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Effect of Sowing Time on Phenology, Growth and Yield Across Lentil Varieties in Lower Gangetic Plains of India

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ABSTRACT

Background: The study was aimed to find the most suitable lentil variety and sowing time in Lower Gangetic Plains (LGP) to meet the growing demands in India under changing climatic conditions.

Methods: Field experiment was conducted with seven varieties of lentils during *rabi* season, 2019-2020 and 2020-2021 at farmer's field under Krishi Vigyan Kendra, Murshidabad, West Bengal, India to evaluate the influence of sowing time *i.e.*, normal sowing (5th November to 12th November) and late sowing (5th December to 17th December) on the yield performance of different lentil varieties, *viz*., Moitree, HUL-57, KLS-218, BM-8, IPL-220, BM-7 and L-4717.

Result: Normal sowing of lentil is better than late sowing. Results revealed that lentil sown during the first fortnight of November produced the highest grain yield (1027 kg ha^{-1}), 104% higher than late sowing (503 kg ha^{-1}). L-4717 genotype was consistently the best in both normal and late planting.

Key words: Date of sowing, Growth attributes, Lentil, Phenology, Varieties, Yield.

INTRODUCTION

Lentil (*Lens culinaris* Medik), a cool-season food legume is a rich source of protein, fibre and essential nutrients, making them a necessary part of Indian diet. India is one of the leading producers of lentil in the world, contributing 28.6% of the world's yearly production from an area of 1.51 million hectares with a total annual output of 1.56 million tonnes and productivity of 1032 kg ha^{-1} (Ministry of Agriculture and Farmer Welfare, 2019). According to FAO, India is the largest producer (25% of global production), consumer (27% of world consumption) and importer (19.5%) of pulses in the world (Mohanty, 2015). However, the productivity of lentil has experienced a decline, attributed to farmers' transition towards alternative crops, the repercussions of the pandemic and prevailing weather conditions. The Lower Gangetic Plains (LGP) in India contributes 10.3% (0.16 million ha^{-1}) of India's total lentil growing area, with annual productivity of 980 kg ha^{-1} and production of 0.15 million tonnes accounting for 9.6% of the country's annual production (Ministry of Agriculture and Farmer Welfare, 2019).

Lentil is generally cultivated in the rice fallow areas on residual soil moisture under rainfed conditions in the rice-lentil cropping system (Malik, 2016). Delayed sowing due to late harvest of rice, rapid soil water loss following rice harvest, a quick drop in the water level, a rise in temperature and mid and terminal drought at the flowering and pod-filling stages, lentil productivity is adversely affected (Baidya *et al.,* 2021; Venugopalan *et al.,* 2021). Delayed planting-related temperature issues, particularly during the reproductive phase, exert a substantial influence on the reproductive biology of lentil that extends to influence yield components and overall productivity (Kumari *et al.,* 2018; Maji *et al.,* 2025). Elevated temperatures following 50% flowering resulted in less seed filling duration, reduced seed growth rate, seed weight and decreased lentil yield (Sehgal *et al.,* 2017). Optimal planting time serves to synchronize phenological development. Sekhon *et al.* (1986) suggested that the optimal sowing window for lentil cultivation in the rainfed regions of India spans from the third week of October to the third week of November. Furthermore, the genetic makeup specific to each variety also plays a role in determining the temperature sensitivity of vegetative and reproductive growth traits that govern yield

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(Maphosa, 2023). Hence, the objective of the present study was to determine optimum sowing time and promising lentil varieties with high yield potential suitable for the Lower Gangetic Plains of India.

