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Satyabrata Majhi
M.Sc. Scholar, Discipline of Plant Physiology, Department of Agricultural Botany, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

RS Shaikh
Assistant Professor, Department of Agricultural Botany, College of Agriculture, Muktainagar, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

VR Awari
Assistant Professor, Department of Agricultural Botany, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar-Maharashtra, India

MR Patil
Professor and Head, Department of Agricultural Statistics, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahilyanagar, Maharashtra, India

NS Kute
Associate Professor, Department of Agricultural Botany, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Corresponding Author:
Satyabrata Majhi
M.Sc. Scholar, Discipline of Plant Physiology, Department of Agricultural Botany, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Assessing the impact of sowing date on the growth attributes and yield components of various chickpea cultivars

Satyabrata Majhi, RS Shaikh, VR Awari, MR Patil and NS Kute

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Abstract
Chickpea (*Cicer arietinum* L.), a vital protein source in India, faces significant yield threats from climate change-induced temperature rise and suboptimal agronomic practices. Terminal heat stress, often caused by delayed sowing, severely impacts growth and productivity. Identifying resilient cultivars and optimal sowing windows is crucial for sustaining yield. A field experiment was conducted during the *Rabi* season of 2024-2025 in a semi-arid region. Ten chickpea cultivars were evaluated across three sowing dates (S1: last week of October, S2: third week of November, S3: second week of December) using a split-plot design. Growth parameters (Leaf Area Index, total dry matter content, Crop Growth Rate) and yield attributes were recorded and analyzed. Sowing date significantly influenced all measured parameters. Early sowing (S1) resulted in superior growth, with the highest Leaf Area Index (2.074 at 90 DAS), total dry matter accumulation (24.20 g plant^{-1}), and grain yield (27.68 q ha^{-1}). Among cultivars, 'Viswaraj' and 'Phule Vikram' demonstrated consistently high performance. Critically, significant interactions between sowing date and cultivar were observed for grain yield and key yield components, where 'Viswaraj' under S1 achieved the highest yield (31.33 q ha^{-1}).

Keywords: Chickpea, sowing dates, terminal heat stress, growth and yield attributes, cultivar performance, split-plot design

Introduction
Chickpea (*Cicer arietinum* L.) is a critical cool-season legume and a vital source of dietary protein, particularly in vegetarian populations (Hulse, 1991) [11]. As the world's largest producer, India's pulse security is heavily reliant on chickpea, which accounts for approximately 40% of the nation's total pulse production (Anonymous, 2023). However, an alarming decline in per capita availability, from 69g in 1961 to 47g in 2023, underscores a major challenge in sustaining supply against a backdrop of rising population demands (Anonymous, 2022-23).
A primary threat to chickpea productivity is climate change-induced temperature rise. Projections indicate a global temperature increase of 1.6 to 3.8°C by 2100 (Anonymous. 2007), with even a 1°C rise during critical growth periods capable of causing massive yield reductions (Lobell & Field, 2007) [15]. Chickpea is highly vulnerable to heat stress, with yields anticipated to decline by 10-15% for every degree centigrade above the optimum temperature (Devasirvatham *et al.*, 2018) [7]. The physiological mechanisms behind this are well-documented, including impaired photosynthesis, loss of pollen viability, and increased ovule abortion, leading to poor seed set (Wahid *et al.*, 2007; Zinn *et al.*, 2010) [23, 24].
Compounding this climatic threat are agronomic constraints, particularly sowing time. In major producing states like Maharashtra, sowing is often delayed due to the late harvest of preceding crops like sugarcane and cotton, pushing the critical pod-filling stage into periods of sharply rising temperatures from mid-February onward. This terminal heat stress severely hinders the plant's ability to reach full maturity and maximize yield. Conversely, early sowing risks exposure to low temperatures (<10 °C), which can cause excessive floral abortion and losses of 15-25% (Ali & Kumar, 2005; Bakht *et al.*, 2006) [1, 5].
While sowing time is recognized as a vital agronomic practice (Sekhar *et al.*, 2015; Bazvand *et al.*, 2015) [20, 6], the optimal window varies by genotype and environment, and research

findings on its impact have given mixed results (Nanda & Saini, 1992; Dixit *et al.*, 2019) [16, 9]. Crucially, there remains a limited understanding of the physiological and biochemical mechanisms that enable certain cultivars to withstand these sowing date-induced stresses.

