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Evaluating the Impact of Sowing Time on Phenology and Yield Attributes in Chickpea (*Cicer arietinum* L.) Germplasm Accessions under Normal and Late Sown Conditions

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ABSTRACT

The study was conducted during the *rabi* seasons (November) of 2021–(April) 2022 and 2022 (November)–2023 (April) in Jabalpur, Madhya Pradesh, India aimed to explore chickpea germplasm responses to high temperature stress under varied sowing conditions. Thirty-two germplasm lines and eight elite varieties were sown under normal and late conditions to coincide with heat stress occurrence (>32°C). The investigation done on phenological data impacted by sowing dates, revealed significant differences between normal and late sowing conditions across critical growth stages. Temporal disparities resulted in an approximate 8-day reduction in days to 50% flowering (DFF), 7 days in days to pod formation (DPF), 9 days in days to seed formation (DSF), and 12 days in days to field maturity (DFM). Conversely, longer-duration genotypes experienced a reduction of around 6 days in DFF, DPF, DSF, and 14 days in DFM. Yield attributes among genotypes varied significantly between different sowing conditions. Under normal (D1) conditions, genotypes exhibited adequate seed yield (kg/ha^{-1}), while late-sown (D2) conditions resulted in considerable percentage decrements of 40.2% reduction in the yield. Post hoc Duncan's New Multiple Range Test (DNMRT) analysis indicated substantial variability among genotypes for all traits, except for primary and secondary branches, observed across both sowing conditions. The correlation analysis uncovered nuanced associations between phenological stages and yield attributes, emphasizing the complexity of chickpea cultivation dynamics. This study provides valuable insights into optimizing chickpea germplasm for high temperature stress resilience, contributing to the ongoing efforts for sustainable and climate-resilient agriculture.

KEYWORDS: Chickpea, germplasm, thermo-tolerance, phenology, yield, correlation

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1. INTRODUCTION

Chickpea (*Cicer arietinum* L.), the major *rabi* season legume crop which is cultivated worldwide mostly in arid and semi-arid regions, belongs to the family Fabaceae, Subfamily Faboideae. It is a self-pollinating diploid (2n=2x=16) pulse crop with 738 Mbp genome size (Varshney et al., 2013). Its origin remains from south eastern turkey (37.3–39.3°N, 38.2–43.6°E). Chickpea production is estimated to be 136.52 mt from 138.84 mha area with average productivity of 983 kg ha^{-1}. India tops the list of pulse crops followed by Australia, despite their cultivation spanning approximately 17.8 million hectares across 56 countries (Gaur et al., 2019). Over a 20 year period *i.e.*, from 2000-01 to 2018-19, in India the harvested area of chickpea has increased from 51.85 to 105.61 lakh hectares, with a corresponding increase of 38.55 to 112.29 lakh tones production and with the yield gains from 744 kg ha^{-1} to 1063 kg ha^{-1} productivity (Samriti et al., 2020). Chickpea production in India amounts to 13.98 mt, cultivated across an area of 11.20 mha, with a productivity of 1249 kg ha^{-1} notably, Madhya Pradesh holds the largest share, accounting for 34% of the country's total production, encompassing an area of 28 lakh hectares and yielding 36.16 lakh tones, resulting in a productivity rate of 1291 kg ha^{-1} (Anonymous, 2021–2022).

The grain yield of chickpea can be hindered by high temperatures (30–35°C) during the reproductive stage (Pipalia et al., 2022). Elevated temperatures, exceeding 30°C, influence the flower initiation and subsequently affect chickpea grain yield (Summerfield et al., 1984; Devasirvatham et al., 2013). The phenological responses (stages of plant development) are the primary response of plants to the elevated temperature. Each species exhibits specific cardinal temperatures which defines the boundaries of observable growth. Phenological development in plants is predominantly influenced by the environmental factors such as thermoperiod, photoperiod and available soil moisture. In order to, survive abiotic stresses crop plants employs various avoidance or tolerance strategies by altering their morpho-physiological traits (Pareek et al., 2019; Bhaskarla et al., 2020). One among such approach is early phenology, which helps the crop to escape late-season stresses. High temperatures particularly pose a considerable risk to legumes, causing substantial yield losses primarily due to poor pod formation and seed setting (kumar et al., 2012; Kadiyala et al., 2016).The consequence of which is a shorter seed filling time, leading to reduced crop duration and overall yield (Jumrani and Bhatia 2014; Rani et al., 2020). The phenological stages of the plant needs to be aligned with the proper duration of seed filling and pod setting for the optimum yield. Genes regulating the phenology and growth duration of chickpeas are extensively characterized and widely recognized. Apart from genetic understanding, employing management strategies such as navigating sowing schedules can help in studying vulnerability of the genotype to environmental stresses and its impact on yield. The, different sowing dates serves as a pragmatic approach in assessing the performance of crop to changing climatic conditions (Sharma et al., 2014). The quantitative information of temperature on phenological development and maturity duration is limited in chickpea. On the other hand, precise forecasting of crop phenology stands as a crucial necessity in developing crop simulation chickpea models. The research findings have demonstrated that the crop duration and flowering time are significantly influenced by genotype and temperature (Soltani et al., 2005). The impact of heat stress during reproductive phase results in reduced grain yield attributed to profligate loss of flowers, decreased pollen viability and reduced pod set and seed filling duration (Devasirvatham and Tan, 2018). The central dogma of this study involves in identifying the plant phenological responses to the increased temperature and its effects on the yield among various germplasm accessions under normal and late sown conditions. As the late sown conditions evinces the putative screening of thermo tolerant genotypes. Therefore, by keeping this aspect into consideration an experiment aiming towards the screening of chickpea germplasm with varying dates of sowing such as normal and late sown conditions.