MATERIALS AND METHODS

The experiment was conducted at a farmer's field under Krishi Vigyan Kendra, Digha, Murshidabad, West Bengal, during the *rabi* seasons of 2019-2020 and 2020-2021. The latitude is 24°27′ N and longitude of 88°28′ E with an altitude of 21 m above sea level. The experimental soil sample was tested to determine the levels of available major nutrients. Soil was sandy loam with 0.45% organic carbon, 180.49 kg ha^{-1} available N, 34.60 kg ha^{-1} P_2O_5 and 172.83 kg ha^{-1} available K_2O. During crop growth, averages temperature in 2019-20 were 30.0°C max / 19.3°C min (Fig 1a), whereas in 2020-21 they were 31.6°C max / 20.4°C min (Fig 1b). The experiment was conducted on medium upland in rice-fallow. Seeds (30 kg ha^{-1}) were sown maintaining 25 cm row to row spacing. The trial was laid out in a split-plot design, replicated thrice, considering sowing dates *viz*. 12th November (normal sowing) and 17th December (late sowing) of 2019 and 5th November (normal sowing) and 5th December (late sowing) of 2020 in the main plot and genotypes (Moitree, HUL-57, KLS-218, BM-8, IPL-220, BM-7 and L-4717) in the sub-plot. Standard agronomic practices were followed. Harvesting was done in mid-February for the normal-sown crops (103-106 days) and in late March for the late-sown crops (90-96 days). Four crucial phenological milestones namely emergence, 50% flowering, 100% flowering and maturity were recorded for each lentil variety under normal and late sowing. Growth and yield data included plant height, primary and secondary branch count, pod count, seeds per pod and test weight, with grain and straw yields measured in kg/ha.

All the data obtained for two consecutive years were statistically analyzed using the two-way analysis of variance (ANOVA) to evaluate the significant differences among

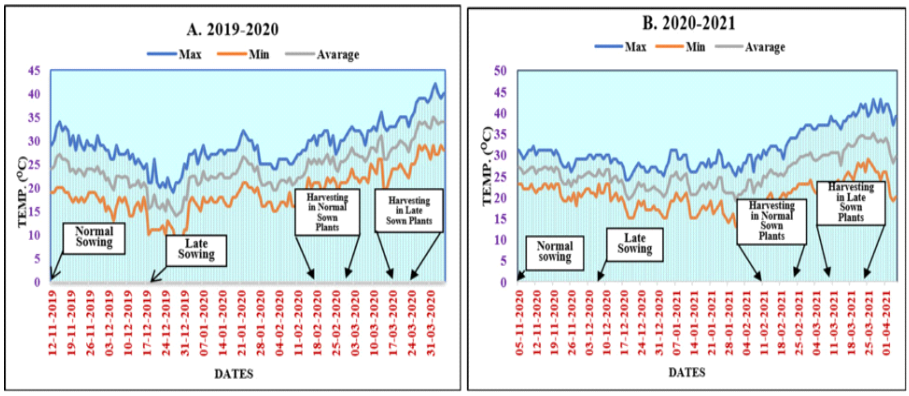


Fig 1: Normal and late sowing and harvesting schedule and temperature during the crop growth period, A 2019-20 and B 2020-21.

Table 1: Effect sowing time on phenophase duration of lentil cultivars.

Treatment	Days to emergence			Days to 50% flowering			Days to 100% flowering			Days to maturity		
	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	Pooled	2019-2020	2020-2021	Pooled
Time of sowing												
Normal sowing	5.86	6.86	6.36	64.90	68.43	66.67	77.48	78.52	78.00	98.57	99.76	99.17
Late sowing	7.29	7.86	7.57	43.24	52.67	47.95	63.57	70.95	67.26	91.38	92.57	91.98
SEM (±)	0.12	0.06	0.07	0.36	0.35	0.25	0.24	0.53	0.29	0.53	0.37	0.32
LSD (p≤0.05)	0.71	0.35	0.26	2.17	2.14	0.98	1.48	3.25	1.15	3.20	2.28	1.27
Genotypes												
Moitree	6.17	7.33	6.75	54.50	61.67	58.08	70.67	76.00	73.33	97.17	97.83	97.50
HUL-57	7.00	8.50	7.75	57.17	63.67	60.42	73.67	78.33	76.00	99.50	100.50	100.00
KLS-218	6.67	7.67	7.17	55.67	60.67	58.17	71.83	75.00	73.42	97.00	97.00	97.00
BM-8	5.83	7.50	6.67	50.67	58.50	54.58	67.00	72.83	69.92	93.17	96.33	94.75
IPL-220	7.00	7.33	7.17	57.00	62.17	59.58	72.17	76.50	74.33	96.33	99.00	97.67
BM-7	7.17	7.00	7.08	52.00	58.50	55.25	69.67	72.83	71.25	91.00	93.67	92.33
L-4717	6.17	6.17	6.17	51.50	58.67	55.08	68.67	71.67	70.17	90.67	88.83	89.75
SEM (±)	0.38	0.19	0.21	0.49	0.55	0.37	0.37	0.39	0.27	0.88	0.59	0.53
LSD (p≤0.05)	NS	0.55	0.61	1.44	1.59	1.05	1.08	1.15	0.77	2.58	1.73	1.51

