *Z* >1.96 and *Z* < -1.96 this parameter becomes aggregated and regular, respectively.

Lloyd's mean crowding **and** ***Index of patchiness*****:** Mean crowding ($\overline{X}$*) to indicate the possible effect of mutual interference or competition among individuals was also determined. The sample estimate of mean crowding was calculated as

$$\overline{X}^* = \overline{X} + \left(\frac{S^2}{\overline{X}} - 1\right)$$

To remove the effect of density changes, the patchiness index $\frac{\overline{X}^*}{\overline{X}}$ was worked out. The ratio of mean crowding to mean density known as patchiness index was also worked out. Values of this index being less than one, equal to or larger than one in under-dispersed, random and clumped distribution, respectively. The values >2 suggests that clumping being due to environmental factors as well as insect behavior; whereas < 2 value reveals only environmental factors influencing clumping.

Taylor's power law**:** According to Taylor's power law, population variance (S^2) is proportional to fractional power of the arithmetic mean $(\overline{X})$ The log function of $S^2 = a(\overline{X})^b$ was used in the following form

$$\log S^2 = \log a + b \log(\overline{X})$$

where, a is sampling factor; b is aggregation parameter

in which '*a*' is sample size-related scaling factor; slope *b* is index of aggregation which in turn recalls uniform (*b<1*), random (*b=1*) and aggregated (*b>1*) dispersion of a population.

Iwao's patchiness regression index quantifies relationship between mean crowding index $\overline{X}^*$ and mean $(\overline{X})$ using the following equation:

$$\overline{X}^* = \alpha + \beta\overline{X}$$

where α indicates the tendency to crowding (positive) or dispersion (negative). The constant β is related to the pattern in which an insect utilizes its habitat and is called density contiguousness coefficient and is interpreted in the same manner as *b* of Taylor's power law. The distribution with β >1 corresponds to the negative binomial series and the distribution with β =1 to models of randomly distributed colonies. This hypothesis was used to test the distribution pattern of greenhouse whitefly under protected environment as elaborated by Subramaniam and Arumugam (2006) and Kianpour *et al.* (2010).

RESULTS AND DISCUSSION

A perusal of data revealed that the mean population of *T. vaporariorum* varied from 0.18 to 4.98 and 0.26 to 1.92 adults per leaf during summer and autumn crops of tomato, respectively, being relatively more during summer season (Table 1 and 2). During summer crop, the value of variance to mean ratio (VMR) remained less than unity upto 41 days after transplanting (DAT) (May 6, 2010) depicting the population to follow binomial distribution. For subsequent observations (45 DAT onward; post-flowering period), the population followed the negative binomial distribution (Table 1). This was further confirmed by the index of clumping of David and Moore (I_{DM}) which revealed the values being positive (>0) for 45 DAT in most of the cases, depicting the distribution of *T. vaporariorum* following negative binomial distribution. In autumn crop, the values of variance were less than their corresponding mean values, depicting the regular distribution. The VMR varied between 0.43 to 0.95, showing that *T. vaporariorum* to follow binomial distribution (Table 2). The index of clumping of David and Moore (I_{DM}) also confirmed the binomial distribution of greenhouse whitefly as all the values being negative in autumn season.

The value of index of dispersion (I_D) revealed that the greenhouse whitefly in summer crop followed random distribution from April 16 to May 14, 2010 (pre-flowering stage), except for one on May 6, 2010 (41 DAT). Thereafter, the population trend was aggregated for most of the observations as the resultant values were >1.96. Morisita's coefficient of dispersion (I_δ) and Lewis index also confirmed the greenhouse whitefly population to be distributed randomly in early growth stages and aggregated in the later stages (49 DAT onward) coinciding with reproductive stage in summer crop of tomato. However, in autumn cropping season, the index of dispersion (I_D) for greenhouse whitefly resulted in values varying between 1.96 =Z =-1.96, depicting random distribution for most of the sampling dates upto 49 DAT. However, in later stages, greenhouse whitefly population was distributed uniformly for most of the observations. Lewis index resulted in all the values being < 1 depicting that *T. vaporariorum* to be distributed regularly. This hypothesis was also confirmed by Morisita's coefficient of dispersion (I_δ).

In summer season crop, the values of Lloyd's mean crowding $\bar{x}$ were more than their respective mean values (45 DAT onwards) further confirmed the clumped distribution of *T. vaporariorum* (Table 1). However, in autumn crop, the values of mean crowding were less than their respective mean values established the under dispersed distribution of greenhouse whitefly (Table 2). The Index of patchiness resulted in value varying from 0.05 to 1.37 and 0.03 to 0.96 in summer and autumn season crop, respectively, being < 2 also suggested that the clumping of *T. vaporariorum* $m/\bar{x}$ in tomato under protected environment being influenced by environmental factors only.

The hypothesis with respect to differential dispersion pattern of *T. vaporariorum* in two cropping seasons was further confirmed by Iwao's patchiness regression (Table 3). This resulted in the value of α being negative during both cropping seasons depicting the tendency of *T. vaporariorum* population for dispersion. The value of β was positive and more than unity for summer crop (1.1808) and less than unity (0.9373) for autumn crop depicting the negative binomial and positive binomial series of distribution in summer and autumn crop, respectively. Taylor's power law also provided a better fit to the data in summer crop as evidenced by the value of coefficient of determination (R^2=0.9584) (Table 3). The dispersion parameter, b of Taylor's power law was significantly different (P > 0.05, t-test) from unity (1.2020) indicating that the distribution of greenhouse whitefly was aggregated. However, during autumn season, the value of aggregation parameters (b) was less than unity (0.9148) indicating greenhouse whitefly to be uniformly distributed.

Present findings to have aggregated distribution of greenhouse whitefly in summer crop are in line to observations by Liu *et al.* (1993) and Basso *et al.* (2001) who recorded *T. vaporariorum* distribution to be aggregated in different crops grown under greenhouse conditions. Shen and Ren (2007) and Gusmao *et al*. (2005) also observed the same distribution pattern for *Bemisia tabaci* Gennadius. However, in autumn season crop, the distribution was uniform/ regular in contrast to the findings of the earlier workers cited above may be attributed to low population levels observed as compared to summer crop in present studies.

On the basis of various indices incorporated for determining the spatial distribution, it was evident that *T. vaporariorum* in tomato had differential dispersion pattern in

Table 1. Indices for spatial distribution of greenhouse whitefly in summer crop of tomato under naturally ventilated polyhouse

Crop stage	Sampling date	Crop age (Days)	Mean population/ leaf ($\bar{X}$)	Variance (S^2)	Variance to mean ratio (VMR)	David & Moore's index of clumping(I_{DM})	Lewis Index	Index of dispersion (I_D)	Morisita coefficient of dispersion (I_δ)	Lloyd's mean crowding $(\overline{X})$	Index of Patchiness $(\overline{X}/\overline{X})$
Vegetative stage	April 16	21	0.18	0.15	0.83	-0.17	0.91	-1.14	-1.19	0.01	0.05
	20	25	0.36	0.34	0.97	-0.03	0.98	-0.18	-0.22	0.32	0.91
	24	29	0.34	[illegible]	0.86	-0.14	0.93	-0.94	-0.97	0.20	0.59
	28	33	0.28	0.27	0.97	-0.03	0.99	-0.14	-0.19	0.25	0.90
	May 2	37	0.66	0.61	0.93	-0.07	0.96	-0.43	-0.47	0.59	0.89
	6	41	1.72	0.88	0.51	-0.49	0.71	-3.78	-3.28	1.23	0.72
Reproductive stage (post flowering stage)	10	45	1.87	2.09	1.12	0.12	1.06	0.83	0.81	1.99	1.07
	14	49	2.42	2.72	[illegible]	0.12	1.06	0.83	0.82	2.54	1.05
	18	53	3.38	4.57	1.35	0.35	1.16	2.22	2.36	3.73	1.10
	22	57	4.98	7.60	[illegible]	0.53	1.24	3.18	3.50	5.50	1.11
	26	61	4.13	6.07	1.47	0.47	1.21	2.87	3.12	4.60	1.11
	30	65	3.50	5.33	1.52	0.52	1.23	3.16	3.48	4.02	1.15
	June 3	69	3.26	5.43	1.67	0.67	1.29	3.92	4.44	3.92	1.21
	7	73	3.04	4.96	1.63	[illegible]	1.28	3.73	4.20	3.68	1.21
	11	77	2.70	4.89	1.81	[illegible]	1.35	4.64	5.39	3.51	1.30
	15	81	2.39	3.30	1.38	[illegible]	1.17	2.37	2.53	2.77	1.16
	19	85	2.47	3.33	1.35	[illegible]	1.16	2.20	2.33	2.82	1.14
	23	89	2.57	3.60	1.40	0.40	1.18	2.49	2.67	2.97	1.16
	27	93	2.54	2.92	1.15	0.15	[illegible]	1.00	1.00	2.69	1.06
	July1	97	2.12	3.14	1.48	0.48	[illegible]	2.93	3.21	2.60	1.23
	5	101	2.21	3.29	1.49	0.49	1.22	2.98	3.26	2.70	1.22
	9	105	2.11	3.74	1.77	0.77	[illegible]	4.45	5.15	2.88	1.37
	13	109	2.16	2.38	1.10	0.10	[illegible]	0.71	0.69	2.26	1.05

Table 2. Indices for spatial distribution of greenhouse whitefly in autumn crop of tomato under naturally ventilated polyhouse

Crop stage	Sampling date	Crop age (Days)	Mean Population/leaf $\overline{X}$	Variance (S^2)	Variance to mean (VMR)	David & Moore's index of clumping (I_{DM})	Lewis Index	Index of dispersion (I_D)	Morisita coefficient of dispersion (I_δ)	Lloyd's mean crowding $\overline{X}$	Index of Patchiness $\overline{X}/\overline{X}$
Vegetative stage	September 19	21	0.26	0.19	0.75	-0.25	0.87	-1.73	-1.71	0.01	0.03
	23	25	0.73	0.40	0.55	-0.45	0.74	-3.45	-3.06	0.28	0.38
	27	29	0.80	0.57	0.71	-0.29	0.84	-2.08	-1.97	0.51	0.63
	October 1	33	1.12	0.92	0.82	-0.18	0.90	-1.24	-1.22	0.94	0.84
	5	37	1.34	1.01	0.75	-0.25	0.87	-1.71	-1.64	1.10	0.82
	9	41	1.34	1.10	0.82	-0.18	0.91	-1.21	-1.19	1.17	0.87
Reproductive stage *(post flowering stage)*	13	45	1.42	1.03	0.73	-0.27	0.85	-1.93	-1.83	1.15	0.81
	17	49	1.27	1.21	0.95	-0.05	0.98	-0.27	-0.30	1.22	0.96
	21	53	1.38	0.93	0.68	-0.32	0.82	-2.32	-2.15	1.06	0.77
	25	57	1.61	0.85	0.53	-0.47	0.73	-3.63	-10.81	1.14	0.71
	29	61	1.92	1.31	0.68	-0.32	0.83	-2.30	-12.89	1.60	0.83
	November 2	65	1.62	1.02	0.63	-0.37	0.79	-2.70	-10.88	1.25	0.77
	6	69	1.54	1.19	0.77	-0.23	0.88	-1.57	-1.51	1.32	0.85
	10	73	1.54	0.95	0.61	-0.39	0.78	-2.85	-2.58	1.16	0.75
	14	77	1.46	1.06	0.73	-0.27	0.85	-1.92	-1.82	1.18	0.81
	18	81	1.62	1.00	0.62	-0.38	0.79	-2.82	-2.55	1.24	0.76
	22	85	1.59	1.05	0.66	-0.34	0.81	-2.44	-2.25	1.25	0.79
	26	89	1.52	0.75	0.49	-0.51	0.70	-3.96	-3.40	1.01	0.67
	30	93	1.53	0.66	0.43	-0.57	0.65	-4.58	-3.82	0.96	0.63
	December 4	97	1.36	0.68	0.50	-0.50	0.71	-3.85	-3.44	0.86	0.63
	8	101	1.22	0.58	0.47	-0.53	0.69	-4.12	-3.52	0.70	0.57
	12	105	1.23	0.68	0.55	-0.45	0.74	-3.43	-3.03	0.78	0.63
	16	109	1.20	0.75	0.62	-0.38	0.79	-2.78	-2.53	0.82	0.68
	20	113	1.14	0.80	0.70	-0.30	0.84	-2.16	-2.02	0.84	0.74

Table 3. Iwao's patchiness regression and Taylor's power law of greenhouse whitefly for summer and autumn crop of tomato

Cropping season	Iwao's patchiness regression			Taylor's power law		
	α	β	R^2	A	B	R^2
Summer crop	-0.1256	1.1808	0.9728	1.0965	1.2020	0.9584
Autumn crop	-0.2592	0.9373	0.8707	0.6607	0.9148	0.7796

both the cropping seasons. The population in summer crop followed negative binomial distribution, whereas the distribution in autumn crop was binomial. It was further observed that at lower population levels in the vegetative growth stage in both the cropping seasons, greenhouse whitefly was distributed randomly whereas in post-flowering stage (reproductive stage), *T. vaporariorum* distribution was aggregated/ clumped in summer crop and regular/ uniform in autumn crop.

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Effect of Plant Extracts on Qualitative Parameters of Guava

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Abstract: The study was carried out to test the potency of some plant extracts for extension of shelf life of guava. Aqueous extract used were obtained from leaves of neem (*Azadirachta indica* A. Juss) and chinaberry (*Melia azedarach*). Guava fruit was dipped in 10% and 20% leaves extract of *A. indica* and *M. azedarach* and were packaged in newspaper and gunny bag and was tested for the storage quality of the fruit at room temperature. The statistical results of the study indicated that coating of leaves extracts and storage period significantly ($P \leq 0.05$) affected all traits. Interaction of aqueous extracts and storage for all traits was also significant. TSS, ascorbic acid and pectin increased with storage and then decreased. Spoilage increased with storage period and at the end, it was highest in control and lowest in fruits dipped in neem 20% and wrapped in newspaper. These results thus showed that surface coating of guava with 20% *A. indica* leaf extract and wrapped in newspaper provided better retention of storage life of fruit.

Key words: Guava, Fruit Quality, Plant Extracts, Post Harvest, Storage

Guava (*Psidium guajava* L.) is grown successfully throughout tropical and sub-tropical regions of India. Guava fruit is highly perishable and has to be marketed immediately after harvest. A number of post harvest treatments like waxing, fungicidal dip, polyethylene film, etc. have been used to extend the shelf life of fruits (Bhardwaj *et al.,* 2010). However, the use of these substances have their own limitations, as some of them are believed to be ecologically unsafe and economically unviable, besides leaving their residue on the fruit surface, which may have the direct effect on human health. Gainge *et al.* (1984) have documented a number of plants belonging to various families having growth regulating and fungicidal properties, therefore extracts of neem (*Azadirachta indica L.*) and chinaberry (*Melia azedarach* L.) were studied for use as a plant protection agents. They have antifungal and antimicrobial properties. Keeping these in view, the present investigation was undertaken to assess the storability of guava fruits to manage appropriate regulated market supply through judicious use of post-harvest treatments of plant extracts.

MATERIAL AND METHODS

Preparation of treatment solutions: Treatment solutions were prepared from extracts of *A. indica* and *M. azedarach* leaves at different concentrations on the percentage weight basis as per the method described by Gakhukar (1996). The flower and leaves were dried in shade followed by grinding them to a powder form in an electric blender. The extract was prepared by adding 100 ml of distilled water to 100 g of leaf or flower powder and kept overnight. This gave 100% concentration of the plant extract (1:1 w/v). Aqueous solutions of different treatments were prepared using distilled water by diluting the extracts to 10 and 20% and passed through two layers of muslin cloth.

Collection of fruits and the treatment: Medium sized guava fruits of cv. 'Allahabad Safeda', free from any damage and with uniform maturity were harvested when colour changed from dark green to light green from orchard of Sher-e-Kashmir University of Agricultural Science and Technology, Jammu. Fruits were then analysed for different physico-chemical characters at harvest and they were dipped for 10 minutes in various plant extracts as per treatment details: (1) neem leaf extract, 10% wrapped in newspaper (NLE, 10% NP); (2) neem leaf extract, 10% wrapped in gunny bag (NLE, 10% GB); (3) Neem leaf extract, 20% wrapped in newspaper (NLE, 20% NP); (4) neem leaf extract, 20% wrapped in gunny bag (NLE, 20% GB); (5) China berry leaf extract, 10% wrapped in newspaper (CLE 10%, NP); (6) chinaberry leaf extract, 10% wrapped in gunny bag (CLE 10%, GB); (7) chinaberry leaf extract, 20% wrapped in newspaper (CLE 20%, NP); (8) chinaberry leaf extract, 20% wrapped in gunny bag (CLE 20%, GB); (9) control. The fruits were surface dried and kept at room temperature to accesses changes in physico-chemical properties on 4^{th}, 8^{th}, 12^{th} and 16^{th} day. Each treatment was replicated thrice having twenty five fruits in each replication.

Quality components like total soluble solids, pectin and texture were estimated by standard methods. Total soluble solids (%) were recorded with Abbes refractometer. Ascorbic acid content (mg/100g) was determined by the procedure using 2, 6-dicholorophenol indophenols dye and pectin was determined by Gravimetric method (Sadasivam, 1996). Fruits were examined visually for per cent spoilage.

RESULTS AND DISCUSSION

TSS of guava on 4th day of storage was maximum (11.37°B) in fruits treated with chinaberry 20% and wrapped in newspaper followed by fruits treated with neem leaf extract, 20% wrapped in newspaper (10.80°B) and minimum (9.80°B) in control. The TSS increased to 12.80°B and 12.50°B in fruits treated with chinaberry and neem leaf extract, 20% and wrapped in newspaper, respectively on 16th day. While in control, TSS on 16th day was 11.20°B. Total soluble solid increased in the increased in the beginning of the storage and then decreased gradually and the decrease was upto 16th day of storage. The results were in accordance with those reported by Chauhan *et al.* (2008) who concluded that neem and chinaberry leaf extracts were capable to retain maximum total soluble solid than control, which might be due to higher respiratory losses in these fruits as there was no barrier to restrict the movement of gases into and out of the fruit.

On 4th day of storage the highest ascorbic acid content of 187.04 mg/100 g pulp was recorded in fruits treated with neem 20% and wrapped in newspaper and in control. The values decreased to 153.09 mg/100 g pulp in fruits treated with neem 20% and wrapped in newspaper and 125.53 mg/100 g pulp in control on 12th day of storage (Table 1). Results reveal that ascorbic acid increased upto 4th day and then decreased gradually during storage. The fall in ascorbic acid content might be due to its oxidation and enzymatic degradation during ripening (Suresh *et al.,* 2008). The decrease might be associated with differential ascorbic acid oxidase activity in fruits as well as its utilization by developing fungi on fruit surface (Singh, 2005). These results are in accordance with the results reported by (Bhardwaj *et al.,* 2010) that neem reduces respiration rate as well as oxidation in the orange. Similar results had been reported by Bhardwaj and Sen (2003) in mandarin orange.

Pectin content decreased significantly after 4th day of storage. The highest pectin content on 4th day was 2.70 per cent in fruits treated with neem 20% and wrapped in newspaper followed by fruits treated with china berry 20% and wrapped in newspaper and lowest pectin content was in control. On 12th day the pectin content decreased to 0.98 per cent in fruits treated with neem 20% and wrapped in newspaper and 0.49 per cent in control. On 16th day of storage further decline was observed. Azadirachtin is reported to retard the deestrification of pectin, thereby slowing down its breakdown resulting in higher pectin content in such fruits (Gakhukar, 1996). These findings are also in line with those reported by Chauhan *et al.* (2008) and Wijewardane and Guleria (2009) in apple that neem extract is the most effective in retaining highest pectin content.

On 8th day maximum (22.22 per cent) spoilage was observed in control. On 12th day, the spoilage percentage increased to 38.89 per cent in control (Table 2). The interaction between treatment and storage was found to be significant. No spoilage was observed on 4th day. However, spoilage per cent showed a steady increase from 8th day to 16th day of storage. Among treatments, neem 20% and news paper wrapping decreased the spoilage significantly followed

Table 1. Effect of plant extracts on total soluble solids, ascorbic acid (mg/100g) and pectin (%) of guava fruits.

Treatments	4th day	8th day	12th day	16th day	Mean	4th day	8th day	12th day	16th day	Mean
	Total Soluble Solids (TSS)					Ascorbic acid (mg/100g)				
NLE 10%, NP	10.50	11.27	11.53	12.03	11.33	173.78	157.04	145.44	132.50	152.19
NLE 10%, GB	10.40	11.10	11.47	11.93	11.23	171.54	153.84	144.86	131.49	150.43
NLE 20%, NP	10.80	11.77	11.83	12.50	11.73	187.04	158.90	153.09	143.76	160.70
NLE 20%, GB	10.60	11.50	11.63	12.10	11.46	184.07	156.64	149.48	138.93	157.28
CLE 10%, NP	10.70	11.63	11.77	12.33	11.61	181.42	155.93	147.39	136.46	155.30
CLE 10%, GB	10.53	11.30	11.40	12.17	11.35	186.73	152.21	145.64	133.77	154.59
CLE 20%, NP	11.37	12.10	12.23	12.80	12.13	181.85	159.16	151.87	141.63	158.63
CLE 20%, GB	10.67	11.50	12.00	12.73	11.73	179.13	154.96	147.64	135.28	154.25
Control	9.80	10.70	10.87	11.20	10.64	143.87	130.72	125.53	120.63	130.19
Mean	10.60	11.43	11.64	12.20		176.60	153.27	145.66	134.94	

Factors	C.D. (p=0.05) (TSS)	Factors	C.D. (p=0.05) (Ascorbic acid)
Treatment (A)	0.22	Treatment (A)	0.47
Storage (B)	NS	Storage (B)	0.31
Interaction (A X B)	0.43	Interaction (A X B)	0.94

NLE: Neem Leaf Extract; CLE: Chinaberry Leaf Extract; NP: Newspaper; GB: Gunny Bag

Table 2. Effect of spoilage (%) and texture of guava fruits

Treatments	8th day	12th day	16th day	Mean	4th day	8th day	12th day	16th day	Mean
	Spoilage % age				Texture				
NLE 10%, NP	0 (0.71)	22.22 (4.77)	33.33 (5.82)	18.52	8.55	8.91	6.34	5.81	7.40
NLE 10%, GB	0 (0.71)	27.78 (5.32)	44.44 (6.70)	24.07	8.42	8.76	6.15	5.59	7.23
NLE 20%, NP	0 (0.71)	11.11 (3.41)	22.22 (4.77)	11.11	8.84	9.03	7.98	6.57	8.11
NLE 20%, GB	0 (0.71)	16.67 (4.14)	38.89 (6.28)	18.52	8.67	8.97	6.45	5.56	7.41
CLE 10%, NP	0 (0.71)	16.67 (4.14)	33.33 (5.82)	16.67	8.46	8.78	6.22	5.73	7.30
CLE 10%, GB	0 (0.71)	22.22 (4.77)	44.44 (6.70)	22.22	8.49	8.89	6.29	6.73	7.60
CLE 20%, NP	0 (0.71)	16.67 (4.14)	27.78 (5.32)	14.82	8.77	8.94	7.39	6.66	7.94
CLE 20%, GB	0 (0.71)	22.22 (4.77)	44.44 (6.70)	22.22	8.66	8.86	6.29	5.26	7.27
Control	22.22 (4.77)	38.89 (6.28)	66.67 (8.20)	42.59	8.34	7.80	5.10	4.47	6.43
Mean	2.47	21.61	39.50		8.58	8.77	6.47	5.82	
	Factors	C.D. (p=0.05)			Factors		C.D. (p=0.05)		
	Treatment (A)	0.11			Treatment (A)		0.15		
	Storage (B)	0.11			Storage (B)		0.10		
	Interaction (A X B)	0.12			Interaction (A X B)		0.31		

*Figures given in parentheses are transformed (square root) values

NLE: Neem Leaf Extract; CLE: Chinaberry Leaf Extract; NP: Newspaper; GB: Gunny Bag

by treatment with chinaberry 20% and wrapping in newspaper. Reduction in spoilage due to rotting with the neem extract may be attributed to the presence of the principle compound azadirachtin, which has the ability to check the growth of microbes that are responsible for causing spoilage. The results are also in conformity with the findings of Chauhan *et al*. (2008) and Okigbo *et al.* (2010). Gakhukar (1996) suggested that botanical extracts have the capability to act as anti-feedent and anti-repellent and thereby inhibiting the pathogenicity of various organisms.

Texture scores of guava fruit of different treatments revealed that on 4th day, the maximum score of 8.84 was recorded in fruit treated with neem 20% and wrapped in newspaper and the minimum score of 8.34 in control. On 12th day of storage, the scores decreased to 7.98 and 5.10, respectively. Texture score of guava decreased with increase in storage period. The better score observed for texture at the optimum stage could be due to conversion of protopectin into pectin and then pectin into pectinic acid, which disintegrated the cell structure, and caused lowering of sensory score (Suresh *et al.,* 2008). The results are in conformity with that of Chauhan (2008) who reported that 20% neem was most effective.

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Effects of Metal Contaminated Soils on the Survival, Growth and Duration of Life Span of Juveniles of Earthworm, *Eisenia fetida* (Savigny)

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Abstract: Juveniles of *Eisenia fetida* were exposed for 11 weeks to soils contaminated with cadmium, lead and nickel collected from four different sites in the vicinity of Buddah Nullah, Ludhiana and uncontaminated soil sample was taken as control. Survival, growth and time taken to reach sexual maturity in juveniles reared in contaminated soils were compared with juveniles in uncontaminated soil. The effects of metal contaminated soils could be attributed both to the direct toxicity of the metals and to changes in scope for growth of the exposed worms. Worms were found sensitive to elevated metal concentrations in first few weeks of the experiment as some mortality occurred in worms during that time of the experiment. Growth was also found affected in worms reared in contaminated soil samples. Duration to attain sexual maturity was found maximum in soil sample taken from the site having highest concentration of lead and nickel among the different samples. Results of the study indicated that elevated metal concentrations in soil adds to the sensitivity of the worms since the different parameters like survival, growth and duration to reach sexual maturity were seen highly affected in the juveniles of *E. fetida* in the contaminated soils.

Key Words*:* Heavy Metals, *Eisenia fetida*, Juveniles, Sexual Maturation, Toxicity

Earthworms are important component of soil system, mainly because of their favorable effects on soil structure and function. In addition, earthworms help to increase soil fertility by formation of an organic matter layer in top soil. Metal pollution may disturb soil ecosystem by affecting the structure of soil invertebrate communities. Heavy metals have been shown to reduce growth, slow sexual development, reduce juvenile viability and cause mortality. The juveniles of *Eisenia fetida* (Savigny) have been found to be more sensitive to pollutants than adults. Acute and chronic earthworm toxicity tests were successfully applied to assess the toxicity of contaminated soils in urban, mining and smelting and industrial areas. Earthworms, especially the compost worm *E. fetida* are model organisms for assessing the effects of various chemicals on terrestrial invertebrates. *E. fetida* (Savigny) are known to be absent or severely reduced in numbers in soils in the vicinity of lead, cadmium and zinc smelting works. Moreover in a polluted environment, changes to individual energy budgets will occur, as the organism expends energy resisting the contaminant by avoidance, exclusion, removal or complexing (Sibly and Calow, 1989; Donker, 1992). This additional energy requirement will decrease the scope for growth of the exposed animals and will reduce growth, differentiation, cocoon production and ultimately a number of important life history characteristics such as time to sexual maturity and generation time. Buddah Nullah has become a major source of pollution in the region as it get polluted after entering the highly populated and industrialized Ludhiana city, turning it into an open drain. Heavy metals in the Buddah Nullah stream leeches into the nearby soil and affects the population of many soil invertebrate communities and earthworms are one of the first receptors to be affected by soil contamination (Zaltauskait and Sodiene, 2010). The objective of present study was to examine the survival, growth and sexual maturation time of juveniles of *E. fetida* in heavy metal contaminated soils collected from different sites around Buddah Nullah stream, Ludhiana since no work has been reported earlier in this area around Buddah nullah using earthworm as a bio-indicator for heavy metal toxicity.

MATERIAL AND METHODS

The present work was carried out in campus of Punjab Agricultural University, Ludhiana. Metal contaminated soils were collected on the same day from four different sites in the vicinity of Buddah Nullah, Ludhiana. The different sites included Chand Cinema, Sunder Nagar, Tajpur Road and Shivpuri Area around Buddah Nullah (Fig.1). All the soil samples were collected at least 2 meters away from the main stream. About 5 kg of soil was collected from top 2 cm layer at each site after removal of surface vegetation and litter in transparent polythene bags. Colored bags were not used to avoid any extra contamination of soil sample. All the bags were marked with respect to the sites from which the samples were collected. A control sample of soil was collected from an uncontaminated field in PAU campus.

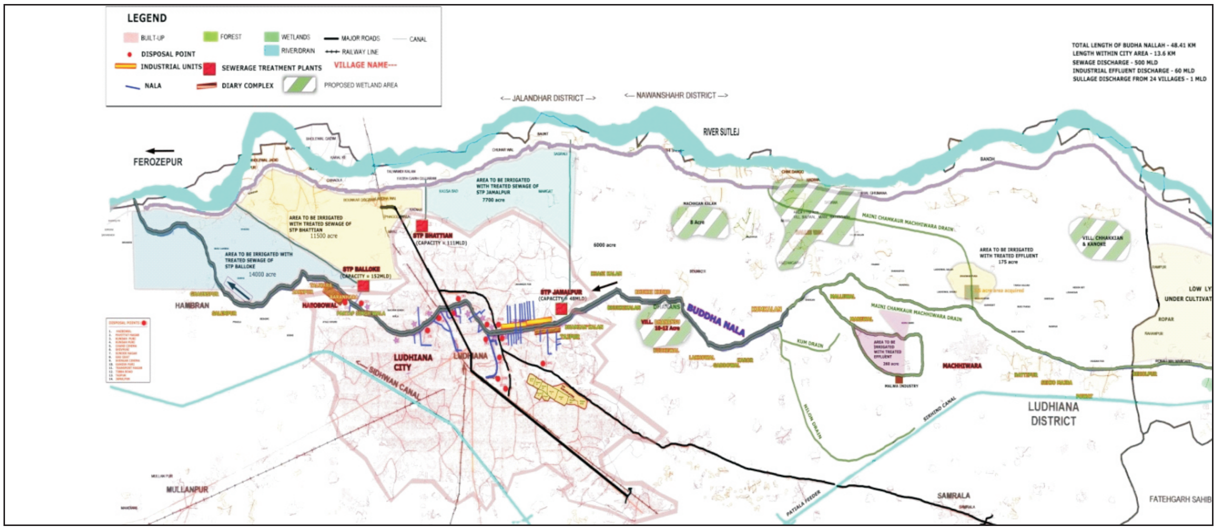

Fig. 1. Map of Buddah Nullah showing location of sites from where samples were collected

Soil aggregates were crushed while still damp and placed in a fan oven at 60°C for 2 days to dry. A subsample of soil was collected for the determination of cadmium, lead and nickel concentrations in the soils by flame atomic absorption spectrophotometry. Results of analysis of soils are depicted in Table 1. All the soil samples were passed through a 2mm mesh and 100 g of soil was placed in each Petri plate of size 14.8cm × 14.8cm. Distilled water was added to give a moisture content of 65% of field capacity and soil was left to stabilize for 72 hours prior to addition of worms.

To study the effect of metal contaminated soil on growth, about one week old hatchlings of *E. fetida* were taken from the mass culture kept at the laboratory of the department. The selected worms were acclimatized for seven days. The juveniles were weighed and inoculated into prepared soil petriplates and after 3 hours they were checked to ensure that all the worms had burrowed into the soil. All the petriplates were covered to prevent water loss. To ensure the growth, the worms were supplied with 5 g dried cattle manure per week.

At weekly intervals worms were sorted from all the soil samples and monitored for different parameters like survival, weight change and sexual maturity. Sexual development of worms was assessed according to scheme described by van Gestel *et al* (1991) to identify different stages of growth of worms. Worms with full clitellum were recorded as adult, those with a full tubercle pubertatis but no clitellum as sub-adults and individuals with neither of these structures as juveniles. The data was statistically analyzed by Analysis of Variance (ANOVA) using computer software CPCS1.

RESULTS AND DISCUSSION

Metal composition of soil: Concentrations of different heavy metals *i.e* cadmium, lead and nickel have been depicted in table 1. All the contaminated samples contained elevated levels of heavy metals. Among all the contaminated soil samples, maximum concentration of cadmium (0.29 ppm), lead (4.18 ppm) and nickel (2.29 ppm) was found in sample 4 and 2. While metal levels at PAU campus was within the range typical for an uncontaminated

Table 1. Concentrations of different heavy metals in soil samples

Soil sample*	Concentration of heavy metals (ppm)		
	Cadmium (Cd)	Lead (Pb)	Nickel (Ni)
S1	0.23	3.86	1.87
S2	0.18	4.18	2.29
S3	0.25	3.35	1.43
S4	0.29	3.96	2.14
Control	0.20	1.75	0.50

*S1, S2, S3 and S4 are the soil samples taken from Chand Cinema, Sunder Nagar, Tajpur Road and Shivpuri area, respectively

Survival of juveniles of *E. fetida*: Hatchlings of *E. fetida* when reared in control soil sample taken from PAU campus did not show any mortality and survived well up to 11 weeks. Maximum mortality was recorded in sample 3 and all the animals died in this soil sample after one week of rearing as shown in table 2. High mortality percentage of juveniles shows the sensitivity of juveniles to elevated levels of heavy metals. 50% survival was recorded in case of sample 2 while worms in sample 4 survived till end of the experiment. No significant mortality of *E. fetida* was observed in the soils collected from the campus and most of the worms died during the first weeks of the experiment in contaminated samples. This pattern of death could indicate that the juveniles were particularly sensitive during the first week of their growth. Increased sensitivity of juveniles of *E. fetida* to metallic pollutants has also been recorded earlier and for worms exposed to the contaminated soil, survival was lower than in the control field soil (Spurgeon and Hopkin, 1999). Earthworms try to escape moderately toxic situations and it was observed by Khalil (2013) that earthworm *Allolobophora caliginosa* feed less and *Pheretima hawayana* escaped into their burrows when exposed to arsenate.