2. MATERIALS AND METHODS

The field experiment was conducted over the period of 6 months of consecutive years (2021–22 and 2022–23) from December to April at the experimental farm of breeder seed production unit, Jabalpur, Madhya Pradesh. It is located at 22°49' and 20°80' North latitude and 78°21' and 80°58' East longitude, and at an altitude of 411.78 meters above mean sea level. The soil at the experimental farm consisted vertisols with the texture of clay loam and with neutral pH ranging from 7.2–8.0. The experimental design was randomized block design with 40 Chickpea genotypes (32 germplasm lines and 8 prominent genotypes) sown under normal (15–November) and late sown (15–December) conditions in three replications with gross plot size 1.80 m^2. The maximum temperature during the normal sowing of first season (2021–22) is 32.3°C and second season (2022–23) is 34.4°C while during the late sown conditions 34.4°C at first season (2021–22) and 38.1°C during second season (2022–23) (Figure 1). The plant phenological stages such as days to 50% flowering (days taken from sowing to 50% of the plants with one flower at any node), days to pod formation (days taken from sowing to 50% of the plants with 0.5 cm pod), days to seed formation (days taken from

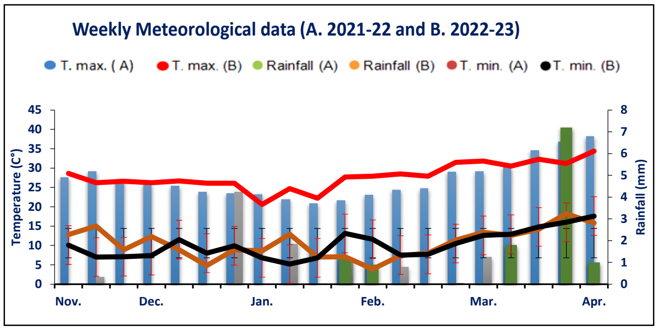

Figure 1: Weekly weather variations during the crop growth season of two consecutive years

sowing to 50% of plants consisting of pods with initiated seed development), days to physiological maturity (days taken from sowing to the occurrence of 75% yellowing of the leaves, and the pods ripened with maximum seed dry weight). The yield and yield attributes such as plant height (PH), Total no. of pods plant^{-1} (TNPP), Seed index (SI) and seed yield (SY) were noted under field conditions. The significance of genotype performances was assessed through analysis of variance (ANOVA) and post hoc mean separation at 5% probability level was carried out using using statistical package (agricole) and the Duncan's multiple range test in R, respectively.

3. RESULTS AND DISCUSSION

3.1. Effect of sowing date on phenological observations

The phenological data collected across two seasons underwent rigorous statistical analysis following prescribed methodologies. Within this investigation, different sowing dates significantly influenced the genotypes, notably impacting the days to 50% flowering (DFF), days to pod formation (DPF), days to seed formation (DSF), and days to physiological maturity (DPM) and days to field maturity (DFM). A temporal difference of 8 days was observed in reaching DFF between D1 (normal sowing) and D2 (late sowing), with 57.162 and 48.648 days, respectively. Under the pooled D1 conditions, G31 demonstrated a minimal DFF of 45.86 days, contrasting with a reduced duration of 37.69 days under pooled D2 conditions. Conversely, G32 displayed an extended DFF, with 63.706 days under D1 and 57.611 days under D2 conditions. This delineates a distinct response among genotypes for days to 50% flowering to varying sowing conditions.Similarly, in days to pod formation (DPF) analysis, G31 showcased a noticeable trend between D1 (normal sowing) and D2 (late sowing) with recorded durations of 59.355 days and 51.485 days, respectively. Contrastingly, G25 taken 76.37 days under D1 to 69.74 days under D2 conditions for days to pod formation.

