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Performance of Planting Methods of *Gobhi Sarson* in Pigeonpea-*Gobhi Sarson* Cropping System in Sub-tropical Zone

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Abstract: The study evaluated the performance of different planting methods of *Gobhi sarson* in the pigeonpea-*Gobhi sarson* cropping system to identify the most effective establishment technique. The study was conducted during *Rabi* 2023-24 and 2024-25 at PAU, Ludhiana, using a randomized complete block design with three planting methods- relay cropping, direct seeding and transplanting. Planting methods significantly influenced growth and yield. Relay cropping performed best due to early establishment, better plant stand and efficient use of residual moisture, resulting in higher growth vigour and superior yield attributes. Direct seeding showed moderate performance, while transplanting exhibited comparatively lower growth and yield. Overall, relay cropping proved most suitable for maximizing productivity. The growth, yield attributes and yield of *Gobhi sarson* were significantly affected by pigeonpea-based cropping systems. Relay cropping systems (pigeonpea + cowpea - *Gobhi sarson* - summer moong) recorded highest growth traits (plant height, dry matter accumulation and LAI), owing to better moisture conservation, improved soil structure and residual fertility from preceding legumes. Relay cropping also enhanced yield attributes, including number of siliquae plant^{-1} and seeds siliquae^{-1}, while test weight remained non-significant. The highest seed yield was obtained in pigeonpea (AL 882) + cowpea (F) - *Gobhi sarson* (relay cropping) - summer Moong (24.26 q ha^{-1}), statistically at par with T1 (24.13 q ha^{-1}), but significantly higher than direct-seeded and transplanted treatments. Improved yield under relay cropping resulted from timely establishment, better plant stand, efficient resource use and an extended effective growth period. Overall, relay cropping proved to be the most suitable, efficient and sustainable establishment method for maximizing productivity of *Gobhi sarson* in pigeonpea-based cropping systems, followed by direct seeding and transplanting.

Keywords: Relay cropping, *Gobhi sarson*, Direct seeding, Transplanting, Pigeonpea-*Gobhi sarson* system

Gobhi sarson (*Brassica napus* L.) is an important *Rabi* oilseed crop grown extensively in northern India due to its high oil content, wider adaptability and stability under diverse agro-climatic conditions (Rathore et al., 2018). India is one of the leading producers of rapeseed-mustard, contributing nearly 40% of the country's total edible oilseed production, with an average productivity of 1.3-1.5 t ha^{-1} in recent years (DES 2023). Enhancing productivity of oilseed crops like *Gobhi sarson* is essential for reducing the national oil import burden and strengthening domestic oilseed security. Pigeonpea (*Cajanus cajan* L.) is a key *Kharif* pulse crop in India, cultivated on about 5.0 million hectares, with an average productivity of 850-900 kg ha^{-1} (DAC & FW 2023). Being a deep-rooted legume, pigeonpea improves soil fertility through biological nitrogen fixation, enhances soil structure and leaves behind considerable residual moisture after harvest (Paroda 2022). This makes it a suitable preceding crop for *Gobhi sarson* in sequential cropping systems. The pigeonpea-*Gobhi sarson* sequence is therefore highly complementary, where pigeonpea enriches the soil and *Gobhi sarson* efficiently utilizes the conserved moisture and nutrients, contributing to improved system productivity and sustainability (Deshmukh et al., 2023). However, in this system, the major challenge is timely sowing of *Gobhi sarson*, as pigeonpea matures late. Delayed sowing often leads to poor crop establishment, reduced branching, fewer siliquae and ultimately lower seed yield (Singh et al., 2024). This challenge is aggravated under climate variability, where erratic rainfall and temperature fluctuations can delay pigeonpea harvest and adversely affect sowing windows for the succeeding oilseed crop. Climate-related constraints such as moisture deficit at sowing, lower temperatures during early growth and fluctuating humidity levels can further limit the productivity of late-sown *Gobhi sarson*. To address these constraints, alternative planting methods such as relay cropping, direct seeding and transplanting are used. Relay cropping allows *Gobhi sarson* to be sown before the harvest of pigeonpea, ensuring timely establishment and better moisture utilization. Direct seeding is simpler but depends heavily on available soil moisture, while transplanting helps manage delays but may cause transplanting shock and reduced early vigour (Chourasiya et al., 2024). Relay cropping has been recognized as a climate-smart and resource-efficient technique that enhances cropping intensity, improves soil health, minimizes the fallow period between crops and ensures more effective use of sunlight, nutrients and moisture. Considering the national need for enhanced oilseed productivity and the agronomic benefits of pigeonpea-*Gobhi sarson* sequence, evaluating suitable establishment techniques becomes essential. Therefore, the present study was undertaken to compare relay cropping, direct seeding and transplanting to identifying the most effective planting method for maximizing growth, yield and overall system productivity of *Gobhi sarson* in pigeonpea-based cropping systems.