Changes in body weight of juveniles: Pattern of body weight changes have been given in Table 3. In the control, hatchlings showed a continuous pattern of body growth. Worms attained their maximum weight during 9th week of the experiment and no change in body weight was observed after that till end of the experiment.

The worms reared in all the metal-contaminated soils reach the lower weight or need more time to reach the maximum weight than in non-polluted control soil. A number of studies on soil invertebrates have recorded a reduction in growth in animals exposed to metal contaminated sites. Growth of earthworm *Octodrilus complanatus* was found affected by aluminum level, which caused reduction in earthworm protein content (Bilialis *et al*., 2013). However such effects can frequently be attributed to a reduction in consumption due to avoidance of the contaminated food (Drobne and Hopkin, 1995).

Duration of life span of juveniles of *E. fetida*: Longer duration in life cycle of juveniles of *E. fetida* was recorded in all the contaminated soil samples as compared to control sample of soil (Table 4). Worms attained sexual maturity earlier in control uncontaminated soil sample as compared to all the contaminated soil samples.

High concentration of heavy metals cadmium, lead and nickel in contaminated soil samples caused the increase in duration of life cycle of juveniles in all the contaminated samples of soil as compared to the uncontaminated control. Juveniles matured earlier in control sample of soil than in contaminated soil samples while maximum delay to reach maturity in juveniles of *E. fetida* was observed in soil sample 2. High concentration of metals *i.e.* lead, cadmium and nickel might have accounted for the longer duration of days to reach maturity. High level of aluminum in acidic red soil was found harmul to *E. fetida* as observed by Zhang *et al*. (2013). Selection of life history parameters can also occur when populations are exposed to different factors (such as pollutants) that reduce survival and lower reproductive effort. If there is an increased energy demand for metal sequestration and elimination, this will decrease the energy available for sexual maturation and will ultimately slow down the maturation in animals exposed to the contaminated soils (Spurgeon and Hopkin, 1996).

The results of the present study indicated that survival, growth and sexual maturation time of juveniles of *E. fetida* was found affective when juveniles reared in metal

Table 2. Per cent survival of hatchlings of *E. fetida* in uncontaminated and metal contaminated soil samples

Soil sample*	Number of weeks										
	1	2	3	4	5	6	7	8	9	10	11
S1	100	100	100	100	100	100	100	100	100	100	100
S2	100	75	75	75	75	75	50	50	50	50	50
S3	100	-	-	-	-	-	-	-	-	-	-
S4	100	100	100	100	100	100	100	100	100	100	100
Control	100	100	100	100	100	100	100	100	100	100	100

Table 3. Weekly changes in body weights (g) of hatchlings of *E. fetida* in uncontaminated and metal contaminated soil samples

Soil sample**	Number of weeks										
	1	2	3	4	5	6	7	8	9	10	11
S1	0.048 ± 0.01	0.050 ± 0.01	0.073 ± 0.02	0.085 ± 0.02	0.098 ± 0.03	0.12 ± 0.03	0.14 ± 0.03	0.14 ± 0.04	0.15 ± 0.04*	0.16 ± 0.05*	0.19 ± 0.06*
S2	0.036 ± 0.00	0.052 ± 0.01	0.044 ± 0.014	0.064 ± 0.02	0.080 ± 0.027	0.064 ± 0.03	0.13 ± 0.02	0.22 ± 0.03	0.33 ± 0.02*	0.33 ± 0*	0.46 ± 0*
S3	0.036 ± 0.00	-	-	-	-	-	-	-	-	-	-
S4	0.033 ± 0.00	0.058 ± 0.01	0.083 ± 0.02	0.12 ± 0.03	0.15 ± 0.04	0.21 ± 0.05	0.25 ± 0.05	0.23 ± 0.05	0.23 ± 0.05*	0.32 ± 0.07*	0.41 ± 0.07*
Control	0.050 ± 0.014	0.051 ± 0.01	0.061 ± 0.01	0.064 ± 0.01	0.088 ± 0.01	0.15 ± 0.02	0.19 ± 0.02	0.35 ± 0.03	0.49 ± 0.007	0.49 ± 0.007	0.49 ± 0.007

Values are mean ± S.E of four replicates
* Values are significant at 5% level of significance

Table 4. Duration of life span of juveniles of *E. fetida* in uncontaminated and metal contaminated soil samples

Soil Sample	Number of days
S1	45.25 ± 0.41
S2	53.25 ± 0.41
S3	-
S4	43.75 ± 0.41
Control	28.50 ± 0.55

contaminated soils. Mortality and discontinuous growth pattern was observed in juveniles reared in metal contaminated soil samples. Delay to gain sexual maturity was also an important point to be considered during the experimental period. Juvenile growth rate and sexual development are important life history parameters for earthworms, since they may modify the dynamics of earthworm populations in the field. The findings of this paper can be helpful in assessing the impact of toxicity of different heavy metals towards population of earthworms in naturally contaminated soils.

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Influence of Edaphic Factors on Population Density of Slug, *Filicaulis alte* Ferussac in Vegetable Crops of Punjab

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Abstract: Studies conducted in vegetable fields of three villages viz; Bhadalwad, Sanghera and Dasaunda Singh Wala, Punjab revealed that slug density varied with weather conditions and soil components like organic matter, nitrogen, phosphorus, potassium, etc. In all the respective villages, slug density was found to be high during month of August and September. Slug density was noted by placing damp sacs in all the three villages. Slug density in Dasaunda Singh Wala village of district Sangrur was found to be significantly ($p>0.05$) more than other two villages that are Bhadalwad and Sanghera village of district Barnala. Bulk density found to be significantly less and potassium, phosphorus, soil electrical conductivity, organic matter and total porosity were found to significantly more in Dasaunda Singh Wala village. As maximum slug density was found in Dasaunda Singh Wala village therefore, slugs preferred low bulk density and high porosity and other soil components.

Key Words: Brown Slug, Damage, Slug Density, Vegetable Crops, Edaphic Factors

Slugs are important molluscan pests of a wide range of ornamental and vegetable plants in permanently moist regions or in rainy months. Slugs move by gliding on a muscular foot. The muscles constantly secrete mucus which later dries to form the silvery “slime trail” that signals the presence of either pest.

Brown slug with black spots (*Filicaulis alte* Ferrusac) was found to inhabit vegetable crop fields in Kaddon village of Ludhiana District, Punjab (Kaur and Mehta, 2013). Slugs injure plants by chewing holes in various sizes in the leaves and stems. These holes may be in the middle of the leaf or on the edge. The early seedlings stages are most susceptible to slugs; slugs can sometimes consume the entire seedling. Once the crop has passed the 6-leaved stage, the damage is generally superficial. The slugs reduce the vigor of some crops by killing seeds, destroying stems or growing points or by reducing leaf area. This may slow down crop development and reduce yield (Jagtap, 2000). Slugs also cause damage to beans, cabbage, cauliflower, tomato, strawberry, grape, banana (Flint, 2007). The older seedlings of vegetable saplings are damaged to an extent in by slug *F. alte,* compared to younger seedlings both by leaf damage and stem cutting (Kaur and Kaur, 2003) sponge gourd leaf margins were of 10.36 per cent and stem cutting was to the extent of 9.99 per cent.

Activity of slug *F. alte* in vegetable fields was affected by interactive effect of various ecological conditions like air and soil temperature, soil texture and structure, pH, soil moisture, soil organic carbon, phosphorus and nitrogen components, availability of shade and shelter and presence of wet and damp conditions (Kaur and Kaur, 2004; Kaur and Kaur, 2006). The slug *F. alte* in vegetable fields and gastropods in plant nurseries preferred sandy loam alkaline soil, medium in organic matter and nitrogen, high in phosphorus and potassium in soil. Higher is the organic matter, phosphorus and potassium in soil, higher is the slug density and hence greater damage (Kaur and Chhabra, 2009). However, soil moisture, soil temperature, sunshine, soil bulk density and porosity were the more effective factors to determine surface active gastropod population (Panjgotra, 2012). Slug density was maximum during third week of August, i.e. 3.33± 0.66 slugs per m^2 (with casein) and 3.00± 1.00 slugs per m^2 (without casein) during first week of September (Mehta, 2010).

MATERIAL AND METHODS

Vegetable fields at three villages viz; Bhadalwad, Sanghera both of district Barnala and Dasaunda Singh Wala of district Sangrur were surveyed. Population density, structure and fluctuation throughout the crop period of various vegetables were studied by counting the number of slugs active at surface by placing damp sacs at 10 sites selected randomly in each village at fortnightly intervals. Sacs were moistened by sprinkling water on them and placed in evening (1800-1900 hr) and slugs under them were collected in the morning (0600-0700 hr) on the third day in all the villages. Length, breadth and weight of caught specimen were measured in the laboratory. Soil moisture and soil temperature were also observed along with slug collection. Soil temperature was noted with the help of thermometer.

Soil samples were taken from the experimental sites at depth of 0-15 cm for testing of soil pH, soil texture, and organic matter, inorganic components like nitrogen, phosphorus and potassium at the Department of Soils, PAU, Ludhiana. Bulk density of soil was determined in the experimental sites with the help of cylindrical steel ring. The ratio of dry mass of the soil inside the soil core to the inner volume of the steel ring was expressed as bulk density in g/cm^3. Porosity and particle density were also calculated. The analysis of all the edaphic factors was carried out with density data of slugs from vegetable fields of three villages.

RESULTS AND DISCUSSION

Slug density population and its structure at Bhadalwad village in relation to edaphic factors: The slugs were available from March to mid November, for remaining period they were in hibernation. In March, slug density was found to be 0.4 slug/m^2 with soil temperature of 21.36ºC (at 5cm) and 20.87ºC (at 10 cm) and soil moisture of 15.6 per cent. This slug density was further increased on first week of May. Slug population further decreased in June i.e. 0.4 slug/m^2 with soil moisture content of 13.50 per cent and with maximum soil temperature of 34.50ºC at 5cm and 33.50ºC at 10cm. Maximum slug density population density was found in last week of August (31 August) in Bhadalwad village i.e. Maximum soil moisture was found on 31 August, so that the slug population. This population further decreased to 0.3 at soil moisture of 22.60 per cent and soil temperature of 19.02ºC (at 5cm) and 17.90ºC (at 10cm). The maximum adult size of the slug, *F. alte* ranged between 6.1 cm in length, 1.4cm in breadth and the average weight was 6.1 g (Table 5) in Bhadalwad village (Table 1 and 5).

Slug density population and its structure at Sanghera village in relation to edaphic factors: The slugs were available from March to mid November, for remaining period they were in hibernation. Least slug population was found in March i.e. 0.1 slug/m^2 with soil moisture content of 15 per cent and soil temperature of 20.77ºC (at 5cm) and 20.27ºC (at 10 cm). This slug density was further increased in May. The slug population decreased to 0.2 on 7 June with soil moisture content of 8.40 per cent and with soil temperature of 33.60ºC at 5cm and 31.01ºC at 10cm. This decrease in slug density might be due to maximum soil temperature. Maximum slug population density was found in first week of September in Sanghera village i.e. 1.3±0.26, where soil moisture found was maximum 25.40 per cent and soil temperature found was 23.80ºC at 5 cm and 23.65ºC at 10 cm. This slug population further decreased in first week of

Table 1. Population density of brown slug, *Filicaulis alte* in vegetable field at Bhadalwad village in relation to edaphic factors (Mean ±SE)

Date/Year 2013	Number of slugs active at surface m^{-2}	Per cent soil moisture	Mean soil temperature* (ºC) at different depth	
			5 cm	10 cm
17-Mar	0.4±0.16	15.6±0.65	21.36±0.18	20.87±0.27
01-Apr	0.3±0.15	20.00±0.84	22.62±0.05	22.40±0.05
17-Apr	0.4±0.16	21.60±1.22	23.75±0.02	23.20±0.00
03-May	1.0±0.21	21.00±1.16	27.27±0.42	26.77±0.57
19-May	0.5±0.22	22.20±0.96	30.95±0.34	30.45±0.15
05-Jun	0.4±0.22	13.50±1.72	34.50±0.05	33.50±0.31
21-Jun	0.6±0.22	13.60±1.02	30.06±0.02	29.98±0.06
07-Jul	0.4±0.16	16.20±0.81	29.92±0.16	30.07±0.40
23-Jul	1.1±0.31	19.20±0.67	28.43±0.22	28.25±0.08
08-Aug	1.0±0.25	17.80±1.13	26.41±0.16	26.28±0.03
24-Aug	0.8±0.24	19.40±0.66	25.98±0.23	25.63±0.26
31-Aug	1.2±0.24	26.40±0.58	23.77±0.02	23.46±0.01
16-Sep	0.4±0.27	25.00±0.68	22.82±0.02	22.76±0.07
02-Oct	0.8±0.29	22.60±0.52	22.92±0.01	22.70±0.00
18-Oct	0.6±0.16	22.80±0.32	22.87±0.07	22.56±0.11
3-Nov	0.3±0.15	22.60±0.42	19.02±0.47	17.90±0.59

* Mean of morning and evening soil temperature

November The maximum adult size of the slug, *F. alte* ranged between 5.8 cm in length, 1.4cm in breadth and the average weight was 6.4 g (Table 2 and 5).

Slug density population and its structure at Dasaunda Singh Wala village in relation to edaphic factors: The slugs population was available from March to November and being in hibernation for remaining period of year. 0.4 slug/m^2 were found on 22 March at soil moisture content of 18.20 per cent and soil temperature of 21ºC (at 5cm) and 20.70ºC (at 10 cm). This slug population was further increased to 1.3 on 9 May at soil moisture content of 24.40 per cent and soil temperature of 26.35ºC (at 5 cm) and 25.55 (at 10 cm). This slug population further decreased in June to. After this period slug population density was stable from July to August. Maximum slug population density was found on 21 September 1.5 slug/m^2 where soil moisture found was maximum i.e. 25.60±0.65 per cent and soil temperature found was 22.92ºC at 5 cm and 22.81ºC at 10 cm. This slug population further decreased 8 November. The maximum adult size of the slug, *F. alte* ranged between 6.2 cm in length, 1.4 cm in breadth and the average weight was 6.5 g (Table 3 and 5).

The results indicated that the seasonal factors (soil moisture and soil temperature) might be optimum for the activity of slugs. Trends of slug activity in present findings were similar to as reported earlier by Kaur *et al.* (2012). They reported that slugs were active from March to November and

Table 2. Population density of brown slug, *Filicaulis alte* in vegetable field at Sanghera village in relation to edaphic factors (Mean ±SE)

Date/Year 2013	Number of slugs active at surface m^{-2}	Per cent soil moisture	Mean soil temperature* (ºC) at different depth	
			5 cm	10 cm
19-Mar	0.1±0.15	15.00±0.90	20.77±0.27	20.27±0.47
04-Apr	0.4±0.16	18.70±1.27	22.28±0.22	21.54±0.24
20-Apr	0.4±0.22	20.60±0.66	23.08±0.29	22.67±0.17
06-May	1.1±0.10	24.00±0.73	26.99±0.38	26.30±0.45
22-May	0.5±0.22	20.60±0.79	30.35±0.20	29.77±0.17
07-Jun	0.2±0.15	8.40±0.40	31.60±0.21	31.01±0.18
23-Jun	0.4±0.22	14.00±0.51	31.17±0.28	30.06±0.46
09-Jul	0.8±0.20	15.40±0.73	28.68±0.09	28.19±0.27
25-Jul	0.5±0.16	17.40±0.66	28.65±0.03	28.96±0.15
10-Aug	0.7±0.21	18.20±0.35	27.62±0.17	27.12±0.27
26-Aug	1.0±0.25	21.20±1.04	25.29±0.06	24.98±0.05
02-Sep	1.3±0.26	25.40±0.78	23.80±0.26	23.65±0.37
18-Sep	0.9±0.23	23.60±0.40	23.24±0.01	23.13±0.04
04-Oct	1.0±0.29	22.60±0.30	22.94±0.02	23.20±0.46
20-Oct	0.5±0.29	22.20±0.20	22.75±0.15	22.41±0.14
05-Nov	0.4±0.16	22.20±0.35	22.37±0.19	21.89±0.34

* Mean of morning and evening soil temperature

Table 3. Population density of brown slug, *Filicaulis alte* in vegetable fields at Dasaunda Singh Wala village in relation to edaphic factors (Mean ±SE)

Date/Year 2013	Number of slugs active at surface m^{-2}	Per cent soil moisture	Mean soil temperature* (ºC) at different depth	
			5 cm	10 cm
22-Mar	0.4±0.16	18.20±0.35	21.00±0.30	20.70±0.20
07-Apr	0.4±0.16	20.50±0.47	23.17±0.26	22.64±0.28
23-Apr	0.6± 0.22	22.60±0.42	24.14±0.32	23.51±0.52
09-May	1.3±0.26	24.40±0.40	26.35±0.13	25.55±0.20
25-May	0.6±0.22	22.20±0.46	30.00±0.17	29.35±0.30
10-Jun	0.5±0.16	12.20±0.96	30.56±0.38	29.90±0.55
26-Jun	0.6±0.22	14.40±1.06	27.14±0.13	26.91±0.01
12-Jul	1.0±0.20	18.40±0.40	27.52±0.45	27.43±0.27
28-Jul	1.0±0.10	17.80±0.55	27.05±0.24	26.83±0.29
13-Aug	1.0±0.21	17.60±1.02	26.25±0.15	26.02±0.42
29-Aug	1.2±0.23	22.40±1.42	24.52±0.07	24.26±0.05
05-Sep	0.8±0.29	24.80±0.53	23.41±0.00	23.23±0.06
21-Sep	1.5±0.24	25.60±0.65	22.92±0.15	22.81±0.22
07-Oct	1.0±0.21	23.20±0.44	22.40±0.05	22.22±0.10
23-Oct	1.2±0.24	22.60±0.30	22.24±0.16	22.03±0.09
08-Nov	0.8±0.20	22.40±0.40	20.75±0.20	20.27±0.22

* Mean of morning and evening soil temperature

more so from June to September. These remained in hibernation from December to February. Higher numbers of slugs were found during the month of August and September in vegetable field of Kaddon village, Ludhiana. According to Jagtap (2000) a close relationship existed between densities of slugs and water holding capacity of soil. Measures undertaken to increase the water holding capacity of the soil, thus create more favorable conditions for gastropods.

Comparison of slug population density in three villages in relation to soil components: The results of comparison of different soil components in vegetable fields at three villages indicate that the slugs at Bhadalwad village preferred sandy loam soil with medium range of organic matter, high range of nitrogen, phosphorus, potassium and alkaline soil. In Sanghera village, slugs preferred sandy loam soil with medium range of organic matter, medium range of nitrogen and high amount of potassium, phosphorus and alkaline soil. At Dasaunda Singh Wala village slugs preferred sandy loam soil with high range of organic matter, medium range of nitrogen and with high range of phosphorus and potassium and alkaline soil. In Dasaunda Singh Wala village significantly more population density was found than other two villages. All the soil components except pH, clay content and particle density were found to be significantly different in Dasaunda Singh Wala village than at Bhadalwad and Sanghera village. Bulk density was found to be significantly less and porosity was found to be significantly more in Dasaunda Singh Wala village than other two villages. Therefore, slug density found was also significantly more in Dasaunda Singh Wala village than other two villages (Table 4).

In findings of present study it was seen that maximum slug density was found in Dasaunda Singh Wala village, where slug density was significantly more than slug density found in other two villages. This might be due to significant difference in soil components in three villages. In Dasaunda Singh Wala village, higher soil EC, organic matter, less nitrogen, more potassium and phosphorus was

Table 4. Analysis of different soil components taken from the vegetable fields of three villages

Soil characteristics	Bhadalwad village	Sanghera village	Dasaunda Singh Wala village	C.V.	CD (5%)
Soil pH	7.93±0.70	7.83±0.41	7.43±0.33	11.35	-
Soil EC	0.41±0.00	0.32±0.01	0.54±0.03	9.98	0.85
Sand (%)	59.10±0.98	48.26±2.54	51.66±0.66	6.31	6.68
Silt (%)	15.20±0.55	9.50±0.68	17.43±0.70	12.38	3.47
Clay (%)	25.43±1.77	27.36±0.29	26.16±2.39	11.34	-
Organic Matter (%)	0.46±0.02	0.51±0.01	0.76±0.02	7.10	0.81
Nitrogen (kg/acre)	230.66±6.40	206.33±8.11	204.33±3.29	5.09	21.73
Phosphorus (kg/ acre)	36.03±2.18	31.40±1.41	44.70±1.67	12.81	9.56
Potassium (kg/ acre)	151±2.08	149.66±3.94	180.00±5.79	4.55	14.56
Bulk density (g/cm^3)	1.44±0.01	1.44±0.01	1.36±0.00	1.84	0.52
Particle density (g/cm^3)	2.26±0.09	2.12±0.06	2.49±0.16	10.57	-
Porosity (%)	47.33±1.09	45.93 ±0.64	53.80±1.48	4.61	4.51
Overall Slug density	0.64±.07	0.63±0.06	0.94±0.08	44.50	0.23

Values are Mean ± SE; * Significant at $p > 0.05$

Table 5. Seasonal variation in number and size of slugs active on surface in vegetable fields at three villages

Period of the year (2013)	Number of slug caught	Length (cm)	Breadth (cm)	Weight (g)
Bhadalwad village (Distt. Barnala)				
March-April	11	2.4-3.2	0.4-0.6	2.8-3.6
May	15	3.0-4.0	0.5-0.7	3.4-4.5
June-July	25	2.1-5.6	0.5-1.4	2.5-5.5
August-September	39	3.6-5.5	0.7-1.2	4.2-6.0
October-November	17	4.2-6.1	0.7-1.2	3.9-6.1
Sanghera village (Distt. Barnala)				
March-April	5	2.5-3.6	0.4-0.6	2.9-4.1
May	16	3.2-4.5	0.5-1.1	3.5-4.8
June-July	19	2.8-5.6	0.7-1.4	2.2-6.4
August-September	39	3.2-5.6	0.7-1.2	3.6-6.2
October-November	20	4.1-5.8	0.6-1.2	3.8-5.2
Dasaunda Singh Wala village (Distt. Sangrur)				
March-April	15	2.5-3.0	0.4-0.7	2.5-3.6
May	19	3.1-4.8	0.6-0.8	3.8-5.2
June-July	37	2.6-5.8	0.6-1.3	3.3-6.5
August-September	49	3.1-6.2	0.6-1.4	3.9-6.2
October-November	31	3.2-5.9	0.7-1.2	4.1-6.0

found than other villages. Less bulk density and high porosity was found in Dasaunda Singh Wala village which was significantly different with other two villages. Therefore, maximum slug density was found in Dasaunda Singh Wala village. Kaur *et al.* (2012) reported that the soil at Kaddon village vegetable fields was more alkaline, with higher EC, nitrogen, phosphorus and total porosity but lower organic matter and bulk density as compared to Doraha village. This indicates that the slugs might prefer alkaline soil with lower bulk density and high porosity. Godan (1983) reported that the number of individuals as well as the variety of species is higher in alkaline soil than on wide variety of soils. Davis (1989) also reported the similar results with present findings that increased soil compaction (bulk density) at levels within the range in arable fields can reduce the slug mobility and thus damage to the crops.

These results, thus pointed out that slug, *F. alte* preferred sandy loam soil in all the three villages. Maximum slug density population was found maximum at Dasaunda Singh Wala village with low bulk density of soil, nitrogen and higher soil EC, organic matter, potassium, phosphorus and porosity than other villages.

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Virulence of *Bacillus thuringiensis* isolates against *Chilo partellus* (Swinhoe)

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Abstract: The spore crystal complex of five *Bacillus thuringiensis* isolates were prepared and evaluated against second and third instar larvae of *Chilo partellus* (Swinhoe) under laboratory conditions. Among these isolates, *Bacillus thuringiensis* 4D4 caused 82.22 per cent mortality against second instar larvae after 10 days of treatment and was at par with MTCC 868 and commercial formulation DELFIN. Similarly, Bacillus isolate MTCC 868 caused 75.55 per cent mortality against third instar larvae and was at par with 4D4 and DELFIN.

***Key Words*:** *Bacillus thuringiensis,* Efficacy, *Chilo partellus*, Bioassay

Maize (*Zea mays* L.) is an important cereal crop which serves as staple food for millions in the world. It is important cereal crop of Punjab having an area of 129 thousand hectares with a production of about 475 thousand tonnes during 2013 (Anonymous, 2014). One of the major factors for the poor maize yield is the insect pest complex as it is attacked by 130 species of insects (Sarup *et al.,* 1987). Among these insect pests, maize borer, *Chilo partellus (Swinhoe) is economically important pest attacking summer maize.* Under Punjab conditions, it is reported to cause 57.70 to 79.40 per cent losses in grain yield (Singh & Sajjan, 1982). Various methods of control of *C. partellus* have been developed to check its damage to maize crop and there have been more emphasis on chemical control. Insecticides cause environmental pollution, residues, development of resistance, pest resurgence. So, an alternative to chemical control is biological control which is a crucial part of integrated pest management. Insecticides based on *Bacillus thuringiensis* formulations are highly specific in their action, safe and effective in control of wide spectrum of agriculture-pests (Mazid *et al* 2011). Therefore, present study was done to screen *Bacillus thuringiensis* isolates for its high insecticidal activity at minimum concentrations against *C. partellus* in maize.

MATERIAL AND METHODS

Five standard isolates of *Bacillus thuringiensis* viz. MTCC 868, MTCC 4715, 4D4, 4J3 and PDBC Bt-1 were procured from different sources. All these isolates were maintained at refrigerated temperature on T3 media. Two commercial formulations of *Bacillus thuringiensis* var. *kurstaki* i.e. DELFIN and LIPEL manufactured by Cetris, USA and Agrilife, SOM Phytopharma (India) limited, respectively were also evaluated alongwith untreated control.

Preparation of spore crystal complex: The spore-crystal toxin (SCT) was produced as per the method of Salama *et al.* (1981) and Dulmage *et al.* (1970) with little modification. The inoculum was prepared by transferring a loopful of cells from nutrient agar slants into 50ml of Luria medium. After overnight incubation at 30±2ºC at 200 rpm, the growth was inoculated into culture flasks containing T3 medium. One ml of the overnight culture was inoculated into 250ml flasks containing 100 ml of the above media. The flasks were fermented at 30±2ºC at 200 rpm on shaker incubator for three days. After that crystal mixture was harvested in pellets by centrifugation. The pellet obtained from 1 litre of culture was re suspended in lactose solution and the mixture was stirred. Then, the high purity acetone (4 volume) was added with stirring to a final volume of 1 litre. The mixture was filtered through Whatmann Filter paper to collect the precipitate containing spores and crystals. The dried powder was then suspended in 100ml of CMC-Triton X-100 .The protein content was estimated as per the method of Lowry *et al.* (1951).

Collection and rearing of *Chilo partellus:* Maize borer, *C. partellus* (Swinhoe) larvae were collected from infested maize and sorghum fields and were reared on artificial diet under laboratory conditions. The second and third instar larvae of *C. partellus* reared on artificial diet were used for bioassay studies. The spore crystal complex of five *Bacillus thuringiensis* isolates and isolates obtained from two commercial formulations at three different concentrations were evaluated against second and third instar larvae of *C. partellus* along with untreated control. There were eight treatments with three replications and ten larvae per replicate.

Insect Bioassay: The crystal toxin complex was inoculated to the test insect larvae by incorporating it into the agar based diet while still in the liquid state (Seshu Reddy and Davies, 1979). Ten milliliter of freshly prepared artificial diet was poured in 50 ml glass or plastic vials. One milliliter of different concentrations of spore crystal toxin (SCT) complex viz. 125, 250 and 500µg/ml was inoculated in diet before solidification. The larvae previously starved for 10 minutes were then individually transferred to each inoculated vial and incubated at room temperature (20-28º C). Untreated controls without any crystal suspension was run simultaneously. The larvae were observed daily for mortality and cumulative mortality was recorded upto 10 days.

RESULTS AND DISCUSSION

Second instar: The mortality of second instar larvae of C. *partellus* was very low and non-significant upto two days of treatment. After three days of exposure, mortality ranged from 2.22 to 20.00 per cent. Maximum mean cumulative per cent mortality was recorded in commercial formulation DELFIN isolate which was at par with isolates MTCC 4715, 4D4 and commercial formulation LIPEL isolate (Table 1). After seven days of exposure, maximum mean cumulative mortality (56.66%) was recorded in 4D4, which was at par with DELFIN (56.66%). This was followed by isolate MTCC 868 and was at par with isolate 4J3, MTCC 4715 and commercial formulation LIPEL SP. However, minimum mean cumulative mortality of 16.66 per cent was recorded in PDBC Bt1. After ten days of exposure, maximum mean cumulative mortality (82.22%) was recorded in 4D4, which was at par with DELFIN (78.88%) and MTCC 868 (76.66%). Among various concentrations, maximum mean larval mortality (68.88 %) was recorded in highest concentration i.e. 500µg/ml and it was significantly better than both the concentrations viz. 250 and 125µg/ml which recorded 64.81 and 57.03 per cent mortality, respectively (Fig 1).

Third instar: After three days of exposure, all the treatments gave significantly higher mortality than control (4.44%). Maximum mean cumulative mortality (15.55%) was in isolate MTCC 868 being at par with all the isolates viz. 4D4, PDBC Bt-1, 4J3, DELFIN and LIPEL SP. However, minimum mortality was in isolate MTCC 4715 (8.88%). After seven days of exposure mean cumulative per cent mortality was maximum (50%) in MTCC 868 which was at par with 4D4 (43.33%) and Delfin (41.11%). After ten days of exposure, cumulative mean per cent mortality was maximum (75.55%) in MTCC 868 which was at par with DELFIN and 4D4 followed by commercial formulation LIPEL which was at par with MTCC 4715 Minimum mean cumulative percent mortality was recorded in isolate PDBC Bt-1 (52.22%) (Table 1). Among various concentrations, maximum mortality was recorded at higher concentration (Fig 1).

It can be concluded that among all seven *B. thuringiensis* isolates 4D4and MTCC 868 were most potent isolates against second and third instar larvae of *C. partellus* which recorded maximum mortality and were at par with DELFIN. Further, it was found that mortality at higher concentration (500µg/ml) was significantly better than middle concentration (250µg/ml) which in turn was significantly better than the lower concentration (125µg/ml) (Fig 1).

The present findings corroborates the earlier results

Table 1. Laboratory evaluation of *Bacillus thuringiensis* isolates against second instar and third instar larvae of *C. partellus*

Treatment	Cumulative per cent mortality of *C. partellus*					
	Second instar larvae			Third instar larvae		
	3 days	7 days	10 days	3 days	7 days	10 days
4J3	8.88 (15.43)	43.33 (41.01)	65.55 (54.28)	12.22 (20.23)	38.88 (38.51)	56.66 (48.85)
PDBC Bt-1	2.22 (4.79)	16.66 (22.20)	28.88 (32.32)	12.22 (20.23)	24.44 (29.43)	52.22 (46.29)
MTCC 868	11.11 (18.28)	45.55 (42.39)	76.66 (61.42)	15.55 (22.77)	50.00 (45.00)	75.55 (60.52)
MTCC 4715	18.88 (25.48)	42.22 (40.34)	66.66 (54.85)	8.88 (15.43)	40.00 (39.06)	65.55 (54.52)
4D4	15.55 (22.77)	56.66 (49.24)	82.22 (66.82)	14.44 (21.21)	43.33 (41.08)	73.33 (59.28)
LIPEL	13.33 (21.13)	45.55 (42.39)	74.44 (59.85)	12.22 (20.23)	37.77 (37.35)	67.77 (55.63)
DELFIN	20.00 (26.22)	56.66 (49.99)	78.88 (63.07)	12.22 (19.18)	41.11 (39.82)	74.44 (59.78)
Control	0.00 (0.90)	14.44 (21.87)	22.22 (27.63)	4.44 (8.49)	16.66 (22.30)	28.88 (32.32)
CD (p=0.05)	(5.50)	(6.33)	(5.65)	(5.98)	(5.24)	(4.49)

Values in parentheses are arc sine transformations

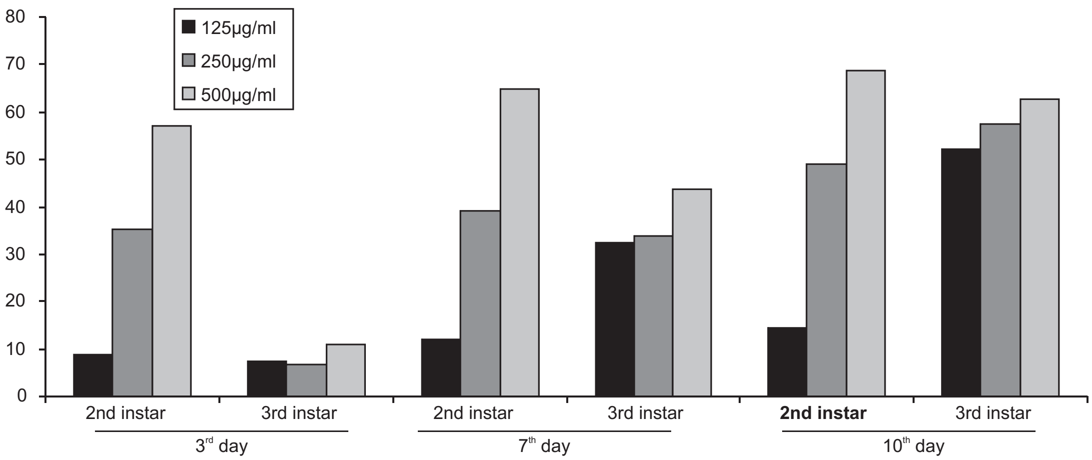

Fig 1. Efficacy of *Bacillus thuringiensis* Spore Crystal Toxin Complex (SCT) for the control of second instar and third instar larvae of *Chilo partellus* at different concentrations

of Kimani *et al* (2010) who observed that two isolates Bt 44 and Bt 48 were the most potent against first instar larvae of *C. partellus*. Opondo *et al* (2010) isolated three *B. thuringiensis* isolates from soil samples and reported that these isolates showed different toxicity to the larval stages of *C. partellus* with isolates 1M exhibiting the highest toxicity of specificity (Pigott and Ellar, 2007).