Materials and Methods

A field experiment was conducted during the Rabi season of 2024-2025 at the Instructional Farm of the Department of Agricultural Botany, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India, located in a semi-arid tropical (scarcity) zone. The soil of the experimental plot was medium black with uniform fertility and good drainage. The study was laid out in a Split Plot Design with three replications. Ten chickpea (*Cicer arietinum* L.) cultivars, namely Phule Vikram, Vishal, Viswaraj, Vikrant, Digvijay, Phule G-1302-3-5, Phule G-1403-18-14, Phule G-1511-17-11, Vijay and Phule G-1131-4, were assigned to sub-plots, while three sowing dates constituted the main plots: S1 (last week of October), S2 (third week of November), and S3 (second week of December). The gross and net plot sizes were 3.0 m × 2.1 m and 2.8 m × 1.5 m, respectively, with a spacing of 30 cm × 10 cm. Field preparation involved one deep ploughing followed by two harrowings to obtain a fine tilth. Farmyard manure was applied at 5 t ha^{-1} during land preparation, and a recommended fertilizer dose of 15 kg N, 40 kg P_2O_5, and 20 kg K_2O ha^{-1} was applied at sowing using urea, single super phosphate, and muriate of potash. Seeds were dibbled with two seeds per hill. The mean maximum and minimum temperatures during the crop season ranged from 26.9 °C to 37.1 °C and 8.0 °C to 31.1 °C, respectively. The data collected for all parameters were subjected to Analysis of Variance (ANOVA) for a split-plot design as outlined by Panse and Sukhatme (1985) [17]. Treatment significance was tested at the 5% probability level, and the Critical Difference (C.D.) was calculated for comparing significant means.

Results and Discussion

Growth Parameters

Leaf area index (LAI)

Based on the data, significant differences in Leaf Area Index (LAI) were observed for both sowing dates and cultivars, though their interaction was found to be non-significant. The earliest sowing date (S1) consistently yielded the highest LAI values at all four stages (0.413, 1.283, 2.074, and 1.312), which were significantly greater than those of S2 (0.374, 1.201, 1.925, 1.135) and the lowest-performing S3 (0.306, 1.080, 1.563, 1.005). Among the cultivars, Phule Vikram recorded the highest LAI at every stage, with values of 0.521 at 30 DAS, 1.278 at 60 DAS, 1.973 at 90 DAS, and 1.269 at maturity. Conversely, the lowest LAI values were generally observed in Phule G-1511-17-11 at 30 and 90 DAS (0.233 and 1.713), Vijay at 60 DAS (1.042) and Digvijay at maturity (1.052). This trend can be attributed to optimal temperature and photoperiod conditions during early sowing, promoting vigorous vegetative growth (Dutta *et al.*, 2018) [10].

Total Dry Matter content (g $plant^{-1}$)

The observed data indicated that the earliest sowing date (S1) resulted in a significantly higher total dry weight at all stages (0.68, 7.77, 16.98, and 24.20 g $plant^{-1}$ at 30, 60, 90 DAS, and maturity, respectively), which was superior to the intermediate S2 and the lowest-yielding S3 (0.46, 6.32, 14.12, and 20.24 g $plant^{-1}$). Among cultivars, Phule Vikram consistently recorded the highest or among the highest dry matter content, reaching 8.03 g $plant^{-1}$ at 60 DAS, 16.15 g $plant^{-1}$ at 90 DAS, and 23.28 g $plant^{-1}$ at maturity. The lowest values were generally observed in Phule G-1511-17-11 at 60 and 90 DAS (5.65 and 14.64 g $plant^{-1}$) and in Phule G-1403-18-14 at maturity (20.97 g $plant^{-1}$). The interaction between sowing dates and cultivars was found to be non-significant at all growth stages. The timing of sowing and temperature, particularly heat stress during the flowering stage, have a major impact on chickpea plant's capacity to develop and generate biomass. These results are in accordance with the findings of Kumar *et al.*, 2019 [14].