MATERIAL AND METHODS

The field experiment was conducted during *Rabi* 2023-24 and 2024-25 at Punjab Agricultural University, Ludhiana, to assess the performance of planting methods of *Gobhi sarson* in the pigeonpea-*Gobhi sarson* cropping system in Sub-tropical zone. Prior to initiating the experiment, representative soil samples were collected from 0-15 and 15-30 cm depths and analyzed for physico-chemical characteristics. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction (pH 7.6-7.8), low in electrical conductivity (0.44-0.46 dS m^{-1}), and low to medium in organic carbon (0.41-0.44%). Available nitrogen content was low (135.4-145.2 kg ha^{-1}), whereas available phosphorus (15.2-18.3 kg ha^{-1}) and potassium (180.6-200.5 kg ha^{-1}) were in the medium range. Bulk density ranged from 1.41 to 1.44 g cm^{-3}. The experiment was laid out in a randomized complete block design with three replications, comprising three planting methods of *Gobhi sarson*; relay cropping, direct seeding and transplanting in standing pigeonpea and after uprooting of Pigeonpea in respect two different genotypes (PAU 881 and AL 882). In the relay cropping of *Gobhi sarson*, sowing was done in standing pigeonpea before harvest. Then under direct seeding method, crop was sown immediately after harvest of pigeonpea and in transplanting, seedlings raised in a nursery were transplanted (30 days old nursery) after pigeonpea harvest. Standard agronomic practices for raised bed technology have been followed in *Gobhi sarson* were uniformly followed across treatments during both the crop seasons (Anonymous 2025-26). Growth parameters such as plant height, number of branches $plant^{-1}$, leaf area index and dry matter accumulation were recorded at regular intervals. Yield attributes including siliquae $plant^{-1}$, siliqua length, seeds $siliqua^{-1}$ and 1000-seed weight were measured at maturity. Seed, stover and biological yields were recorded from the net plot area. The data on growth and yield attributes were statistically analyzed using analysis of variance (ANOVA), and treatment means were compared using the critical difference at 5% probability level using SAS statistical software (SAS Institute Inc. 2014).