In the assessment of days to seed formation, under D1 conditions, G4 displayed the shortest duration of 76.13 days, highlighting its capability for swift seed development. Conversely, G25 exhibited an extended period of 94.73 days, indicating a comparatively longer duration for seed formation under the same planting schedule. Under D2, G4 again demonstrated its efficiency with a minimized duration of 67.126 days, whereas G25 showed an increased time span of 88.68 days, signaling a slower seed formation rate compared to G4 under late sown conditions. For the days to physiological maturity, under D1 conditions, G1 exhibited the shortest period of 91.67 days while, G32 required a maximum of 108.72 days to reach physiological maturity, indicating their respective early and delayed maturation tendencies. Under D2, G1 showcased an early maturation period, reducing to 87.91 days, while G36 required an extended period of 102.55 days for physiological maturity, emphasizing its comparatively delayed maturation under late sowing conditions. In examining the days to field maturity, G1 illustrated the shortest duration of 103.86 days under D1, while G36 required the most prolonged period of 121.78 days for field maturity in the same conditions. Shifting to D2, G1 displayed a reduced duration of 91.65 days for field maturity, whereas G36 still required an extended period of 107.43 days, emphasizing its comparatively delayed field maturity under late sowing conditions. The study observed a noteworthy reduction in the durations of key growth stages among the shortest-duration genotypes. Specifically, there was a reduction of 8 days in days to 50% flowering (DFF), 7 days in days to pod formation (DPF), 9 days to seed formation (DSF), and 12 days in days to field maturity (DFM). On the contrary, longest genotypes exhibited 6 days in DFF, DPF, DSF, and 14 days in days to physiological maturity. These findings underscore the varied responses among genotypes in terms of the duration of critical growth stages, highlighting the varying photoperiod sensitivity of different genotypes under different sowing conditions. Richards et al., 2020 reported the effect of delayed sowing on shortened vegetative and podding stages.

3.2. Effect of sowing date on yield and its attributes

Significant variations were observed in yield and its associated attributes among genotypes subjected to both normal (D1) and late-sown (D2) conditions. To assess the sensitivity of genotypes to heat stress, certain parameters including plant height (PH), primary and secondary branches (PB and SB), total number of pods plant^{-1} (TNPP), seed index (SI), and seed yield (SY) (kg ha^{-1}) were examined. During D1 conditions, diverse responses among genotypes were noted. Specifically, G28 displayed the tallest plant height (62.83 cm), while G13 exhibited the maximum number of primary branches (5). Notably, G27 stood out with the highest pods per plant, benefiting from a double-podded trait and an abundance of secondary branches (Table 1 and 2). In

Table 1: Combined analysis of phenological, yield and yield attributes of chickpea germplasm under normal sown conditions