Crop growth rate (CGR)(g dm^{-2} day^{-1})

The data revealed that the earliest sowing date (S1) consistently yielded the highest crop growth rate (CGR) across all intervals (0.0082, 0.079, 0.102, and 0.084 g dm^{-2} day^{-1}), with S2 (0.0061, 0.072, 0.090, 0.079 g dm^{-2} day^{-1}) performing intermediately and S3 (0.0051, 0.065, 0.087, 0.073 g dm^{-2} day^{-1}) recording the lowest, a result of the longer, more favorable growing period from early sowing. Among cultivars, significant differences were found in the first three stages: Phule Vikram recorded the highest CGR at 0-30 DAS (0.0075 g dm^{-2} day^{-1}) and 30-60 DAS (0.084 g dm^{-2} day^{-1}), while Viswaraj was highest at 60-90 DAS (0.107 g dm^{-2} day^{-1}); Vijay consistently showed the lowest values in the 0-30 DAS and 30-60 DAS (0.0056 and 0.057 g dm^{-2} day^{-1}). No significant differences between cultivars were found from 90 DAS to maturity, and the interaction between sowing dates and cultivars was non-significant at all growth stages. Crop growth rate (CGR) varies among genotypes of chickpeas due to genetic diversity affecting important morphological and physiological characteristics. These characteristics impact a plant's growth and environmental response and are based on the distinct genetic composition of a genotype. Similar results have been observed by Kabir *et al.*, 2009 [12].

Yield and yield contributing traits

Plant height (cm)

The data revealed that sowing date had a significant effect on plant height, with the earliest sowing (S1) producing the tallest plants (49.99 cm) and the late sowing (S3) have shortest (42.33 cm). Among cultivars, Phule Vikram recorded the significantly highest plant height (52.60 cm), which was statistically on par with Vikrant (50.18 cm), while Vijay was the shortest (39.48 cm). The interaction between sowing dates and cultivars for plant height was significant**.** The combination of the optimal sowing date and cultivar, S1 (early sowing) with Phule Vikram (V1), yielded the absolute highest plant height (53.96 cm). Several other combinations, including S1V4 (53.67 cm), S1V3 (52.88 cm), S1V2 (52.70 cm), S2V1 (52.20 cm), S3V1 (51.64 cm), and S1V5 (50.50 cm), were statistically on par with Phule Vikram under S1. Conversely, the worst-performing combination was Vijay under the late S3 sowing, which resulted in the significantly lowest plant height (33.30 cm).The superior performance of Phule Vikram across all sowing dates, especially when sown early (S1), highlights its genetic potential for vigorous vegetative growth. The drastic reduction in height for the late-sown Vijay (S3) underscores the severe negative impact of terminal heat stress on susceptible cultivars, as supported by the findings of Devasirvatham *et al*., (2020) [8] and Saxena *et al*., (2019) [19].