treatments, genotypes and genotype × treatment interaction on the measured traits (Gomez, 1984). Means were separated and compared using Tukey's posthoc test at P≤0.05 with Origin Pro Software. Partial regression was analyzed by SPSS 22. Principal Component Analysis, done in Origin Pro software (version 2021), was utilized to discern patterns within the dataset, emphasizing the similarities and dissimilarities among data points based on their inter-distances (Jollife and Cadima, 2016).

RESULTS AND DISCUSSION

Phenology and yield attributes

Results revealed that normal-sown plants exhibited quicker emergence (1.21 days), extended flowering (18.72 days in 50% flowering and 10.74 days in 100% flowering) and maturity time (7.19 days) (Table 1), greater plant height (4.89 cm), increased branching (0.7 and 1.9 nos. in primary and secondary branches, respectively) (Table 2), more pods per plant (24.7 nos.), higher seed production per pod (0.5 nos.), test weight (0.6 g) and biological yield (1585 kg ha^{-1}) (Table 3).

Normal-sown seeding emerges substantially faster (0.84 times) than late sowing, most likely due to superior retention of residual soil moisture following rainy season. Venugopalan *et al.* (2021) found similar result, observing delayed emergence with late sowing in lentil. Sehgal *et al.* (2017) also stated that lentil is extremely sensitive to high temperatures (35/20°C) throughout flowering and seed-filling stages. Wright *et al.* (2021) reported 1.5°C temperature increase resulted in faster blooming, cutting the time to lower by 2.5 to 18.1 days. Even late-sown lentil reached maturity 26% earlier due to soil moisture stress (Saha *et al.,* 2020). Heat stress in late sowing reduced plant height by 1.49% in chickpea (Kumar *et al.,* 2022). In lentil also, earlier emergence produces more branches than late emergence (Maphosa *et al.,* 2023). November 10 (normal) sown crop produced more branches than November 20 or 30 (late) sown and led to 26.7% decrease in pods per plant compared to normal-sown (Sen *et al.,* 2016). Similar results were also shown in faba beans and chickpeas, where late sowing resulted in lower seed weight and quantity because of higher pod losses and fewer completely matured pods (Manning *et al.,* 2020; Chetariya *et al.,* 2025).

Grain yield

Normal sowing recorded significantly higher grain yield (1027 kg ha^{-1}), while late-sown lentil varieties recorded minimum grain yield (503 kg ha^{-1}) (Table 3). Among tested cultivars, under normal-sown condition, L-4717 genotype (1308 kg ha^{-1}) revealed significantly highest grain yield, followed by BM-7 (1211 kg ha^{-1}). In contrast, the HUL-57 genotype (731 kg ha^{-1}) showed a significantly lower grain yield. In case of late sowing condition, the L-4717 genotype (589 kg ha^{-1}) showed the highest grain yield, followed by BM-7 (553 kg ha^{-1}), while IPL-220 (418 kg/ha) showed significantly lowest grain yield (Fig 2).

The grain production of lentil plants cultivated under heat stress (25/14°C day/night temperature) was 39.13% lower than that of plants grown under no stress (22/12°C) (Choukri *et al.,* 2022). The prolonged maturation time in normal condition promoted healthier plant growth, which in turn increased the production of pods and seeds and, eventually grain yield. Delaying crop sowing from November to December, for example, shortens the days to maturity by 11.4 days (113.4 vs. 101.7), which has a detrimental effect on lentil output (Kumari *et al.,* 2022). Similar findings were also observed in chickpeas where the grain yield decreased by 10.6% and 9.6% for crops sown in December

Table 2: Effect sowing time on growth parameters of lentil cultivars.