Germplasm	DF	DPF	DSF	DPM	DFM	PH	PB	SB	NPP	SI	SY
G1: IC 83686	48.48^{de}	61.51^{def}	76.82^{ef}	91.67^{d}	103.86^{d}	42.75^{d-h}	3.52^{a}	13.22^{ab}	51.75^{r}	15.25^{bc}	652.80^{g}
G2: IC 95100	59.82^{a-d}	70.18^{a-f}	85.78^{a-f}	98.60^{a-d}	114.91^{a-d}	39.41^{h}	2.99^{a}	13.22^{ab}	81.50^{q}	15.50^{bc}	1045.00^{z}
G3: IC 83958	52.87^{a-e}	62.08^{b-f}	78.44^{def}	95.83^{bcd}	109.48^{a-d}	39.58^{gh}	3.41^{a}	12.47^{ab}	82.00^{q}	16.75^{bc}	870.83^{c}
G4: IC 27238	50.37^{b-e}	60.73^{def}	76.13^{f}	97.20^{a-d}	112.87^{a-d}	43.08^{d-h}	3.66^{a}	14.22^{ab}	87.00^{pq}	21.25^{abc}	1060.83^{y}
G5: IC 83346	58.40^{a-e}	68.01^{a-f}	83.29^{a-f}	97.26^{a-d}	110.75^{a-d}	46.08^{c-h}	3.63^{a}	12.91^{ab}	108.00^{mno}	18.50^{bc}	1324.45st
G6: IC83720	62.12^{ab}	71.40^{a-f}	78.80^{def}	97.33^{a-d}	114.73^{a-d}	39.08^{h}	3.45^{a}	11.22^{ab}	122.75^{kl}	17.00^{bc}	918.33^{b}
G7: IC 487371	61.12^{a-d}	70.14^{a-f}	85.01^{a-f}	101.03^{a-d}	115.36^{a-d}	41.25^{e-h}	3.00^{a}	9.14^{ab}	102.75^{o}	16.25^{bc}	1203.33^{w}
G8: IC 83374	56.07^{a-e}	65.74 $^{a-f}$	82.17^{a-f}	96.41^{a-d}	110.14^{a-d}	53.27^{a-f}	3.49^{a}	12.25^{ab}	63.00^{r}	15.50^{bc}	918.33^{b}
G9: IC 83383	61.59^{abc}	72.89^{a-e}	87.14^{a-f}	102.17^{a-d}	115.52^{a-d}	42.08^{d-h}	3.41^{a}	12.36^{ab}	149.00^{j}	18.00^{bc}	981.66^{a}
G10: IC 486759	56.37^{a-e}	66.29^{a-f}	83.59^{a-f}	97.65^{a-d}	108.56^{bcd}	40.76^{fgh}	3.58^{a}	12.53^{ab}	106.75^{no}	17.75^{bc}	1330.00^{s}
G11: IC326761	61.15^{a-d}	75.00^{ab}	90.09^{a-d}	100.31^{a-d}	112.72^{a-d}	41.50^{d-h}	2.55^{a}	7.750^{b}	119.75^{lm}	16.75^{bc}	1043.89^{z}
G12: IC83448	61.52^{a-d}	73.62^{a-d}	87.79^{a-f}	98.53^{a-d}	115.38^{a-d}	46.05^{c-h}	3.46^{a}	13.72^{ab}	126.75^{kl}	16.75^{bc}	1282.50^{v}
G13: IC 83767	57.35^{a-e}	61.93^{c-f}	88.12^{a-f}	103.95^{a-d}	117.03^{abc}	60.16^{ab}	5.16^{a}	20.01^{ab}	244.25^{b}	23.25^{abc}	3024.16^{c}
G14: IC 83474	61.47^{a-d}	70.07^{a-f}	80.83^{c-f}	99.99^{a-d}	112.99^{a-d}	48.08^{b-h}	4.23^{a}	14.94^{ab}	165.75^{fg}	16.75^{bc}	1678.33^{o}
G15: IC 83448	55.00^{a-e}	65.68^{a-f}	83.55 $^{a-f}$	99.33^{a-d}	110.29^{a-d}	46.75^{c-h}	2.83^{a}	7.64^{b}	150.00^{ij}	15.00^{bc}	823.33^{e}
G16: IC 83537	57.59^{a-e}	67.38^{a-f}	80.98^{b-f}	97.79^{a-d}	112.78^{a-d}	44.50^{c-h}	3.02^{a}	9.42^{ab}	162.00^{fghi}	15.25^{bc}	855.00^{d}
G17: IC 83653	62.47^{ab}	71.27^{a-f}	85.76^{a-f}	103.67^{a-d}	116.54^{a-d}	44.33^{c-h}	3.47^{a}	11.54^{ab}	121.75^{l}	17.00^{bc}	1393.33^{r}
G18: IC 83677	63.19^{ab}	68.93^{a-f}	82.91^{a-f}	103.91^{a-d}	113.90^{a-d}	42.16^{d-h}	3.47^{a}	9.29^{ab}	117.00^{lmn}	10.75^{c}	1187.50^{x}
G19: IC 83843	62.04^{abc}	72.01^{a-f}	92.47^{abc}	104.89^{abc}	118.14^{abc}	46.66^{c-h}	3.05^{a}	8.82^{ab}	106.25^{no}	15.25^{bc}	1203.33^{w}
G20: IC 83892	53.50^{a-e}	66.23^{a-f}	88.19^{a-f}	100.92^{a-d}	115.69^{a-d}	44.50^{c-h}	2.66^{a}	7.17^{b}	96.50^{op}	16.25^{bc}	1330.00^{s}
G21: IC 84011	55.53^{a-e}	63.70^{a-f}	89.33^{a-e}	96.16^{a-d}	110.24^{a-d}	48.45^{b-h}	3.30^{a}	12.55^{ab}	108.75^{mno}	16.75^{bc}	1298.33^{u}
G22: IC 3171	51.93^{a-e}	62.07^{b-f}	82.32^{a-f}	95.90^{a-d}	115.13^{a-d}	41.66^{d-h}	3.52^{a}	10.72^{ab}	88.50^{pq}	19.25^{bc}	1314.16^{t}

Table 1: Continue...