Number of primary and secondary branches plant^{-1}

Based on the data, significant differences were observed in the number of primary and secondary branches per plant due to sowing dates and cultivars, though their interactions were non-significant. For primary branches, the earliest sowing date (S1) resulted in the highest number (3.56), followed by S2 (2.58), with the late sowing (S3) producing the fewest (1.90). Among cultivars, Viswaraj recorded the most primary branches (3.45), which was statistically on par with Phule Vikram (3.19) and Vikrant (3.02), while Phule G-1511-17-11 had the fewest (1.88). These findings highlight the role of genetics in determining branching potential, as noted by Satish *et al*., (2006) [25]. For secondary branches, a similar trend was observed. Sowing date S1 yielded the highest number (10.02), statistically at par with S2 (9.56), while S3 resulted in the lowest (8.57). Among cultivars, Viswaraj had the most secondary branches (11.01), which was statistically at par with Phule Vikram (10.33), whereas Phule G-1511-17-11 again had the fewest (8.08). As documented by Tomar *et al*., (1991) [22], this confirms that branching is influenced by both sowing time and genetic potential, directly impacting the plant's reproductive architecture and ultimate yield potential.

Number of pods plant^{-1}

There were significant interaction between cultivars and the dates of sowing for number of pods plant^{-1}. The data revealed the earliest sowing date (S1) yielded the significantly highest pod count (74.41 pods plant^{-1}), followed by S2 (67.99 pods plant^{-1}), while the late sowing (S3) resulted in the lowest pod number (60.01 pods plant^{-1}). This decline is attributed to terminal heat stress impairing reproductive development as noted by Devasirvatham *et al*., 2020 [8]. Among cultivars, Viswaraj produced the highest pod number (76.86 pods plant^{-1}), which was statistically on par with Phule Vikram (73.38 pods plant^{-1}). In contrast, Phule G-1511-17-11 recorded the lowest pod count (55.94 pods plant^{-1}), highlighting genetic differences in pod-setting ability and stress tolerance. The combination of the optimal sowing date and cultivar, S1 (early sowing) with Viswaraj (V3), produced the absolute highest number of pods (86.28 pods plant^{-1}). This was statistically at par with the combination S1V6 (80.17 pods plant^{-1}). Conversely, the worst-performing combination was Phule G-1511-17-11 under the late S3 sowing, which yielded the lowest pod count (50.25 pods plant^{-1}). This interaction underscores that maximizing pod output requires both an high-performing cultivar and an appropriate sowing window, a finding consistent with Dixit *et al*., (2019) [9].

Grain Yield (q ha^{-1})

The data revealed that the earliest sowing date (S1) produced the significantly highest grain yield (27.68 q ha^{-1}), outperforming S2 (24.78 q ha^{-1}) and the lowest-yielding S3 (17.53 q ha^{-1}), a reduction attributed to terminal heat stress during reproductive stages as documented by Kumar *et al*,. (2013) [13]. Among cultivars, Viswaraj yielded the highest (25.57 q ha^{-1}) which was statistically at par with Phule Vikram (24.42 q ha^{-1}), Digvijay (23.90 q ha^{-1}) and Phule G-1302-3-5(23.78 q ha^{-1}) while Phule G-1511-17-11 recorded the lowest (21.04 q ha^{-1}). A significant interaction between sowing dates and cultivars was found, indicating that the best yields are achieved by combining the optimal genotype with the correct sowing window. The absolute highest yield (31.33 q ha^{-1}) was achieved by growing Viswaraj under the early S1 sowing condition. This combination was followed by other S1 combinations: S1V6 (30.54 q ha^{-1}), S1V2 (28.84 q ha^{-1}), S1V5 (28.52 q ha^{-1}), and S1V1 (28.43 q ha^{-1}). Conversely, the lowest yield (15.98 q ha^{-1}) was recorded for Phule G-1131-4 under the late S3 sowing, highlighting the severe penalty of combining a susceptible cultivar with a stressful environment. Thudi *et al.* (2021) [21] emphasize the necessity of genotype-specific planting advice due to the noteworthy interplay between cultivars and Sowing dates. Same results were reported by Kumar *et al.* (2013) [13] who noted that early sowing ensures optimal use of resources, enhancing yield components and final productivity.