RESULTS AND DISCUSSION

Growth parameters: Growth parameters *viz.* plant height, dry matter accumulation, leaf area index (LAI) were significantly influenced by pigeonpea-based different cropping systems (Table 1). Among the treatments, pigeonpea (AL 882) + cowpea (F) - *Gobhi sarson* (relay cropping) - summer moong (T4) recorded the highest plant height (100.9 cm), which was statistically at par with pigeonpea (PAU 881) + cowpea (F) - *Gobhi sarson* (Relay cropping) - summer moong (100.7 cm) but significantly highest than the direct-seeded and transplanted treatments. The lowest plant height was observed under transplanted *Gobhi sarson* following pigeonpea in both cultivars (T3 and T6). The plant height showed that higher growth under relay cropping may be attributed to better soil moisture retention, improved soil structure and residual fertility due to the preceding pigeonpea-cowpea system, which provided a favourable microenvironment for vegetative development (Morya et al., 2023). The, dry matter accumulation exhibited a pattern closely associated with plant height. The highest dry matter accumulation was recorded under pigeonpea (AL 882) + cowpea (F) - *Gobhi sarson* (relay cropping) - summer moong T4 (452.9 g m^{-2}), which was closely followed by T3 (416.9 g m^{-2}). This improvement may be ascribed to better canopy development, greater leaf area index and enhanced photosynthetic activity due to improved soil fertility and moisture conditions left by the preceding pigeonpea-cowpea system. The residual nitrogen and organic matter from legume crop likely promoted higher photosynthetic rate and assimilate production, resulting in increased biomass. These observations are supported by the findings of Pandey et al. (2021). The leaf area index (LAI), indicated non-significant differences among treatments. But numerically highest LAI was in T4 (2.65) whereas the lowest LAI was in T3 (2.24) and T6 (2.28). The LAI across treatments (T1-T6) remained non-significant because *Gobhi sarson* exhibits strong compensatory leaf growth, resulting in a uniform canopy under similar plant population, moisture and nutrient conditions (Table 1). Singh et al. (2019) also observed the same trend. Among the cultivars, the differences in weed population and dry matter accumulation were non-significant. Shergill et al. (2012) also reported that Hyola PAC 401 and GSC 6 have no difference in competitive ability for control of weeds, irrespective to their yield potential.

Yield attributes and yield: Yield attributes and yield *viz.* number of branches $plant^{-1}$, number of siliquae $plant^{-1}$, number of seeds $siliquae^{-1}$, test weight and seed yield were significantly influenced by pigeonpea-based different cropping systems demonstrate in (Table 1). The number of primary branches, showed non-significant differences among treatments. The numerically highest number of primary branches was in pigeonpea (AL 882) + cowpea (F) - *Gobhi sarson* (relay cropping) - summer moong (T4) (6.3).

Table 1. Growth, yield attributes and yield of *Gobhi sarson* under varied sowing/transplanting methods (Pooled data of two years)

Treatments	Plant height (cm)	Dry matter accumulation ($g\ m^{-2}$)	Leaf area index	Number of primary branches	Number of secondary branches	Number of siliquae $plant^{-1}$	Number of seeds $siliquae^{-1}$	Test weight (g)	Seed yield ($q\ ha^{-1}$)
Days after sowing (DAS) and Transplanted (T)									
T1: Pigeonpea (PAU 881) + Cowpea (F) - *Gobhi sarson* (Relay cropping) - Summer Moong	100.7	451.2	2.54	6.2	288.0	22.8	8.65	4.64	24.13
T2: Pigeonpea (PAU 881) + Cowpea (F) - *Gobhi sarson* (DS) - Summer Moong	99.0	431.2	2.33	5.9	269.1	21.5	7.85	4.06	22.14
T3: Pigeonpea (PAU 881) + Cowpea (F) - *Gobhi sarson* (T) - Summer Moong	97.0	416.9	2.24	5.6	253.1	21.2	6.70	3.91	21.22
T4: Pigeonpea (AL 882) + Cowpea (F) - *Gobhi sarson* (Relay cropping) - Summer Moong	100.9	452.9	2.65	6.3	288.9	23.1	8.75	4.71	24.26
T5: Pigeonpea (AL 882) + Cowpea (F) - *Gobhi sarson* (DS) - Summer Moong	100.3	430.2	2.36	6.0	270.3	22.1	8.05	4.08	22.27
T6: Pigeonpea (AL 882) + Cowpea (F) - *Gobhi sarson* (T) - Summer Moong	98.2	416.6	2.28	6.1	254.2	21.4	6.90	3.95	21.32
CD (p=0.05)	1.86	34.47	NS	NS	34.83	1.75	1.68	NS	1.63