Treatment	Plant height (cm)			Number of primary branches/plants			Number of secondary branches/plants		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Time of sowing									
Normal sowing	55.27	57.78	56.52	3.8	4.0	3.9	10.1	10.3	10.2
Late sowing	50.62	52.64	51.63	3.1	3.3	3.2	7.5	9.2	8.3
SEM (±)	0.29	0.73	0.39	0.05	0.09	0.05	0.03	0.27	0.14
LSD (p≤0.05)	1.76	4.41	1.53	0.32	0.57	0.21	0.18	1.63	0.53
Genotypes									
Moitree	56.62	53.30	54.96	3.7	4.2	4.0	7.4	7.8	7.6
HUL-57	52.90	54.53	53.72	3.5	3.5	3.5	9.0	9.2	9.1
KLS-218	52.82	57.62	55.22	3.6	3.5	3.6	10.8	10.4	10.6
BM-8	54.15	58.08	56.12	3.4	3.4	3.4	7.4	8.9	8.1
IPL-220	53.97	59.07	56.52	3.7	3.3	3.5	10.4	9.5	10.0
BM-7	50.57	52.55	51.56	3.1	3.8	3.5	7.3	9.9	8.6
L-4717	49.60	51.33	50.47	3.1	3.8	3.4	9.2	12.5	10.8
SEM (±)	0.47	0.87	0.50	0.09	0.13	0.08	0.33	0.22	0.2
LSD (p≤0.05)	1.38	2.54	1.41	0.26	0.37	0.22	0.97	0.65	0.57

compared to October and November, respectively (Kumar *et al.,* 2023).

Pearson correlation analysis

In normal and late sowing conditions, Pearson correlation analysis revealed various levels of significant positive relationships between grain yield and various phenological, growth and yield parameters in pooled data analysis. Grain yield in both the sowing conditions was positively correlated with pods per plant (r = 0.75*** and 0.74***, respectively), seeds per pod (r = 0.52* and 0.72***, respectively), indicating that grain yield depends on these parameters. In contrast, grain yield was negatively correlated with 50% flowering (r = -0.78*** and -0.72***, respectively), 100% flowering (r = -0.79*** and -0.66**, respectively) and date of maturity (r = -0.89*** and -0.69***, respectively) in both normal and late sowing. In the late-sown condition, the yield showed a strong significant negative correlation with emergence (r = -0.58**) and plant height (r = -0.70***) (Fig 3).

Multiple regression analysis

The regression model significantly predicted the grain yield, where adjusted R^2 = 0.883 depicted 88% of the total variance. The model also included three predictors with the highest predictive power days: 50% flowering, 100% flowering and pods per plant. The result revealed that pods per plant (β= 1.4, t = 6.7, p = <0.001) and 50% flowering (β = 10.5, t = 3.61, p = <0.001) significantly and positively influenced the grain yield. However, days to 100% flowering (β = 16.1, t = -2.52, p = 0.016) negatively and significantly impact grain yield (Table 4). Grain yield was directly affected by days to 50% flowering and pods per plant (Fig 4A, 4B and 4C).

Principal components analysis

The combined contribution of the first principal component *i.e.*, genotype (PC1) and the second principal component *i.e.*, sowing time (PC2), accounts for 82.41% of the overall variance across the genotypes. PC1 predominantly contributes 64.75%, explaining the genotype variability, while PC2 contributes 17.66%, explaining the sowing time variability. It is evident that all parameters, except for the 'days to emergence', exhibit positive loading on PC1. Notably, the parameter 'biological yield' demonstrates the highest favourable loading on PC1 (0.349), whereas 'days of maturity' holds the highest favourable loading on PC2 (0.497). In the PCA bi-plot, grain yield, pods/plant, seeds/pod and secondary branches/plant occupy the same quadrant. This implies that grain yield is predominantly influenced by these parameters. Four genotypes in normal sowing, namely Moitree, HUL-57, KLS-218 and IPL-220, cluster together in quadrant 1 of the bi-plot, indicating minimal significant differences among these genotypes. Four varieties in late-sown condition, namely Moitree, HUL-57, KLS-218 and IPL-220, form a cluster together in quadrant 2 and show a significant difference from other quadrants. Quadrant 3 contains three varieties in late-sown

Table 3: Effect of sowing time and genotypes on yield of lentil.