Germ-plasm	DF	DPF	DSF	DPM	DFM	PH	PB	SB	NPP	SI	SY
G23: IC 83449	49.04^{de}	67.25^{a-f}	80.68^{c-f}	103.16^{a-d}	116.60^{a-d}	40.94^{fgh}	3.77^{a}	11.85^{ab}	86.25^{pq}	16.00^{bc}	791.66^{f}
G24: IC 83983	56.85^{a-e}	67.76^{a-f}	86.96^{a-f}	96.54^{a-d}	111.57^{a-d}	40.96^{fgh}	2.99^{a}	8.94^{ab}	96.00^{op}	18.25^{bc}	791.66^{f}
G25: IC 83811	63.56^{a}	76.37^{a}	93.91^{ab}	106.25^{abc}	121.41^{ab}	51.24^{a-h}	3.77^{a}	11.52^{ab}	152.75^{hij}	18.00^{bc}	2090.00^{k}
G26: IC 84049	53.48 $^{a-e}$	65.37^{a-f}	88.72^{a-f}	99.36^{a-d}	110.48^{a-d}	62.83^{a}	5.38^{a}	21.33^{a}	229.25^{c}	34.00^{a}	2881.66^{d}
G27: P 554	58.21^{a-e}	66.67^{a-f}	89.46^{a-e}	102.45^{a-d}	118.22^{abc}	54.47^{a-d}	5.10^{a}	21.31^{a}	286.00^{a}	23.00^{abc}	3420.00^{b}
G28: ICC 7855	55.81^{a-e}	62.68^{b-f}	83.15^{a-f}	94.33^{cd}	108.05^{cd}	50.50^{a-h}	5.85^{a}	20.92^{a}	203.25^{e}	19.00^{bc}	3594.16^{a}
G29: P 558	62.20^{ab}	66.81^{a-f}	81.95^{a-f}	103.68^{a-d}	109.61^{a-d}	53.52^{a-f}	3.13^{a}	7.57^{b}	134.50^{k}	21.00^{abc}	2042.50^{l}
G30: P 556	62.02^{abc}	72.52^{a-e}	93.56^{abc}	106.44^{abc}	121.46^{a}	52.66^{a-g}	3.05^{a}	10.30^{ab}	169.25^{fg}	22.25^{abc}	1440.83^{q}
G31: IC 251855	45.86^{e}	59.35^{f}	78.32^{def}	102.58^{a-d}	112.15^{a-d}	43.55^{d-h}	3.41^{a}	10.66^{ab}	163.75^{fgh}	18.25^{bc}	1725.83^{n}
G32: ICC 4425	62.33^{ab}	74.72 ^{abc}	94.73^{a}	108.72^{a}	120.51^{abc}	45.91^{c-h}	2.94^{a}	11.20^{ab}	158.00^{ghij}	20.00^{bc}	2010.83^{m}
G33: IC 83985	58.00^{a-e}	66.82^{a-f}	85.63^{a-f}	100.80^{a-d}	117.91^{abc}	60.41^{ab}	4.85^{a}	16.93^{ab}	244.25^{b}	25.75^{ab}	2739.16^{e}
G34: JG 14	51.77^{a-e}	60.19^{ef}	82.41^{a-f}	98.57^{a-d}	113.45^{a-d}	50.33^{a-h}	3.85^{a}	13.26^{ab}	197.00^{e}	21.25^{abc}	2349.66^{h}
G35: JG 36	52.81^{a-e}	63.26^{b-f}	83.43^{a-f}	103.49^{a-d}	118.86^{abc}	52.60^{a-g}	3.91^{a}	13.79^{ab}	201.50^{e}	26.75^{ab}	1504.32^{p}
G36: JG 24	58.84^{a-e}	71.09^{a-f}	90.67^{a-d}	107.42^{ab}	121.78^{a}	48.99^{b-h}	3.61^{a}	14.89^{ab}	193.00^{e}	22.25^{abc}	2633.71^{f}
G37: JG12	53.62^{a-e}	66.73^{a-f}	84.95^{a-f}	99.19^{a-d}	116.31^{a-d}	52.88^{a-f}	4.08^{a}	14.49^{ab}	201.25^{e}	23.25^{abc}	2121.66^{j}
G38: JAKI 9812	59.13^{a-d}	68.38^{a-f}	87.64^{a-f}	104.67^{abc}	116.11^{a-d}	53.70^{a-f}	3.80^{a}	14.05^{ab}	217.00^{d}	21.75^{abc}	2533.33^{g}
G39: JG 315	55.17^{a-e}	63.92^{a-f}	82.38^{a-f}	100.03^{a-d}	110.68^{a-d}	56.97^{abc}	3.83^{a}	15.28^{ab}	172.50^{f}	23.00^{abc}	2042.50^{l}
G40: JG 11	56.00^{a-e}	64.10^{a-f}	84.75^{a-f}	106.39^{abc}	115.93^{a-d}	54.08^{a-e}	4.11^{a}	14.29^{ab}	190.25^{e}	23.00^{abc}	2169.16^{i}
SEm±	0.68	0.880	1.390	0.758	0.768	1.280774	0.18	0.67	13.730	0.646	105.284
CD	1.957	2.520	3.974	2.169	2.197	3.663	0.516	1.908	39.288	1.848	301.121

DF: Days to 50% flowering; DPF: Days to pod formation; DSF: Days to seed formation; DPM: Days to Physiological maturity; DFM: Days to field maturity; PH: Plant height (cm); PB: Primary branches; SB: Secondary branches; NPP: No. of pods plant^{-1}; SI: Seed index (g); SY: Seed yield (kg ha^{-1})

contrast, under D2 conditions, G28 maintained its stature with a plant height of 60.73 cm, while G33 showcased the highest number of pods plant^{-1}. Distinct responses to varying sowing conditions were evident among the five genotypes displaying maximum seed index. Under D1 conditions, G26, G33, G13, G27, and G28 showcased seed indices of 34, 25.75, 23.25, 23, and 19, respectively. Conversely, during D2 conditions, these genotypes demonstrated altered

Table 2: Combined analysis of phenological, yield and yield attributes of chickpea germplasm under late sown conditions