The lowest number of primary branches was observed in T3 (5.6). The primary branches remained non-significant because all treatments followed uniform sowing time, plant density and nutrient management, leading to similar early vegetative growth. However, secondary branches varied significantly as relay cropping (T1 and T4) created a more favourable micro-environment with better soil moisture, and improved residual fertility, resulting in greater assimilate availability and enhanced axillary bud development. Additionally, the superior varietal vigor of AL 882 in T4 contributed to increased secondary branching compared to other treatments. Similar observations were reported by Vibhanshu and Sarlach (2023). The number of secondary branches also indicated significant differences among treatments. The highest number of secondary branches was under relay cropping in T4 (288.9), which was statistically at par with T1 (288.0) and significantly superior to direct-seeded and transplanted treatments. The lowest number of secondary branches was observed in T3 (253.1), followed by T6 (254.2). The siliquae $plant^{-1}$ were higher in relay-cropped treatments (T1 and T4) because relay sowing improved early establishment, conserved soil moisture and provided a longer effective growth period, creating a favourable microclimate for reproductive branching, siliqua formation and seed set compared to direct seeding and transplanting (Table 1). The results are in agreement with the findings of Kumar (2020). The number of siliquae $plant^{-1}$ was highest in T4 (23.1), which remained at par with T1 (22.8) and significantly highest to transplanted treatments. The minimum number of siliquae $plant^{-1}$ was observed in T3 (21.2). The relay cropping systems (T1 and T4) provided a more favourable microenvironment with better light interception and reduced intra-plant competition, leading to higher siliquae formation and seed set. The genotypic differences, as seen between PAU 881 and AL 882, could influence reproductive efficiency, resulting in higher seeds per siliqua in AL 882 under relay cropping. These findings are in agreement with the results reported by Sharma et al. (2025). The test weight did not differ significantly among treatments in the pooled analysis.

The numerically highest test weight was observed in T4 (4.71 g) and T1 (4.64 g), while the lowest test weight was in T3 (3.91 g). The lack of significant variation suggests that seed size was comparatively less sensitive to differences in establishment methods. Seed yield exhibited significant variation among treatments. The highest seed yield was in T4 (24.26 q ha^{-1}), which was statistically at par with T1 (24.13 q ha^{-1}) and significantly superior to direct-seeded and transplanted treatments. The lowest seed yield was recorded in T3 (21.22 q ha^{-1}), followed closely by T6 (21.32 q ha^{-1}). The enhanced seed yield under relay cropping can be attributed to better growth conditions, extended period for vegetative and reproductive development and improved partitioning of assimilates towards seeds. Relay cropping likely facilitated efficient use of available nutrients, moisture, and light, reducing interspecific competition during the critical growth stages of *Gobhi sarson*. The double sowing and timely sown systems exhibited lower seed yields, possibly due to restricted growth duration and greater competition for resources. These findings are in agreement with previous studies, Kaparwan et al. (2020) reported that relay cropping in pulse-based intercropping systems significantly improves seed yield of mustard by optimizing crop growth and resource utilization.

CONCLUSION

Planting methods significantly influenced the growth and yield of *Gobhi sarson* in the pigeonpea-based cropping system. Relay cropping pigeonpea (AL 882) + cowpea (F) - Gobhi sarson (relay cropping) - summer Moong recorded the highest plant height, dry matter accumulation, leaf area index, number of branches, siliquae plant^{-1}, seeds siliqua^{-1}, test weight and seed yield. Enhanced performance under relay cropping was due to timely establishment, better light interception, efficient moisture and nutrient use and minimal interspecific competition. Direct seeding showed moderate performance, while transplanting resulted in comparatively less productive. Therefore, relay cropping may be recommended as an efficient and sustainable planting method for enhancing *Gobhi sarson* productivity in pigeonpea-based cropping systems.

AUTHOR'S CONTRIBUTION

This study was conducted as part of the Doctoral Research Project under Punjab Agricultural University. Coauthor GK contributed to the conduct of experiment, data collection, analysis of data and manuscript writing. KSS planned the experiment, time to time field operation guidelines, conceptualization of the study and provided theoretical, academic inputs and interpretation of results. JK contributed in data analysis and writing of paper. Shreya assisted in data collection and helped in data analysis.

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