In the present investigation, it was observed that the per cent mortality was very low and non-significant upto two days of exposure. This might be due to the fact that *B. thuringiensis* being stomach poison, when enters into the midgut of insect, it gets dissolved in the alkaline pH, releasing endotoxins (Schnepf*et al*., 1998) thereby killing the insect. Present results showed that with increase in concentration there is increase in mortality. Therefore, there is direct relationship between increase in concentration and mortality. Mortality at higher concentration (500µg/ml) was significantly better than middle concentration (250µg/ml) which in turn was significantly better than the lower concentration (125µg/ml) when evaluated against both 2nd and 3rd instar larvae of spotted stem borer, *Chilo partellus* (Swinhoe). Kamala and Padmavathamma (1997) reported that the per cent larval mortality in all the instars of *B. mori* was higher at higher concentrations of *B. thuringiensis*.

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Optimization of Spawn Production Technology of *Agaricus bisporus* (Lange) Sing.

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Abstract: The present investigation was carried out to improve the existing technology of spawn production technology of *Agaricus bisporus* (Lang) Singh to produce quality spawn with high yield potential to make this venture a profitable. Various factors that could affect spawn mycelial growth rate are the substrate boiling period (20-50 minutes), supplementation with $CaCO_3$:$CaSO_4$ and inoculum size. The grains boiled for 30 minutes supplemented with $CaCO_3$:$CaSO_4$ in ratio 1:2 produced maximum linear mycelial growth. Beneficial in mycelial growth rate was observed by using one and two bits of inoculum with two bits of culture. Yield data after four weeks of harvest gave 10.5 -15.25 kg mushrooms per quintal compost.

***Key Words*:** *Agaricus bisporus*, Spawn Supplement, Spawn Age, Yield Potential

Agaricus bisporus, the white button mushroom is an important cultivated variety grown with 35-40% share in the world production. The process of mushroom cultivation involves selection of an acceptable mushroom species/development of active spawn, preparation of selective substrate/compost, care of mycelial (spawn) running, management of fruiting/ mushroom development and harvesting mushrooms carefully. Failure to achieve a satisfactory harvest may often be traced to unsatisfactory spawn. The process of spawn production is a technical process and requires a lot of experience and specialized knowledge and care (Chinda and Chinda, 2007). It has been estimated that 15-20 per cent of commercial spawn is lost due to contamination by bacteria, fungi, or actinomycetes every year. The availability of the quality of spawn, free from contaminants is the most critical factor in boosting the mushroom production. Most of the grains are good substrate for spawn preparation of *A. bisporus*. Reddy *et al.* (2013) carried out spawn production of *A. bisporus* by using sorghum grains. There is a need to improve upon the existing technology to obtain pure culture at minimum incubation period with minimum loss due to contamination. During the process of spawn production, selection of raw material and their disinfection is very important. Therefore, boiling and soaking of grains, addition of calcium carbonate and calcium sulphate and sterilization of substrate assumes special significance. Although protocol for spawn preparation has been standardized yet a problem of high rate of contamination could make it non- profitable. Present study has been planned to standardize the existing spawn preparation protocol in order to minimize the rate of contamination and to obtain maximum biological efficiency.

MATERIAL AND METHODS

Agaricus bisporus strain U3 was procured from Mushroom Research Lab, Department of Microbiology, Punjab Agricultural University, Ludhiana. The culture was grown on Potato Dextrose Agar (PDA) medium at 25$\pm$ 1°C. Wheat grain spawn was prepared using the standard methodology of Garcha (1997). Three wheat grain varieties (PBW 343, PBW 621 and HD 2967) were used to prepare spawn to study the effect of boiling period on the mycelial growth; grains were boiled for 20-50 minutes. The boiled grains were then mixed with gypsum ($CaSO_4.2H_2O$, Lab grade) and chalk powder ($CaCO_3$) @ 2 and 4% w/w, respectively. These grains were then filled in the spawn tubes (25 mm×198 mm) to a height of approximately 120 mm, autoclaved at 20 ± 1 lbs for 90 min. After overnight cooling, each tube was inoculated aseptically with mycelial bits of size 10 mm of standard inoculum (15 days old) of A. bisporus U3, incubated at 25+1°C and linear growth was measured periodically at 3 day interval till complete impregnation for a period of 33days.

To study the effect of supplementation with calcium carbonate and gypsum on the mycelial growth rate, boiled and cooled grains were supplemented with three different ratios of $CaCO_3$ (chalk powder) and $CaSO_4$ (gypsum) i.e., 1:1 (30g: 30g) 1:2 (20g: 40g), 2:1 (40g: 20g) and filled in spawn tubes, autoclaved, inoculated with culture and incubated at 25+1°C to measure linear growth periodically at 3 day interval till the complete impregnation of the grains upto a period of 33days as above.

Agaricus bisporus is a slow growing mushroom. There is a need to obtain pure culture at minimum incubation period with minimum loss due to contamination. Boiled, mixed grains were filled in bottles up to a height of 100 mm in bottles. These bottles were divided into two groups and then inoculated aseptically with mycelial bits from the standard inoculum. First set of bottles was inoculated with one bit of the mycelium of size 10 mm. The second set of bottles was inoculated with two bits of mycelium. Bottles were incubated at 25±1°C to study mycelium growth rate and rate of contamination in both set of bottles. The linear growth in mm was recorded till the mycelium growth get merged in the bottles

Cultivation study: Cultivation trials using *A. bisporus* were conducted indoor under natural climatic conditions of temperature (14-22°C) and relative humidity (70-90%) at the University Mushroom Research Complex using standard methodology (Garcha, 1997). The observations were made on the period taken for case run, pinning, and first harvest after spawning, yield (kg quintal^{-1} compost) and no. of fruit bodies along with average weight of a fruit body.

RESULTS AND DISCUSSION

Effect of wheat variety and boiling period on mycelial growth of *Agaricus bisporus:* A periodic increase in linear mycelial growth was observed from 18.3 mm upto 117.3 mm from 3-33 days incubation at 25±1°C. There was no significant variation among the wheat varieties indicating that any of the three varieties can be used for the preparation of the mushroom spawn.

A gradual increase in linear mycelial growth was observed from 12.7 mm to 118.3 mm with maximum on grains boiled for 30 min (Table 1). Royse *and* Zaki (1991) reported that the preparation of grain spawn may vary depending on the type of spawn manufacturing system used. Pre-cooking, or boiling in water for 20-30 min, of millet was required because the grain tends to become soft and sticky if water is added immediately prior to sterilization. Pre-cooking, followed by coating the millet with 2-3% (dry weight) precipitated calcium carbonate (PCC) before sterilization had minimized the stickiness of the grain to provide a more flowable product. Rye grain, on the other hand, had a much thicker seed coat so precooking was not required and water and PCC were added immediately before sterilization.

Effect of calcium carbonate and calcium sulphate on spawn preparation: Out of three ratios of $CaCO_3$ and $CaSO_4$ (1:1(30g: 30g) 1:2 (20g: 40g), 2:1 (40g: 20g), maximum linear mycelial growth was observed when 1:2 ratio, whereas other two ratio showed no significant variation in linear mycelial growth (Table 2). Khan *et al.* (1991) reported that a combination of 2 per cent gypsum and 6 per cent lime added to the wheat grain was best for spawn production of *Agaricus bisporus*. Spawn production studied by Pandey (1998) revealed that the addition of chalk powder and gypsum decreased the stickiness of grains, made them free flowing besides decreasing the incidence of bacterial contamination, which is important in commercial spawn production. The linear mycelial growth was found fully covered in 12 days when 2 bits were inoculated, whereas it took 21 days for complete impregnation when one bit was used (Table 3).

Table 1. Effect of different boiling periods on the mycelial growth of *Agaricus bisporus*

Boiling period (min)	Linear mycelial growth (mm) at different incubation periods (days)					
	3	6	12	18	24	30
20	12.7	18.7	31.3	45.0	57.3	72.3
30	20.3	31.0	50.7	67.7	88.6	109.0
40	17.6	25.7	45.3	63.3	80.3	96.3
50	16.7	24.3	40.3	56.6	74.7	91.3
CD (0.05)	2.55	2.30	2.54	2.30	2.17	2.66

Table 2. Effect of $CaCO_3$: $CaSO_4$ ratio on mycelial growth of *Agaricus bisporus*

Additives $CaCO_3$:$CaSO_4$	Linear mycelial growth (mm) at different incubation periods (days)				
	6	12	18	24	30
1:1(30:30g/1000g)	22.7	36.3	50.7	65.0	80.7
1:2(20:40g/1000g)	30.3	39.3	67.7	88.3	107.0
2:1(40:20g/1000g)	21.6	26.7	51.3	67.7	81.7
CD (0.05)	4.47	4.57	4.32	4.11	2.75

Table 3. Effect of inoculums size on mycelial growth of *Agaricus bisporus*

Inoculum size	Linear mycelial growth (mm) at different incubation periods (days)						
	3	6	9	12	15	18	21
1 bit of inoculum	14.3	27.0	41.0	53.3	69.3	83	mycelium merged
2 bits of inoculum	28.0	53.7	79.6	mycelium merged	-	-	-
CD (0.05)	2.4	2.6	3.7	-	-	-	-

Yield evaluation of *Agaricus bisporus* U3 spawn produced under standardized conditions: *A. bisporus* spawn bottles were used for sowing after 10, 20, 30, 40 days of incubation wheat straw based compost. The case run took 17-22 days while pinning started 37-42 days after spawning (Table 4). First harvest was made 40-45 days of spawn run. Yield data after 4 weeks of harvest gave 10.5 -15.25 kg mushrooms per quintal compost.

Table 4. Effect of spawn age on the yield potential of *Agaricus bisporus*

Spawn age (d)	Case run weight (d)	Pinning after spawning (d)	First harvest after spawning (d)	Yield (kg q^{-1} compost)	No. of fruit bolls	Average weight of FB (g)
10d	19	39	43	13.00	1252	10.3
20d	17	37	40	15.25	1048	14.5
30d	19	39	42	13.50	1400	936
40d	22	42	45	10.50	885	11.8
CD (0.05)				0.72	112	

Maximum yield was harvested when G1 spawn after 20 days of incubation was used for sowing. The yield from 10 day and 30 day spawn was at par, while it was lowest in 40 day old spawn. The number of fruit bodies ranged between 885-1252 with maximum from 30 day old spawn. Average weight of fruit body was between 9.6 – 14.5 g with maximum from 20 day old spawn harvest. No disease incidence was recorded in the crop sown with 10 and 20 day old spawn, whereas *Coprinus* and green mould was recorded from 30 d and 40 d old spawn crop harvest. The observations suggested that 20 day old spawn could be used for maximum harvest (Table 4). Pani (2011) reported that the increase in spawn age beyond 21 days reduced the number of sporophores, which could have been due to apparent loss of vigor and viability of fungal mycelia. Two month old spawn sustained the least weight of sporophores but supported maximum individual weight of fruiting body.

Present investigation had shown that any of the wheat variety can be used as substrate for the preparation of the spawn. The grains should be boiled for 30 min, supplemented with $CaCO_3$:$CaSO_4$ in 1:2 ratio. Use of two bit culture was beneficial for early impregnation of grains in 12 days in two bit culture, whereas, it took 21 days in one bit culture at temperature 25°C. Yield harvested was maximum (15.25 kg q^{-1} compost) in 20 day old spawn prepared under conditions optimized during the present study.

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Physico-Chemical and Phycological Profile of River Pandu at Kanpur

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Abstract: River Pandu flowing on the southern outskirts of Kanpur is severely subjected to anthropogenic stress all along its stretch passing through Kanpur. Municipal and industrial wastes of the southern Kanpur is disposed into it without any pre- treatment, which is likely to adversely affect its physico-chemical and phycological profile. The river was investigated during 2009-2010 revealed that discharge of wastes in to the river adversely affected its water quality and algal profile. Water quality was adversely affected in terms of transparency and dissolved oxygen, which were quite low while colour, total solids, B.O.D. and nutrients were quite high indicating the eutrophic nature of water. Water had detectable amounts of heavy metals specially Cu^{+2}, Cr^{+6} and Zn^{+2}. Only 30 genera and 42 species were recorded. Algal profile of the river at different stations lacked consistency of results due to fluctuating quality and quantity of wastes discharged. Low diversity and similarity index values reported are indicative of an unhealthy and stressed ecosystem.

Key Words: Anthropogenic Stress, Waste Effluents, Algae, River Pandu, Kanpur

River Pandu- a wee tributary of river Ganga, owes its provenance from the pumped storage of Lower Ganga Canal approximately 110 kilometers north-west of Kanpur. It flows on the southern outskirt of Kanpur through Panki Industrial Estate (PIE) covering a distance of about 64 kilometers before its confluence with river Ganga in south-west of Kanpur in Fatehpur district. During its course through Kanpur, five major drains carrying sullage water, sewage and industrial effluent discharge their wastes in to it without any pre-treatment (Tiwari, 2004; Tiwari and Bajpai, 2011). Lean flow of the river does not permit enough dilution of the pollutants to permit natural purification of the river to the desired extent, which is likely to affect the phyco-diversity of the river. Hence the present study was undertaken to assess its physico-chemical and phycological profile at its Kanpur stretch.

MATERIAL AND METHODS

Material sampling was done approximately half kilometer downstream of five major outfalls discharging waste into it and sixth sampling station, just half kilometer upstream of its confluence with river Ganga at Fatehpur district during 2009-2010. The major outfalls are Thermal Power Plant drain, Panki Municipal drain, Ganda Nala, Halwa Khanda drain and Central Ordinance Depot (COD) drain. Sampling stations on the river were Tikra village, Panki Industrial Area, Mardanpura, Meharbanpura, Hamirpur Road Bridge and Sher Shah Suri bridge. Effluent, water and algal samples were collected and analyzed for qualitative and quantitative estimation of the pollutants and algae as per standard procedure (APHA, 1989). Samples were collected in thoroughly cleaned plastic bottles and were transported to the laboratory for qualitative and quantitative analysis. Algal cell number was estimated using Sedgewick-Rafter Counting cell (SR Counting Cell) and results have been expressed as number of individuals per liter after applying the appropriate correction factor. Algal identification was done with the help of pertinent literature on algae (Desikachary, 1959; Smith, 1950; Tiffany and Britton, 1952). Algal diversity was computed using standard indices (Shannon-Weaver 1963, Margalef, 1958). Taxonomic similarity was computed following Sorenson (1948).

RESULTS AND DISCUSSION

Results of the physico - chemical investigation of the waste effluents and river water are depicted in Table 1 and 2. River is a shallow river with a depth ranging from 1-2.5 meters but also has a few interspersed deeper zones of about 4 meters. Except a few small portions where the river bed is rocky and composed of small pebbles, it has a muddy bottom. River discharge fluctuates in between 3240-5450 m^3 per hour. River flows with a slow velocity that ranged from $<0.01 m^{-s}$ to 0.07 m^{-s}. Peak velocity was noticed in September and minimum in June.

Colour: Colour of the waste effluents varied widely ranging from light brown, red brown, blue, blackish brown to light black or murky. The qualitative as well as the quantitative variations in the effluent characteristics may be

Table 1. Physico-chemical characteristics of waste effluents of drains

Parameters	Tikra village	Panki industrial area	Mardanpura	Meharbanpura	Hamirpur road bridge	Sher Shah Suri bridge
Present status	Untapped	Untapped	Untapped	Untapped	Untapped	
Colour	Murky black	Murky black/Red brown	Murky	Black	Murky black	*
Odour	foul	Organic/pungent	Faecal foul	Faecal foul	Faecal foul	*
pH	7.7	8.6	7.9	7.9	8.3	
Temp. ^{o}C	34	36.2	37.4	33	32.4	
Transp.	Nil	Nil	Nil	Nil	Nil	
Total solids	1699	1308	1254	1112	760	
Suspended solids	1540	183	251	200	70	100
Dissolved oxygen	Nil	Nil	Nil	Nil	Nil	
B.O.D.$_5$	141	202	229	180	130	30
C.O.D.	304	440	475	302	271	250
Nitrate	Nil	Nil	Nil	Nil	Nil	
Ammonia	143.4	205	107.6	151.6	136.6	50
Urea	Nil	1.6	Nil	Nil	Nil	
Chloride	125	175	285	178	140	1000
Phosphate	1.6	2.4	4.4	1.8	2.2	5
Oil and Grease		+	+	+	+	

All values in mg l^{-1}except colour, odour, temperature (^{o}C) pH and transparency (cm)
+ Presence, - absence * all efforts should be made to remove colour and odour as far as possible

Table 2. Physico-chemical characteristics of the river water at different stations (n=12)

Parameter	Tikra village	Panki industrial area	Mardanpura	Meharbanpura	Hamirpur road bridge	Sher Shah Suri bridge
Colour	Murky	Murky Black	Murky black	Murky	Muddy	-
Odour	Nil	Foul	Faecal foul	Faecal foul	Nil	-
Temperature	25.3	27.8	25.7	26.8	25.6	27.1
Transparency	17.2	2.3	6.2	7.3	15.4	13.7
Total solids	121	934	587	830	417	469
pH	7.8	8.2	8.5	8.3	8	8.2
Total alkalinity	110.0	159.6	270.6	211.7	145.8	138.0
D.O.	5.5	2.4	1.8	2.3	3.7	4.1
B.O.D$_5$	10.3	39.5	45.2	67.1	44.4	30
C.O.D	20.3	220	165	144	69	23.7
Chloride	25.5	80.7	62.6	75.4	54.9	45
Total hardness	135	366	457	599	387	517
Ammonia	0.46	3.64	18.6	9.95	8.92	2.0
Nitrate	0.15	0.05	0.02	0.09	0.13	1.28
Phosphate	0.24	1.72	1.76	1.86	1.44	1.22
Sulphate	0.78	5.3	4.4	12.5	3.66	4.6

Values in mg l^{-1}l except colour, temperature (^{o}C), odour, transparency (cms) and pH

attributed to varied chemical and technical processes used in different industries, effluent of different industries in different drains and also to the relative proportion of the municipal and industrial wastes carried by them. A critical perusal of the data pertaining to effluent characteristics with prescribed ISI standards (IS: 1981) for wastes to be discharged into surface waters revealed that most of the parameters were either beyond or approaching the permissive limits. Discharge of these wastes in to the river adversely affected the river water quality as is obvious from the water quality gradients depicted in Table 3. Coloured water, low transparency, low dissolved oxygen coupled with significantly high values of BOD, COD, hardness, chloride, ammonia and phosphate all indicated the oxygen stressed polluted condition of the river. Except station 1, all the downstream stations were heavily polluted. The impact of this anthropogenic stress was also evident on the algal community of the river (Table 3-5).

An important factor affecting chemical reactions

Table 3. Phyco-Profile of the river

Algae	Tikra village	Panki industrial area	Mardanpura	Meharbanpura	Hamirpur road bridge	Sher Shah Suri bridge
Cyanophyceae						
Anacystis sp.	+	-	-	-	-	+
Merismopedia minima	+	-	-	-	-	+
Microcystis sp.	-	-	-	+	-	+
Nostoc sp.	+	-	-	-	-	-
Oscillatoria tenuis	-	+	+	+	+	-
Oscillatoria limosa	-	+	-	+	-	+
Oscillatoria princeps	+	-	-	+	+	-
Oscillatoria sancta	+	-	-	+	+	+
Oscillatoria curviceps	+	-	-	-	-	-
Phormidium tenue	+	+	+	+	+	-
Phormidium uncinatum	+	+	+	+	+	+
Chlorophyceae						
Actinastrum sp.	+	-	+	+	-	+
Ankistrodesmus sp.	-	+	-	+	+	-
Chlamydomonas sp.	-	-	+	+	+	+
Chlorella vulgaris	+	+	-	+	+	-
Cladophora glomerata	-	+	+	+	+	-
Closterium sp.	+	-	+	+	+	-
Coelastrum sp.	+	-	-	-	-	-
Hydrodictyon reticulatum	+	-	+	-	-	+
Pandorina morum	-	+	+	+	+	-
Pediastrum boryanum	+	-	-	-	-	-
Pediastrum duplex	+	-	-	-	-	-
Pediastrum simplex	+	-	-	-	-	+
Pediastrum tetras	+	-	-	-	-	+
Scenedesmus quardicauda	+	+	+	+	-	+
Scenedesmus abundans	+	-	-	-	-	+
Spirogyra sp.	+	-	+	+	+	+
Stigeoclonium tenue	+	+	+	+	-	+
Zygnema sp.	+	-	-	-	+	+
Bacillariophyceae						
Achnanthes sp.	+	-	-	-	-	-
Asterionella sp.	+	-	-	-	-	+
Cyclotella sp.	+	-	-	-	+	+
Cymbella sp.	+	-	-	-	-	+
Diatoma elongatum	+	-	-	-	-	+
Fragilaria pinnata	+	-	-	-	-	-
Fragilaria capucina	+	-	-	-	-	-
Melosira granulatum	+	-	+	+	+	-
Navicula cryptocephala	-	+	+	+	+	+
Navicula cuspida	+	+	-	-	-	+
Nitzschia palea	-	+	+	+	+	+
Nitzschia acicularis	+	-	-	+	+	+
Pinnularia appendiculata	+	-	-	+	+	-
Synedra sp.	-	+	-	+	+	-
Tabellaria floculosa	+	-	-	+	-	-
Euglenophyceae						
Euglena sp.	-	+	-	-	+	-
Phacus sp.	+	+	+	+	+	+

+ Denotes presence; -denotes absence

occurring in an aquatic ecosystem as well as on the soil water interphase is well within the biokinetic range of 10-45°C. Transparency ranged from 2.3 to 17.2 cms. Low water transparency as a result of huge waste discharge adversely affected the euphotic zone of the river and consequently the algal population and diversity.

Total solids and H^+ Ion concentration (pH): Total solids (suspended and dissolved) contributed by carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of Ca, Mg, Fe, Mn and other compounds exerted a pronounced effect on osmoregulatory phenomenon of aquatic phototrophs and also adversely affected transparency of the river water. Low transparency as shown above may be attributed to this fact. The total solids in the river ranged from 121 mg l^{-1} to 934 mg l^{-1}. pH serves as an important index of nature and intensity of pollution. The pH of the river water at different stations ranged from 7.8-8.5 and was suitable for propping the algal growth. pH values are indicative of alkaline nature of the water as is obvious from the reported alkalinity values ranging from 110-270.6 mg l^{-1}. Minimum at station 1 and maximum value reported at station 3.

D.O. and B.O.D.: D.O. of the river water at any point is a tell-tail sign of the nature and intensity of pollution. Low D.O. (<4 ppm) and high B.O.D. (>2 ppm) at downstream stations 2-6 is an indication of anthropogenic pollution stress on the river. At times nil D.O. was reported at stations 2 and 4 in the months of May and June respectively (Table 2) indicating that at these stretches anoxygenic conditions prevailed for a short while. Invariably high ammonia and low nitrate values in the river water further insinuate the oxygen stressed condition of the river.

Nutrients and heavy metals: River is rich in nutrients as is obvious from the reported values of nitrate, ammonia and phosphate (Table 2). Nitrate content ranged from 0.02 to 1.28 mg l^{-1}, whereas ammonia concentration varied from 0.46 to 8.95 mg l^{-1}. A significant inverse correlation (r= -0.815) has been noticed between nitrate and ammonia content of the river. Low nitrate content of the river as compare to ammonia content further affirms the oxygen stressed condition of the river, which hampered the natural oxidation of ammonia in to nitrate. Phosphate concentration ranged from 0.24 to1.86 mg l^{-1} at different stations of the river. Thus, it is apparent that nutritional status of the river was quite suitable for propping the algal flora. Heavy metals reported in the river water include Cu^{+2}, Ni^{+2}, Pb^{+2}, Zn^{+2} and Cr^{+6}. Their respective concentration at each station is depicted in Fig.1. It is evident that Cu^{+2} was the most dominant metal followed by Cr^{+6} and Zn^{+2}

Algal profile: Algal profile of the river is depicted in Table 3, whereas, quantitative data pertaining to its abundance, species number, and diversity values are given in Table 4. Table 5 depicts the coefficient of similarity values between the algal profiles at different stations. Despite the nutrient rich water, low algal diversity and population of the river may be attributed to the presence of toxic materials in water. Maximum species number was recorded at station 1 (35), which drastically declined at station 2 (16) and 3 (16) and could not reach at par to station 1 till station 6. Chlorophyceae outnumbered the other algal groups in species representation but so far as the numerical strength is concerned cyanophyceae and bacillariophyceae dominated the other groups.

Algal diversity values computed for the present study also indicated the adverse impact of effluent discharged on river algae (Table 3). Maximum values were recorded at station 1. Values declined sharply at stations 2 and 3 and remained quite low at rest of the downstream stations. It is evident from the table that not only the species number but algal population too declined sharply at stations 2 and 3 as compared to station 1. At rest of the downstream stations, it was slightly better than station 1. This may be attributed to certain obvious reasons such as low transparency and reduced illumination as a consequence of residual fly ash discharged by Panki Thermal Power Plant drain upstream of station 2 and discharge of coloured industrial effluent from Panki municipal drain upstream of station 3 and presence of heavy metals in the effluents (Fig. 1). These factors probably acted synergistically declining the algal growth and diversity. The present findings are in agreement with some earlier reports on the same river (Handa *et al.,* 1985; Tiwari, 2006). Albeit domestic sewage is also discharged via these drains in to the river but probably its growth-stimulating effect on algal population was nullified by the presence of heavy metals coupled with low transparency of water at these stations. As river flowed downstream, toxicants got diluted in due course of time and natural

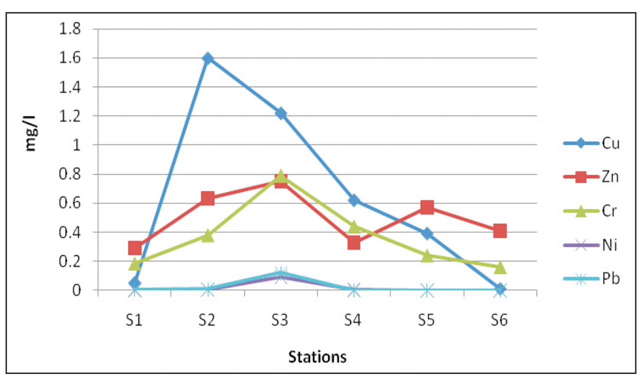

Fig. 1. Concentration of heavy metals in river water

Table 4. Algal individuals l^{-1} (n=24) species number and diversity values at different stations

	Tikra village	Panki industrial area	Mardanpura	Meharbanpura	Hamirpur road bridge	Sher Shah Suri bridge
No of individuals	174	63	73	199	339	336
No of species	35	16	16	25	22	25
Shannon-Weaver Index	4.41	1.73	1.68	2.49	2.09	2.96
Margalef Index	3.95	1.06	1.18	2.08	1.44	1.93

Table 5. Cofficient of taxonomic similarity among different stations

Stations	Tikra village	Panki industrial area	Mardanpura	Meharbanpura	Hamirpur road bridge	Sher Shah Suri bridge
S_1	-	0.27	0.39	0.52	0.44	0.66
S_2	-	-	0.63	0.63	0.58	0.41
S_3	-	-	-	0.73	0.63	0.51
S_4	-	-	-	-	0.68	0.54
S_5	-	-	-	-	-	0.44

removal of pollutants enhanced the euphotic zone. Further addition of sewage through other drains enriched the river water with nutrients. Thus reduced toxicity, improved transparency and nutrient enriched water triggered the algal growth at stations 4, 5 and 6 reaching a maximum of 339 individuals at station 5 (Table 3). But despite this the algal diversity as well as algal population in the river was quite low as compared to other perennial rivers of India. Out of total 46 species, 8 were reported exclusively at station 1 and were never reported from any other station. This shows that discharge of anthropogenic wastes in the river severely disturbed the ecosystem resulting in disappearance of more than 50% species at the very next downstream stations 2 and 3. At station 4, a few of them reappeared but the species number could not reach at par to station 1 till station 6. Highest taxonomic similarity (0.73) was recorded between stations 3 and 4 indicating that these stations had similar physico-chemical ambience. Lowest taxonomic similarity was recorded at stations 1 and 2 indicating that anthropogenic stress exerted a pronounced adverse effect on algal spectrum of the river. The study indicated that the river is under severe pollution stress and needs corrective measures to be adopted both at governmental and nongovernmental level so that it can be recuperated and saved from further deterioration.

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Performance of Yield Characters and Suitability for Pickling in Different Medicinal Coleus [*Plectranthus forskohlii* (Willd) Briq.] Genotypes

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Abstract: Studies were conducted on the performance of yield characters of ten medicinal coleus [*Plectranthus forskohlii* (Willd) Briq.] genotypes collected from different geographical locations. Among the genotypes evaluated for yield parameters maximum number of tubers per plant (20.20) recorded in KRCCH-7, while highest tuber length (20.68 cm) and tuber diameter (2.51 cm) was observed in genotype KRCCH-8, highest tuber density (1.97 cc) was observed in KRCCH-2, highest fresh weight of tubers per plant (417.67 g) was observed in KRCCH-1, highest dry weight of tubers per plant (56.05 g) was recorded in genotype KRCCH-3 and highest total dry matter accumulation per plant (205.20 g) was observed in genotype KRCCH-2. Among the genotypes evaluated for use as condiment, KRCCH-5 was found to be highly suitable.

Key Words: KRCCH , *Plectranthus forskohlii* (Willd) Briq.

Medicinal plants traditionally occupied an important position in rural and tribal lives of India and are considered as one of the most important sources of medicines since the dawn of human civilization. One such important medicinal plant is medicinal coleus [*Plectranthus forskohlii* (Willd) Briq.]. It is an ancient root drug recorded in Ayurvedic Materia Medica under the sanskrit name '*Makandi*' and '*Mayani*'. *Plectranthus forskohlii* [(Willd) Briq.] (*Coleus forskohlii* Briq.), belonging to the family Lamiaceae is an important medicinal plant indigenous to India. It is a perennial herb, popularly known as '*mainmool*' or '*makandiberu*' or '*mangani beru*' in the state of Karnataka and '*garmar*' in Maharashtra. It is distributed in subtropical Himalayas from Garwal to Nepal upto an altitude of 2500 m. The tuberous roots of medicinal coleus yield forskolin, a diterpenoid, which is used for glaucoma, asthma, congestive cardiomyopathy and certain cancers. It grows wild as an indigenous medicinal plant and the knowledge of its variability is an essential prerequisite for direct exploitation as a cultivar and indirectly as a base material for breeding programmes. Vegetative method of propagation adopted in this species for commercial cultivation heightens the prospects of utilizing the superior genotypes indentified in the present study. In this species, occurrence of wide genetic diversity in nature for tuber yield has been reported by Hegde (1992). Though there have been several earlier studies on evaluation of medicinal coleus not much progress has been achieved for its exploitation as a condiment. The present study was undertaken to assemble the variability in coleus for its utility as a condiment.

MATERIAL AND METHODS

Medicinal coleus genotypes were collected from different geographical locations in Karnataka state (Table 1). The unrooted cuttings from the terminal portion of each genotype were planted in polythene bags filled with 1:1 (v/v) mixture of well decomposed farmyard manure (FYM) and red soil. The cuttings were watered daily till 30 days in the nursery. The experiment was laid out in randomized complete block design (RCBD) with three replications and ten genotypes. The net plot size was 4.32 sq. m and provision was made for irrigation channels. After 30 days in the nursery, the rooted cuttings of each genotype were transplanted in the main field at a spacing of 60 cm x 45 cm. The polythene bags were removed without disturbing the root system and planted with minimum damage to the system. The plants were applied with recommended dose of fertilizers at 40 : 60 : 50 kg N:P_2O_5: K_2O per ha in the form of urea, super phosphate and muriate of potash. Nitrogen was applied in split doses, 50 per cent nitrogen was applied as basal dose at the time of planting along with P and K and remaining 50 per cent of nitrogen was top dressed at 30 days after transplanting. Plant protection measures were taken up to control the pests and diseases.

Among ten genotypes of medicinal coleus, nine were used for pickle making, because of one genotype is non-tuberous type. The experimental design followed for the evaluation of pickles was completely randomized design (CRD). For pickling, tubers were harvested at 120 days after transplanting. The freshly harvested tubers of each genotype of coleus were washed and outer layer was peeled and cut into small pieces of 1.0 to 1.25 cm size and were pickled. The ingredients used for pickling were common for all the genotypes. The pickles so prepared were evaluated for organoleptic characters like taste and aroma, flavor and overall acceptability at 30 days after pickling on a five point hedonic scale (Ranganna, 1986).

RESULTS AND DISCUSSION

The yield components like number of tubers, tuber length, tuber diameter, fresh and dry weight of tubers varied significantly among the genotypes. Highest number of tubers per plant (20.20) was observed in KRCCH-7 genotype, whereas, tuber length (20.68 cm) and tuber diameter (2.51 cm) was in KRCCH-8 genotype and tuber density (1.97 cc) in KRCCH-2 genotype (Table 1). These variations are mainly attributed to the genetic makeup of these genotypes. The least number of tubers per plant (5.03) was recorded in genotype KRCCH-6, whereas, tuber length (10.16 cm) in genotype K-8, tuber diameter (0.56 cm) and tuber density (0.36 cc) was observed in genotype KRCCH-6. Highest total fresh weight of herbage (968.80 g) was observed in KRCCH-8 genotype, total dry weight of herbage (152.01 g) in KRCCH-6 genotype and per cent herbage dry matter (16.23) in KRCCH-5 genotype.

Highest fresh weight of tubers (417.67 g) was observed in KRCCH-1 genotype which was on par with KRCCH-3 and KRCCH-5 genotype (Table 2). This could be attributed to better vegetative growth parameters like plant height, plant spread, stem diameter, total number of branches and number of leaves. It is evident that, the yield of genotype is dependent on vigour of the plant. The genotype KRCCH-6 recorded highest plant spread, number of branches and number of leaves but tuber yield was very low, as it is a non tuberous type. Highest dry weight of tubers (56.05 g) was observed in KRCCH-3 genotype which was on par with KRCCH-1 and KRCCH-5 The variations in fresh and dry weight of tubers per plant among the different genotypes was mainly due to genetic makeup of these genotypes. The least fresh weight of tubers per plant (21.07 g) and dry weight of tubers per plant (3.13 g) was observed in non tuberous genotype KRCCH-6. Highest per cent tuber dry matter (17.53) was observed in KRCCH-6, tuber yield per plot (6.53 kg) in KRCCH-1 genotype, and total dry matter accumulation per plant (205.20 g) was in KRCCH-2 genotype. The highest tuber yield per hectare (15.31 t) was observed in genotype KRCCH-5 and was *on par* with KRCCH-1 and KRCCH-3 .