Table 1: Leaf area index as influenced by sowing dates, cultivars and their interaction in chickpea

Factors	30 DAS	60 DAS	90 DAS	At maturity
a. Sowing dates				
S1-Last week of October	0.413	1.283	2.074	1.312
S2- 3rd week of November	0.374	1.201	1.925	1.135
S3- 2nd week of December	0.306	1.080	1.563	1.005
SE (m) ±	0.008	0.017	0.033	0.034
CD at 5%	0.030	0.067	0.131	0.134
b. Cultivars				
V1-Phule Vikram	0.521	1.278	1.973	1.269
V2 -Vishal	0.301	1.238	1.877	1.251
V3-Viswaraj	0.390	1.173	1.958	1.174
V4-Vikrant	0.408	1.167	1.868	1.093
V5-Digvijay	0.478	1.255	1.838	1.052
V6-Phule G-1302-3-5	0.415	1.267	1.851	1.148
V7-Phule G-1403-18-14	0.328	1.097	1.762	1.120
V8-Phule G-1511-17-11	0.233	1.170	1.713	1.141
V9-Vijay	0.261	1.042	1.887	1.159
V10-Phule G-1131-4	0.309	1.195	1.812	1.100
SE (m) ±	0.012	0.023	0.051	0.045
CD at 5%	0.034	0.064	0.146	0.126
Interactions(sowing dates × cultivars)				
SE (m) ±	0.020	0.039	0.089	0.077
CD at 5%	NS	NS	NS	NS
General mean	0.364	1.188	1.854	1.151

Table 2: Total dry matter content (g plant^{-1}) as influenced by sowing dates, cultivars and their interaction in chickpea

Factors	30 DAS	60 DAS	90 DAS	At maturity
a. Sowing dates				
S1-Last week of October	0.68	7.77	16.98	24.20
S2- 3rd week of November	0.55	7.05	15.14	21.72
S3- 2nd week of December	0.46	6.32	14.12	20.24
SE (m) ±	0.01	0.07	0.12	0.34
CD at 5%	0.04	0.26	0.46	1.32
b. Cultivars				
V1-Phule Vikram	0.46	8.03	16.15	23.28
V2 -Vishal	0.53	7.95	15.73	21.73
V3-Viswaraj	0.63	7.87	15.84	21.24
V4-Vikrant	0.58	7.77	16.06	22.65
V5-Digvijay	0.59	6.35	14.95	22.54
V6-Phule G-1302-3-5	0.54	7.11	15.07	22.35
V7-Phule G-1403-18-14	0.68	6.96	15.13	20.97
V8-Phule G-1511-17-11	0.51	5.65	14.64	21.71
V9-Vijay	0.60	7.07	15.29	21.87
V10-Phule G-1131-4	0.51	5.68	15.28	22.17
SE (m) ±	0.02	0.20	0.34	0.41
CD at 5%	0.06	0.55	0.98	1.17
Interactions (sowing dates × cultivars)				
SE (m) ±	0.04	0.34	0.596	0.715
CD at 5%	NS	NS	NS	NS
General mean	0.56	7.04	15.41	22.05

Table 3: Crop growth rate (g dm^{-2} day^{-1}) as influenced by sowing dates, cultivars and their interaction in chickpea

Factors	0-30 DAS	30-60 DAS	60-90 DAS	90 DAS - maturity
a. Sowing dates				
S1-Last week of October	0.0082	0.079	0.102	0.084
S2- 3rd week of November	0.0061	0.072	0.090	0.079
S3- 2nd week of December	0.0051	0.065	0.087	0.073
SE (m) ±	0.0002	0.001	0.001	0.002
CD at 5%	0.0008	0.003	0.003	0.007
b. Cultivars				
V1-Phule Vikram	0.0075	0.084	0.090	0.084
V2 -Vishal	0.0070	0.082	0.096	0.078
V3-Viswaraj	0.0071	0.081	0.107	0.088
V4-Vikrant	0.0067	0.058	0.091	0.085
V5-Digvijay	0.0064	0.080	0.088	0.086
V6-Phule G-1302-3-5	0.0061	0.072	0.093	0.083
V7-Phule G-1403-18-14	0.0060	0.070	0.100	0.08
V8-Phule G-1511-17-11	0.0061	0.064	0.089	0.063
V9-Vijay	0.0056	0.057	0.091	0.07
V10-Phule G-1131-4	0.0062	0.072	0.086	0.07
SE (m) ±	0.0003	0.002	0.004	0.007
CD at 5%	0.0010	0.006	0.012	NS
Interactions(sowing dates × cultivars)				
SE (m) ±	0.00061	0.004	0.007	0.013
CD at 5%	NS	NS	NS	NS
General mean	0.0064	0.072	0.093	0.079