Germ-plasm	DF	DPF	DSF	DPM	DFM	PH	PB	SB	NPP	SI	SY
G1: IC 83686	38.03^{f}	52.19^{ef}	67.12^{f}	87.91^{c}	91.65^{b}	37.93^{g}	2.95^{a}	10.23^{a}	37.50^{t}	15.50^{c}	450.61^{c}
G2: IC 95100	51.90^{a-e}	63.08^{a-f}	76.18^{a-f}	88.24^{bc}	101.99^{ab}	42.73^{d-g}	2.59^{a}	9.53^{a}	61.50^{n-r}	15.25^{c}	241.45^{d}
G3: IC 83958	42.04^{c-f}	53.23^{def}	72.95^{def}	90.67^{abc}	96.92^{ab}	40.62^{d-g}	2.95^{a}	9.92^{a}	63.25^{n-q}	15.25^{c}	789.45^{v}
G4: IC 27238	39.64^{def}	57.90^{a-f}	78.78^{a-f}	92.63^{abc}	100.07^{ab}	44.40^{d-g}	2.58^{a}	11.94^{a}	71.25^{mno}	17.25^{bc}	594.70^{z}
G5: IC 83346	49.37^{a-f}	60.30^{a-f}	78.68^{a-f}	91.68^{abc}	99.12^{ab}	44.40^{d-g}	2.80^{a}	10.18^{a}	74.50^{k-n}	17.75^{bc}	962.19^{r}
G6: IC83720	52.87^{abc}	65.30^{a-d}	73.97^{def}	93.06^{abc}	99.51^{ab}	40.89^{d-g}	3.12^{a}	10.62^{a}	76.75^{klm}	14.25^{c}	452.35^{c}
G7: IC 487371	52.63^{a-d}	65.19^{a-e}	81.14^{a-e}	98.44^{abc}	101.69^{ab}	41.48^{d-g}	2.70^{a}	5.92^{a}	74.00^{lmn}	16.00^{c}	840.59^{u}
G8: IC 83374	47.66^{a-f}	60.44^{a-f}	77.04^{a-f}	91.93^{abc}	99.23^{ab}	45.10^{b-g}	2.62^{a}	10.14^{a}	52.00^{qrs}	14.50^{c}	585.51^{z}
G9: IC 83383	50.75^{a-f}	67.21^{abc}	84.65^{a-d}	95.65^{abc}	102.23^{ab}	38.77^{fg}	2.45^{a}	11.11^{a}	97.00^{hij}	17.00^{c}	476.10^{b}
G10: IC 486759	43.78^{b-f}	62.16^{a-f}	78.38^{a-f}	93.41^{abc}	94.98^{ab}	44.17^{d-g}	3.08^{a}	9.95^{a}	87.50^{jk}	15.25^{c}	644.73^{y}
G11: IC326761	52.55^{a-d}	69.20^{ab}	81.85^{a-e}	95.99^{abc}	99.00^{ab}	44.70^{c-g}	2.21^{a}	8.43^{a}	70.25^{mno}	15.00^{c}	744.16^{w}
G12: IC83448	50.09^{a-f}	62.65^{a-f}	77.15^{a-f}	94.90^{abc}	103.73^{ab}	49.32^{a-g}	2.70^{a}	10.30^{a}	79.00^{klm}	15.00^{c}	522.50^{a}
G13: IC 83767	50.86^{a-f}	57.95^{a-f}	81.37^{a-e}	98.16^{abc}	104.32^{ab}	58.14^{ab}	4.94^{a}	13.33^{a}	148.75^{b}	22.75^{abc}	2032.20^{b}
G14: IC 83474	49.03^{a-f}	59.33^{a-f}	76.35^{a-f}	94.66^{abc}	98.30^{ab}	48.19^{a-g}	3.24^{a}	13.28^{a}	101.50^{ghi}	16.00^{c}	1250.83^{l}
G15: IC 83448	44.73^{a-f}	56.94^{a-f}	78.53^{a-f}	94.51^{abc}	102.52^{ab}	43.57^{d-g}	2.45^{a}	7.32^{a}	103.00^{f-i}	13.50^{c}	733.87^{w}
G16: IC 83537	49.76^{a-f}	57.86^{a-f}	74.63^{c-f}	94.13^{abc}	99.42^{ab}	42.90^{d-g}	2.62^{a}	7.47^{a}	95.25^{ij}	16.25^{c}	703.79^{x}
G17: IC 83653	52.26^{a-e}	64.10^{a-f}	78.49^{a-f}	99.13^{abc}	104.39^{ab}	43.35^{d-g}	3.05^{a}	10.91^{a}	42.25st	15.50^{c}	1203.33^{n}
G18: IC 83677	52.95^{abc}	65.66^{a-d}	78.77^{a-f}	99.50^{abc}	100.381^{ab}	42.21^{d-g}	2.83^{a}	8.20^{a}	54.50^{p-s}	11.75^{c}	584.88^{z}
G19: IC 83843	52.47^{a-e}	62.77^{a-f}	83.88^{a-d}	102.06^{a}	104.26^{ab}	44.90^{b-g}	2.79^{a}	9.66^{a}	74.50^{k-n}	13.75^{c}	1013.01^{q}
G20: IC 83892	48.57^{a-f}	58.19^{a-f}	84.66^{a-d}	94.51^{abc}	101.76^{ab}	44.70^{c-g}	2.66^{a}	7.50^{a}	61.50^{n-r}	16.75^{c}	1107.70^{o}
G21: IC 84011	46.32^{a-f}	54.36^{c-f}	77.57^{a-f}	92.34^{abc}	99.18^{ab}	46.93^{b-g}	2.54^{a}	9.95^{a}	49.00^{rst}	13.75^{c}	712.65^{x}
G22: IC 3171	38.71^{f}	51.64^{f}	73.05^{def}	91.98^{abc}	101.36^{ab}	42.78^{d-g}	3.28^{a}	10.53^{a}	48.75^{rst}	16.75^{c}	1095.35^{p}

Table 2: Continue...