Organoleptic evaluation for the overall acceptability of pickles prepared from the nine genotypes revealed that pickles of genotype KRCCH-5 were highly acceptable. The factors that were found to influence the overall acceptability of the pickles seems to be its constituent factors like taste, aroma and flavour of the pickles. The genotype KRCCH-5 had significantly highest scores for taste and aroma (4.02), flavour (4.03) and overall acceptability (4.43) (Table 3).

In the present study, the highest tuber yield was registered in KRCCH-1, KRRCCH-3 and KRCCH-5 genotypes under Ghataprabha Left Bank Canal (GLBC) command area of Karnataka.

These genotypes can be used for further selections in the crop improvement programmes. High overall acceptability was recorded in genotype KRCCH-5 for use as condiment. Therefore, KRCCH-5 can be exploited by small scale cottage industries for pickling.

Table 1. Tuber characters, fresh weight, dry weight and per cent dry matter content of herbage in medicinal coleus genotypes at harvest (150 DAP)

Place of collection	Genotypes	Number of tubers/ plant	Tuber Length (cm)	Tuber diameter (cm)	Tuber density (cc)	Fresh weight of herbage (g/plant)	Dry weight of herbage/plant (g/plant)	Herbage dry matter content (%)
Hiriyur	KRCCH-1	18.80	12.59	2.48	1.83	833	108.02	13.60
Bastwad	KRCCH-2	14.80	13.62	2.36	1.97	891	141.23	15.07
UAS, Bangalore	Aisiri	14.53	12.34	2.16	1.58	786.67	115.10	13.73
Belgaum	KRCCH-3	16.67	13.11	2.22	1.54	689.07	98.94	15.05
Alarwad	KRCCH-4	15.53	13.81	2.46	1.78	452.07	71.35	15.75
Chikkodi	KRCCH-5	14.80	13.29	2.24	1.57	498.93	81.41	16.23
Arabhavi	KRCCH-6	5.03	12.24	0.56	0.36	931.73	152.01	15.98
Arabhavi	K-8	9.27	10.16	2.26	1.54	530.27	72.75	14.52
Madapur	KRCCH-7	20.20	12.15	2.37	1.64	678.93	100.47	14.77
Magihundi	KRCCH-8	10.20	20.68	2.51	1.69	968.80	133.47	13.33
	CD(p=0.05)	2.52	2.27	0.27	0.48	177.93	27.32	1.54

Table 2. Fresh weight, dry weight, and per cent dry matter content of tubers and yield of medicinal coleus genotypes at harvest (150 DAP)

Genotypes	Fresh weight of tubers (g/plant)	Dry weight of tubers (g/plant)	Per cent dry matter content of tubers	Tuber yield (kg/plot)	Tuber yield (t/ha)	Total dry matter accumulation (g/plant)
KRCCH-1	417.67	53.75	12.73	6.53	15.18	172.11
KRCCH-2	315.60	44.01	13.19	4.70	11.59	205.20
Aisiri	224.53	30.70	14.06	3.90	9.10	144.15
KRCCH-3	399.87	56.05	12.91	6.23	14.48	151.28
KRCCH-4	330.80	45.25	13.59	4.70	10.98	117.11
KRCCH-5	398.47	51.27	12.44	6.30	15.31	130.02
KRCCH-6	21.07	3.13	17.53	0.33	0.76	148.36
K-8	124.53	16.88	13.39	1.73	4.09	89.63
KRCCH-7	322.18	45.38	13.32	5.30	12.34	147.18
KRCCH-8	321.47	36.10	12.65	5.40	12.65	185.37
CD(P=0.05)	54.90	5.49	1.86	0.91	2.05	26.52

Table 3. Sensory evaluation of medicinal coleus genotypes for pickles

Genotypes	Taste and aroma	Flavour	Overall acceptability
KRCCH-1	3.19	3.20	3.20
KRCCH-2	3.11	3.15	3.10
Aisiri	3.41	3.48	3.45
KRCCH-3	3.21	3.12	3.40
KRCCH-4	3.09	2.92	3.10
KRCCH-5	4.02	4.03	4.43
K-8	3.24	2.93	3.16
KRCCH-7	3.27	3.25	3.46
KRCCH-8	3.31	3.36	3.41
Mean	3.32	3.27	3.41
CD P=0.05)	0.30	0.23	0.19

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Comparative Yield Responses of Wheat Genotypes Under Sowing Date Mediated Heat Stress Conditions on Basis of Different Stress Indices

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Abstract: To evaluate the sensitivity or tolerance level of 24 wheat genotypes grouped in to early maturing genotypes (EMG) and late maturing genotypes (LMG) to heat stress, seven indices namely TOL, STI, stress susceptibility index, mean productivity, geometric mean productivity, relative performance and heat susceptibility index (HSI) were studied. Correlation coefficient analysis was performed between grain yield in timely and late sown environments with other yield indices. With respect to relative performance in yield components and HSI, EMG was characterized as tolerant to high temperature but it was found to be low yield potential group while LMG was found to be the sensitive group and high yield potential group. STI and GMP were found the strong indices which positively correlate with the yield under timely (Yp) and late (Ys) sown conditions in both the maturing groups and therefore these can be considered as a produced potential indices. In consideration of grain yield in timely and late conditions, different tolerance indices and correlation coefficient analysis on these traits, early maturing genotypes were selected for terminal heat stress tolerance.

Key Words: Early Maturity, Late Maturity, Heat Stress, Wheat, Yield Indices

Wheat productivity depended upon the joint effects of numerous factors. Major challenge facing modern crop production is maintaining crop yield under adverse stress environmental conditions. Wheat is the thermo-sensitive long day crop, the weather conditions during the growing season, especially the temperature, have a substantial influence on the plant metabolic processes, and thus on wheat quality (Patil *et al.,* 2003). Genetic diversity for heat tolerance in wheat is well established and varieties that show improved yield stability under heat stress have been identified (Hays *et al.,* 2007). High temperature stress during reproductive development result in a reduction in both individual kernel weight and kernel number. Terminal heat stress during anthesis and grain filling period, accelerate maturity and significantly reduces grain size and weight. One approach to dealing with these heat-related constraints is to improve wheat germplasm to provide higher tolerance to stresses associated with these environments. Many regions need wheat cultivars that are capable of high yields when the weather is beneficial but produce stable yields when conditions are adverse. These genotypes should have high yield potential in both favorable and high temperature environments. Yield and yield components in stress condition are still the most effective tools for stress evaluation The main objective of this study was to identify some improved wheat genotypes facing high temperatures during and after anthesis under field conditions that have high yield potential in both relatively favorable and high temperature environments.

MATERIAL AND METHODS

A set of germplasm consisting of various lines under the variable trial names (QTLs POPMAP G1-G9, CSIRO GCP G10-G12, SQ ELIT TD Sq G13-G16, PT CAN CAL II G17-G24) had been assembled by CIMMYT for evaluation for drought tolerance and heat tolerance under Generation Challenge Program. This germplasm was being evaluated in India at School of Agricultural Biotechnology and Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana for screening for drought tolerance under Punjab conditions. To observe the effect of terminal heat stress on these twenty four wheat genotypes, a field experiment was conducted with normal sowing (November 30) and late sowing (December 30) at the research field of Department of Botany, Punjab Agricultural University, Ludhiana, India. Plants in delayed sowing date experienced heat stress after anthesis. Studied genotypes had different growth durations and maturity periods. Hence on that basis, studied genotypes were further grouped in to two- early maturing (G1-12) and late maturing genotypes (G13-24). All the genotypes were planted in three replications, with a 5-row plot, row length of 2.5 m and 23 cm spacing between rows. Besides, the compact block was used to avoid soil heterogeneity effects and recommended agronomic practices for timely sown crop were followed to avoid moisture and other stresses so as to ensure proper expression of different traits. The genotypeswere compared for different attributes by estimating critical difference for each attribute. The various stress indices, relative performance (RP), heat susceptibility index (HSI), stress susceptibility index (SSI), stress tolerance index (STI), geometric mean performance (GMP), mean productivity (MP) and tolerance index (TOL) were measured by the following equation.

$$\text{Relative Performance (RP)} = \frac{\text{Grain weight per plant under stress conditions}}{\text{Grain weight per plant under normal conditions}} \times 100$$

$$\text{Heat Susceptibility Index (HSI)} = \frac{1 - yh / yn}{1 - yg/ya}$$

where, yh is mean yield of individual genotype under heat stress and yn under normal conditions and yg mean yield of all genotypes under high temperature and ya under normal conditions.

Stress Susceptibility Index (SSI) = ((1-(Ys/Yp))/SI

Susceptibility Index (SI) = $(\hat{Y}\ p\hat{Y}\ s)/\ p$

Mean Productivity (MP) = (Yp+Ys)/2

Tolerance Index (TOL)=Yp – Ys

Geometric Mean Performance (GMP) =Yp * Ys

Stress Tolerance Index (STI) = $[Ys * Yp]/(Y p)^2$

Where, Yp indicates yield of a given genotype under favorable environment (less heated environment), Ys indicates yield of a genotype in unfavorable environment (more heated environment), *vp* indicates mean yield in favorable environment, and *vs* indicates mean yield in unfavorable environment. Least significant differences and coefficient of variation were calculated to compare the concurrent grain yield in more and less heated conditions and various indices were studied based on correlation matrix. LSD (0.05) represents the minimal difference between the genotypes which is statistically significant at the 5% level.

RESULTS AND DISCUSSION

The results on yield and yield indices of 24 wheat genotypes as influenced by sowing date mediated heat

Table 1. Cross identity and genotype identity along with their cross details of the genotypes

Genotype	CID	GID	Cross Name
G1	285851	4748166	BAV92/SERI
G2	285851	4748122	BAV92/SERI
G3	285851	5899052	BAV92/SERI
G4	285851	5899053	BAV92/SERI
G5	285851	4748051	BAV92/SERI
G6	285851	4748043	BAV92/SERI
G7	285851	4748041	BAV92/SERI
G8	7691	3895	SERI M 82
G9	8626	447649	BAVIACORA M 92
G10	321283	342030	SILVERSTAR
G11	479296	3828890	WYALKATCHEM
G12	334948	3827751	SOKOLL
G13	473245	6056159	MEX94.2.19//SOKOLL/WBLL1
G14	473248	6143869	OAX93.24.35//SOKOLL/WBLL1
G15	473243	6143870	PASTOR//HXL7573/2*BAU/3/MEX94.2.19//ATTILA/3*BCN
G16	472923	6143871	FRTL/SOKOLL
G17	452470	6056135	PASTOR//HXL7573/2*BAU/3/CMH82.575/CMH82.801
G18	460354	6056142	SOKOLL/WBLL1
G19	460356	6056147	PASTOR//HXL7573/2*BAU/3/WBLL1
G20	472927	6056184	MEX94.2.19/PUB94.15.1.12
G21	460334	6056185	W15.92/WBLL1
G22	460360	6056064	PUB94.15.1.12/WBLL1
G23	473269	6056186	PUB94.15.1.12/3/FRTL//ATTILA/3*BCN
G24	472924	6056175	PUB94.15.1.12/FRTL

stress are presented in Table 2. Analysis of mean yield of both the groups differ significantly. Early maturing genotype (EMG) was found to be the low yield potential crop as compared to the late maturing genotype (LMG). The percentage decrease in the yield of EMG was 17.63% in turn it was found to be 31.67% in LMG that was almost twice of EMG. It may be due to environmental effect on the number of days required for the occurrence of different growth stages of wheat, which also varied with genotypes. The planting wheat at optimum sowing date would realize optimum season length and achieve high grain yield as a result of suitable weather conditions prevailing through different wheat growth stages in both the groups. LMG group genotypes had more yield under timely sown conditions as compared to the EMG under same conditions. But the results were vice versa under late sown more heated environment stress conditions. It may be due to late sown wheat crop, which were generally exposed to high temperature stress during the months of March and April (at anthesis stage), which in turn reduced the yield mainly by shortening the reproductive and ripening growth phases. The response of wheat to both chronic heat stress and short term heat shock is well documented and many of the current wheat grown in the Southern Great Plains region have shown susceptibility in terms of their inability to maintain yield and quality under high temperatures (Yang *et al.,* 2002). Delay of wheat sowing date reduced wheat yield as a result of exposure to high temperature, which reduce season length (Mostafa *et al.,* 2009).

From among the genotypes, EMG had the minimum TOL (33.0) in early group and in LMG group G17 and G24 had a value of TOL 41.9 and 73.1, respectively. Late sown conditions may cause sterility and in turn low yields and more

Table 2. Grain yield in less (Yp) and more heated (Ys) conditions and different stress indices for early and late maturing groups of wheat genotypes

Genotype	Yp	YS	MP	TOL	STI	SSI	GMP	RP	HSI
Early maturing genotype									
G1	508.5	354.4	685.7	154.1	0.743	1.761	424.51	61.52	1.489
G2	516.3	436.8	734.7	79.50	0.930	0.895	474.88	77.13	0.885
G3	513.7	358.9	693.1	154.8	0.760	1.751	429.37	64.81	1.362
G4	492.1	422.1	703.1	70.00	0.857	0.827	455.75	85.77	0.550
G5	545.5	457.8	774.4	87.70	1.030	0.934	499.72	77.00	0.890
G6	531.3	460.6	761.6	70.70	1.010	0.773	494.68	86.69	0.515
G7	546.0	466.8	779.4	79.20	1.052	0.843	504.84	85.49	0.561
G8	523.6	454.6	750.9	69.00	0.982	0.766	487.88	90.64	0.362
G9	536.8	478.4	776.0	58.40	1.059	0.632	506.75	79.10	0.808
G10	424.8	304.8	577.2	120.0	0.534	1.642	359.83	73.302	1.033
G11	446.2	376.8	634.6	69.40	0.693	0.904	410.03	81.189	0.728
G12	345.8	312.8	502.2	33.00	0.446	0.554	328.88	84.09	0.615
Mean	494.22	407.06	697.74	87.15	0.841	1.024	448.10	78.89	0.816
LSD (0.05)	1.31	1.82	2.28	1.74	0.060	.125	1.08	2.56	0.098
CV%	12.1	15.3	12.5	22.7	14.6	22.4	13.2	11.2	21.9
Late maturing genotype									
G13	470.4	388.5	664.6	81.90	0.703	0.544	427.49	82.58	0.674
G14	569.2	359.6	749.0	209.6	0.788	1.150	452.42	68.72	1.210
G15	506.8	383.6	698.6	123.2	0.748	0.759	440.91	75.69	0.941
G16	557.9	337.4	726.6	220.5	0.725	1.235	433.86	60.47	1.530
G17	408.8	366.9	592.2	41.90	0.577	0.320	387.28	97.08	0.112
G18	359.1	241.5	479.8	117.6	0.334	1.023	294.48	67.25	1.267
G19	521.5	373.8	708.4	147.7	0.750	0.885	441.51	71.67	1.096
G20	512.4	363.3	694.0	149.1	0.717	0.909	431.45	70.90	1.126
G21	486.5	208.6	590.8	277.9	0.390	1.785	318.56	42.87	2.211
G22	533.4	288.4	677.6	245.0	0.592	1.435	392.21	54.06	1.778
G23	579.7	349.3	754.3	230.4	0.780	1.242	449.98	51.39	1.882
G24	549.5	476.4	787.7	73.1	1.008	0.415	511.64	90.31	0.374
Mean	504.6	344.77	676.99	159.83	0.676	0.975	415.15	69.42	1.183
LSD (0.05)	1.009	2.431	2.811	1.885	0.052	0.123	1.240	4.583	0.177
CV%	13.0	20.5	12.7	37.4	26.9	34.0	14.4	22.9	32.0

The table is the mean of periodic experiments conducted in the year 2011-12 and 2012-13

Table 3. Correlation coefficient for grain yield in two different environmental conditions and indices of early maturing group

Yield Indices	Ys	MP	TOL	STI	SSI	GMP	RP	HIS
Yp	0.815***	0.978***	0.244	0.923***	0.025	0.938***	-0.031	0.031
Ys		0.917***	-0.361	0.973***	-0.554	0.965***	0.485*	-0.485
MP			0.038	0.982***	-0.180	0.989***	0.152	-0.151
TOL				-0.143	0.970***	-0.105	-0.864	0.864***
STI					-0.355	0.998***	0.305*	-0.305
SSI						-0.319	-0.864	0.864***
GMP							0.276*	-0.276
RP								-0.999

*, **, *** significant at 0.05, 0.01 and 0.001 probability, level, respectively

TOL value. Singh and Pal (2003) found that the late sowing caused shortening in the total growth duration and significant reduction in the biological and economic yields through reduction in the number of spikes per plant, number of grains per spike and grain dry weight per shoot. This could be attributed to reduction in the rate of leaf appearance as a result of water stress which reduces assimilate production by tillers and consequently reduce wheat grain (Auld and Paulsen; 2003). Yang *et al.* (2002) also reported that grain yield was positively correlated with HSI at 20/15°C. Results indicated that, the G12 and G24 in early and late group, respectively had the lowest SSI among the other genotypes in their respective groups. G24 with high grain yield in optimum and post-anthesis heat stress conditions, had higher STI compared to other genotypes in the late maturing group, but G12 had the lesser value for STI in early maturing group. Thus, the problem with using SSI as a measure of adaptation to stress is that there were cases where SSI has been positively correlated with grain yield reduction in that genotypes whose yield was affected little by the stress also had very low yield potential. This means that the genotypes with low SSI also may have had low stress resistance yield (G12). On the other hand, selecting varieties based on individual index or binary compare of them is tedious, and requires the method that can distinguish the performance of each cultivar in both environments with moderate and severe heat stress in the presence of different indices simultaneously. Analyses of descriptive statistics on grain yield and other yield indices also differ significantly. Therefore, these indices should be considered as produced potential indices and can be used to separate the genotypes with good production and high tolerance towards the stress conditions. In order to study the simultaneous effects on grain yield, correlation matrix characteristics were used. Table 3 and 4 showed the highest variation between data expressed by all the indices. The close positive association (r=.998***) in early group and (r=.996***) in late group also indicated that STI and GMP were more suitable traits for screening the genetic material for heat tolerance under variable stress conditions. These yield indices (STI, MP and GMP) had a high match with yield in both environments and therefore these can be named as a produced potential indices.

It's clear from the proceeding discussion that all stress indices were adversely affected by temperature stress, which were finally reflected in yield reduction. The impact of this adversity could be clearly seen to a large extent in late maturing genotypes, However, there was clear cut variation among the genotypes for late planting conditions. The existing variability in relation to various stress indices had immense importance for selection of parents, which could be

Table 4. Correlation coefficient for grain yield in two different environmental conditions and indices of late maturing group

Yield indices	Ys	MP	TOL	STI	SSI	GMP	RP	HIS
Yp	0.385*	0.925***	0.508**	0.722**	0.278*	0.736**	-0.314	0.315*
Ys		0.707**	-0.598	0.911***	-0.773	0.907***	0.724**	-0.724
MP			0.143	0.929***	-0.104	0.937***	0.056	-0.056
TOL				-0.222	0.964***	-0.206	-0.949	0.949***
STI					-0.447	0.996***	0.392*	-0.392
SSI						-0.439	-0.974	0.974***
GMP							0.384*	-0.380
RP								-0.999

*, ** and ***, significant at 0.05, 0.01 and 0.001 probability levels, respectively

utilized for improvement of these traits. The measurement of STI, MP and GMP was found to be important because they are closely related to yield production. Their significance becomes crucial particularly under stress environment.

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Land Reforms and Agrarian Relations in The State of Kerala, India- A Socio-Economic Evaluation

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***Abstract*:** Kerala is one among the few Indian States which took initiation in the area of land reforms in early years. The reforms brought about considerable change in socio-economic status of the local inhabitants. This article attempts to analyze the evolution of various land reforms implemented in the state from 1956 to 2012. This article also seeks to examine the changes in the agricultural scenario in addition to the socio-economic and cultural changes brought by such reforms in the state. Attempts were also carried out to critically evaluate the inadequacies associated with the reforms and scope for its modification.

Key Words: Land Reforms, Agrarian Relations, Socio-Economic Evaluation

Land reforms have been a national agenda of rural reconstruction since independence. They refer to attempts by the Government to achieve social equality and optimum utilization of land by redistributing the land holdings. These reforms are also intended to reorder the agrarian relations in order to achieve a democratic social structure, to eliminate exploitation and social injustice within the agrarian system and thereby enlarging the land base of the rural poor, to provide security for the tiller of the soil and to remove obstacles arising from the agrarian structure that has been inherited from the past and to increase agricultural productivity and infusing an element of equality in local environments. But despite this vision of the Nation, there was inertia, lack of sincerity by governments and pressure tactics of powerful land owning class discouraged land reforms in most of the states. Moreover, land demand for industrial, urban and other complicated economic development issues have resulted in the evacuation of many thousands of marginal farmers and those who were living in agriculture-oriented cottage industries. They were thrown out of their livelihood, drove off their habitats, resulting in their agglomeration in the outskirts of big cities forming slum clusters.

Kerala is one of the few Indian States which implemented land reforms. The present article is an attempt to analyze the effectiveness of such reforms on the socio-economic and cultural aspects of the people of Kerala, right from the origin of State. Attempts were also carried out to critically evaluate the inadequacies associated with the reforms in the contemporary situations and scope for their modification.

Kerala-A Profile: The State of Kerala, stretching for about 590 Kms., with a width varying from 32 to 120 Kms., is a long but narrow strip in the south-west coast of India, sandwiched between towering mountains and the deep blue sea. The networking rivers together with backwaters form an attractive feature of Kerala. The deltas of the rivers interlink the backwater and provide excellent water transport facility in the low lands. The tall, exotic coconut palm dominates the landscape.

The state is divisible into three geographical regions, the highlands, midlands and the low lands (coastal plains). The highlands are dominated by the Sahya Mountains (Western Ghats) with dense tropical evergreen forests, misty peaks, extensive ridges and ravines. Anamudi is the highest peak with an altitude of 2775 m. above MSL. Tea, coffee, rubber, cardamom, cinnamon, oil Seeds and sandalwood are extensively cultivated in the mountainous areas. The midlands have undulating hills and valleys growing coconut, arecanut, banana, mango, tapioca, pepper, ginger etc. The sandy coastal region or the low lands has extensive coconut groves, paddy fields, river deltas, backwaters and the sea. The diversity in geographical set up is reflected in the climate as well. While the highland areas experience biting cold, the climate is pleasant in the midland areas and low land area is comparatively hot because of humidity especially in summer months. South-West monsoon, which is the major monsoon in Kerala begins sometime in June-July and continues till August-September. North-East monsoon commences in October-November.

The state occupies an area of 38,863 Sq.Kms., representing only 1.18 percent of the total area of the country.

Nevertheless with a total population of more than 30 million people, Kerala has 3.43 percent of the total population of the country.

Landmark Legislations-Land Reforms: The state of Kerala was officially formed in the year 1956. Even before its formation, there had been endeavors at land reforms in the State. The Restriction on Possession and Ownership of Lands Bill (1954) being the best example of the same.

The first democratically elected government assumed office on 5th April, 1957. The first elected government issued the Stay of Eviction Proceedings Ordinance to afford interim protection to tenants, including the 'kudikidappukars' (hutment dwellers). Reports say that close to two million acres were transferred to 1.3 million households. In spite of delays in implementation and circumvention of the legislation, the abolition of tenancy was a remarkable success. The aggregate area transferred to the lessee amounted to 36.5% of the net sown area in the state, or 42.9% of the area excluding plantation crops (Eashvaraiah 1993).This was followed by the agrarian reform bill, which was adopted by the Kerala assembly in June 1959.Its outcome, the Kerala Agricultural Relations Bill (KARB) was a land mark in the history of Kerala. It contained three important features.

(1) No holding of land by permanent tenants, including farm servants and mortgagees, would be subject to resumption by the landowners. The rent to be paid by tenants was reduced to a maximum of one fourth of the gross produce, and to much less, as low as one twelfth, in the case of less fertile land.

(2) All rights of the landlords in land held by the tenants were vested in the state which then would act as an intermediary in transferring (part of) sixteen annual installments of the fair rent to the landowner. After paying all installments, the ex-lessee would receive full ownership of the land. The total abolition of tenancy involved in this arrangement was an exemplary feature of the KARB.

(3) All land above the ceiling limit (15 acres of double cropped land per family, with no additional allowance for adult or minor family members) was to be distributed by the Land lords.

The KARB was a radical departure, not in terms of an anti-capitalist agenda, but in terms of "its democratic revolution which aimed at breaking the backbone of feudalism and semi-feudalism of all kinds, and parasitic landlordism, with a serious concern for development of the forces of production" (Eashvaraiah, 1993).But the implementation of this comprehensive land reform programme was scotched by the overthrow of the first government, the verdict of the Kerala High Court against certain provisions of the bill and the presidential disapproval. The KARB, after the extended legislative procedure, was sent to the President of India on 27 July 1959. Four days later, on July 31, 1959, the government was dismissed by the President, arguing on the basis of Article 356 of the Constitution that law and order in the state had been eroded. This argument was with reference to the prevalence of a violent agitation, the Liberation Movement (Vimochana Samaram).

In February 1960, second ministry assumed power. The Hon. President later sent the KARB back to the Government for modification. The resulting KLR Act of 1964 was a diluted version of the KARB in the sense that it contained more loopholes for ineffective implementation such as the bureaucratic composition of the Land Boards and the exemptions for charitable trusts and plantations. The ideas, which the first government had introduced in 1957, remained intact, and the jenmi landlords in Kerala, and the political parties representing their interests, apparently had changed their tactics. Kerala Land Reforms Act, 1963 is the principal land reform law in the State of Kerala and was included in the Ninth Schedule to the Constitution.

The re-adornment of the first Government for a further term in 1967, allowed for new legislation to undo the evictions (Kerala Stay of Eviction Proceeding Act of 1967), with retrospective effect and to re-modify the KLR Act, resulting in the Kerala Land Reforms (Amendment) Act 1969.This is because in the course of implementation, the State Government had faced serious practical difficulties and to overcome them, that Act was extensively amended by the Kerala Land Reforms (Amendment) Act, 1969 (Act 35 of 1969) and by the Kerala and Reforms (Amendment) Act, 1971 (Act 25 of 1971). Certain crucial provisions of the principal act as amended were challenged in the High Court of Kerala and in the Supreme Court, creating a situation of uncertainty in the effective implementation of land reforms. Although the High Court of Kerala have upheld the scheme of land reforms envisaged in the principal act as amended, a few vital provisions have been struck down. Even in regard to the provisions upheld by the High Court, the affected parties had moved the Supreme Court in appeal. The Supreme Court in its judgments delivered on 26th and 28th April, 1972, have upheld the scheme of land reforms as envisaged in the principal Act as amended, but agreed with the High Court, invalidating certain crucial provisions.

Efficacy of Land Reforms / Evaluation of the Success: The major economic problems of the newly independent nation could be income-poverty, hunger, illiteracy, lack of schooling, avoidable disease, and subject to what were among the worst forms of class, caste, and gender oppression in the world.

To solve the agrarian question is to free the countryside of landlordism, old and new; to free the working peasantry and agricultural workers from their present fetters and to guarantee them the means of income and livelihood; to redistribute agricultural land; to provide the rural working people with house-sites and homes; to create the conditions for the liberation of the people of the oppressed castes and tribes and of women; to ensure universal formal education; and to achieve the general democratization of life and progressive cultural development in rural India. Kerala was one of the few states which took brave step of land reforms in early years, where the landless agricultural workers were provided land to settle down. The result was highest public health and distribution of basic educational facilities and least slum dwelling.

The Land Reforms Bill of 1959 introduced by the first ministry had the very clear objective of breaking landlordism. It wanted to realize the slogan of “land to the tiller” which had been the promise of the freedom struggle. The idea was to make tenants the owners of the land they cultivated and to ban future tenancy in all forms. Resuming land for “own-cultivation” which was a euphemism for tenancy-at-will or wage-based cultivation, and which had been the bane of land reforms undertaken by other governments, was not permitted.

But even though the first government could not implement its proposed legislation, the lead it provided started a process that broke to a considerable extent the feudal shackles over Kerala's society and economy. In the assessment of Nossiter (1982), the land reforms program indeed was "the first comprehensive measure of its kind attempted in India; and it tackled tenurial relations of greater complexity than anywhere else in India" (Herring 1983; Radakrishnan 1989). It is also noticed there was no going back on the agenda, the first government had put forth, and in the course of time Kerala emerged as the most successful state in the area of land reforms. But even in the midst of various success stories, it remains as a fact that there are enough of setbacks. One among such is the case of tribal population and fishermen community, two important segments of the poor who could not directly benefit much from the land reforms measures.

Recent Allegations / Proposal for Modification: Nearly 50 years after the first elected government in the state started redistributing land to the poor, politicians and academics are still debating its efficacy. Success stories are many. Some of them states that more than 3.3 million people in the state have benefited from land reforms and today, landless population of the state has been dwindled to only 4.8%. The government has already taken over more than 99,277 acres and redistributed 71,400, and is still to acquire another 43,776 acres. It is also stated that 5.28 lakh persons, mostly agricultural labourers, many of them belonging to the Scheduled Castes, had received allotments of house sites and dwellings. Apart from the direct benefits, the movement for land reforms had led to a series of successful struggles against caste oppression and for mass education, public health and public distribution of food and essential commodities. What is significant about the picture is that while there has been redistribution of power, influence, opportunities and wealth from the highest level of the former agrarian hierarchy, which largely coincided with the highest in the caste structure, to the middle level of both the agrarian and caste-community structure, such redistribution has not happened in the same manner further down.

Some school of thought argues that land reform, implemented in the State was a diluted version of the Bill introduced by the first government in 1959. Those reforms were flawed for the primary reasons that it excluded the estates and plantation sector from the purview of the land ceilings fixed then and it dropped the concrete schemes for reaching land to the real farmers. The Bill had actually set a liberal land ceiling of 15 acres for a five-member family, but even this was scuttled through legal loopholes and benami deals. As a result, the surplus land for redistribution, which was estimated initially as three lakh acres, got reduced to 0.5 lakh acres.

Few political groups have decided to launch agitations for restructuring the land ownership pattern in the State by taking up its earlier slogan `land to the tiller.' Agitations, demanding the continuation of agrarian reforms are also in operation. A call for a second round of land reforms in Kerala has also triggered friction within the government and among various segments of the society. It was pointed out that the reforms in Kerala had several historic achievements to its credit. The process broke the backbone of landlordism and abolished the jenmi system. By 1993 it had conferred ownership rights / protection on 28 lakh tenants, and 6 lakh acres (242812 ha) had been accrued to tenants. Much of the recent criticisms have come from economists who argue the reforms haven't achieved their real purpose as most beneficiaries were not from the lowest rung of society. According to them, an impression of success was created as several intermediate castes and the middle-class are benefited from the reforms. The results of the reforms have been that the tenants (`kudiyans'), who were actually the middle class sections in the State, became the owners of the land while the genuine landless farmers and the poor agricultural workers were driven away to settlement colonies. It was also argued that while the middle classes in rural Kerala had gained substantially from land reforms, these had not substantially benefited the landless agricultural labourers, the tribal people or the fisher folk.

As land reforms are considered the one outstanding achievement of the Kerala development experience, the obvious question to ask is why this has not solved the food problem once and for all. Why after 50 years does Kerala depend on Andhra Pradesh for rice, Tamil Nadu for vegetables and Karnataka for meat∑ Can such a society based on external dependence on food to such an extent be considered a model∑

Precisely, land reform did not increase agricultural production or rural employment in the State. In fact, one of the most visible results of the land reform legislation was the extreme fragmentation of land, the oft-cited reason for making agriculture a low-profit venture in the State. Many new landlords realised that they could not make a living out of agriculture and turned to less labour-intensive crops or were forced to seek avenues that could generate additional income. Increasingly, they displayed a tendency to leave their lands fallow. The result was a drastic fall in employment in the agricultural sector also and a rise in farm wages disproportionate to the yield. Workers began to migrate to non-agricultural sectors, especially to satisfy the demand caused by large-scale construction activity. At one point, the Gulf boom pushed up land prices so high that selling agricultural land for real estate development became an enticing option.

Thus it has stated that land has become a mere speculative asset instead of becoming the primary means of production. The tendency to leave the land barren became predominant and consequentially this led to gross decline in the agricultural production, particularly rice. Large-scale concentration of land with the NRIs and the consequent `absentee-landlordism' has aggravated these trends. Accordingly rice cultivation has been shrunken to about 275,000ha in 2006-07 from more than 800,000ha in the 1960s and production had halved to 630,000 tonnes. The state has already lost about 500000 hectares of paddy fields in the last three decades causing acute food insecurity and severe groundwater shortage. The high costs and lack of farm labour as an indirect result of higher education, have contributed to rice fields being converted for cultivation of other crops or real estate. It is also as a consequence of the simultaneous increase in two categories of people—those who have land but are unable to cultivate and those who have the labour and skills but do not have any or enough land of their own to cultivate. On the current situation in Kerala, the coexistence of high wages in agriculture and high levels of unemployment was noted as an issue that had to be addressed by bringing about cooperation between peasants and agricultural labourers, and promoting investment in agriculture. Another major adverse consequence of the land reforms implemented in Kerala was the emergence of the middle class sections that did not consider land as a primary source of generating livelihood. The middle class had wrested a major clout in the political, economic, bureaucratic and cultural arena of Kerala, and it was their development agenda that was the root of the stagnation of the productive sector and of the degeneration that has gripped the entire gamut of Kerala society. It was also pointed out that periodic change of governments had made it difficult to implement land reforms in a thoroughgoing manner. The major challenge of declining prices of agricultural products in the context of Globalisation and Liberalisation was also a key issue and had to be seen as being as important as the land issue. The problem of management of an open economy like Kerala in the era of globalisation was a task that had to be addressed.