Treatment	Pods/plant			Seeds/pod			Test weight (g)			Biological yield (kg ha^{-1})			Grain yield (kg ha^{-1})		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Time of sowing															
Normal sowing	84.0	97.0	90.5	1.8	1.8	1.8	19.9	19.9	19.9	3206	3670	3438	978	1077	1027
Late sowing	62.5	69.1	65.8	1.2	1.4	1.3	19.5	19.1	19.3	1798	1908	1853	491	514	503
SEM (±)	0.8	1.9	1.0	0.02	0.02	0.01	0.10	0.10	0.08	12.3	79.3	40.1	25.4	19.2	15.9
LSD (p≤0.05)	4.8	11.6	4.1	0.11	0.11	0.05	0.30	0.50	0.20	74.9	482	158	154.4	116.7	62.4
Genotypes															
Moitree	69.2	72.3	70.7	1.4	1.5	1.5	19.9	19.5	19.7	2236	3433	2835	678	835	757
HUL-57	65.2	68.2	66.7	1.4	1.5	1.4	18.9	18.7	18.8	2139	2228	2183	581	580	580
KLS-218	72.6	81.3	76.9	1.5	1.6	1.5	18.5	17.7	18.1	2500	3150	2825	733	750	742
BM-8	75.9	82.2	79.0	1.5	1.7	1.6	22.5	22.8	22.6	2569	2789	2679	775	823	799
IPL-220	62.0	77.8	69.9	1.5	1.5	1.5	20.1	19.8	20.0	2389	2711	2550	636	656	646
BM-7	79.6	103.5	91.5	1.5	1.7	1.6	18.2	18.3	18.2	2831	2556	2693	844	920	882
L-4717	88.3	96.2	92.2	1.7	1.8	1.8	19.8	19.8	19.8	2847	2656	2751	894	1003	949
SEM (±)	1.3	2.7	1.5	0.04	0.05	0.03	0.20	0.40	0.20	61.9	104	60.7	21.0	28.3	17.6
LSD (p≤0.05)	3.9	7.8	4.2	0.12	0.13	0.09	0.50	1.10	0.60	181	305	173	61.4	82.5	50.1

Table 4: Coefficients of the multiple linear regression model.

Predictors	β	SE	t	p	Result
Pods per plant	0.536	1.4	6.700	< 0.001	Supported
Days of 50% flowering	1.240	10.5	3.608	< 0.001	Supported
Days of 100% flowering	- 0.800	16.1	-2.522	0.016	Supported

(*** p = 0.001).

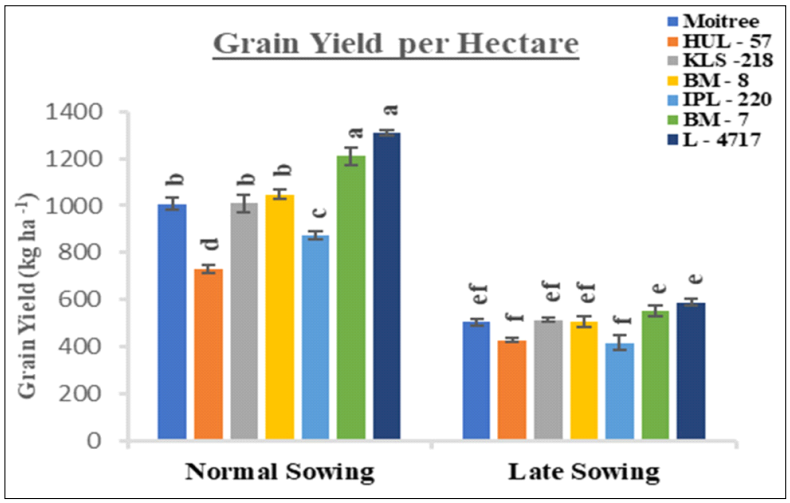
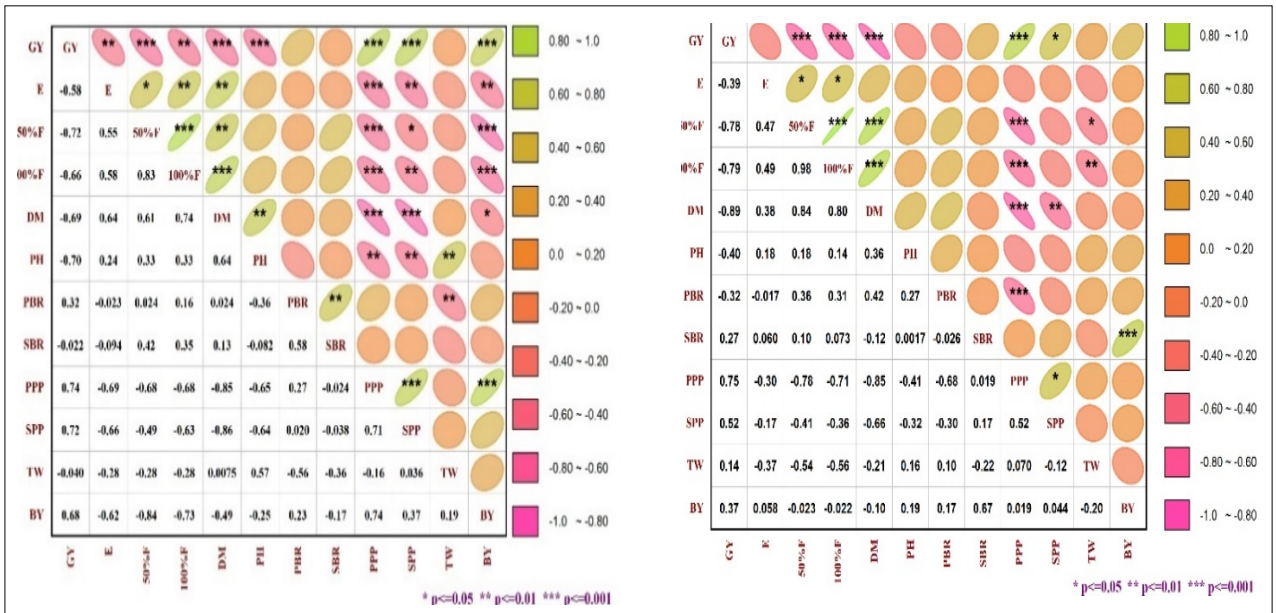