Germ-plasm	DF	DPF	DSF	DPM	DFM	PH	PB	SB	NPP	SI	SY
G23: IC 83449	50.51^{a-f}	58.04^{a-f}	70.82^{ef}	97.94^{abc}	104.21^{ab}	40.36^{d-g}	3.50^{a}	10.14^{a}	58.00^{o-r}	13.75^{c}	532.79^{a}
G24: IC 83983	49.966^{a-f}	59.070^{a-f}	81.41 $^{a-e}$	92.79^{abc}	100.645^{ab}	39.72^{efg}	2.75^{a}	9.70^{a}	85.75^{jkl}	16.25^{c}	836.47^{u}
G25: IC 83811	52.833^{a-d}	69.740^{a}	88.68 ^{a}	100.92^{ab}	107.271^{a}	43.90^{d-g}	3.33^{a}	9.61^{a}	92.00^{ij}	17.50^{bc}	1647.61^{i}
G26: IC 84049	45.953^{a-f}	56.071^{c-f}	78.38^{a-f}	94.21^{abc}	99.78^{ab}	60.73 ^{a}	4.41^{a}	17.58^{a}	130.50^{c}	32.25^{a}	2019.85^{c}
G27: P 554	47.028^{a-f}	58.495^{a-f}	78.33^{a-f}	100.01^{abc}	102.87^{ab}	53.30^{a-d}	4.25^{a}	17.96^{a}	121.50^{cde}	20.75^{abc}	1992.30^{d}
G28: ICC 7855	41.745^{c-f}	53.455^{def}	74.12^{c-f}	91.02^{abc}	95.72^{ab}	47.15^{b-g}	4.74^{a}	16.23^{a}	110.25^{efg}	21.00^{abc}	2153.96^{a}
G29: P 558	52.425^{a-e}	55.991^{c-f}	71.77^{def}	100.39^{abc}	98.38^{ab}	51.75^{a-f}	2.87^{a}	7.30^{a}	67.50^{m-p}	18.00^{bc}	1760.66^{f}
G30: P 556	56.205^{ab}	65.051^{a-e}	87.03^{a-c}	100.72^{abc}	106.30^{a}	49.98^{a-g}	3.12^{a}	9.50^{a}	79.25^{klm}	18.25^{bc}	908.67^{t}
G31: IC 251855	39.470^{ef}	51.485^{f}	71.99^{def}	97.97^{abc}	99.09 ^{ab}	44.12^{d-g}	3.29^{a}	9.69^{a}	62.75^{n-q}	18.50^{bc}	927.99^{s}
G32: ICC 4425	57.611^{a}	69.661^{a}	88.56^{ab}	102.47^{a}	107.15^{a}	44.58^{c-g}	2.83^{a}	7.75^{a}	67.75^{mno}	15.75^{c}	1751.16^{f}
G33: IC 83985	48.890^{a-f}	58.138^{a-f}	83.96^{a-d}	96.84^{abc}	104.95^{a}	57.77^{abc}	3.83^{a}	15.65^{a}	168.25^{a}	30.50^{ab}	2036.00^{b}
G34: JG 14	41.948^{c-f}	54.466^{c-f}	75.58^{b-f}	94.82^{abc}	99.66 ^{ab}	50.59^{a-g}	3.53^{a}	11.38^{a}	127.25^{cd}	17.50^{bc}	1349.79^{k}
G35: JG 36	47.063^{a-f}	56.228^{b-f}	77.53^{a-f}	97.73^{abc}	104.12^{ab}	48.40^{a-g}	3.37^{a}	11.15^{a}	114.75^{def}	24.00^{abc}	1224.23^{m}
G36: JG 24	54.570^{abc}	65.938^{a-d}	83.05^{a-e}	102.55^{a}	107.43^{a}	45.49^{b-g}	3.41^{a}	11.49^{a}	108.75^{e-h}	20.25^{abc}	1798.98^{e}
G37: JG12	49.080^{a-f}	61.860^{a-f}	81.48^{a-e}	95.60^{abc}	96.48^{ab}	51.56^{a-f}	3.73^{a}	12.46^{a}	115.25^{def}	22.25^{abc}	1472.34 ^{j}
G38: JAKI 9812	53.818^{abc}	62.408^{a-f}	83.45^{a-e}	98.75^{abc}	101.30 ^{ab}	52.12^{a-e}	3.59^{a}	12.51^{a}	112.00^{efg}	19.75^{abc}	1692.10^{g}
G39: JG 315	49.950^{a-f}	57.766^{a-f}	77.79^{a-f}	95.44 ^{abc}	101.55^{ab}	53.23^{a-d}	3.62^{a}	12.81^{a}	117.00^{de}	21.00^{abc}	1471.70^{j}
G40: JG 11	49.788^{a-f}	56.740^{a-f}	77.34^{a-f}	95.65^{abc}	100.26^{ab}	52.86^{a-d}	3.88^{a}	12.06^{a}	126.25^{cd}	20.00^{abc}	1666.61^{h}
SEm±	1.05	0.380	0.357	0.536	0.405	1.825	0.177	0.602	5.832	0.495	78.687
CD	3.008	1.081	1.023	1.535	1.159	5.218	0.507	1.722	16.682	1.417	225.052