The crisis in Kerala's agricultural sector, which has a large part dominated by cash crops, was complete with the introduction of the liberalisation policies in the 1990s. The price of coconut, a major crop, fell sharply with the reduction of import tariffs on edible oil. The market for rubber, another important crop, was depressed following large-scale import of natural rubber. All plantation crops in which Kerala had a substantial stake, namely, tea, coffee, rubber and cardamom, had also to compete with low-cost imports. The most discernible trend in the past few decades, indeed, has been the marked shift in the cropping pattern towards less labour-intensive crops. In food-deficit Kerala, as stated earlier, the area under paddy fell drastically by over five lakh hectares (from eight lakh hectares) in the past three decades. Although over 60 per cent of the land that went out of paddy cultivation continued to be used for agriculture, the preference was to grow coconut, rubber, areca nut or crops such as banana, tapioca and vegetables. Now, farmers are turning increasingly to quick-profit cultivation of exotic varieties such as vanilla, horticulture and medicinal plants, which have markets outside India.

But, despite the fall in agricultural production and agricultural employment as a result of land reforms, until recently there had been no attempt to undermine the reform measures. For over three decades after the 1970s, farmers and farm workers were, however, living with a new set of problems, of low profits from the fragmented land and lack of employment despite guaranteed minimum wages.

There is a need to re-look at the reforms and promote agriculture without taking away land rights and legalize collective farming on fallow land. It is still not too late for the Government of Kerala to decree that beneficiaries of the land reforms must transfer the land to the Government if they do not cultivate it. Such lands can be leased out to those many willing to cultivate them. Further, reversal of the, by now, irrelevant anti-tenancy legislation is long overdue. The existing law banning tenancy is fuelled by the dogma that all tenancy is exploitation. It prevents the needed re-allocation of resources and hastens the alienation of agricultural land. The state government, in response, recently legislated the Kerala Conservation of Paddy Land and Wetland Act, which calls for three years imprison and penalty ranging from Rs. 50,000 to Rs1 lakh for those diverting rice land for other uses is a good inititiative in the direction of ensuring food security to the nation.

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Characterization of Farming System in North Gujarat Agro-Climatic Zone

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Farm economic efficiency is an important factor of productivity and growth, where resources are scarce and opportunities for developing and adopting better technologies have lately started declining. Several researchers have suggested farming system as an approach for meeting the multiple objectives of poverty reduction, food security, competitiveness and sustainability (Norman, 1978). The system approach emphasizes the need to view the farm situation as a whole and not in compartmentalized manner. A farming system is the result of complex interactions among a number of interdependent components. To achieve it, a farmer allocates certain quantities and qualities of land, labour, capital and management i.e., the four factors of production to which he has an access. An alternative farming system, which yields not only higher income but also utilizes family labour efficiently, needs to be evolved. Further, the system should help in restoration of ecological balance. The basic aim of integrated/sustainable farming system is to derive a set of resource development, management and utilization practices that lead to a substantial and sustained increase in agricultural production. Since farming systems differ in different situations such studies should be location specific (Singh, 1998). The present study attempts to evaluate the economics and sustainability of different farming systems and to suggest optimum farming system for realizing higher income and ensuring environmental security.

Survey on characterization of farming system was carried out in Mehsana and Banaskantha districts of north Gujarat, which falls under 4.2 Agro-ecological Sub Zone. Using the stratified random sampling technique and following the proportional allocation method. 144 farmers belonging to the size groups, based on the size of operational holding *viz*., marginal (up to 1 ha), small (1-2 ha), medium (2-4 ha) and large (above 4 ha) were selected from these two districts. The data on socio-economic parameters, existing farming system, economics of different enterprises, farm constraints, etc. were obtained in pre-tested schedules by personally interviewing the selected farmers. The study pertained to the year 2009-10.

The survey revealed that out of 144 farmers, report in Table 1 selected farmers according to their land holding were categorized as marginal farmers (48), small farmers

Table 1. Details information regarding selected farmers of north Gujarat agro-climatic zone (n=144)

Name of district	Name of taluka	Name of village	Categories of farmers				Total farmers
			Marginal	Small	Medium	Large	
Mehsana	Mehsana	Hebuva	4	4	2	2	12
		Piludara	4	4	2	2	12
		Virampura	4	4	2	2	12
	Vijapur	Rampura	4	4	2	2	12
		Dhanpura	4	4	2	2	12
		Madhi	4	4	2	2	12
		Sub total	24	24	12	12	72
Banaskantha	Deesa	Pedal	4	4	2	2	12
		Sherpura	4	4	2	2	12
		Gugal	4	4	2	2	12
	Danta	Aderan	4	4	2	2	12
		Bachadiya	4	4	2	2	12
		Kundel	4	4	2	2	12
		Sub total	24	24	12	12	72
		Grand Total	48	48	24	24	144

(48), medium farmers (24) and large farmers (24 nos.). The distribution of selected farmers under study engaged in various farming system according to their percentage is depicted in Table 2. It can be seen that 49.31 per cent of the selected farmers were engaged with oilseed farming, followed by 18.06 per cent who were engaged in fruit-vegetable farming system. The lowest number of farmers people were engaged in cereal farming system (2.08 %).

Table 2. Distribution of Farming system in per cent among North Gujarat agro-climatic zone (n=144)

Farming system	Marginal	Small	Medium	Large	Total
Cereal	4.17	0.0	0.0	4.17	2.08
Oilseed	41.67	54.17	58.33	45.83	49.31
Cotton	14.58	16.67	16.67	16.67	15.97
Fruit -veg	22.91	12.50	16.67	20.83	18.06
Spice	4.17	2.08	4.17	4.17	3.47
Livestock	12.50	14.58	4.17	8.33	11.11
Total	100.0	100.0	100.0	100.0	100.0
Sample size	48	48	24	24	144

Table 3. Distribution of farming systems according gross income in north Gujarat agro-climatic zone (n=144)

Farming systems	Source of income							
	PO	LS	CT	CL	SP	VF	Other	Total
Cereal	26.32	21.75	2.72	44.56	0.0	1.90	2.75	100.0
Oilseed	43.77	13.38	14.12	16.16	6.59	4.71	1.27	100.0
Cotton	26.29	13.16	39.16	17.57	1.85	0.26	1.71	100.0
Fruit -veg	15.11	12.24	2.34	16.13	1.13	50.88	2.17	100.0
Spice	17.07	15.57	16.59	9.15	41.62	0.0	0.0	100.0
Livestock	20.57	36.60	7.66	17.44	4.12	9.43	4.18	100.0

Table 4. Predominant Farming systems in North Gujarat Agro climatic zone (n=144)

Farming systems	Marginal	Small	Medium	Large	All
CL+OS+CT	4.17	0.0	0.0	4.17	2.08
Cereal based	4.17	0.0	0.0	4.17	2.08
OS+CL+LS	10.42	18.75	8.33	12.50	13.19
OS+CL+CT+LS	12.50	18.75	16.67	8.33	14.58
OS+CL+SP+LS	0.0	0.0	8.33	8.33	2.78
OS+CL+CT+SP+LS	8.33	10.42	20.83	16.67	12.50
OS+CT+SP+LS	10.42	6.25	4.17	0.0	6.25
Oilseed based	41.67	54.17	58.33	45.83	49.31
CT+CL+OS+LS	14.58	12.50	8.33	12.50	12.50
CT+CL+OS+Fruit	0.0	25.00	8.33	25.00	3.47
Cotton based	14.58	37.50	16.67	37.50	15.97
FT+CL+CT+LS	8.33	0.0	0.0	8.33	4.17
V+CL+OS+LS	10.42	10.42	4.17	8.33	9.03
V+CL+LS	4.17	2.08	4.17	4.17	3.47
V+CL+OS+LS+Tob	0.0	0.0	8.33	0.0	1.39
Fruit -veg based	22.92	12.50	16.67	20.83	18.06
SP+CL+OS+FT+LS	4.17	2.08	4.17	4.17	3.47
Spice based	4.17	2.08	4.17	4.17	3.47
LS+CL+OS+Tob	4.17	6.25	0.0	0.0	3.47
LS+CL+OS	6.25	2.08	0.0	0.0	2.78
LS+CL+OS+Veg	0.0	4.17	4.17	4.17	2.78
LS+CL+OS+CT+SP	2.08	2.08	0.0	4.17	2.08
Livestock based	12.50	14.58	4.17	8.33	11.11
Total	100.0	100.0	100.0	100.0	100.0
Sample size	48	48	24	24	144

The distribution of selected farmers under study engaged in various farming system according to their gross income is depicted in Table 3. It can be observed that the farmers of cereal farming system are getting highest (44.56%) of gross return from cotton and livestock whereas, lowest (1.90%) gross returns from vegetable-fruit based farming system. Similarly, farmers of oilseed farming system are getting highest returns (43.77 %). The farmers engaged in livestock are getting gross returns 36.60 per cent from livestock followed by oilseed farming system (Table 3).

The predominant cereal, oilseed, cotton, fruit-vegetable, spice and livestock farming systems were recorded in the area (Table 4). The highest per cent of people were engaged in oilseed farming system (49.31 %) whereas, lowest in cereal based farming system (2.08 %).

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Effect of Biomethanated Distillery Spentwash on Growth, Yield and Anatomy of Maize (*Zea mays* L.)

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In India, approximately 40 billion litre of distillery spentwash are being discharged annually from 319 distilleries (Kanimozhi and Vasudevan, 2010). However, its direct use in agricultural field is generally not considered safe because of its high Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Alternatively, the raw spentwash is subjected to biomethanation treatment to decrease BOD and COD and the product is known as Biomethanated Distillery Spentwash (BDS). The agricultural use and the beneficial effect of spentwash have been well documented by many authors. The main problem with the distillery effluent is potassium and chloride ion concentration. The K that enters the xylem stream may enter through many putative uptake pathways. Some of those pathways have been identified through molecular and the electrophysiological level, but the identity of the primary K^+ uptake pathway is still not clear. BDS is rich in K ion might have altered the respiration and it may change the anatomy of roots. The work on BDS effect on anatomical study is quite limited. The present work is focused on the study of growth, yield and anatomy of maize due to BDS application and also determination of the adaption level in the field.

The BDS was collected from the distillery unit of M/S. Bannari Amman Sugars Ltd., Periyapuliyur, Erode, Tamil Nadu and analyzed for its physico-chemical properties by following standard procedures (APHA, 1998). BDS was dark brown colour and a neutral pH (7.42) with high EC (32.5 dS m^{-1}), BOD (6,545 mg L^{-1}) and COD (34,476 mg L^{-1}). It contained highest K (8,376 mg L^{-1}), N (2,116 mg L^{-1}), Ca (2,072 mg L^{-1}), Mg (1,284 mg L^{-1}) and P (52.8 mg L^{-1}). Field experiment was conducted during August to December, 2009 at Research and Development farm of M/S. Bannari Amman Sugars Distillery Division Ltd., Erode. Different doses of BDS along with inorganic fertilizers using maize hybrid COH (M) 5 as test crop have been tried. The experiment was laid out in Randomized Block Design with seven treatments and three replications (Table 1). Spentwash was applied as per the treatment and incorporated into the soil at 30 days before sowing in order to reduce the BOD and COD load. Seed rate was 18 kg ha^{-1} with the spacing of 60 x 25 cm and the plots were irrigated immediately after sowing. Recommended dose of nitrogen @ 150 kg ha^{-1}, phosphorus @ 75 kg ha^{-1} and potassium @ 75 kg ha^{-1} were applied. Fifty per cent of N and full doses of phosphorus and potassium were applied as basal and the remaining half dose of N was top-dressed after 30 days of sowing. Biometric observations were made by randomly selecting five plants in the net plot area of individual treatments at four stages *viz.,* vegetative (30 DAS), flowering (60 DAS), maturity (90 DAS) and harvest (120 DAS). The leaf area index was calculated by the method as suggested by Williams (1946). Crop growth rate was estimated by the method suggested by Watson (1958). The cobs from the net plot were harvested separately and expressed in kg ha^{-1} and yield attributes *viz.,* cob length, cob weight $plant^{-1}$ and number of grains cob^{-1} were recorded. Anatomical changes of root tissues were compared with control and spentwash applied treatments by using rotary microtome as suggested by Allen and Sanders (1997).

Effect of BDS on Growth Parameters: Application of BDS significantly influenced the growth parameters compared to control. Among the different stages, harvest stage (120 DAS) recorded the highest plant height and stem girth (Table 1) and the highest leaf area index was recorded at 60 DAS . Among the various doses, BDS @ 100 kilo litre ha^{-1} + RD of NPK registered the highest plant height, stem girth, leaf area index and crop growth rate. The spentwash contained various cations and anions, which promotes the plant growth by increasing water absorption and other metabolic processes of plants. The highest growth attributes might be due to the addition of increased plant nutrients to the maize crop through the distillery spentwash. Better utilization of available resources might have increased the functional leaves and in turn enhanced the LAI (Sivasankari, 2009). Significant difference in crop growth rate was observed from 30 to 60 DAS onwards. The increased in CGR due to BDS might be attributed to be increased LAI. Enhanced effect of

BDS on CGR might be due to higher accumulation of photosynthates in the sink which lead to higher CGR.

Effect of BDS on Quality Parameters: The highest total chlorophyll content and soluble protein was recorded in BDS @ 100 kilo litre ha^{-1} + RD of NPK and the lowest in control. An increase in chlorophyll content was recorded in leaves of maize at all the BDS concentration on 60 and 90 DAS and subsequently decreased due to the onset of senescence (Table 2). This reflects the high manurial potential of the distillery effluent. The increased soluble protein might be due to cells retained higher water potential with the application of spentwash. This might have prevented protein degradation metabolism and enhanced soluble protein synthesis by activating enzyme activity (Nandakumar, 2009).

Effect of BDS on Yield and Yield Attributes: BDS application caused a significant increase in yield attributes. Among the treatments, BDS @ 100 kilo litre ha^{-1} + RD of NPK recorded the highest cob length , cob weight, number of grains per cob and grain yield which was on par with BDS @ 100 kilo litre ha^{-1} + RD of NP (Table 3). The reason was due to be the BDS is essentially a plant extract, the increased nutrient supply and coupled with good soil fertility status and improved physical properties, which were made available to the plants, thus resulting in better growth, development and yield attributes of the maize (Madhumitadas *et al.,* 2010).

Effect of BDS on Anatomy: The anatomical structure in the cross-section of the root and the possible modification of the root tissues were corresponded with the changes due to the BDS application. The cross section of the control roots showed a normal cellular composition with no aerenchymatous tissue and the spentwash applied roots of maize showed many aerenchymatous cells in the parenchyma and it was not uniformly distributed (Fig. 1). The aerenchyma cells in the roots are an adaptation of plant to overcome certain stresses, which commonly affect the oxygen supply to root for respiration. The results from present study revealed that the application of BDS @ 100 kilo litre ha^{-1} + Recommended dose of NPK increased the growth and physiological parameters and these are highly correlated

Table 1. Effect of BDS on plant height, stem girth, leaf area index and crop growth rate at varies stages of maize

Treatment*	Plant height (cm)				Stem girth (cm)				Leaf Area Index				Crop growth rate x ($g\ m^{-2}\ day^{-1}$)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	65.1	213	230	233	1.45	4.22	6.82	7.03	0.42	1.48	1.07	0.74	3.45	5.37	24.3	7.46
T_2	69.4	228	254	256	1.87	4.85	7.24	7.46	0.66	1.76	1.32	0.97	3.87	5.48	25.8	7.85
T_3	70.4	232	256	260	2.06	5.17	7.53	7.72	0.75	2.04	1.58	1.11	4.04	5.64	25.9	8.56
T_4	77.2	246	269	272	2.69	5.84	8.14	8.27	1.13	2.47	2.06	1.54	4.89	6.02	28.2	9.24
T_5	80.2	252	276	279	2.78	5.95	8.38	8.54	1.27	2.67	2.24	1.82	5.12	6.34	29.6	9.95
T_6	71.8	239	260	263	2.25	5.36	7.72	7.93	0.94	2.13	1.75	1.28	4.15	5.89	26.0	8.87
T_7	73.5	242	265	268	2.34	5.68	7.86	8.02	1.08	2.35	1.89	1.35	4.36	5.97	26.7	9.13
CD 5%	3.61	11.8	12.9	13.6	0.11	0.25	0.37	0.44	0.04	0.12	0.09	0.07	0.29	0.47	2.28	0.92

*T_1: RDF; T_2: BDS @ 50 kilo l ha^{-1} + NP; T_3: BDS @ 50 kilo l ha^{-1} + NPK; T_4: BDS @ 100 kilo l ha^{-1} + NP; T_5: BDS @ 100 kilo l ha^{-1} + NPK; T_6: BDS @ 150 kilo l ha^{-1} + NP; T_7: BDS @ 150 kilo l ha^{-1} + NPK

Table 2. Effect of BDS on total chlorophyll and soluble protein at varies stages of maize

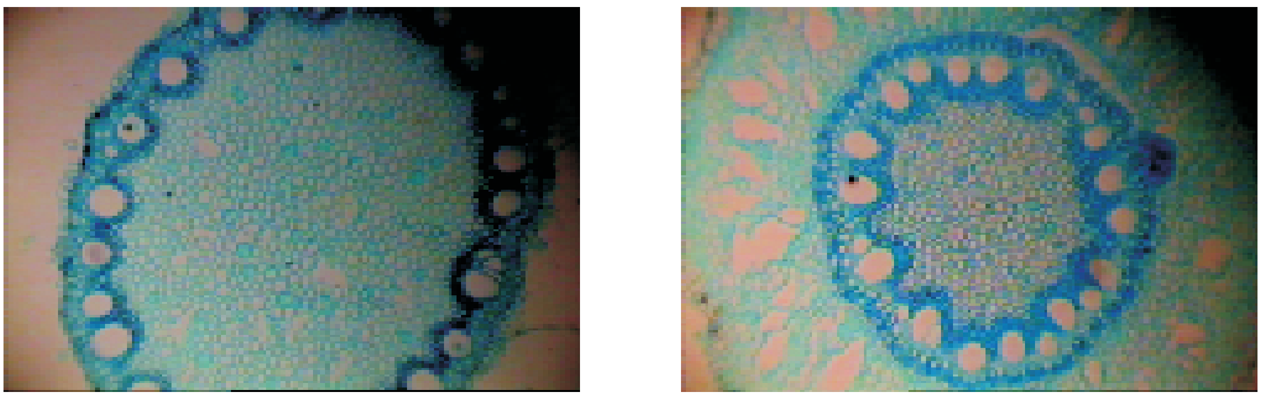
Treatment*	Total chlorophyll ($mg\ g^{-1}$)				Soluble protein ($mg\ g^{-1}$)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	2.45	2.52	2.67	2.51	1.45	4.22	6.82	6.49
T_2	2.56	2.63	2.79	2.67	1.87	4.85	7.24	6.78
T_3	2.58	2.67	2.82	2.72	2.06	5.17	7.53	7.05
T_4	2.74	2.91	3.01	2.92	2.54	5.74	8.14	7.59
T_5	2.85	3.02	3.13	2.99	2.78	5.95	8.38	7.87
T_6	2.63	2.72	2.88	2.77	2.25	5.36	7.72	7.18
T_7	2.69	2.84	2.99	2.87	2.34	5.68	7.86	7.39
CD (p=0.05)	0.09	0.09	0.10	0.09	0.07	0.14	0.18	0.15

*As in Table 1

Table 3. Effect of BDS on yield attributes and grain yield of maize

Treatment*	Cob length (cm)	Cob weight plant^{-1} (g)	No. of grains cob^{-1}	Grain yield (kg ha^{-1})
T_1	14.52	158.4	516.5	3917
T_2	15.48	170.5	538.6	4265
T_3	16.26	192.4	543.8	4493
T_4	21.42	260.3	576.3	5759
T_5	23.84	278.7	581.8	5815
T_6	17.75	220.5	544.6	5543
T_7	18.63	228.5	558.4	5670
CD (p=0.05)	0.88	10.12	21.06	87.90

*As in Table 1



(a) (b)

Fig.1. Transverse section of maize root grown with normal (a) and effluent (b) water irrigation under the high resolution fluorescent microscope

with yield of maize crop. Hence, distillery spentwash from sugar mills hitherto considered as factory waste could be used as a source of nutrients to maize.

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Influence of Land Use Pattern on the Nitrate Contamination of Groundwater in Coimbatore District, Tamil Nadu

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Nitrate contamination in groundwater is a common problem in any part of the world arising from diffuse reasons, e.g. intensive agriculture, unsewered sanitation in densely populated areas, or from point sources such as irrigation of land by sewage effluents. Nevertheless, the heavy use of nitrogenous fertilizers in cropping system is the largest contributor to anthropogenic nitrogen in groundwater worldwide. Nitrogenous fertilizer rapidly converts into NO_3^- form in soils, which is readily available to plants, but is highly soluble and hence easily leachable to deep soil layers and ultimately accumulates into the groundwater (Kundu *et al*., 2008). Elevated concentrations of nitrate in drinking water can cause low oxygen levels in the blood of infants, known as methemoglobinemia or blue baby syndrome, a potentially fatal condition (Wolfe and Patz, 2002), and have been associated with the occurrence of cancer in adults through the formation of carcinogenic N-nitroso compounds (Weyer *et al*., 2001) and to non-Hodgkin's lymphoma (Ward *et al*., 1996). As such, the US Environmental Protection Agency (US EPA) has established a maximum contaminant level of 10 mg/l NO_3-N (US EPA, 2000).

Nitrate occurs naturally in groundwater. However, septic leakage, dairy and poultry farmings, nitrogen fertilizers and animal manures applied to soil can cause elevated levels of nitrate in groundwater (Babiker *et al*., 2004). Many research projects have examined the relationship between specific land use patterns, corresponding pollutant emissions and the resulting groundwater quality (Lerner and Harris, 2009; Chen *et al*., 2010). High groundwater nitrate has been positively correlated with surrounding agricultural land use (Lockhart *et al*., 2013). Thus, the objective of this present investigation was to study the influence of different land use pattern (crop field area, habitation area and dairy / poultry farming areas) on nitrate contamination of groundwater.

Water samples were collected from different sources *viz*., open well, bore well and hand pump located in crop field area (346 samples), habitation area (109 samples) and dairy / poultry farming areas (22 samples), at different villages spread over in the 18 blocks of the Coimbatore district of Tamil Nadu during the month of January, 2008. Due to the industrial influences, the samples were not collected from two blocks *viz*., Palladam and Tirupur. Sampling was done at a spatial distance of approximately 2 to 3 km away from each other areas. While sampling from agricultural fields, care was taken to select the sites having almost similar type of cropping systems over a large area around them for ascribing any possible effects of cropping system on the loading of NO_3–N in the aquifers beneath.

The pH and EC values of the water samples were measured *in-situ* immediately after collection by using portable pH meter and conductivity meter. The NO_3-N content was measured by forming a purple azo-dye out of a coupling reaction between a diazo compound of sulphanilamide and N- (1-napthyl)-ethylene diamine dihydrochloride and recording the colour intensity at 540 nm with the help of a Flow Injection Autoanalyzer (FIASTAR 5000, FOSS Analytical AB, Sweden) with a detection limit of 0.01 µg mL^{-1} NO_3-N following the method described by US EPA (1979). Means of three replicates, range and standard deviation were calculated for all the parameters analysed.

There were little variations in pH and EC values of the groundwater samples. On average, they were neutral to slightly alkaline in reaction and non saline to slightly saline in nature. The NO_3-N content in the sample, however, varied significantly (0.00 to 37.2 mg L^{-1}) in different land uses of the district (Table 1). The mean NO_3-N content was the highest in the water samples collected from dairy/poultry farming areas (9.72 mg L^{-1}) followed by habitation/community areas (6.80 mg L^{-1}) and the lowest in crop field areas (5.93 mg L^{-1}). The formation of nitrate out of ammonia in the dairy farming areas and in the sewage effluents of the habitation areas is higher which may subsequently transported in to the subsoil and then to groundwater for contamination. It might be the reason for higher NO_3-N concentration in the groundwater of dairy farming and habitation areas.

Table 1. Variations in pH, EC and NO_3-N content of water samples collected from different land use pattern

Land use	Number of samples	pH	EC (dS m^{-1})	NO_3-N (mg L^{-1})
		Mean±SD	Mean±SD	Mean±SD
Crop field area	346	8.18±0.45 (7.11-9.16)	1.67±1.40 (0.03-8.63	5.93±5.49 (0.00-26.5)
Habitation/ Community area	109	8.20±0.48 (7.07-9.13)	1.72±1.46 (0.06-9.31)	6.80±6.28 (0.00-35.4)
Dairy/Poultry farming area	22	8.14±0.41 (7.48-9.06)	1.97±1.37 (0.32-5.42)	9.72±8.40 (0.08-37.2)
Total	477	8.18±0.45 (7.07-9.16)	1.70±1.41 (0.03-9.31)	6.31±5.89 (0.00-37.2)

Figures in parenthesis are range values

Out of 477 samples analyzed, 14.7, 38.2 and 27.5 % water samples contained 0-1, 1-5 and 5-10 mg L^{-1} NO_3-N content respectively. Whereas 19.7 % samples recorded NO_3-N content more than 10 mg L^{-1}. Groundwater contamination of NO_3-N was more in dairy/poultry farming areas followed by habitation/community areas and less in crop field areas. About 40.9 % samples collected from the dairy/poultry farming areas contained NO_3-N more than 10 mg L^{-1} compared to only 17.3 % of the samples from the crop field areas.

Among the predominant cropping systems, the mean NO_3-N content in the samples was highest (7.56 mg L^{-1}) in the areas were the vegetables - pulses cropping system was followed and it was followed by turmeric-pulses > millets-pulses > banana-ratoon banana/vegetables > coconut > sugarcane – ratoon sugarcane > cotton-millets/pulses > rice-rice/pulses (Table 2). Ju *et al.* (2007) reported that under shallow rooted heavily fertilized vegetable crops, nitrate losses as a result of leaching could be very large. The crops which have deep and wide rooting pattern can absorb more NO_3-N from the soil profile thus minimizing its percolation to the groundwater. Similar findings were reported by Babiker *et al*. (2004). The lower concentration of NO_3-N in the rice-rice cropping system might be due to an increased loss of nitrate through denitrification under the anaerobic condition existing in the rice-rice system. Andrade and Stigter (2009) stated that in low land rice fields with fine textured soils, leaching loss of nitrogen are low because of restricted percolation.

Results indicated that inspite of intensive cultivation with heavy fertilization, the water samples collected from dairy/poultry farming areas and habitation/community areas were highly polluted compared to crop field areas. Nitrate-N build up in groundwater is possible, where shallow rooted crops such as vegetable crops and turmeric are grown with high nitrogenous fertilizers.

Table 2. NO_3-N content in groundwater under different cropping system

Cropping System	Mean Nitrate-N content (mg L^{-1})
Millets-Pulses	6.53
Vegetables - Pulses	7.56
Coconut	5.25
Cotton-Millets/Pulses	5.13
Banana-Ratoon banana/Vegetables	6.23
Turmeric-Pulses	6.95
Rice-Rice/Pulses	3.64
Sugarcane – Ratoon sugarcane	5.19

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Competitiveness of Wheat (*Triticum aestivum* L.) Cultivars under Spacing and Weed Levels

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The yield of wheat crop is controlled by a number of genetic and external factors. An optimum level of single factor will not cause any appreciable increase in the yield itself, but a combination of factors contributes to the yield of wheat. It is well recognized that by keeping proper row spacing and inputs like varieties, fertilizers and seed rate etc. have an effective role in increasing the yield of crops (Bakht *et al.,* 2007; Kour *et al*., 2011 and Sekhon *et al*., 2012). It is well documented that infestation of weeds cause substantial yield losses in various crops, accounting for 45 per cent yield losses in wheat (Kler *et al*., 2002). It is imperative to control the weeds to increase the grain yield of wheat. For smothering weeds, it is desirable to optimize crop competitiveness, which depends upon genotypic characters of the varieties and also proper spacing etc. Competitive cultivars may therefore be an important component of integrated weed management strategies (Mahajan *et al*., 2013). In modern cropping systems, herbicide application is the most effective weed management. However, the increasing use of herbicides leads to herbicide resistance in weeds and enhancement of environmental and human health risks. Therefore, reducing herbicide application is one of the most important approaches. In the absence of herbicides, weeds are controlled through agronomic practices, including crop rotations, cover crops, intercropping, tillage (Barberi, 2002) and improvement of crop competitiveness (Rezvani *et al*., 2013). Some crop traits such as tillering, height (Lemerle *et al.*, 2001) canopy diameter, leaf area and partitioning of leaf area and dry matter (Rezvani *et al.,* 2010) can play effective role in increasing competitiveness. In Punjab, several commercial wheat cultivars are adopted by farmers, with little information on their performance in weedy condition. This study evaluated the competitiveness of three wheat cultivars against weed flora and to find out the suitable spacing for effective weed management.

The experiment was conducted on wheat at Students' Agriculture Farm, Khalsa College, Amritsar, situated at 31º 38' North latitude, 74º 52' East longitude and at an attitude of 236 metres above mean sea level during r*abi* season. The treatments comprised of three cultivars of wheat (PBW 621, PBW 550 and PBW 343), three spacing (15 cm, 20 cm and bidirectional 22.5 x 22.5 cm) and two weed levels (weed free and unweeded check) in Factorial RBD with 3 replications. The soil of the experimental field was loamy sand with pH 7.5, low in organic carbon 0.35. Sowing of the crop was done manually with single row hand driven drill on 12 November 2011. For variety PBW 343 and PBW 621, seed rate of 100 kg ha^{-1} was used, whereas for PBW 550, 112.5 kg ha^{-1} seed was used. Seed was treated with Chloropyriphos 20 EC (4 ml kg^{-1}) and Vitavax (2 g kg^{-1}) and RDF was applied at the time of sowing and N (urea) was applied in two splits after sowing. Cultural practices followed were in accordance with the recommendations of PAU Ludhiana. Plant height (cm), number of grains per ear, thousand grains weight (g), straw yield (kg ha^{-1}), grain yield (kg ha^{-1}), weed count and weed dry weight were recorded for evaluation.

Plant Height: The maximum plant height was attained by the variety of PBW 621, which was statistically at par that plant height of PBW 343. It was significantly better than the of PBW 550. It shows that PBW 621 and PBW 343 being tall cultivars have a competitive advantage over cultivar of PBW 550. The bi-directional sowing at 22.5 cm x 22.5 cm and closer spacing of 15 cm attained significantly better plant height than sowing at 20 cm. Similar results were also reported by Bakht *et al.* (2007). They reported that plant height varied due to varieties. In weed free plots, plants attained significantly better height than plants of unweeded check plots.

Weed Count: Cultivars PBW 621 and PBW 343 had 34.77 and 27.79 per cent less weed count, respectively than PBW 550. The difference in the ability of cultivars PBW 621 and PBW 343 to suppress weed growth more than PBW 550 might be due to taller plants (Dhima *et al.,* 2008) and more tillers. Presence of these attributes in cultivars of PBW 621 and PBW 343 conferred better competitiveness against most

Table 1. Effect of different treatments on yield and yield attributing characters of wheat, weed count and weed dry matter accumulation.

Treatment	Plant height (cm)	Effective tillers (per sq m)	1000-grain weight (g)	Ear length (cm)	Grains per ear	Straw yield ($q\ ha^{-1}$)	Grain yield ($q\ ha^{-1}$)	Weed count (per sq m)	Weed dry weight ($q\ ha^{-1}$)
Cultivars									
PBW 621	99.5	383.5	39.1	11.0	46.2	84.09	58.55	7.9 (109.9)*	3.3(15.7)*
PBW 550	86.8	336.5	39.6	10.2	40.5	75.25	52.39	9.1 (148.2)	3.8(21.2)
PBW 343	95.9	369.0	37.0	10.1	39.9	75.01	52.22	8.1 (115.9)	3.4(16.6)
CD (5%)	5.8	34.2	2.1	0.6	1.9	6.73	4.69	0.4	0.2
Spacing									
15 cm	96.8	372.6	39.1	10.6	43.2	80.51	56.05	8.0 (112.0)	3.6(16.0)
20 cm	87.0	328.3	37.0	10.0	38.5	71.74	49.94	9.3 (153.3)	3.8(21.9)
Bi- directional (22.5 x 22.5 cm)	98.4	388.1	39.6	10.8	44.8	82.10	57.18	7.9 (108.7)	3.3(15.6)
CD (5%)	5.8	34.2	2.1	0.6	1.9	6.73	4.69	0.4	0.2
Weed Treatment									
Weed free	97.1	388.7	40.0	11.3	44.4	82.88	57.71	1.0 (.0)	1.0(.0)
Unweeded check	91.1	337.3	37.1	9.6	40.0	73.35	51.07	15.7 (249.4)	6.0(35.6)
CD (0.05)	4.7	27.9	1.72	0.47	1.53	5.49	3.83	0.3	0.1

*Figures in the parentheses are the means of original values before the transformation (square root transformation) of data.

weeds than cultivar PBW 550 with shorter plants and less tillers. Bidirectional sowing (22.5 cm x 22.5 cm) and closer spacing of 15 cm reduced the weed count by 41.0 per cent and 36.9 per cent, respectively in comparison with spacing of 20 cm. Crop sown with bidirectional method and closer spacing of 15 cm provided the more competition to weeds for space, moisture, nutrients and light, which resulted in less weed population.

Weed Dry Weight: Data recorded on weed dry weight on statistical analysis revealed that cultivar PBW 621 had a competitive advantage over weeds as it recorded minimum weed dry weight, which was followed by cultivar PBW 343 and maximum weed dry weight was observed in cultivar PBW 550. It could be due to the less population of weeds, which resulted in less weed dry weight. Bidirectional sowing (22.5cm x 22.5cm) and closer spacing 15 cm also reduced the weed dry matter accumulation by 15.66 and 5.49 per cent, respectively in comparison with normal spacing 20 cm (Table 1).