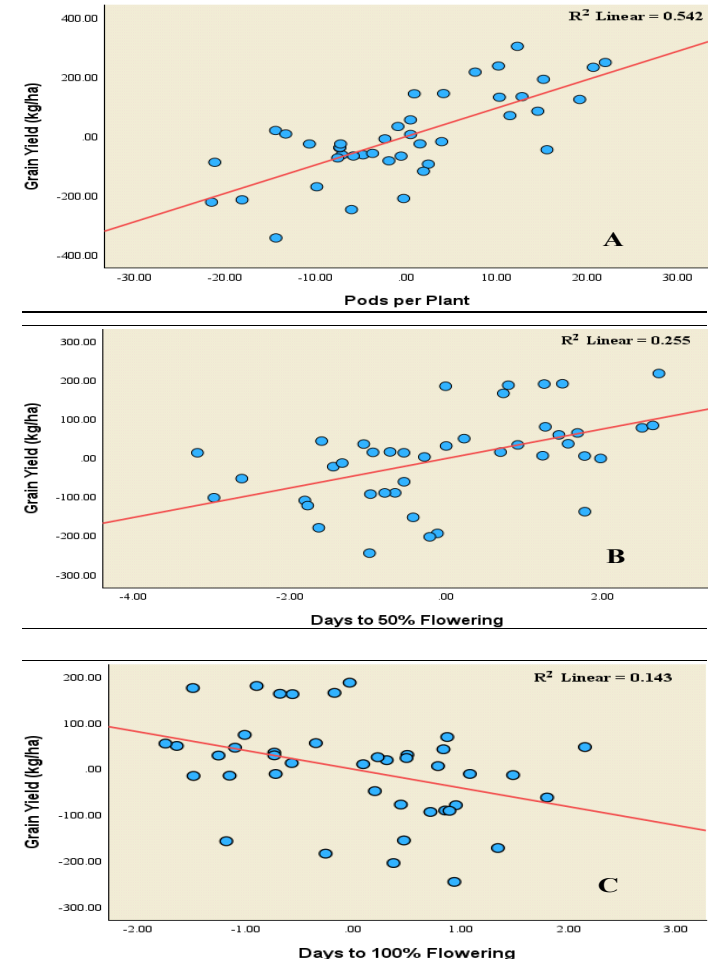
Fig 2: Interaction effect of sowing time and genotypes on grain yield of lentil cultivars.