Table 4: Plant height (cm) and Number of pods plant^{-1} as influenced by sowing dates and their interaction in chickpea

Factors	Plant height (cm)	Number of pods plant^{-1}
a. Sowing dates		
S1- Last week of October	49.99	74.41
S2- 3rd week of November	45.10	67.99
S3- 2nd week of December	42.33	60.01
SE (m) ±	0.49	0.46
CD at 5%	1.91	1.79
b. Cultivars		
V1-Phule Vikram	52.60	73.38
V2 -Vishal	48.69	64.11
V3-Viswaraj	45.18	76.86
V4-Vikrant	50.18	67.94
V5-Digvijay	48.49	70.06
V6-Phule G-1302-3-5	44.72	69.94
V7-Phule G-1403-18-14	44.73	63.92
V8-Phule G-1511-17-11	43.13	55.94
V9-Vijay	39.48	69.32
V10-Phule G-1131-4	40.89	63.25
SE (m) ±	0.86	1.27
CD at 5%	2.44	3.59

Table 5: Plant height (cm) at maturity as influenced by interaction between sowing dates and cultivars

FACTORS	S1	S2	S3	Mean
V1-Phule Vikram	53.96	52.20	51.64	52.60
V2 -Vishal	52.70	47.98	45.40	48.69
V3-Viswaraj	52.88	44.93	37.73	45.18
V4-Vikrant	53.67	49.05	47.82	50.18
V5-Digvijay	50.50	48.89	46.10	48.49
V6-Phule G-1302-3-5	48.26	43.43	42.48	44.72
V7-Phule G-1403-18-14	48.45	43.85	41.88	44.73
V8-Phule G-1511-17-11	47.60	41.75	40.04	43.13
V9-Vijay	47.02	38.12	33.30	39.48
V10-Phule G-1131-4	44.89	40.84	36.93	40.89
Mean	49.99	45.10	42.33	45.81
Interactions(sowing dates × cultivars)				
SE (m) ±	CD at 5%	General mean		
1.49	4.22	45.81		

Table 6: Number of pods plant^{-1}at maturity as influenced by interaction between sowing dates and cultivars.

	S1	S2	S3	Mean
V1-Phule Vikram	75.78	69.56	74.81	73.38
V2 -Vishal	69.21	65.01	58.11	64.11
V3-Viswaraj	86.28	76.82	67.47	76.86
V4-Vikrant	72.47	70.01	61.34	67.94
V5-Digvijay	80.01	70.61	59.55	70.06
V6-Phule G-1302-3-5	80.17	70.54	59.09	69.94
V7-Phule G-1403-18-14	73.61	64.55	53.60	63.92
V8-Phule G-1511-17-11	60.69	56.87	50.25	55.94
V9-Vijay	77.15	68.61	62.19	69.32
V10-Phule G-1131-4	68.74	67.36	53.65	63.25
Mean	74.41	67.99	60.01	67.47
Interactions(sowing dates × cultivars)				
SE (m) ±	CD at 5%	General mean		
2.196	6.226	67.47		

Table 7: Number of primary branches plant^{-1} and Number of secondary branches plant^{-1} as influenced by sowing dates, cultivars and their interaction in chickpea