Grain and Straw Yield: Cultivar of PBW 621 was superior to the other two varieties in terms of grain yield. Cultivar of PBW 621 gave significantly more grain yield i.e., 11.75 and 12.12 per cent than cultivars of PBW 550 and PBW 343, respectively. The differences among the varieties in grain and straw yields might be due to the genetical differences among cultivars and different genotypes concerning dry matter partitioning where wheat cultivars might differ in carbon equivalent, yield energy per plant (Abd El-Gawal *et al.,* 1987). Bidirectional sowing of crop at 22.5x22.5 cm and unidirectional sowing at 15 cm gave 12.66 and 10.9 per cent more grain yield, which was significantly better than grain yield obtained from unidirectional spacing with 20 cm. These results are in conformity with the findings of Fonts *et al.* (1997) who reported that grain yield decreased with increase in spacing. Also, the unweeded check resulted in significant reduction of yield as compared to weed free treatment. Cultivar of PBW 621 was superior to the other two varieties in terms of straw yield and gave significantly higher straw yield (11.75 and 12.10%) than cultivars of PBW 550 and PBW 343. In case of spacing, significantly higher straw yield was found under bidirectional sowing at 22.5 cm 22.5 cm as well as in closer spacing of 15 cm than in spacing of 20 cm. Weed free treatment recorded significantly higher straw yield in comparison to unweeded check treatment.

Wheat cultivars had the differential weed suppression ability due to the variation in yield, growth and yield contributing characters. Cultivar of PBW 621 proved highly competitive genotype against weeds, which had higher plant height, effective tillers that led to more yield contributing characters. Bidirectional (22.5 x22.5 cm) and closer spacing (15 cm) sown wheat showed significant smothering effect on weeds and produced significantly higher yield than spacing of 20 cm. It also showed that crop should be weed free for higher yield.

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Biology of Sugarcane Aphid (*Ceratovacuna lanigera* Zehntner) upon Selected Sugarcane Host Plants

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Sugarcane (*Saccharum officinarum*) is the most important economic crop of the tropical area and contributes nearly 70 per cent of the world's total sugar production. Besides, it is also a source of fuel, food and fodder. The sugar industry is the second largest agro-based industry in India with 64.6 tone/acre and 10.36 per cent sugar recovery. The crop is attacked by about 288 species of insect and non-insect pests based on their damage causing 20 per cent in cane yield and 15 per cent in sugar recovery. The sugarcane woolly aphid (SWA), *Ceratovacuna lanigera* Zehntner (Homoptera: Aphididae) has become a threat to the sugarcane crop as well as sugar industry (Patil and Nerker, 2004)

There is lack of research about biology of sugarcane woolly aphid related to varietal resistance plant belonging to Bixaceae and Combretaceae. Patil *et al.*(2004) studied the colonization of *C. lanigera* on sugarcane varieties and found that the released aphids could not colonize on resistant clones even after 2nd to 3rd days of release, whereas on susceptible genotypes including commercial varieties, aphids immediately colonized within 42 hours, after infestation, indicating the possibility of antibiosis and /or non-performance mechanisms in suppressing the pest and arresting further colonization and spread. Also, Wensler and Fishie (1969) reported that aphids have a more intimate relationship with their host plants than many other pests and are affected by small changes in the nitrogen status of the host. The present study was conducted to evaluate relationship between sugarcane aphid and six selected genotypes with the special reference to biology and distribution of pest in sugarcane fields.

The four selected genotypes were planted by taking each genotype in a row of six meter length under the greenhouse condition with a spacing of 40 cm x 10 cm between rows and plants, respectively with four replications. For studying the biology of apterous/alate form of sugarcane aphid, single apterous/alate adults were confined on the lower surface of leaf with the help of perforated OHP sheet cage. Thereafter, daily observations were recorded to study the duration of each nymphal period, total nymphal period, fecundity and longevity.

Freshly laid first apterous nymphs were yellowish green in colour without any woolly matter on their body. The nymphal duration was shortest (2.25 days) on CoC 671, while it was longest (3.00 days) on Co 91010 (Table 1). The second apterous instar nymphs were yellow in colour without woolly coat on the tested varieties; the nymphal duration varied from 3 to 5 days. The nymphal duration was again shortest (3.25±0.5 days) on Co C 671 and it was longest (4.50 days) on Co 91010, whereas similar nymphal duration was recorded on other varieties of sugarcane.

The third apterous instar nymphs were yellowish brown in colour with whitish waxy filaments all over their bodies. The duration of the nymphs ranged from 6 to 11 days among different varieties. The shortest nymphal period of 7.50±1.29 days was observed on CoC671, being at par with Co 99004 (7.75±1.50days), Co2001-09 (8.50 days) and Co 91010 (8.75±1.26 days). The duration of the third instar nymph was longest on Co 79158 (10.00±1.15 days) and being at par with Co 2001-09 (8.50±1.91 days).

The body of the fourth instar nymph apterous was covered with white matter and the nymphal duration ranged from 7 to 11 days among the different varieties. The duration of the subsequent instar nymphs remained same on all the varieties tested as they were statistically at par with each other.The moulted aphids in all the instars were bright yellow in colour and easily distinguishable.

The total nymphal period varied from 18 to 27 days among the different varieties. The nymphs duration varied from 21.50 to 24.50 in CoC 671 and Co 91010 days. The adult apterous aphids had woolly matter covering their body on dorsal remaining same on all the varieties which ranged from 9-16 days as they were on par with each other. The apterous aphids were parthenogenetic, but viviparous type of reproduction was also observed and the adult aphid gave birth to first instar nymphs among the different varieties. Significantly highest (84.00±14.99 nymphs/adult) fecundity was recorded on CoC 671, which was at par with Co 2001-09 (83.25±7.63 nymphs/adult) and it was lowest (50.00±13.83 nymphs/adult) on Co 91010, being at par with Co 79158 (55.50±14-71 nymphs/adult). The total nymphal period was shortest in highly susceptible variety CoC 671 (21.50 days), whereas it was longest in moderately resistant variety Co 91010 (25.75 days). Adult longevity remained same in different genotypes as they were statistically on par with each other. Fecundity was comparatively higher in susceptible varieties than highly resistant varieties via Co 91010 and Co 79158.

The present finding revealed that there was five days difference in the total nymphal duration of CoC 671 and Co 79158 that may be due to antibiosis mechanism operating in the variety and it helps to reduce the number of generations/year. Several studies carried out on the biology of apterous SWA, but there is no literature to discuss its biology in resistant and susceptible sugarcane varieties to evaluate the antibiosis mechanism of resistance.

Puttanwar (2004) reported the mean duration of first, second, third and fourth instar SWA as 2.43, 4.21, 7.31 and 8.06 days, respectively and mean total nymphal period as 23.01 days. Takano (1941) from Japan reported that the nymphal period lasted from 23-33 days. Chang *et al*. (2000) from Taiwan reported adult longevity of 20-24 days and Shankar and Shitole (2004) mentioned that nymphal period lasted for 20 days. These results are more or less similar with the present study which supports rearing of SWA on different genotypes. Puttanawar (2004) reported the mean longevity of SWA as 15.90 days and is consistent with the present study. The fecundity of SWA on different varieties in the present study is similar with the result of Puttanawar (2004) who reported it as 46.51 nymphs/ female and Chang *et al.* (2000) reported 41.0-56.6 nymphs/adult in the lifetime which agrees with the present study. But, it was contradictory with Patil and Nerker (2004) who reported 21.7 young ones in the life span of the female.

The biology of alate SWA was studied under greenhouse condition from March 2012 to July 2012 in four different sugarcane varieties and the results are presented in Table 2. Freshly laid first instar nymphs were blackish to olive green in colour without woolly matter on their body. After 1-2 days, thin layer of woolly matter development was seen around their body. First instar nymphs duration remained same which ranged from 2 to 4 days on different varieties being at par with each other. Similarly, the second instar (3-5 days), third instar (10-12 days) and fourth instar (9-11 days) nymphal duration were also remained same on all the varieties under test. Second instar nymphs were greenish yellow in colour, where as third and fourth instar nymphs were yellowish brown in colour with whitish waxy filaments on their body. The total nymphal period remained same on all the varieties as they were at par with each other and it varied from 24 to 30 days among the different varieties. Also, adult longevity remained same on all the varieties which ranged from 6 to 12 days as they were at par with each other. The adult alates were parthenogenetic but viviparous type of reproduction was observed in sugarcane woolly aphid and adult aphid gave birth to first instar nymphs directly. The fecundity ranged from 12-33 aphids/adult among the different varieties. Significant highest (19.50 nymphs/adult) fecundity was recorded on CoC 671 which was at par with all the varieties except co 79158 (13.50 nymphs/adult). The mean duration of alate SWA in different instars ranged from 3.25, 3.75, 4.25, 4.75, 10.50, 11.25 and 9.25-10.00 days in first, second, third and fourth instars respectively in different sugarcane genotypes with no significant difference. The total nymphal period and adult longevity remained same in all the evaluated genotypes, as they were statistically on par with each other. Highest fecundity was observed in CoC 671(19.50 nymphs/female) and it was longest in Co 79158 (13.50 nymphs/female) as indicated in figure 2.

Based on the present study, it is clear that no

Table 1. Biology of sugarcane woolly aphid (apterous) on four different sugarcane genotypes (Mar- July 2012)

Varieties	Life Stage Duration (days)						
	Instar I	Instar II	Instar III	Instar IV	Total N. P.	Adult	Fecundity (nymphal adult)
	Mean ±SD (Range)	Mean ±SD (Range)	Mean ± SD (Range)	Mean ±SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)
CO 91010	3.00 ± 0.72 ab (2 – 4)	4.50±0.58 ab (4 – 5)	8.75±1.50 ab (7 – 10)	8.25±1.50 (7 – 10)	24.57±1.91 abc (22 -26)	13.75±1.89 (11 – 15)	50.0±13.83 b(33 – 64)
CO 79158	2.75±0.50 ab(2 – 3)	3.75 ±0.96 ab (3 – 5)	10.0±1.15a (9 – 11)	9.25 ±1.26 (8 – 11)	25.75 ± 1.71 ab (24 – 28)	13.00 ±1.41 (11 – 14)	55.5 ±14.71 b (38 – 70)
CO 2001-09	2.75 ± 0.50 ab (2 – 3)	3.75 ±0.50 bc (3 – 4)	8.50 ± 1.91 ab (7 - 11)	9.00 ±1.63 (7 – 11)	24 ± 3.83 abc(19 – 27)	13.25 ±2.03 (11 – 16)	83.25±7.63 a (74 - 90)
COC 671	2.25 ± 0.50 (2 – 3)	3.25 ±0.50 c(3 – 4)	7.50 ±1.29 b (6 – 9)	6.50 ±1.29 (7 – 10)	21.50±2.05 c(18 – 24)	12.75 ±2.75 (10 – 16)	84 ± 14.99 a (83 – 97)

Table 2. Biology of sugarcane wooly aphid on four different sugarcane genotypes (Mar -July 2012)

Varieties	Life stage duration in days (Mean±SD)						
	Instar I	Instar II	Instar III	Instar IV	Total N.P.	Adult	Fecundity (nymphs/adult)
CO 91010	3.50 ±0.58 (3 – 4)	4.75±0.50 (4 – 5)	10.50±1.00 (10 – 12)	9.50±0.58 (9 – 10)	28.25±0.96 (27 – 29)	9.00±2.58 (6 – 12)	17.50±4.95 (12 – 33)
CO 79158	3.25 ±0.50 (3 – 4)	4.50±0.58 (4 – 5)	11.00±0.82 (10 – 12)	10.00±0.82 (9 – 11)	28.75±0.50 (28 – 29)	9.50±0.58 (9 – 10)	13.50±1.29 (12 – 15)
CO 2001-09	3.25 ±0.50 (3 – 4)	4.25±0.50 (4 – 5)	10.50±0.58 (10 – 11)	9.50 ± 1.00 (9 – 11)	27.50±1.29 (26 – 29)	9.00±1.41 (7 – 10)	18.50±1.73 (17 – 21)
COC 671	3.25 ±0.96 (2 – 4)	4.25±0.96 (3 – 5)	10.75±0.50 (10 – 11)	9.25 ± 0.50 (9 – 10)	27.50±2.38 (24 – 29)	9.25±0.50 (9 – 11)	19.50±5.07 (12 – 23)

Figures in parentheses indicate the range

antibiosis operated in resistant varieties against SWA. There is no available literature to justify the result thought many studies have been carried out on the biology of alate SWA. Puttanawar(2004) reported 7.52 days of alate longevity with a fecundity of 15.33 nymphs/female is in agreement with present findings. Singh *et* al. (2004) observed antibiosis on sorghum varieties IS12609L, IS 12664C and TMK428 against sugarcane aphid (*Melanaphissachari*) and reported least number of days to reproduction, greater mortality, shorter longevity and fecundity of fewer nymphs.

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Biology of *Tetranychus ludeni* Zacher (Acari: Tetranychidae) on Brinjal

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Many phytophagus mites have attained pest status causing considerable losses to cultivated crops, particularly vegetables. Phytophagus mites feed on the plants and cause injury. *Tetranychus ludeni* Zacher (Acari: Tetranychidae) is one of the most serous mite pest of vegetable in India (Singh, 1995).The spider mite species, *T. ludeni* is a serious pest of a wide variety of economically important plants. The mite often infests the upper surface of the leaves cause yellowing of leaves, followed by formation of necrotic patches and drying up. It is one of the important mite pests of vegetable crops in India reported to attack French bean, brinjal, potato, watermelon and many other vegetable and fruit crops limiting the production of these crops (Jeppson *et al*., 1975; Puttaswamy and ChannaBasavanna, 1980b). As a highly polyphagus mite, *T. ludeni* occurs in the field almost throughout the year. Moreover, this is the only spider mite in India known to be a vector of the plant viral disease, *viz.* Dolichos enation mosaic virus (DEMV) (Rajagopalan, 1974). The high intensity of *T. ludeni* infestation on brinjal and the extensive degree of visible damage caused due to the mite attack led to the selection of this plant for the study. The present study gives an account of the developmental strategies of *T. ludeni* infesting *Solanum melongena.*

Culture of *T. ludeni* was raised in the laboratory of Department of Entomology, T. D. Collage Jaunpur by bringing *T. ludeni* infested brinjal and releasing them on leaf disc on wet cotton swab kept in petri dishes. The cotton swab was kept moist so that the leaf containing mites remained green. The leaf discs were changed once in 3-4 days. The mites multiplied rapidly and thus, a fairly pure laboratory culture was obtained. Several such petri dishes were maintained in the laboratory and kept in room temperature. Biology of the mite was studied on leaf discs on wet cotton swab and maintained in the same manner as stated above. Female deutonymph and adult male were released on leaf disc in a series of petri dishes. As soon as the female emerged out of deutonymph, the male mated with female and fertilized female, thus obtained, was allowed to lay eggs. The eggs, obtained on the next day, were observed until they hatched and thus, incubation period was recorded. Subsequent observations regarding duration of different stages were recorded at six hourly intervals. Fecundity of a single fertilized female was observed by isolating an adult female to separate leaf disc as soon as it was fertilized by males just after the emergence of the female. In case of unfertilized female, the deutonymph quiescent stage was transferred to a separate leaf disc. From the same set of experiment, longevity of adult female was recorded. The longevity of a male was obtained by isolating a male at deutonymph stage and transferring it to a separate leaf disc. The observations were made under the stereoscopic binocular microscope..

Adult females exhibited a general preference to the upper surface of leaves though no specific selection of site for depositing of eggs was noticed. Ovipositing females constructed silken web prior to the deposition of the eggs. Eggs were laid single on the under surface of the leaf, preferably along the thick veins under the webbing. The fertilized female produced both males and females.

The incubation period was 4.60 ± 0.89 and 5.00 ± 0.70 days at average temperature of 31.3°C and 37.3°C, respectively. The larval stage was completed in 1.90 ± 0.50, 1.30 ± 0.44 and 1.76 ± 0.53 day at an average temperature of 31.3°C relative humidity 75.0 per cent, and 1.90 ± 0.65, 1.90 ± 0.41 and 1.30 ± 0.27 days at 37.3°C, relative humidity 54.0 per cent (Table 1 and 2). The time required to complete the life cycle was 9.60 ± 1.15 and 10.16 ± 0.42 days at average temperature of 37.3°C and 31.3°C, respectively. The adult male remained for 5.40 ± 0.65 and 5.60 ± 0.92 days while as the adult female lived for 9.45 ± 0.70 and 9.60 ± 0.96 days at above mentioned temperatures, respectively. Average fecundity was 116.6 ± 8.08 and 119.4 ± 6.42 for fertilized female and 57.4 ± 5.85 and 59.2 ± 4.76 for unfertilized female on under similar conditions (Table 1).

The effect of temperature and relative humidity on the development and oviposition was studied by Puttaswamy and ChannaBasavanna (1980a), Gotoh *et al*. (2003) and Haque *et al*. (2007). Among the five temperature (20 ± 1°C,

Table 1. Duration (in days) of different stages and fecundity of *Tetranychus ludeni* (Mean±SD)

Period	Incubation period	Larva	Protonymph	Deutonymph	Total period	Longevity		Average fecundity	
					Egg to adult	Male	Female	Fertilized ♀	Unfertilized ♀
April 2012	5.00±0.70	1.90±0.54	1.30±0.44	1.76±0.53	10.16±0.42	5.60±0.92	9.45±0.70	116.60±8.08	57.40±5.85
May 2012	4.60±0.89	1.90±0.65	1.90±0.41	1.30±0.27	9.60±1.15	5.40±0.65	9.60±0.96	119.40±6.42	59.20±4.76

24 ± 1 °C, 27 ± 1 °C, 30 ± 1 °C and 32 ± 1°C) and five relative humidity (55 ± 3%, 65 ± 3%, 75 ± 3%, 85 + 3% and 95 ± 3 %), the optimum condition for development and maximum survival of eggs were found between 32 ± 1 °C and 35 ± 1°C and 65 ± 3% and 75 ± 3% relative humidity. The optimum condition for development of immature were 30 ± 1 °C to 35 ± 1°C. The lowest numbers of eggs were laid at 20 ± 1°C. High humidity (95 ± 3% R.H.) reduced egg production capacity of adults irrespective of temperature ranges. In their another study by Puttaswamy and ChannaBasavanna (1980), it was found that females took 12.48 ± 0.16 days and males took 11.96 ± 0.38 days to complete the life cycle. Mated and unmated female had oviposition period of 1.54 ± 0.30 days and 1.43 ± 0.11 days, respectively and laid on an average 165.88 ± 47.04 eggs and 132.00 ± 28.54 eggs during their ovipositional periods of 22.83 ± 4.56 days and 27.98 ± 4.50 days and 32.14 ± 4.08 days, respectively. In the present findings, incubation period, larval, protonyphal and deutonymphal period of *T. ludeni* being 5.00 ± 0.70 days and 4.60 ± 0.86 days, 1.90 ± 0.54 days and 1.90 ± 0.65 days; 1.30 ± 0.44 days, 1.90 ± 0.41 days; 1.76 ± 0.53 days and 1.30 ± 0.27 days, respectively. The time taken to complete the life cycle of *T. ludeni* was found to be 10.16 ± 0.42 days and 9.60 ± 1.15 days at relative humidity 75 and 54 per cent and average temperature 31.3 °C and 37.3°C. Its life history has been studied by Mallik and ChannaBasavanna (1983), Nandagopal and Gedia (1995), Haque *et al*. (2007). According to the latter report, the life cycle (egg-adult) took an average of 14.3 days during January. The duration of other stages are; egg (5-8 days), protonymph (3-4 days), deutonymph (3-5 days) and longevity of adult male is 1-4 days whereas female survive from 4-14 days. Sangeeta and Ramani (2007) obtained almost similar result.

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Eco-Friendly Management of Fruit Flies, *Bactrocera* spp. in Guava with Methyl Eugenol Traps in Punjab

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Guava is an important fruit crop of Punjab occupying 8.07 thousand hectares. However, fruit flies, *Bactrocera* spp. are the major limiting factors in successful cultivation causing almost 100 per cent damage to rainy season guava crop (Singh and Sharma, 2013) as it is the most preferred host of fruit flies. The fruit flies are very difficult to manage as they are polyphagous, multivoltine, adults have high mobility and fecundity and all the developmental stages are unexposed. Only adults are exposed while eggs and maggots remain protected in the host tissues and most of insecticidal treatments are ineffective. Application of insecticides disrupts the ecosystem and causes numerous hazards, which in the present scenario warrants the need of integrated approach for fruit fly management (Verghese *et al.,* 2012). The use of methyl eugenol traps stands as the most outstanding alternative among the various alternate strategies available for the management of fruit flies. Methyl eugenol, when used together with an insecticide impregnated into a suitable substrate, forms the basis of male annihilation technique (MAT). Thus, keeping in view the importance of fruit flies on guava crop, a technology was devised for management of male fruit flies with methyl eugenol based mineral water bottle traps designated as PAU Fruit Fly Traps.

The trials were conducted in guava orchards for the management of fruit flies by using methyl eugenol based MAT (PAU Fruit Fly Traps) during 2013-14 at 13 locations in 10 districts of Punjab. One litre capacity mineral water bottle trap was used (Plate-1). The trap consisted of a plywood dispenser suspended vertically inside the bottle, aligning with the four vents that allowed entry of fruit flies inside the bottle. The traps used in MAT technique consisted of immersing water absorbable plywood blocks of size 7.5 cm x 6.0 cm x 2.0 cm in a solution of ethyl alcohol, methyl eugenol and malathion mixed in a glass jar in the ratio of 6:4:1 (v/v) for 72 hrs so that this solution could be properly absorbed in the plywood blocks (Singh and Sharma, 2013). For hanging on tree, a hole in the plywood block was made to put wire. Four holes were made on the upper side of the bottle for entry of fruit flies. Bottles were cut from bottom and plywood block was hanged inside the bottle with two sides of wire coming out from the top of the bottle.

Four random holes of 3-4 mm diameter were made at the bottom to drain the rain water. The wire was twisted to make a loop. Sixteen traps/acre were fixed in each guava orchard alongwith an untreated control of one acre area. The baited bottles were hanged with the trees at equidistance. The traps were fixed in the first week of the July till end-October when the fruit harvesting was over.

The height of trap was 1-1.5 metre from ground level at a place receiving no direct sunlight. The lower cut portion of the bottle (lid) was removed and all the fruit flies trapped in the bottle were collected after every 7 days. The fruit flies trapped/trap were counted in the laboratory at weekly interval when the number was low (< 100) but when the large was large enough, the count was made on weight basis. From both the treatments (16 traps/per acre and control), a sample of 50 fruits at random/treatment collected at weekly interval were sorted out as infested (based on the oviposition punctures), maggots emerging out of fruits, fallen

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Plate 1. PAU fruit fly trap

fruits and healthy fruits. Impact of traps on the number of marketable fruits was also assessed by counting number of marketable fruits from five trees.

Consolidated data revealed that a total number of 2,51,621 male fruit flies were trapped at 13 locations in 10 districts. In orchards with 16 traps/acre, fruit fly infested fruits were 37.0 per cent as compared to 82.3 per cent in untreated orchards (Table 1). The marketable fruits/tree were 581 fruits/tree in orchards where 16 traps/acre were fixed as compared to 224 fruits/tree in untreated orchards. The data on the male fruit fly catch at different locations indicated that the highest fruit flies/16 traps were at Bahadurgarh (1,20,311 flies) followed by at Ballowal (41,668 flies) whereas minimum flies trapped were at Faridkot (1098 flies). The results further showed that the maximum infested fruits were observed at Jalandhar (57.2 %) followed by 48 per cent each at Pathankot and Ballowal, in 16 traps/acre. In untreated orchard, maximum infested fruits were recorded in Jalandhar (100%) followed by 95 per cent each at Ludhiana-1 and Patiala. The highest number of marketable fruits/tree was recorded at Bathinda (950 fruits/tree), in 16 traps/acre whereas in untreated orchards, maximum number of marketable fruits were recorded at Pathankot (628 fruits/tree).

Jalaluddin *et al.* (2001) assessed the population fluctuations of the *Bactrocera correcta* (Bezzi) in guava orchards using methyl eugenol traps and recorded a distinct population peak from July to August, which coincided with the ripening. Singh *et al.* (2011) recorded number of adult male fruit flies captured/trap at weekly interval in pear in Punjab. Trap catch ranged from 74.9 to 326.4 flies/trap/week during different years.

According to Singh and Sharma (2012), 16 traps/acre fixed in peach orchards at Ludhiana had significantly more population of male fruit flies compared to 4, 8 and 12 traps/acre. More the number of males captured, less was the number of maggots/fruit in the field and 16 traps/acre had significantly less number of maggots/fruit as also observed in the present study. It was further observed that number of traps had a significant impact on the quality marketable fruits and yield. Palam Trap, a lure based mineral water bottle trap was found effective in monitoring and management of 10 species of fruit flies including *B. dorsalis* (Hendel) and *B. zonata* (Saunders) in fruits and vegetables in Himachal Pradesh (Mehta *et al.* 2010) and 16 traps/acre in the present studies with methyl eugenol also attracted both the species. The results on capture of male fruit flies in the present study are comparable with Sharma (2012) who also found that methyl eugenol traps were effective against *Bactrocera* complex on mango, guava, sapota and peach.

This technique has been successfully used for the eradication and control of several *Bactrocera* species (Stonehouse *et al.,* 2007, Vargas *et al.,* 2010). The present findings showed a significant impact in reducing the damage and increasing the number of quality fruits as also reported in earlier studies (Singh and Sharma, 2013). The findings also indicated that 16 traps/acre in guava were very effective in reducing fruit fly damage as also reported by Viraktamath and Ravikumar (2006) in India. It is concluded that successful eco-friendly management of fruit flies in guava can be achieved by fixing PAU fruit fly traps @ 16 traps/acre in the first week of July to get higher number of marketable fruits.

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Table 1. Efficacy of PAU fruit fly traps in guava in Punjab

Treatment	Locations													
	LDH 1	LDH 2	FKA	HSX	PTA	PTK	JUC	BDG	FDK	ASR	BLW	JLW	BTI	Grand total /mean
	Total fruit flies captured/16 traps													
	12,025	10,728	1529	6775	17,836	17,986	2541	1,20,311	1098	NR	41,668	15,744	3380	2,51,621
	Mean per cent infested fruits													
16 traps/acre	30	35	45	12	33	48	57.2	45.4	33	20	48	14	6.6	37.0
Control	95	90	90	78	95	55.2	100	65.8	57.2	90	76	85	92.3	82.3
	Number of marketable fruits/tree													
16 traps/acre	430	365	298	640	801	676	664	193	611	NR	SP	762	950	581
Control	65	58	49	65	295	628	437	86	408	NR	SP	80	300	224

LDH-1 & LDH-2 - Ludhiana, FKA-Fazilka, HSX-Hoshiarpur, PTA-Patiala, PTK-Pathankot, JUC-Jalandhar, BDG- Bahadurgarh, FDK-Faridkot, ASR-Amritsar, BLW-Ballowal, JLW-Jallowal, BTI-Bathinda; NR-Not recorded; SP-Small plants (yield not worth recordable)

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Varietal Preference of Aphid, *Myzus persicae* (Sulz.) on Cumin

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Cumin, *Cuminum cyminum* Linn. is an important spice crop, cultivated in North India. Cumin seeds contain 2-5 per cent volatile oil, which consists of 25-35 per cent aldehydes, pinene and alphaterpineol. The seeds also contain flavonoids (including apigenin). Cumin is extensively cultivated in irrigated sandy loam to loamy soils of South-Western and North-Eastern regions of Rajasthan during *Rabi* season. The cumin aphid, *Myzus persicae* (Sulz.) was reported as the major insect pest of cumin in Rajasthan. This pest was observed causing serious damage at flowering stage of the crop and decreased the crop yield. With the view to provide a sound base to the IPM strategy against a pest, it is essential to study the varietal preference of aphid to generate the useful information on host plant resistance.

The cumin varieties, *viz.,* RZ-19, RZ-209, RZ-223, UC-336, UC-267, UC-293 and UC-339 and local were screened for their resistance against aphid. The crop was sown in a simple randomized block design (RBD) with three replications. The populations of nymphs and adult aphids were *recorded* on five plants per replication at weekly intervals starting from third week of January (initiation of aphid population). The plant height, number of umbels plant^{-1}, days to 50 per cent flowering, days to maturity of each genotype was also recorded. The mean aphid population of cumin varieties recorded during the crop season was categorized on the basis of formula, X $\pm$ (Where, X = Mean of peak aphid population, = Standard deviation of peak aphid population). Accordingly, the varieties were categorized as least susceptible (X -), moderately susceptible (X - to X +) as highly susceptible (above X +).

Population of aphid: The aphid population started to build up from second week of January (8 January, 2012) on all genotypes and ranged from 8.23 to 28.35 aphids/three umbels. The minimum population was recorded on RZ-223 which was significant at par with RZ-209 and RZ-19, these genotypes were found significantly superior over other genotypes. More or less similar trend was observed on 15th, 22nd and 29th January, 2012**.** The aphid population reached to peak in 5th observation recorded on 5th February, 2012. The population was found to be in the range of 101.84 to 130.47 aphids/ three umbels, the minimum being on RZ-223 and maximum on local genotype. The genotype RZ-223 was at par with RZ-209 with respect to aphid population. The maximum population on local genotype was non significant with UC-339 and UC-267.

The population was in declining trend after 5th February, 2014. On 11th March, 2012 the aphid population was very low on all the genotypes and ranged from 10.65 to 48.05 aphids per three umbels. Based on overall mean population of the season, the increasing trend of aphid numbers was observed in the order of RZ-223, RZ-209, RZ-19, UC-293, UC-336, UC-267, UC-339 and local.

Based on the statistical categorization (X $\pm$ σ), the mean aphid population was found to be below 63.29 per three umbels and the two genotypes, RZ-223 and RZ-209 were categorized least susceptible to *M. persicae.* The population of aphid was in the range of 63.29- 86.29 per three umbels on genotypes, UC-293, UC-267, UC-336, and RZ-19, therefore, categorized as moderately susceptible. The population of aphid was above 86.29 per three umbels in genotypes UC-339 and local, and categorized as highly susceptible. The results are in full conformity to Kumawat *et al.* (2007), who reported RZ-19, RZ-223 and RZ-209 as least susceptible. The findings also got support from the findings of Meena (1993) who reported RZ-19 as moderately susceptible.

Morphological characters of different genotypes of cumin: The plant height and number of primary branches/plant ranged from 27.96 to 33.02 cm and 4.05 to 6.02, respectively, which showed significant negative correlation with population of aphid. The number of umbels plant^{-1} ranged from 21.82 to 30.37, which had significant negative correlation (r= -0.70) with aphid population (Table 2). The days to 50 per cent flowering influenced the aphid population as these revealed significant correlations (r= 0.80). However, the seed yield was drastically influenced by the aphid population as it ranged from 3.05 to 4.25 q ha^{-1} in different genotypes. The minimum being on local and maximum on RZ-209. Further the seed yield revealed a negative but significant correlation with aphid population (r= -0.76).

The present studies revealed that RZ-223 and RZ-

Table 1. Mean population of aphid, *Myzus persicae* (Sulz.) on different genotypes of cumin during *rabi* 2011-12

Genotypes	Weekly mean aphid population / three umbels										
	08/01/12	15/01/12	22/01/12	29/01/12	05/02/12	12/02/12	19/02/12	26/02/12	04/03/12	11/03/12	Mean
RZ-19	16.23	70.62	92.25	105.65	120.84	92.74	69.12	51.02	28.72	12.65	66.08
	(1.21)	(1.85)	(1.96)	(2.02)	(2.08)	(1.97)	(1.84)	(1.71)	(1.46)	(1.10)	(1.82)
RZ-209	10.30	67.62	85.96	98.96	105.55	88.68	70.55	55.34	30.00	12.96	62.64
	(1.01)	(1.83)	(1.93)	(2.00)	(2.02)	(1.95)	(1.85)	(1.74)	(1.48)	(1.11)	(1.80)
RZ-223	8.23	65.62	87.25	95.65	101.84	91.74	67.12	50.02	26.72	10.65	60.28
	(.91)	(1.82)	(1.94)	(1.98)	(2.01)	(1.96)	(1.83)	(1.70)	(1.43)	(1.03)	(1.78)
UC-336	20.56	76.52	96.95	101.05	106.08	97.82	85.69	78.49	55.83	31.53	75.09
	(1.31)	(1.88)	(1.99)	(2.01)	(2.03)	(1.99)	(1.93)	(1.89)	(1.75)	(1.50)	(1.88)
UC-267	22.54	82.03	100.92	108.65	119.05	107.01	93.45	85.34	67.92	40.06	82.69
	(1.35)	(1.91)	(2.00)	(2.04)	(2.08)	(2.03)	(1.97)	(1.93)	(1.83)	(1.60)	(1.92)
UC-293	21.44	78.76	94.09	100.11	108.62	104.64	88.36	73.36	48.43	28.04	74.58
	(1.33)	(1.90)	(1.97)	(2.00)	(2.04)	(2.02)	(1.95)	(1.87)	(1.69)	(1.45)	(1.87)
UC-339	25.30	85.35	103.33	112.41	122.93	111.90	99.65	88.74	74.22	45.04	86.88
	(1.40)	(1.93)	(2.01)	(2.05)	(2.09)	(2.05)	(2.00)	(1.95)	(1.87)	(1.65)	(1.94)
Local	28.35	90.06	110.64	118.99	130.47	115.43	102.75	94.00	72.15	48.05	91.08
	(1.44)	(1.95)	(2.04)	(2.07)	(2.12)	(2.06)	(2.01)	(1.97)	(1.86)	(1.68)	(1.96)
C.D. at 5%	0.04	0.05	0.06	0.06	0.08	0.06	0.06	0.05	0.05	0.05	0.07

Figures in the parentheses are log X value

Table 2. Morphological characters of different genotypes of cumin and their relationship with population of aphid, *Myzus persicae* (Sulz.)

Genotypes	Mean aphid population three umbel^{-1}	Plant height (cm)	No. of primary branches plant^{-1}	No. of umbels plant^{-1}	Days to 50% flowering	Seed yield (q ha^{-1})
RZ-19	66.08	33.02	6.02	30.37	52.33	3.91
RZ-209	62.64	31.55	5.64	28.13	55.00	4.25
RZ-223	60.28	32.47	5.12	29.87	58.00	4.14
UC-336	75.09	29.35	4.84	22.72	55.67	3.32
UC-267	82.69	30.02	5.11	24.87	63.00	4.02
UC-293	74.58	28.24	4.05	26.43	56.33	3.85
UC-339	86.88	27.96	4.43	27.37	60.67	3.5
Local	91.08	28.28	4.50	21.82	59.00	3.05
Correlation coefficient with mean aphid population (r)		-0.81*	-0.73*	-0.70*	0.80*	-0.76*

* Significant at 5 per cent level

209 were least susceptible and UC-339 and local genotypes highly susceptible to aphids. The moderately susceptible genotypes were RZ-19, UC-267, UC-336 and UC-293 were the moderately susceptible genotypes. The seed yield was significantlynegatively correlated with aphid population.