A. Normal sowing B. Late sowing

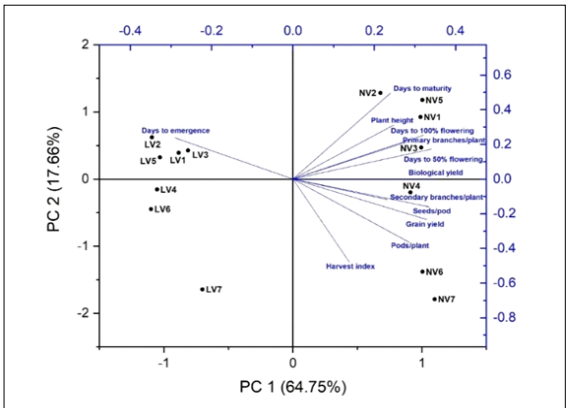
The correlations were measured from -1 to +1 from negative to positive correlation. Values with a significance level alpha represent * p= 0.05; ** p= 0.01; *** p= 0.001. The correlation coefficients were calculated using mean data of 2 years, having a total number of 3 samples. Grain yield (GY), Emergence (E), 50 % Flowering (50%F), 100 % Flowering (100%F), Days to maturity (DM), Plant height (PH), Primary branching (PBR), Secondary Branching (SBR), Pods per plant (PPP), Seeds per pods (SPP), Test weight (TW) and Biological yield (BY).

Fig 3: Pearson correlation matrix between studied phenological, yield attributes and yield traits under normal (A) and late sowing conditions (B).



It shows the residuals of the criterion (on the Y-axis) and the residuals of the predictor (on the X-axis) when both variables are regressed on the rest of the predictors. Each dot represents an observation and the solid line shows the linear regression fit.

Fig 4: Partial regression plot of (A) Pods per plants, (B) Days to 50% flowering and (C) Days to 100% flowering.



(N=Normal sowing, L=Late sowing, V1= Moitree, V2=HUL-57, V3=KLS-218, V4=BM-8, V5=IPL-220, V6=BM-7 and V7=L-4717).

Fig 5: Principal component Bi-plot from principal component analysis of the growth and yield parameters predictors of the grain yield of the test plots having each numbered dot represents treatment as NV1, NV2, NV3, NV4, NV5, NV6, NV7, LV1, LV2, LV3, LV4, LV5, LV6 and LV7 respectively.

condition, *i.e.*, BM-8, BM-7 and L-4717, among which L-4717 notably distanced from BM-8 and BM-7 in the bi-plot. Quadrant 4 includes three genotypes of normal-sown varieties (BM-8, BM-7 and L-4717), among which BM-8 stands apart from BM-7 and L-4717 in the bi-plot (Fig 5).

In addition to sowing time, grain yield under late-sown condition is mostly determined by genotype selection. Some of the genotypes consistently show early or delayed maturity, demonstrating the impact of both genetic and environmental influences on crop maturity. Moreover, the ability of various lentil genotypes to withstand heat stressors, such as shorter maturity periods or heat tolerance characteristics, varies. For instance, genotypes of lentil with shorter lifespans are better able to turn photosynthetic assimilations into yield (Choukri *et al.,* 2022). The PCA bi-plot demonstrated that late-planted varieties had negative PC1 scores, whereas normally-planted kinds fared better, as evidenced by positive PC1 scores. Both normal and late sowing conditions yielded better in case of genotype L-4717. Despite reaching the lowest height, it developed more secondary branches, which led to faster flowering, bushier and denser growth and higher grain output. On the other hand, genotype HUL-57 produced the fewest pods per plant and the lowest grain yield due to its delayed emergence, blooming.

CONCLUSION

The experiment's findings suggest that planting the L-4717 variety in the first half of November holds great promise for farmers in the Lower Indo-Gangetic plains of India and comparable agro-ecological regions to achieve increased crop yields. Choosing genotypes well-suited for late-sown conditions can improve the lentil crop's ability to tolerate heat and enhance productivity. If farmers fail to sow during the optimal sowing window, they can select a suitable variety to achieve a sound output comparable to the yield of normal-sown other varieties. In the face of changing climate conditions, the first two weeks of November are recommended as the ideal planting window, with L-4717 emerging as the top choice for maximizing grain production and maturation.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided but do not accept any liability for any direct or indirect losses resulting from using this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish or preparation of the manuscript.

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