Factors	Number of primary branches plant^{-1}	Number of secondary branches plant^{-1}
a. Sowing dates		
S1- Last week of October	3.56	10.02
S2- 3rd week of November	2.58	9.56
S3- 2nd week of December	1.90	8.57
SE (m) ±	0.09	0.20
CD at 5%	0.37	0.79
b. Cultivars		
V1-Phule Vikram	3.19	10.33
V2 -Vishal	3.00	9.66
V3-Viswaraj	3.45	11.01
V4-Vikrant	3.02	9.21
V5-Digvijay	2.51	9.80
V6-Phule G-1302-3-5	2.72	9.03
V7-Phule G-1403-18-14	2.45	8.93
V8-Phule G-1511-17-11	1.88	8.08
V9-Vijay	2.37	9.23
V10-Phule G-1131-4	2.23	8.57
SE (m) ±	0.15	0.26
CD at 5%	0.43	0.73
Interactions(sowing dates × cultivars)		
SE (m) ±	0.265	0.446
CD at 5%	NS	NS
General mean	2.68	9.38

Table 8: Grain yield (q ha^{-1}) as influenced by sowing dates, cultivars and their interaction in chickpea

FACTORS	S1	S2	S3	Mean
V1-Phule Vikram	28.43	27.23	17.61	24.42
V2 -Vishal	28.84	24.84	16.43	23.37
V3-Viswaraj	31.33	26.97	18.42	25.57
V4-Vikrant	26.88	25.24	18.42	23.51
V5-Digvijay	28.52	25.89	17.27	23.90
V6-Phule G-1302-3-5	30.54	24.34	16.46	23.78
V7-Phule G-1403-18-14	27.79	22.28	17.88	22.65
V8-Phule G-1511-17-11	23.39	21.54	18.20	21.04
V9-Vijay	26.34	26.01	18.64	23.67
V10-Phule G-1131-4	26.52	23.42	15.98	21.98
Mean	27.86	24.78	17.53	23.39
Interactions(sowing dates × cultivars)				
SE (m) ±	CD at 5%	General mean		
1.135	3.217	23.39		

Table 9: Grain yield (q ha^{-1}) as influenced by interaction between sowing dates and cultivars

Factors	Grain yield (q ha^{-1})
S1- Last week of October	27.68
S2- 3rd week of November	24.78
S3- 2nd week of December	17.53
SE (m) ±	0.52
CD at 5%	2.02
V1-Phule Vikram	24.42
V2 -Vishal	23.37
V3-Viswaraj	25.57
V4-Vikrant	23.51
V5-Digvijay	23.90
V6-Phule G-1302-3-5	23.78
V7-Phule G-1403-18-14	22.65
V8-Phule G-1511-17-11	21.04
V9-Vijay	23.67
V10-Phule G-1131-4	21.98
SE (m) ±	0.66
CD at 5%	1.86

Conclusion

Based on the comprehensive analysis, it is conclusively established that sowing date is a paramount factor influencing chickpea growth and yield, with early sowing providing significantly superior outcomes compared to delayed sowing. The advantages of early sowing are manifested through enhanced physiological traits such as leaf area development, dry matter accumulation, and crop growth rate, which collectively contribute to robust vegetative growth and higher productivity. This is largely attributed to the avoidance of terminal heat stress, which severely constrains the performance of late-sown crops. Furthermore, significant genotypic variation exists among cultivars, with certain genotypes demonstrating exceptional vegetative vigor and others excelling in reproductive output and stress tolerance. Critically, the interaction between sowing date and cultivar is highly significant for key yield components, revealing that the highest yields are achieved by synergistically combining early sowing with high-yielding, stress-resilient cultivars. Therefore, the optimal strategy for maximizing chickpea productivity necessitates the integration of early sowing dates with carefully selected, high-performing cultivars suited to the local growing environment. This approach effectively mitigates the adverse effects of terminal stress and capitalizes on favorable seasonal conditions, as supported by established agronomic research.

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