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Tritrophic Interaction among Manure Schedule, Fertilizers, Varieties and Incidence of Pests in Cowpea *Vigna unguiculata* (L.)

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Cowpea [*Vigna unguiculata* (L.) Walp] is an important grain legume of the tropics and fodder crop of India. It is an inexpensive source of dietary protein, and a hardy crop well adapted to relatively dry environments (Hafiz and Damarany, 2006). The crop is also important in soil fertility improvement and is reported to fix nitrogen. A well-nourished crop boosts the inherent capacity of the variety to tolerate insect incidence (Alghali, 1992). In this paper emphasis has been given to highlight the influence of fertilizers/ biofertilizer/organic manure on insect resistance and other growth and yield components in three selected cowpea accessions. To evaluate the influence of fertilizer/ biofertilizer/organic manure and resistance of the three selected cowpea accessions CO4, CO6 and P-152 against aphids (*Aphis craccivora* Koch), thrips *Megalurothrips sjostedti* (Trybom) and pod borer (*Lampides boeticus* Linnaeus), a field trial was conducted at the Experimental farm, Department of Agronomy, Annamalai University, Annamalai Nagar with six treatments including control (Table 1).

The field trial was laid out in randomized block design with three replications adopting a plot size of 18 × 9 m and a spacing of 45 × 30 cm between plants. Organic manure, biofertilizer (Rhizobium) and fertilizers (N, P and K) were applied alone or in combination in different blocks. No insecticidal application was given during the entire crop period. Incidence of *A. craccivora, M. sjostedti* and *L. boeticus* were recorded from 30 days after sowing (DAS) at seven days interval till the harvest of the crop. The observations were recorded from five plants selected at random in each accession at weekly intervals. The population of *A. craccivora* and *M. sjostedti* was recorded on three leaves from each plant viz., one top, middle and bottom leaf each respectively. The population of *L. boeticus* larvae was recorded on whole plant basis.

The results revealed that the effect of application of different fertilizers, biofertilizers and organic manures alone or in combination showed that least population of aphids was in T_6 (OM+R+NPK). This may be due to the combination of N P and K with biofertilizer and organic manure. The aphid population and thrips population did not vary significantly among different accession. Among the treatments, (OM + R + NPK) and the control treatment recorded the maximum thrips population, whereas it was minimum in rhizobium treated plots. The selected cowpea accessions differed significantly with regard to *L. boeticus* larval population. The accession CO4 recorded minimum *L. boeticus* larval population and the treatment T_5 (R+NPK) recorded the minimum number of *L. boeticus* larvae (0.55) whereas accession P-152 recorded maximum *L. boeticus* larval population.

The application of fertilizers alone or in combination with rhizobium and organic manure leads to the reduction in pod damage by *L. boeticus* larvae. Among the treatments T6 (OM+R+NPK) showed least population damage by *L. boeticus* larvae. The present results are in agreement with the findings of Umaru *et al.* (2002) on maize and Cowpea. The percent pod damage was also negatively correlated with plant height (-0.93), number of pods per plant (-0.93), hundred seed weight (-0.95) and seed yield/plant (-0.94). The present paper revealed that the accession CO6 and P-152 can be well advocated as insect tolerant accessions with higher yield potential tolerant (Table 2).

Table 1. Interaction of fertilizers, organic manures and biofertilizers with selected cowpea accessions on the Incidence of *A. craccivora, M. sjostedti* and *L. boeticus*

Treatments	Population/plant in accessions												Per cent Pod damage by *L.boeticus*			
	A. craccivora				*M. sjostedti*				*L. boeticus*							
	CO4	CO6	P-152	Mean	CO4	CO6	P-152	Mean	CO4	CO6	P-152	Mean	CO4	CO6	P-152	Mean
Control	9.13	10.86	9.00	9.66	1.53	1.60	1.33	1.48	1.20	1.60	1.53	1.44	47.02	43.22	34.68	41.64
Organic manure (OM)	7.46	6.86	5.46	6.60	0.53	0.46	1.13	0.71	1.13	0.53	1.06	0.91	31.43	30.76	29.22	30.47
Rhizobium (R)	4.3	4.46	4.26	4.35	0.40	0.26	1.00	0.55	0.46	0.53	0.73	0.57	26.70	26.20	24.68	25.86
NPK	5.60	4.66	8.00	6.08	1.13	0.93	0.73	0.93	1.00	1.20	1.46	1.22	24.80	23.83	21.19	23.27
OM + NPK	7.93	5.80	6.60	6.77	0.93	0.66	0.46	0.68	0.40	0.66	1.20	0.75	21.47	20.70	19.96	20.71
R + NPK	5.06	6.53	6.33	5.97	1.06	1.26	0.46	0.93	0.60	0.60	0.46	0.55	16.10	14.88	13.10	14.69
OM + R + NPK	3.20	5.53	3.60	4.11	1.06	1.26	2.13	1.48	0.80	1.80	1.33	1.31	15.29	14.65	12.28	14.07
Mean	6.10	6.39	6.18		0.95	0.92	1.03		0.80	0.99	1.11		26.12	24.89	22.16	
	$CD_{(p=0.05)}$															
Among accessions	NS				NS				0.23				0.40			
Among treatments	1.72				0.46				0.36				0.61			
Accessions x Treatments	2.97				0.86				0.63				1.06			

Table 2. Correlation between percent pod damage and growth characters and yield components of cowpea

		X_1	X_2	X_3	X_4	X_5	X_6
Percent pod damage	X_1	1.0000					
Plant height	X_2	-0.9005	1.0000				
Number of seeds per pod	X_3	-0.9374	0.9783	1.0000			
Number of pods per plant	X_4	-0.9309	0.9590	0.9950	1.0000		
Hundred seed wt. (g)	X_5	-0.9521	0.9747	0.9957	0.9933	1.0000	
Seed yield plant (g)	X_6	-0.9491	0.9735	0.9974	0.9962	0.9993	1.0000

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Tomato Leaf Curl Virus Incidence and Association Studies in Tomato

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Tomato (*Solanum lycopersicum* L.) is one of the most widely grown vegetable in India. Efforts are being made to increase its productivity by developing superior varieties. Yield, being a complex quantitative character, it depends on a number of contributing traits. Therefore, the knowledge of association of different components together with their relative proportion indicates only the interrelationships of the characters but does not furnish information on cause and effects. So to increase plant productivity, consideration should be given to susceptibility to tomato leaf curl virus disease (Kaur *et al*., 2012). Therefore, the present study was undertaken to get the information on resistance to TLCV disease in tomato genotypes, which ultimately helps in developing the superior varieties.

Thirteen genotypes, which included 10 progenies of cross M-3-1 × H-36 along with two parents and check Dhanashree were sown in randomized block design (RBD) with three replication at MPKV, Rahuri during autumn-summer season 2010-11. Transplanting was done at a spacing of 90 × 30 cm in a plot size of 3.60 × 3.0 m^2. All the recommended cultivation practices were followed to raise a good crop. Observations were recorded on five randomly tagged competitive plants from each genotype for yield and yield contributing characters. Twelve important productivity traits, *viz.,* days to initiation of flowering, days to 50% flowering, days to first harvest, harvesting duration, number of harvestings, number of fruits per plant average fruit weight, fruit length, fruit width, pericarp thickness, total soluble solids (TSS) and fruit yield per plant were studied to find out genotypic and phenotypic correlation coefficients. The per cent disease incidence and coefficient of infection was calculated as per the procedure recommended by Banerjee and Kalloo (1987).

Estimates of genotypic and phenotypic correlation coefficient (Table 1) revealed that the genotypic correlation was in higher magnitude than the corresponding phenotypic

Table 1. Estimates of genotypic (G) and phenotypic (P) correlations coefficient for different characters in tomato

Character	r	1	2	3	4	5	6	7	8	9	10	11	12
Days to initiation of	G	1.00	1.00**	1.00**	-0.50**	-0.47**	-0.37*	-0.59**	-0.62**	-0.53**	-0.19	-0.55**	-0.84**
flowering	P	1.00	0.83**	0.55**	-0.34*	-0.34*	-0.25	-0.40*	-0.28	-0.31	0.16	-0.32*	-0.53**
Days to 50% flowering	G		1.00	1.00**	-0.58**	-0.59**	-0.45**	-0.70**	-0.73**	-0.64**	-0.18	-0.53**	-0.95**
	P		1.00	0.63**	-0.38*	-0.40*	-0.32*	-0.40*	-0.32*	-0.38*	0.13	-0.29	-0.60**
Days to first harvest	G			1.00	-0.97**	-0.98**	-0.85**	-0.67**	-0.82**	-0.59**	-0.10	-0.40*	-1.15**
	P			1.00	-0.34*	-0.37*	-0.34*	-0.34*	-0.26	-0.36*	-0.11	-0.21	-0.59**
Harvesting duration	G				1.00	0.97**	0.94**	-0.23	-0.16	-0.22	0.62**	0.34*	0.48**
	P				1.00	0.93**	0.87**	-0.24	-0.13	-0.16	0.13	0.27	0.49**
Number of Harvesting	G					1.00	1.00**	-0.11	-0.07	-0.10	0.58**	0.27	0.60**
	P					1.00	0.94**	-0.12	-0.05	-0.08	0.16	0.22	0.61**
Number of Fruits/	G						1.00	-0.13	-0.10	-0.17	0.68**	0.13	0.57**
plant	P						1.00	-0.15	-0.13	-0.14	0.14	0.10	0.61**
Average fruit weight	G							1.00	0.98**	0.96**	-0.51**	-0.03	0.74**
(g)	P							1.00	0.87**	0.88**	-0.29	-0.01	0.65**
Fruit length (cm)	G								1.00	1.00**	-0.61**	0.10	0.75**
	P								1.00	0.93**	-0.25	0.11	0.52**
Fruit width (cm)	G									1.00	-0.65**	0.15	0.67**
	P									1.00	-0.34*	0.11	0.56**
Pericarp thickness	G										1.00	0.03	0.02
(cm)	P										1.00	-0.06	-0.06
Total Soluble Solids	G											1.00	0.07
(ºBrix)	P											1.00	0.05
Fruit yield/plant (kg)	G												1.00
	P												1.00

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

correlation for most of the traits. Thereby establishing dominant role of heritable factors (Singh, 2009). This indicates that the role of environment was limited in expression of these traits.

The genotypic and phenotypic association of fruit yield per plant was significantly positive with harvesting duration, number of harvesting, number of fruits per plants, average fruit weight, fruit length and fruit width. Reddy *et al.* (2013) reported similar findings for all the traits except total soluble solids which were positively correlated. A negative significant correlation was observed with days to initiation of flowering, days to 50% flowering and days to first harvest. These results suggesting that number of fruits per plant, number of harvest, harvesting duration, average fruit weight, fruit length and fruit width may be considered for selection.

Days to first harvest showed negative significant association with harvesting duration, number of fruits per plant, number of harvests and fruit length and fruit width, while, non-significant with pericarp thickness at both genotypic and phenotypic levels. A positive significant correlation was noticed between fruit width, number of harvesting, average fruit weight, pericarp thickness, T.S.S. with fruit length. Rani and Anitha (2011) reported that number of locules was positively correlated with number of fruits per plant at both level and total soluble solids at phenotypic level. Number of locules was negative but significantly correlated with plant height and fruit width.

Average fruit weight was negatively correlated with days to initiation of flowering, days to 50% flowering, days to first harvest, harvesting duration, number of harvesting and number of fruits per plants. While positively correlated with fruit width and fruit yield per plant. Similar results were also reported by Das *et al.* (1998). Days to first harvest was negatively correlated with number of fruit per plant, fruit length, fruit width, and number of locules. Number of harvest was positively correlated with number of fruit per plant. Total soluble solid was positively correlated with number of fruit per plant and negatively with pericarp thickness at phenotypic level.

The per cent disease incidence of the parents M-3-1 and H-36 at 120 DAT was observed very less *i.e.,* 8.58 and 6.25 per cent, respectively. While in F_5 generation, the per cent disease incidence at 120 DAT was very less *i.e.,* 8.19% whereas, it was very high in susceptible check Punjab Chuhhara (63.78%), and Dhanashree (55.00%) showed moderate resistance to TLCV disease at 120 DAT.

The coefficient of infection of the parent M-3-1 and H-36 at 120 DAT was observed very less *i.e.*, 0.22 and 0.21, respectively indicating resistance to TLCV while the F_5 generation showed less value (0.24) The coefficient of infection of Dhanashree at 120 DAT was 10.31, whereas, Punjab Chuhhara (susceptible check) was observed to be very high i.e., 40.98 at 120 DAT, so they are moderately resistance and susceptible, respectively. The per cent disease incidence ranged from 3.57 to 63.78 while Coefficient of infection varied from 0.03 to 40.98.

The desirable genotypes observed indicated great scope for improvement beyond normal range of parents and

Table 2. Disease Incidence and Coefficient of Infection of different genotypes in tomato

Genotype / Generation	Per cent Disease Incidence (%)			
	30 DAT	60 DAT	90 DAT	120 DAT
M-3-1	3.57 (10.89)	8.58 (17.03)	8.58 (17.03)	8.58 (17.03)
H-36	5.00 (12.92)	6.25 (14.48)	6.25 (14.48)	6.25 (14.48)
F_5	3.74 (11.15)	8.03 (16.46)	8.19 (16.63)	8.19 (16.63)
Dhanashree (Standard Check)	12.5 (20.70)	22.5 (28.32)	45 (42.13)	55 (47.87)
Punjab chuhhara (Susceptible Check)	41.56 (40.14)	58.65 (49.98)	63.78 (53.00)	63.78 (53.00)
CD (0.01)	0.98	0.66	0.95	0.90

Genotype / Generation	Coefficient of Infection				Reaction
	30 DAT	60 DAT	90 DAT	120 DAT	
M-3-1	0.03 (0.99)	0.22 (2.69)	0.22 (2.69)	0.22 (2.69)	HR
H-36	0.09 (1.72)	0.21 (2.63)	0.21 (2.63)	0.21 (2.63)	HR
F_5	0.05 (1.28)	0.22 (2.69)	0.23 (2.75)	0.24 (2.81)	HR
Dhanashree (Standard Check)	0.70 (4.80)	2.25 (8.63)	7.31 (15.69)	10.31 (18.73)	MR
Punjab chuhhara (Susceptible Check)	8.01 (16.44)	19.75 (26.39)	32.40 (34.70)	40.98 (39.80)	S

thus extremely helpful in crop improvement programme for development of cultivar having resistance to TLCV disease along with high yield.

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Performance of Indian Mustard (*Brassica juncea* L.) in Response to Foliar Spray of Thiourea and Thioglycollic Acid Under Different Irrigation Levels

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Indian mustard (*Brassica juncea L.* Czernj. & Cosson) is predominantly cultivated in Rajasthan, UP, Haryana, Madhya Pradesh, and Gujarat. It is also grown under some nontraditional areas of South India including Karnataka, Tamil Nadu, and Andhra Pradesh. The crop can be raised well under both irrigated and rainfed conditions (DES, 2012). The irrigated area under this crop is 62% of its total cropped area. General practice of growing this crop is in the fields, which are kept fallow during rainy season to conserve moisture, and farmers also provide one or two irrigation depending on the availability of water even to the crop grown on conserved moisture. The recent research findings indicate the use of bio-regulators for increasing productivity. These bio-regulators acts as chemical catalyst in the plant and improve physiology and reproductive efficiency in the plant. These bio-regulators possibly improve the sucrose transport and increase dry matter partitioning for grain production. Thiourea and thioglycollic acid are sulphydral bio- regulators. In arid areas, despite constraints imposed by lack of water and high temperatures, the crop plants mostly survive in average rainfall years. In view of the above, it is conceivable to assume that if antioxidants are sprayed onto the crop plants, most of the damaging free radicals can be quenched and the crop plants can be able to maintain an improved metabolic energy status, which will then facilitate translocation and partitioning of assimilates for yield formation. Since sulphydryl compounds are strong antioxidants and also supply reactive sulphydryl group for the functioning of sucrose transport protein, they can more effectively improve assimilate partitioning and yield of crops under arid environment (Sharma *et al*., 2005). Keeping in view and the paucity of information available on these aspects, a study was conducted on Indian mustard.

A study was conducted during *rabi* season of 2008 and 2009 at the farm field at Bikaner, Rajasthan, 28º 01'N latitude and 73º 22' E longitude at an altitude of 234.70 meters above mean sea level. The experiment was laid out in a split-plot design with three levels of irrigation [Water sufficient (four irrigation), water limited (two irrigation) and water deficient (pre sowing irrigation)] in main plots and nine levels [control (water spray), one foliar spray of thiourea (500 ppm) at initiation of branching, two foliar spray of thiourea (500 ppm) at initiation of branching and flowering, one foliar spray of thiourea (1000 ppm) at initiation of branching , two foliar spray of thiourea (1000 ppm) at initiation of branching and flowering, one foliar spray of thioglycollic acid (50 ppm) at initiation of branching, two foliar spray of thioglycollic acid (50 ppm) at initiation of branching and flowering , one foliar spray of thioglycollic acid (100 ppm) at initiation of branching and two foliar spray of thioglycollic acid (100 ppm) at initiation of branching and flowering] of thiourea and thioglycollic acid spray in sub-plots with four replications. Indian mustard cultivar Bio-902 was sown at a spacing of 30 cmx15 cm on 24 October in 2007 and 23 October in 2008. The soil was loamy sand having 109.50 kg available nitrogen ha^{-1}, 13.91 kg available ha^{-1} phosphorus, 165.0 kg available potassium ha^{-1}, 8.79 ppm available sulphur, pH 8.35 and organic carbon 0.059 %. In addition to irrigation applied as per treatments crop received 8 mm rainfall during 2008 and 13 mm rainfall during 2009. Data on various growth and yield attributes, grain and straw yields of mustard were calculated as per the standard procedures. The experimental data were analysed statistically by applying the technique of analysis of variance prescribed for the design to test and conclusions were drawn at 5% probability levels.

Yield attributes : ***S***uccessive increase in the levels of irrigation and thiourea and thioglycollic acid spray significantly improved the all yield parameters (Table 1). The sufficient four irrigations were significantly improved the number siliqua $plant^{-1}$, siliqua length, seed $siliqua^{-1}$ and 1000 seed weight, which were significantly higher than all other irrigation levels of Indian mustard, all growth parameters increased significantly with increasing number of irrigations. These results corroborated with the results of Singh *et al.*

(2000) and Issa and Sharma (2007). Number of iliqua plant^{-1}, siliqua length(cm), seed siliqua^{-1} and 1000 seed weight significantly improved with corresponding increase in levels of thiourea spray up to 1000 ppm and thioglycollic acid up to100 ppm at initiation of branching and flowering stages. Spray at initiation of branching and flowering stages of thioglycollic acid 100 ppm produced significantly higher growth parameters. However, the differences between thiourea and thioglycollic acid spray were statistically at par in both the years in respect of all growth parameters. These effects increased the dry matter accumulation by the crop plants, and the effects were found consistent at all the stages of growth parameters. It appears that the photosynthetic process of the crop was improved under the influence of thiourea and thioglycollic acid spray.

Seed and straw yield: Seed yield increased significantly with each successive increase in irrigation levels upto four. in both the years. The seed and straw yield in sufficient irrigations was 22.72 and 64.11 q ha^{-1} against 11.78 and 26.06 q ha^{-1} in pre sowing irrigation, respectively (Table 1). The sufficient irrigation resulted in more number of branches, longer plants and more yield attributes, which consequently helped in the production of higher straw yield and biological yield. Application of thiourea up to 1000 ppm and thioglycollic acid up to100 ppm spray at initiation of branching and flowering stages in both the years recorded significantly higher seed yield and straw yield. Spray at initiation of branching and flowering stages of thioglycollic acid 100 ppm *produced* significantly higher seed yield and straw yield. Thiourea spray up to 1000 ppm and thioglycollic acid spray up to100 ppm were statistically at par in both the years in respect of seed yield and straw yield parameters. The beneficial results were also reported by Premi, *et al.* (2004), Deshveer and Singh (2003).

Interactions: The interaction between thiourea, thioglycollic acid spray and irrigation levels was significant on seed yield of Indian mustard (Table 2). At the spray levels of thiourea up to 500 ppm and thioglycollic acid 100 ppm at initiation of branching and flowering stages, increase in spray levels significantly increased the seed yield of Indian mustard and thereafter decreased significantly at reducing rate of spray levels of thiourea and thioglycollic acid. Similarly at the same decreased irrigation levels significantly decreased seed yield up to pre-sowing irrigation. The maximum seed yield was in treatment combination four irrigation levels and thioglycollic acid 100 ppm spray at initiation of branching and flowering stages during both the years, respectively (Sharma *et al*., 2005). The favorable effect of optimum level of irrigation, thiourea up to 500 ppm and thioglycollic acid up to 100 ppm spray at initiation of branching and flowering stages. The favorable effect of thioglycollic upt o 500 ppm and thioglycollic acid up to 100 ppm spray at initiation of branching and flowering stages, combination might be because spray is likely to make the crop more responsive to the growth. Addition of irrigation may maintain a favorable environment and balance between the applied thiourea, thioglycollic acid spray in the plant for its optimum growth.

The present studies indicate that foliar spray

Table 1. Effect of different levels of irrigations, thiourea and thioglycollic acid spray on yield attributes and yields of Indian mustard (Two year pooled data)

Treatment	No of siiqua plant^{-1}	Siliqua length (cm)	No of seeds sliqua^{-1}	1000 seed wt (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})
Water conditions						
Water sufficient (Four irrigation)	209.96	4.51	13.54	8.76	22.72	64.11
Water limited (Two irrigation)	177.21	4.15	12.47	8.19	16.48	35.67
Water deficient (Pre-sowing irrigation)	148.38	3.19	10.84	7.96	11.78	26.06
CD (*P*=0.05)	2.28	0.14	0.32	0.19	0.62	2.56
Foliar spray						
Control (water spray)	151.08	3.31	11.07	7.83	13.43	30.30
Thiourea (500 ppm) at initiation branching-One spray	178.35	3.99	12.12	8.44	17.06	42.99
Thiourea (500 ppm) at initiation branching & flowering-Two spray	194.12	4.50	13.12	8.62	18.63	46.59
Thiourea (1000 ppm) at initiation of branching- One spray	166.93	3.61	11.67	7.97	15.74	38.58
Thiourea (1000 ppm) at initiation .of branching & flowering-Two spray	178.70	3.84	12.32	8.16	17.63	43.55
Thioglycollic acid (50 ppm) at initiation of branching- One spray	169.47	3.74	11.65	8.15	15.72	39.29
Thioglycollic acid (50 ppm) at initiation of branch. & flow. -Two spray	183.24	3.83	12.37	8.33	17.38	43.33
Thioglycollic acid (100 ppm) at initiation of branching- One spray	183.20	4.09	12.65	8.49	17.77	44.17
Thioglycollic acid (100 ppm) at initiation of branch. & flow.-Two spray	201.55	4.64	13.57	8.78	19.57	48.72
CD (*P*=0.05)	13.52	0.29	0.79	0.40	0.88	2.76

Table 2. Interaction effect levels of irrigation and foliar spray of thiourea and thioglycollic acid on seed yield (q ha^{-1}) of Indian mustard (Pooled)

Treatment	Water sufficient (Four irrigation)	Water limited (Two irrigation)	Water deficient (Pre sowing irrigation)
Control (water spray)	18.69	13.00	8.59
Thiourea (500 ppm) at initiation branching-One spray	22.75	16.68	11.76
Thiourea (500 ppm) at initiation branching & flowering-Two spray	24.67	18.10	13.12
Thiourea (1000 ppm) at initiation of branching- One spray	22.28	15.02	9.92
Thiourea (1000 ppm) at initiation .of branching & flowering-Two spray	23.72	17.49	11.69
Thioglycollic acid (50 ppm) at initiation of branching- One spray	20.91	15.50	10.76
Thioglycollic acid (50 ppm) at initiation of branch. & flow. -Two spray	22.58	16.99	12.57
Thioglycollic acid (100 ppm) at initiation of branching- One spray	23.37	16.82	13.11
Thioglycollic acid (100 ppm) at initiation of branch. & flow.-Two spray	25.56	18.67	14.49
CD (*P*=0.05)	1.38		

thiourea an thioglycollic acid with sufficient irrigation water (four irrigations) at initiation of branching and flowering stages increased the productivity of grain and straw The results also suggest that application of bio-regulators to enhance yield of mustard under arid environment.

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Effect of Additional Dose of Fertilizers on the Growth, Yield and Fruit Quality of Litchi (*Litchi chinensis* Sonn.) var. Calcuttia

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Litchi cultivation is confined to Bihar, West Bengal, Uttar Pradesh, Jharkhand, Assam, Punjab, Chhattisgarh, Uttrakhand. In India, it occupied an area of 80.4 thousand ha with annual production of 5.38 lacs Mt (Anonymous, 2011). Litchi is successfully grown in sub-mountainous region of Punjab comprising of Gurdaspur, Hoshiarpur, Pathankot and Patiala districts. Nutrient supply plays an important role in increasing productivity and quality of litchi crops. Determination of nutrient needs of litchi orchard is of utmost importance to litchi growers. Various experiments have been conducted earlier on foliar spray of micro-nutrient in different fruit crops and shown significant response to improve yield and quality of fruits by Kumar *et al.* (2004). It is also well established fact that acute shortage of nitrogen, phosphorous and potassium seems to check litchi vegetative growth and floral primordia initiation. The application of macro nutrients(N,P and K) substantially enhanced fruit yield and quality in various litchi cultivars. Micronutrients (Zn,B and Cu) also play vital role in litchi nutrition and significantly improved flowering, fruit set, fruit drop, fruit size and and fruit quality.

The present investigation was conducted at Punjab Agricultural University, Regional Research Station, Gurdaspur (Punjab) on litchi cv. Calcuttia during the years 2011 and 2012. Plants of uniform growth and good health were selected with three number of replications in each treatment. The different treatments were, T_1 (1.6 kg Urea+2.25 kg SSP+0.6 kg MOP), T_2 (T_1+0.5 kg urea during 1st week of July, T_3 (T_1+ 1.0 kg urea during 1st week of July),T_4 (T_1+ two foliar sprays of $ZnSO_4$ @0.3% in Aug. and Feb.), T_5 (T_1+ soil application of urea@ 0.5 kg during 1st week of July+ two foliar sprays of $ZnSO_4$ @0.3% during Aug. and Feb.),T_6 (T_1+ soil application of urea @ 1.0 kg during 1st week of July+ foliar sprays of $ZnSO_4$ @0.3% in Aug. and Feb.) and T_7 as control (No fertilization). Vegetative growth characters tree spread (N-S and E-W), trunk girth (cm) and tree volume (m^3) of the plant were recorded annually in January before the start of flowering season. The four branches growing uniformly in different directions were tagged at the time of fruit set in each replication. Fruit yield was calculated by multiplying total number of fruits with average fruit weight and expressed in kg/tree at the time of fruit harvest. Physical characteristics (fruit colour, fruit length, fruit breadth, fruit weight , pulp weight, seed weight and peel weight) were also recorded as per standard procedure. Total soluble solids (TSS) of the fruit juice was determined with Refractometer (Brand) and expressed in per cent (%) TSS after correction at 20° C. The fruit colour was judged with the help of Royal Horticultural Colour Chart. The titrable juice acid content in maleic acid was determined as per A.O.A.C. (2000).

It is evident from the data that tree spread (N-S and E-W) in different treatments was found statistically non-significant (Table 1), however higher trunk girth (125.1 cm in

Table 1. Effect of additional dose of fertilizers on the growth and yield of litchi *(Litchi chinensis* Sonn.) var. Calcuttia

Treatments	Girth (cm)		Height (m)		Spread (m)		Tree Volume (m^3)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
T_1	105.1	109.0	7.1	7.5	8.5	8.9	24.6	27.8
T_2	110.0	119.2	7.2	7.6	8.2	8.5	27.3	33.6
T_3	106.0	108.7	5.8	6.2	7.6	7.9	20.6	22.8
T_4	117.3	128.1	7.3	7.8	7.9	8.1	31.5	39.9
T_5	125.1	133.1	6.5	6.8	8.4	9.2	25.4	37.7
T_6	108.2	111.3	6.7	6.9	8.3	9.0	24.5	26.5
T_7	105.2	107.7	7.1	7.4	7.9	8.1	24.7	26.6
CD (P=0.05)	8.4	NS	2.5	1.2	NS	NS	2.4	3.0

2011 and 133.1 cm in 2012) was recorded in T_5 followed by T_4. The minimum plant girth was recorded to be in control (105.2 cm) which was at par with T_1 treatment. Significant differences were observed among the different treatments with regard to plant height and tree volume, the maximum plant height and tree volume were observed in T_4 (7.3 m plant height, 31.5 m^3 tree volume in 2011 and 7.8m plant height, 39.9 m^3 tree volume in 2012). These findings are in agreement with the results of Sharma *et al.* (2005) in Ber cv. Umran. The highest fruit yield (93.2 kg per tree) was recorded in T_6 followed by T_5 (90.4 kg/ tree) and minimum in T_7. Similarly, these results are in accordance with the findings reported by Sindhu *et al.* (1999), they observed that the urea alongwith the spray of zinc sulphate subtantially increased bunch weight, yield and soluble solids in grapes. Maximum fruit breadth,weight and soluble solids were noticed in T_6 and minimum in T_7 (Table 2). These findings are corroborated with the observations of Kumar and Pathak (1992) who reported that urea as foliar feeding improved fruit size, weight, yield and fruit quality attributes in grapes. However, the differences among different treatments in terms of fruit peel and stone weight were statistically non-significant. The values recorded for total soluble solids and juice acid content were statistically at par with each other except T_7.

Fruit juice acid content was decreased with the application of higher doses of urea and zinc sulphate. Likewise, the intensity of fruit colour among different treatments was almost remained the same except T_7 (control), where the colour development was very poor (Table 3). The data mentioned in Tables 1-3, depicted that fruit yield, fruit weight, fruit length, fruit breadth, pulp weight, TSS were highest in T_6 as compared to other treatments. These results are in line with those reported by Kumar *et al.*(2004) on litchi cv. Dehradun and Kassem *et al.* (2011) in jujube tree, Meena *et al*. (2005) in guava and Khyyat *et al*.(2007) in date palm.

Table 2. Effect of additional dose of fertilizers on the fruit physical characteristics of litchi *(Litchi chinensis* Sonn.) var. Calcuttia

Treatments	Yield (kg per tree)		Fruit weight (gm)		Fruit length (cm)		Fruit breadth (cm)		Pulp weight (gm)		Seed weight (g)		Peel weight (g)	
	2010-11 (off year)	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
T_1	8.6	61.3	18.5	17.6	3.5	3.6	3.2	3.2	15.0	14.0	2.3	2.3	1.2	1.4
T_2	6.5	74.6	19.5	18.5	3.6	3.6	3.5	3.3	15.2	14.4	2.9	2.8	1.4	1.3
T_3	10.4	76.2	20.0	19.0	3.6	3.7	3.5	3.4	16.0	15.1	2.5	2.5	1.5	1.4
T_4	5.3	81.6	20.5	20.5	3.7	3.7	3.3	3.5	16.4	16.0	2.7	2.7	1.4	1.5
T_5	7.7	90.4	21.0	21.5	3.8	3.8	3.4	3.6	17.2	17.8	2.4	2.3	1.5	1.4
T_6	6.3	93.2	21.5	22.7	4.2	4.0	3.6	3.8	17.4	18.7	2.7	2.5	1.4	1.4
T_7	7.2	55.1	16.5	16.7	3.4	3.5	2.5	2.7	12.4	12.8	2.6	2.5	1.4	1.4
CD (5%)	NS	4.3	2.1	2.1	0.4	0.3	0.6	0.5	0.9	0.9	NS	NS	NS	NS

Table 3. Effect of different doses of fertilizer application on the TSS, acidity and colour of litchi *(Litchi chinensis* Sonn.) fruit var. Calcuttia

Treatments	TSS (%)		Acidity (%)		Fruit colour	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
T_1	18.2	18.0	0.5	0.5	50% Pinkish red	50% Pinkish red
T_2	18.3	18.0	0.5	0.5	65% Pinkish red	60% Pinkish red
T_3	18.3	18.1	0.5	0.4	70% Pinkish red	75% Pinkish red
T_4	18.3	18.0	0.4	0.4	75% Pinkish red	80% Pinkish red
T_5	18.2	18.1	0.4	0.4	80% Pinkish red	80% Pinkish red
T_6	18.3	18.1	0.4	0.4	90% Pinkish red	95% Pinkish red
T_7	14.1	14.7	0.8	0.9	10% Pinkish red	20% Pinkish red
CD (5%)	0.2	0.5	NS	NS	-	-

It is concluded that the application of recommended dose of fertilizers along 1.0 kg urea in first week of July + foliar spray of $ZnSO_4$ @ 0.3% in August and February to the litchi plant significantly improved the fruit yield and quality.

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Effect of Spacing on Growth, Seed Yield and Tuber Yield of Glory Lily (*Gloriosa superba* L.)

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Glory lily (*Gloriosa superba* L.) native to tropical Asia and Africa is an important medicinal crop and is currently distributed extensively throughout the tropics as a potted plant. In India, it is usually found in Himalayan foot-hills, central India, Tamil Nadu, Andhra Pradesh, Karnataka and West Bengal. The seeds are exported to Europe, USA, Australia and African companies based in Nigeria, Cameroon and Zimbabwe for extraction of phytochemicals, coclchicine and its derivatives and to use in pharmaceutical industry (Anonymous, 2012). The phytochemicals present in glory lily have analgesic, anti-inflammatory, antithrombotic, enzyme inhibitory, anti-venom and chemotherapeutic potential. The tubers and other parts of this plant are used in Indian system of medicines for different purposes.

There is very little variability available for seed yield and colchicine content in glory lily. Hence the only way to improve the yield is through manipulation of plant population under cultivation. However, in glory lily, there is no standardized scientific spacing recommendation available, as the work on this crop is very meager. The farmers adopt spacing based on their personal experiences and this lacuna eventually results in low productivity. In this regard, an investigation was taken up with an objective to study the effect of different spacings on growth, seed and tuber yields of glory lily.

The study was carried out in the farmer's field at Antravalli, Kumta taluka of Uttar Kannada district (Karnataka) from June, 2012 to January, 2013. There were eight treatments with different spacings viz. 60 x 30 cm, 60 x 60 cm, 90 x 30 cm, 90 x 60 cm, 120 x 30 cm, 120 x 60 cm, 150 x 30 cm, 150 x 60 cm. The experiment was laid out in randomized block design with three replications. Good quality and healthy tubers (weighing approx. 50g each) were selected for plating. Observations on growth and yield parameters were recorded in five randomly selected uniform plants and labeled.

In present study, the vine length was highest (153.61cm) in 90 x 60 cm spacing and it was on par with with a spacing of 90 x 30 cm (Table 1). The lowest vine length (102.87 cm) was observed in 150 x 60 cm spacing. The increased vine length in closer spacing is due to linear growth of the vine which might be due to the inter plant competition for space and light as a result of higher plant density. These results are in accordance with findings of Mastiholi (2008) and Jayalakshmi (2003) in coleus, Akhani et al. (2012) in coriander and Taleie et al. (2012) in stevia. Jayalakshmi (2003) reported the increased stem girth in wider spacing but in the present study, the highest stem girth (6.32 mm) was recorded in 60 x 60 cm spacing and was on par with 150 x 60 cm spacing. The lowest value for stem girth was in 120 x 60 cm spacing. On an average, crop took 70.71 days for flower initiation. The flower initiation was earlier (68.67 days) in 90 x 30 cm spacing. The possible reasons may be the induction of stress for nutrients and water and thus early flowering under closer spacing compared to wider spacing. The number of days for flower initiation was statistically on par with 60 x 30 cm, 90 x 60 cm, 120 x 30 cm and 150 x 60 cm spacings.

The number of flowers per plant ranged from 7.8 to 15.07 in 150 x 60 cm and 90 x 60 cm spacing, respectively. The number of flowers per plant was statistically on par in 60 x 60 cm, 90 x 30 cm, 90 x 60 cm, 120 x 30 cm and 120 x 60 cm spacings. The increase in number of flowers may be the consequence of better growth and branching with more number of flowering shoots under closer spacing. Though the number of flowers per plant was statistically on par in T_2 to T_6 spacings, 90 x 30 cm (T_3) spacing recorded significantly increased number of pods per plant (10.67) and lowest (4.73) was in 150 x 60 cm spacing. Similarly, the per cent fruit set was also significantly higher (78.47) in 90 x 30 cm spacing followed by 60 x 30 cm where as lowest (59.85) per cent fruit set was recorded in 120 x 30 cm spacing. The results are in conformity with Akhani *et al.* (2012) in coriander and Sundareswaran *et al*. (2012) in ambrette. The decrease in yield contributing characters in closer spacings (60 x 30 and 60 x 60 cm) might be due to higher interplant competition which limited the availability of nutrients and light. As far as

Table 1. Effect of spacing on growth and yield characters of glory lily (*Gloriosa superba* L.)

Treatment	Vine length (cm)	Stem girth (mm)	Days to flower initiation	No. of flowers per plant	No. of pods per plant	Fruit set (%)	No. of seeds per pod	Yield per ha (q)		
								Fresh seed	Dry seed	Tuber
60 x 30cm	108.08	5.35	70.67	8.87	6.60	74.43	58.27	12.45	1.82	18.64
60 x 60cm	128.95	6.32	69.33	13.33	9.07	68.02	61.07	8.53	1.27	9.67
90 x 30cm	143.39	5.74	68.67	13.73	10.67	78.47	59.80	14.28	2.04	16.34
90 x 60cm	153.61	5.70	71.67	15.07	9.00	61.12	59.33	5.74	0.86	7.68
120 x 30cm	125.49	5.22	75.33	14.2	8.47	59.85	60.67	8.69	1.26	10.15
120 x 60cm	138.36	5.08	69.67	12.13	8.00	66.66	57.07	4.04	0.61	4.61
150 x 30cm	117.39	5.63	69.00	9.47	6.07	64.09	59.20	4.76	0.69	5.51
150 x 60cm	102.87	5.78	71.33	7.8	4.73	60.49	59.47	1.95	0.30	2.84
CD (0.05)	14.62	0.57	5.49	3.05	1.45	9.02	2.31	1.41	0.19	2.96
CV (%)	6.56	5.83	4.43	14.74	10.6	7.73	2.23	10.67	9.93	17.91

the number of seeds per pod is concerned, 60 x 60 cm (T_2) spacing showed the highest number of seeds per pod (61.07) which was on par with other treatments except 60 x 30 and 120 x 60 cm spacings.

There was increase in fresh seed yield with decrease in spacing up to 90 x 30 cm. Further decrease in spacing did not show increase in fresh seed yield. The estimated fresh seed yield per hectare was statistically superior (14.28 q) in 90 x 30 cm spacing and lowest (1.95 q) in 150 x 60 cm spacing. The longer vines, more number of branches and early flowering due to better growth and increased number of pods per plant due to increased cross fertilization have been contributed to higher fresh seed yield in closer spacing. The similar trend was observed in dry seed yield also. The mean dry seed yield per ha was 1.11 q. The estimated dry seed yield per hectare has shown significantly higher values at 90 x 30 cm followed by 60 x 30 cm spacing. The 150 x 60 cm spacing recorded the lowest dry seed yield per ha. Akhani *et al*. (2012) reported the highest seed yield in coriander at a plant population of 25 plants per m^2. Sundareswaran *et al*. (2012) also reported the decreased yield in closer spacing (60 x 30 cm) in ambrette. The mean tuber yield per ha was 9.43 q and there was statistically significant difference among the spacing levels. The tuber yield increased with decrease in spacing. There was highest estimated tuber yield per ha (18.64 q) in 60 x 30 cm spacing which was on par with 16.34 q in 90 x 30 cm. The lowest was in 150 x 60 cm spacing. The significant increase in tuber yield per ha was due to optimum plant population and better growth of tubers which resulted in increased tuber weight. Patel *et al.* (2008) reported the highest tuber yield per ha in safed musli at closer spacing (30 x 15cm). Similar results were obtained by Ramchandra and Jha (2003) and Kothari and Reddy (2009) in safed musli and Veeraraghavathatham *et al*. (1985) and Patil and Hulamani (1999) in coleus. A closer spacing helps in increased cross fertilization thereby increasing pod set and thus yield. The maintenance of optimum plant population will pave a way to maximize the seed yield. In conclusion one can infer that the glory lily planted at 90 x 30 cm spacing results in better plant growth, increased seed and tuber yields under coastal environment of Karnataka.

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Assessment of Shelf Life of Garlic (*Allium sativum* L.) Ecotypes

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Among the spices grown in India, garlic (*Allium sativum* L.) is the most important bulbous crop and widely cultivated *Allium* throughout country. It is consumed in both vegetarian and non-vegetarian dishes and valued highly for its characteristic flavour (Roy and Chakraborti, 2002). The successful storage of garlic bulbs depends upon the variety, maturity, cultural practices and post-harvest handling (Sidhu, 2008). Water loss, sprouting and post harvest diseases caused considerable deterioration in quality of stored bulbs and the contribution of each of these components to the total weight loss varies between different cultivars.

The lack of high yielding and better storage varieties of garlic are the main constraints limiting the production and productivity. Garlic exhibits greater susceptibility to agro-techniques and environmental condition and possesses a wide range of variability for bulb traits and yield attributes as well as the storability in spite of being vegetatively propagated crop. To meet out the domestic as well as export requirement, selection of suitable genotypes for growing under different agro-climatic conditions and better self-life is required. However, very less attention have been paid by plant breeders on this aspect. Thus, the present investigation was conducted to evaluate garlic genotypes for storability under Punjab conditions.

The experiment was conducted to study the performance of 45 garlic clones under ambient storage conditions at Vegetable Research Farm of Punjab Agricultural University, Ludhiana. The crop was harvested in April. These were thoroughly sorted to remove all damaged, injured, split, off-type and diseased bulbs. Each lot consists of 25 uniform bulbs and stored in netted nylon mesh bags and kept in ventilated room storage at ambient temperature in well spaced stacks for five months beginning from May to September end. The sample lots were arranged in a completely randomized design (CRD) with three replications. The data was recorded at 30 days interval starting from May upto September end. The mean temperature range during experiment was 25 to 32°C and relative humidity between 45 to 85%. The bulbs were critically examined for three parameters viz. physiological loss in weight (PLW), rotting incidence and sprouting percentage. The initial weight of all the samples was recorded before putting in the storage. The data were analyzed using the analysis of variance procedure.

No sprouting was observed during the entire storage period i.e. from May to September, however considerable losses were observed due to physiological loss in weight (PLW) and rotting incidence (Table 1 and 2).

After one month of storage, genotype AVTG-1 (0.25) and AVTG-4 (0.25) showed minimum physiological loss in weight, while maximum physiological loss in weight was observed in BG-107 (0.73), but it did not show significant differences (Table 1). A significant difference was observed among all the genotypes for physiological loss in weight after two months of storage. Minimum physiological loss in weight was reported in AVTG-4 (1.23) followed by other 36 genotypes, while maximum physiological loss in weight was observed in BG-107 (3.63). After three months of storage the minimum physiological loss in weight was noted for PG-18 (5.56) and maximum was found in JGL-96-1988 (16.44), followed by AVTG-10 (15.89). After four months of storage, the minimum physiological loss in weight was noted for PG-31 (11.59), which was at par with PG-19 and AVTG-4 (12.32). Maximum physiological loss in weight was observed in AVTG-10 (25.61), followed by BG-107 (25.46). After five months of storage the minimum and significant physiological loss in weight was observed in PG-31 (15.94), while, maximum physiological loss in weight was observed in JGL-96-1988 (30.66), followed by BG-107 (30.30) and IETG-5 (30.04).

The storage data pertaining to rotting incidence have been presented in Table (2), which revealed that there was no incidence of rotting in all the genotypes after one month of storage except DARL-52 (13.34). After two months of storage 24 genotypes resulted in no incidence of rotting, however highest rotting incidence was observed in DARL-52 (24.00). After three months of storage the minimum rotting incidence was noted for PG-20 (0.00) and AG-102 (0.00), while maximum was found in DARL-52 (48.00). After four months of storage the minimum rotting incidence was noted

Table 1. Physiological loss in weight (%) during storage in garlic

Genotypes	Storage intervals					Mean	TSS (^{o}Brix)	Dry matter (%)
	I_1 (30 days)	I_2 (60 days)	I_3 (90 days)	I_4 (120 days)	I_5 (150 days)			
PG-9	0.44	2.22	13.35	20.03	26.70	12.55	43.93	37.86
PG-19	0.32	1.61	7.60	11.80	19.67	8.20	37.57	38.35
PG-24	0.36	1.77	9.69	14.05	20.48	9.27	42.60	41.50
AVTG-5	0.36	2.03	13.60	19.72	25.50	12.25	33.10	36.63
G-282	0.31	1.56	11.71	16.14	22.39	10.42	44.60	42.73
PG-31	0.28	1.45	7.24	11.59	15.94	7.30	40.07	41.50
IETG-6	0.35	1.76	11.08	19.36	28.21	12.15	41.33	38.88
IETG-4	0.43	2.18	14.14	20.26	23.24	12.05	36.10	38.48
IETG-9	0.38	1.91	10.91	20.23	23.29	11.35	47.87	38.69
IETG-5	0.49	2.48	13.57	22.18	30.04	13.76	39.80	40.05
IETG-2	0.35	1.75	8.17	12.85	19.29	8.48	36.38	40.08
IETG-1	0.35	1.75	8.17	12.85	19.29	8.48	46.34	39.33
AVTG-1	0.25	1.24	8.61	13.57	17.50	8.24	39.77	35.10
AVTG-2	0.32	1.59	10.59	14.26	19.81	9.32	38.50	36.63
AVTG-4	0.25	1.23	9.46	12.32	18.11	8.27	32.80	38.50
AVTG-6	0.34	1.71	12.76	22.25	26.03	12.62	29.10	37.47
AVTG-7	0.33	1.64	10.64	18.85	22.39	10.77	38.50	38.10
AVTG-10	0.44	2.22	15.89	25.61	28.95	14.62	20.03	33.66
JGL-96-1988	0.53	2.67	16.44	19.98	30.66	14.06	40.03	33.94
JGL-03-263	0.55	2.74	15.52	21.94	28.76	13.90	39.37	35.74
JNDG-213	0.35	1.75	13.45	22.53	27.19	13.05	30.10	39.08
JNDG-219	0.38	1.93	12.21	19.62	24.43	11.71	35.37	39.73
AC-50	0.42	2.03	11.11	18.53	24.25	11.27	45.67	42.61
AC-200	0.41	2.03	11.11	20.19	28.32	12.41	41.33	34.80
DARL-52	0.35	1.75	11.69	20.47	27.19	12.29	24.00	34.10
NRCRG-1	0.32	1.59	9.59	14.32	23.99	9.96	48.17	40.97
RAUG-5	0.31	1.56	9.29	14.32	20.40	9.18	35.20	34.71
PG-3	0.37	1.83	9.37	18.19	22.43	10.44	31.10	37.34
PG-20	0.31	1.54	5.62	12.77	19.39	7.93	48.10	41.50
PG-1	0.40	2.02	10.33	19.35	25.96	11.61	37.03	38.71
PG-17	0.41	2.07	11.36	14.39	20.64	9.77	33.57	36.60
PG-32	0.35	1.74	9.55	18.27	22.59	10.50	35.40	38.11
PG-12	0.34	1.68	10.64	15.68	20.45	9.76	49.10	41.26
PG-18	0.27	1.39	5.56	13.65	18.52	7.88	21.47	39.39
PG-35	0.27	1.35	8.11	12.61	17.34	7.94	20.17	41.49
G-189	0.29	1.46	9.52	16.66	20.45	9.67	31.97	37.61
PG-26	0.33	1.67	10.55	18.34	22.77	10.73	48.10	40.23
PG-30	0.47	2.38	13.48	20.63	25.39	12.47	38.50	38.05
PG-33	0.44	2.22	15.34	22.23	27.41	13.53	47.97	16.50
PG-282	0.43	2.17	11.59	20.28	26.45	12.18	34.63	42.11
G-1	0.33	1.65	8.54	13.50	17.35	8.27	48.03	45.16
G-50	0.39	1.98	9.57	18.47	24.43	10.97	23.50	36.19
AG-102	0.38	1.94	9.71	19.42	26.53	11.59	38.50	35.14
BG-107	0.73	3.63	14.54	25.46	30.30	14.93	40.10	40.10
BG-108	0.36	1.79	10.58	20.36	24.49	11.52	39.20	40.25
Mean	0.37	1.88	10.92	17.78	23.44		37.65	38.11

C D (0.05) Genotypes (G)= 0.257, Storage intervals (I)= 0.858, GI=0.575 ; CV= 3.26

Table 2. Rotting incidence (%) during storage in garlic

Genotypes	Storage intervals					
	I_1 (30 days)	I_2 (60 days)	I_3 (90 days)	I_4 (120 days)	I_5 (150 days)	Mean
PG-9	0.00	0.00	4.00	12.00	16.00	6.40
PG-19	0.00	4.00	8.00	16.00	32.00	12.00
PG-24	0.00	4.00	8.00	12.00	20.00	8.80
AVTG-5	0.00	4.00	8.00	13.34	20.00	9.06
G-282	0.00	4.00	8.00	12.00	20.00	8.80
PG-31	0.00	4.00	8.00	16.00	28.00	11.20
IETG-6	0.00	4.00	8.00	16.00	24.00	10.40
IETG-4	0.00	8.00	16.00	36.00	56.00	23.20
IETG-9	0.00	8.00	13.34	24.00	32.00	15.47
IETG-5	0.00	0.00	8.00	32.00	48.00	17.60
IETG-2	0.00	0.00	8.00	16.00	28.00	10.40
IETG-1	0.00	0.00	8.00	16.00	28.00	10.40
AVTG-1	0.00	0.00	8.00	12.00	20.00	8.00
AVTG-2	0.00	0.00	8.00	20.00	36.00	12.80
AVTG-4	0.00	0.00	8.00	12.00	16.00	7.20
AVTG-6	0.00	0.00	12.00	28.00	40.00	16.00
AVTG-7	0.00	4.00	12.00	28.00	48.00	18.40
AVTG-10	0.00	4.00	8.00	16.00	28.00	11.20
JGL-96-1988	0.00	8.00	16.00	24.00	28.00	15.20
JGL-03-263	0.00	4.00	12.00	20.00	24.00	12.00
JNDG-213	0.00	8.00	16.00	32.00	56.00	22.40
JNDG-219	0.00	4.00	8.00	36.00	56.00	20.80
AC-50	0.00	0.00	4.00	8.00	20.00	6.40
AC-200	0.00	0.00	8.00	16.00	28.00	10.40
DARL-52	13.34	24.00	48.00	72.00	96.00	50.67
NRCRG-1	0.00	0.00	8.00	12.00	20.00	8.00
RAUG-5	0.00	0.00	4.00	8.00	12.00	4.80
PG-3	0.00	0.00	4.00	12.00	16.00	6.40
PG-20	0.00	0.00	0.00	8.00	20.00	5.60
PG-1	0.00	8.00	16.00	24.00	36.00	16.80
PG-17	0.00	0.00	8.00	16.00	20.00	8.80
PG-32	0.00	0.00	8.00	12.00	16.00	7.20
PG-12	0.00	0.00	4.00	12.00	24.00	8.00
PG-18	0.00	0.00	4.00	8.00	12.00	4.80
PG-35	0.00	0.00	8.00	16.00	28.00	10.40
G-189	0.00	8.00	16.00	20.00	36.00	16.00
PG-26	0.00	0.00	8.00	16.00	32.00	11.20
PG-30	0.00	0.00	8.00	12.00	20.00	8.00
PG-33	0.00	4.00	8.00	16.00	24.00	10.40
PG-282	0.00	8.00	12.00	24.00	32.00	15.20
G-1	0.00	0.00	4.00	16.00	24.00	8.80
G-50	0.00	0.00	8.00	16.00	24.00	9.60
AG-102	0.00	0.00	0.00	4.00	8.00	2.40
BG-107	0.00	8.00	16.00	32.00	48.00	20.80
BG-108	0.00	4.00	8.00	24.00	40.00	15.20
Mean	0.29	3.02	9.45	18.96	29.78	

C D (0.05) Genotypes (G)= 0.193, Storage intervals (I)= 0.644, GI=0.432; CV= 2.17

in AG-102 (4.00) and maximum was observed in DARL-52 (72.00). After five months of storage the minimum and significant rotting incidence was observed in AG-102 (4.00). Whereas, maximum rotting incidence was observed in DARL-52 (96.00). Earlier workers viz. Shaha *et al.* (1992), Brar *et al.* (1994), Kumar *et al.* (1995), Sidhu (2008) and Dubey and Singh (2012) also reported similar variation in storage life of onion and garlic and such variation in shelf life in different cultivars was due to genetic differences only (Kumar *et al.,* 1989).

From the study it may be conducted that the lines PG-31, RAUG-5 and AG-102 can be used for development of good quality planting material for long term storage. The genotypes PG-31, RAUG-5 and AG-102 showed high total soluble solids and dry matter content and also gave minimum losses after five months of storage which implies that the genotypes having high total soluble solids and dry matter content can be stored for long duration of time in storage godowns.

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Food Safety Practices of Slum Dwellers in Ludhiana

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Food Safety is the assurance that food will not cause harm to the consumers when it is prepared or eaten. Food safety scenario in India reveals that Indian people are aware of the risks involved with food. The retail concentration is very low in India. There are standards and guidelines, but the 'street trade' cannot be controlled. In India, the low level of food hygiene stems from poor infrastructure, a lack of technology, and shortcomings in education. Development programs have previously focused more on quantity than quality in production. India is a price-critical country where price is a higher priority than quality. On the other hand, there is a consuming middle class that wants to buy products that are perceived as quality products.

Poor food handling and hygiene practices in the domestic kitchen are thought to cause a significant number of food borne illnesses. Surveys of food borne disease outbreaks worldwide have shown that most cases of food borne diseases occur in handling food during preparation whether in homes or in food sector. Most cases of food borne illnesses are preventable if food protection principles are followed from production to consumption. Between 50 and 87 per cent of the reported outbreaks of food borne illnesses are associated with food prepared at home (Redmond and Griffith, 2003) .

A significant proportion of food borne illnesses arises from preparations in the home kitchen. Home food preparers are the final line in defense against food borne illnesses. In over 90% of households in India, it is the women who are involved in the preparation of meals. Their role in ensuring food safety and hygiene at household level is pivotal. An understanding of the status of their food handling knowledge and practices is needed. So, the role of mothers in ensuring food safety at homes is well accepted (Subba *et al.*, 2008). Adequate nutrition during infancy and early childhood is essential to ensure the growth, health, and development of children to their full potential. In order to ensure food safety; consumers need to follow certain rules at the stages of keeping/storing, preparing, cooking and serving food, starting from purchasing it. Thus, home food preparers need to know the techniques to minimize the presence of pathogens in food.

Poor children's feeding practices can lead to malnutrition which is a major public health problem in developing countries. Under nutrition is associated with 35% of child death. It is also major disabler preventing children to survive from reaching therefore potential development. The effects of poor nutrition continue throughout their life, contributing to poor school performance, reduced productivity and impaired intellectual and social development. Nearly 20 million children under 5 suffer from severe acute malnutrition. Adequate nutrition during infancy and early childhood is essential to ensure the growth, health and development of children (WHO, 2011). Inappropriate feeding practices and their consequences are major obstacles to sustainable socio-economic development and poverty reduction. Malnutrition has been responsible directly or indirectly for 60 per cent of the 10.9 million deaths annually among children under 5 (Israel and Glenn, 2009).

Several studies have revealed that the mothers' level of education has a positive impact on her knowledge and how she deals with child health care issues. Providing nutritional and health education to the infant's mothers should be helpful for improving infant's feeding pattern and ensuring the adequate growth and development of infants (Yin, 2009).

The present study was undertaken to see the impact of nutrition counseling on food safety practice score of respondents belonging to slum areas of Ludhiana. The methodology used for the study included the survey of 150 young mothers (children below 5 years). A random selection of 10 slums in Ludhiana city was made and from each slum 15 young mothers were randomly selected, thus, making the sample of 150 young mothers.

Data was collected by personally administering the questionnaire to the mothers of slum areas pertaining to feeding practices of the respondents regarding various concepts of food safety. Total 13 questions were framed regarding food safety issues the respondents were asked to rate these statements on the basis of regularity of following the practices from 'Always' to 'Never'. For the analysis of food safety feeding practices, response of 'Always' was given a score of 5 and 'Never' was given a score of 1. For the purpose of finding out the relation between food safety practice score and incidence of food borne diseases, correlation analysis was used. For the purpose of analyzing the overall food safety feeding practices of the respondents, the scores thus obtained from the statement of feeding practices were added for every respondent and have been termed as 'Practice Score'. Maximum possible practice score for all the statements (thirteen) related to food safety could be 65.

Nutrition counseling was imparted to the subjects for a period of three months through the lecture cum discussion methods with the help of audio visual aids. The feeding practices of the respondents pertaining to food safety were assessed before and after imparting nutrition counseling .

Food Safety Practice Score: It is worth mentioning that the results available from the study have been analyzed on the basis of various parameters pertaining to the profile of the respondents i.e. age, family size and family income. As the respondents were mothers of children (<5 yrs), so in order to assess their food safety practices, their feeding practices were analyzed as they were involved in the preparation, serving, feeding and storage of food. The children were too young to eat on their own, so it was the main responsibility of the mothers to feed the child. The results obtained from the subjects regarding their feeding practices about the food safety issues before and after the nutrition counseling are discussed below:

Food Safety Practice Score (Pre Intervention): The results of feeding practices before nutrition counseling revealed that the respondents were following various practices on regular basis were proper washing of utensils with the highest mean score of 4.2, regular cutting of nails (3.87), tying of hair while working in kitchen (3.73). The food safety practices that were rarely followed by the respondents were: giving leftover food to child (1.53), anybody else feeding the child if mother is not available (1.47), preparing child's milk in morning itself and add sugar to it (1.33), boiling of water before consumption (1.07).

Detailed analysis of the 'Practice Score' according to various parameters such as age, family income and family size has been presented in Table 1. It can be seen from the table that out of the possible maximum score 65, the mean Practice Score for all the respondents came out to be 26.40. Thus, indicated that the respondents covered under the study were having below average performance when it came to following good food safety practices.

There was a significant difference in the mean practice score of categories based on the age. The food safety practices being followed between 24-26 years were given the mean Practice Score of 27.50 which is highest among all 3 categories followed by 21-23 years i.e. 26.67 and 27-29 years (24).

Further it can be seen from the table that the highest mean Practice Score was acquired by the respondents having monthly income of Rs. 1000-1500 (27) and the respondents in large families (27.25) as compared to other categories. A comprehensive consumer survey in 2002 reveled that women, lower income households, people 65years and older practiced safer food handlings than men, higher income households and people younger than 65 years (Li-Cohen and Bruhn, 2002).

Food Safety Practice Score (Post Intervention): After imparting nutrition counseling for 3 months, the feeding practices of the respondents was again enquired by administering the questionnaire with 13 statements related to the feeding practices pertaining to food safety. The results revealed that the respondents followed the food safety practices on regular basis were washing of utensils and cutting of nails with the highest mean score of 4.87, tying of hair while working in kitchen (4.67), feeding the child immediately after making the food/milk (3.33). There were few food safety practices that were followed rarely by the respondents were preparing child's milk in morning itself and add sugar to it (1.2), boiling of water before consumption (1.07). These practices were still not above average due to the scarcity of resources among the respondents belonging to slum areas.

Detailed analysis of the 'Post Practice Score' i.e. practice score after imparting nutrition counseling for 3 months, according to various parameters such as age, family income and family size has been presented in Table 1. It can be seen from the table that out of the possible maximum score 65, the mean Practice Score for all the respondents came out to be 29.93. Thus, indicating that after nutrition counseling, the respondents were having an average performance(but better than before nutritional counseling) when it came to following the good safety practices . There was a significant difference in the mean practice score of groups based on the age. The food safety practices being followed by 21-23 years was 31 which is highest among all 3 categories followed by 24-26 years (30.38) and 27-29 years (28.25).

Further it can be seen from the table that the respondents having monthly income of Rs 1600-2000 (30.33) and with large families (31) had the highest mean Practice Score as compared to other groups.

Table 1 Practice score (N=150)

	Pre Intervention		Post Intervention	
Category	Mean score± S E	F-value	Mean score± S E	F-value
Total (n=150)	26.40 ±0.215	-	29.93± 0.246	-
Age				
21-23 (n=30)	26.67 ± 0.487	34.254**	31.00± 0.401	10.105**
24-26 (n=80)	27.50 ± 0.252		30.38 ±0.369	
27-29 (n=40)	24.00 ±0.253		28.25 ±0.347	
Family income				
1000-1500 (n=20)	27.00 ± 0.459	.892	29.00 ±0.688	0.221
1600-2000 (n=60)	26.50 ± 0.268		30.33 ±0,316	
More than 2000 (n=70)	26.14 ±0.378		29.86 ±0.4043	
Family size				
Large (n=80)	27.25 ± 0.256	8.378**	31.00± 0.276	13.194**
Small (n=70)	25.43 ±0.321		28.71± 0.374	

** Significant at 1%

A significant positive relationship was observed between improvement in nutritional status of = 5 years children and adoption of proper infant-feeding practices by their mothers. Adolescent girls, pregnant and lactating mothers and also elderly women should be educated for promotion and protection of optimal infant-feeding practices for improving nutritional status of children. (Dinesh *et al.*, 2006).

The paired t-test was applied to find out the difference in the pre and post feeding practice scores of the respondents. Even though there were limited resources present to put the knowledge in practice and the results reveals that there was a significant difference in the pre and post feeding practices of the respondent's i.e. 0.153 ($p<0.05$). This shows that the impact of nutrition counseling was effective as it improved the practices of the young mothers (children below 5 years). A study conducted in Nepal emphasizes an appropriate mix of health education and food supplements to improve the number of children who meet the recommended infant feeding guidelines, reduce under nutrition and improve the survival rates of young children (Khanal *et al.,* 2013) . Nutrition training of health workers can help to reduce child's under nutrition. Specifically, trained health workers might contribute to this end through frequent nutrition counseling of caregivers. This may improve child-feeding practices and thus reduce the risk of under nutrition among children of counseled caregivers (Sunguya *et al.*, 2013).

Correlation between feeding practices and incidence of food borne diseases: A significant negative correlation was found between feeding practices and incidence of food borne disease with a coefficient of -0.297 ($p<0.05$) among all the respondents included in the study. This show with improvement in feeding practices there was a decrease in food borne disease prevalence among children. A study was conducted in Melbourne, Australia in which the cases of gastroenteritis were examined to identify if dietary intake prior to an episode and food-handling and storage practices in the home were risk factors for illness. Although food-handling and storage practices were considered important, but no association was detected in the study(Mitakakis *et al.*, 2004). The results of another study suggested that food-hygiene practices of mothers in the home had a potential impact on the prevention of diarrhea. The improvement of food-hygiene practices of mothers could be an effective strategy to prevent diarrhea among children (Kumiko *et al.,* 2009).

- From present studies it can be concluded that imparting nutrition counseling for the period of 3 months helps to improve the feeding practices pertaining to food safety and there was a significant negative correlation between food safety practices and incidence of food borne diseases.

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OBITUARY

Prof. Avtar Singh Atwal
FOUNDER PRESIDENT
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Prof. Avtar Singh Atwal was born on June 25, 1927 at village Khanewal, District Multan, now in Pakistan. He did his B.Sc. (Agriculture) from Punjab Agricultural College and Research Institute, Lyallpur (Pakistan) in 1947, where he obtained first position in the University and was awarded the Gold Medal. He completed his Ph.D. from the Waite Agricultural Research Institute, University of Adelaide, South Australia in 1954 under the Colombo Plan. He remained Post Doctorate Research Fellow of the National Research Council of Canada during 1955-57. It was during his doctoral research when he came into contact with eminent ecologists working and visiting the Section of Ecology and thus, he imbibed the spirit of ecological principles and practices which he later introduced in the academics of the Punjab Agricultural University, Ludhiana.

Prof. Atwal started his professional career as Lecturer in Entomology in 1947 and worked as Assistant Professor/Associate Professor till 1960. He was Entomologist to the Government of Punjab and State Locust Control Officer (1961-63), when he introduced successfully the aerial spraying for locust control. He was the first Professor and Head, Department of Zoology-Entomology of the newly formed Punjab Agricultural University (PAU), Ludhiana (1963-66). He worked as Dean, College of Agriculture (1966-73 and 1975-79) and Dean, Post Graduate Studies (1979-85), PAU, Ludhiana. In between, he was Advisor to Jammu & Kashmir Government and Vice-Chancellor (Designate), J & K Agricultural University (1973-75) and prepared the project for establishing the University. He worked as full time Member, Punjab State Planning Board (1986-89). Even when he worked on other positions, he maintained his interest in ecological approach to pest control and agricultural development for the first 20 years, and in the role of honey bees and other insects for the pollination of crops for the next 20 years. He has published 15 books, 150 research papers and 100 reviews and strategy papers on agricultural education, research and development.

Prof. Atwal has made outstanding contributions in the fields of agricultural research, education and development. He was the first scientist in India to successfully introduce the Italian honey bee, *Apis mellifera* Linnaeus in early sixties through a unique experiment, using the technique of interspecific queen introduction. *A. mellifera* colonies were raised by introducing the fertilized queens among the workers of *Apis cerana* Fabricius. Persistent efforts spread over a decade led to the successful establishment of *A. mellifera* in Punjab and the entire Indo-Gangetic plains where Honey Revolution has followed the Green Revolution. Prof. Atwal will be remembered as the Father of Modern Beekeeping in India as he opened new vistas of commercial beekeeping in the country. As one of the founder Deans of Punjab Agricultural University, Prof. Atwal played a pivotal role in introducing many innovative programmes and developing several new Departments. He was instrumental in revising and restructuring the PAU course curricula keeping in view the changing educational needs. For making education wholesome many new disciplines were started and trained faculty was recruited by making personal contacts from throughout India and even foreign countries. Some of the new disciples of Ecology, Forestry, Agrometeorology, Food Science and Technology, and Floriculture and Landscaping at PAU are the outcome of his visionary approach in planning. The College of Agriculture being the premier institute of PAU, played the most significant role in ushering Green Revolution in the state. It was during his tenure as Dean, when this college had won the Institution Award of the Federation of Indian Chambers of Commerce and Industry in 1977.

Prof. Atwal established the Indian Ecological Society in 1974 and was its founder President. The Indian Ecological Society is one of the oldest in this field and has been responsible for bringing the ecological perspective in the academic and applied spheres of life in India. He nurtured this society with complete devotion and organized several symposia and conferences.

The books written by Prof. A. S. Atwal would continue to shape up the destiny of students and teachers in many Asian countries. His monumental book "Agricultural Pests of South Asia and Their Management" is one of the most popular text books ever written on this subject; since its first publication in 1976, the book has been reprinted many times with eight revisions. Even after his retirement, he continued to publish for the benefit of students and farmers; his recent book "*Mellifera* Beekeeping and Pollination" has been acclaimed as a master piece giving details of behaviour of four species of honey bees and their role in crop pollination.

Prof. Atwal was a widely traveled person, visiting more than 35 countries in almost all the continents of the world. He has been a member of several national and international bodies associated with agricultural research and development. He has attended 20 World Congresses and 25 International Conferences related to various aspects of agriculture, ecology and environment.

Prof. Atwal expired on September 26, 2014 after a brief illness. The Indian Ecological Society deeply mourns his sad demise and prays for peace to the departed soul.

G S Dhaliwal
President
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