DF: Days to 50% flowering; DPF: Days to pod formation; DSF: Days to seed formation; DPM: Days to Physiological maturity; DFM: Days to field maturity; PH: Plant height (cm); PB: Primary branches; SB: Secondary branches; NPP: No. of pods plant^{-1}; SI: Seed index (g); SY: Seed yield (kg ha^{-1})

indices, registering values of 32.25, 30.5, 22.75, 20.75, and 21, respectively. These observed variations highlight the diverse reactions of these genotypes to differing sowing timings, emphasizing the genotype-specific adaptability and sensitivity to environmental changes. These differences signify decrements in seed index values for each genotype transitioning from D1 to D2 conditions, indicating their sensitivity to altered sowing timings. Specifically, G26 experienced a decrease of 1.75%, G33 by 4.25%, G13 by 0.5%, G27 by 2.25%, and G28 by 2%. Among the 40 genotypes, five demonstrated maximum seed yield (kg ha^{-1}) under D1 conditions: G28 (3594), G27 (3420), G13 (3024), G26 (2881), and G33 (2739) (kg ha^{-1}). Conversely, under D2 conditions, these same genotypes maintained relatively higher yields, recording 2153, 1992, 2032, 2019, and 2036 (kg ha^{-1}), respectively. Comparing yields from D1 to D2, these genotypes experienced decrement percentages reflecting the impact of altered sowing timings with G28 decreased by approximately 40.2%, G27 by 41.8%, G13 by 32.8%, G26 by 29.9%, and G33 by 25.7%. The results are in accordance with Kumar et al., 2012, demonstrated the reduction of PH, TNPP, SI and SY. Devasirvatham et al., 2015 reported upto 39% yield reduction under temperatures >35°**C.** Vance et al., 2014 emphasised that late planting exposed seedlings to low temperatures (<15°C), which limited biomass formation and extended vegetative growth phase into periods with high maximum temperatures (>35°C), resulting in unfilled pods and depressed grain yield. The study underscores significant genotype-specific responses to varying sowing conditions, highlighting diverse responses in yield and associated attributes. Among all the genotypes, G13, G26, and G33 demonstrated remarkable adaptability, maintaining relatively higher yields across both normal and late-sown conditions.

3.3. Correlation studies

To investigate the correlation between phenological studies and yield attributes, Pearsons R linear correlation analysis was conducted, and the summarized results are presented in Figure 2 and Figure 3. Under normal conditions,a significant negative correlation ($^{*}p<0.05$) was observed between DPF and PB (-0.35*), supporting the findings with kauret al. (2019). Non-significantnegative correlation ($p>0.05$) was observed between DFM and PB (-0.02), DPM and PB (-0.06), SB (-0.09), DSF and PB (-0.05), DPF and SB (-0.30), DPF and TNPP (-0.07), DPF and SY (-0.15), PH, SI, DFF and PB, SB, SI. Gulwaneet al., (2022) stated the negative correlation between days to maturity and secondary branches. A significant positive correlation ($^{***}p<0.001$) was observed between primary branches and secondary branches (0.93^{***}), seed yield (0.79^{***}), total number of pods $plant^{-1}$ (0.68^{***}), plant height (0.64^{***}), seed index (0.60^{***}). Seed

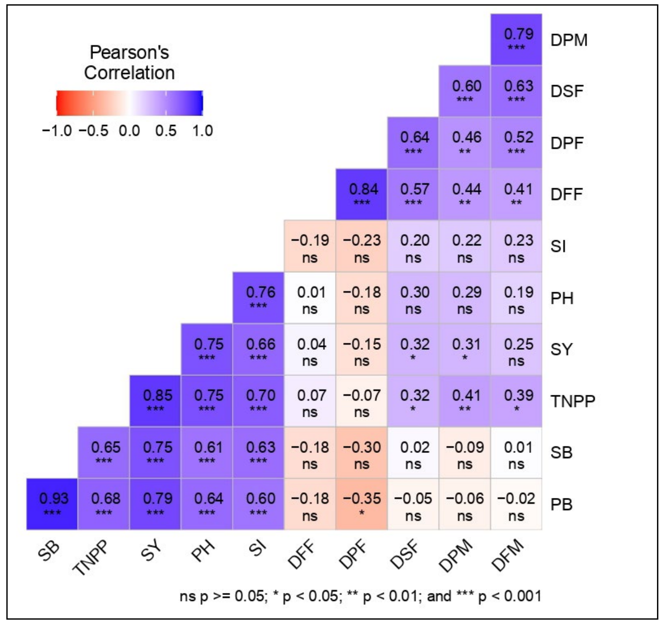

Figure 2: Correlogram indicating the pearson correlation matrix between the phenological parameters and yield and its attributes under normal sown conditions

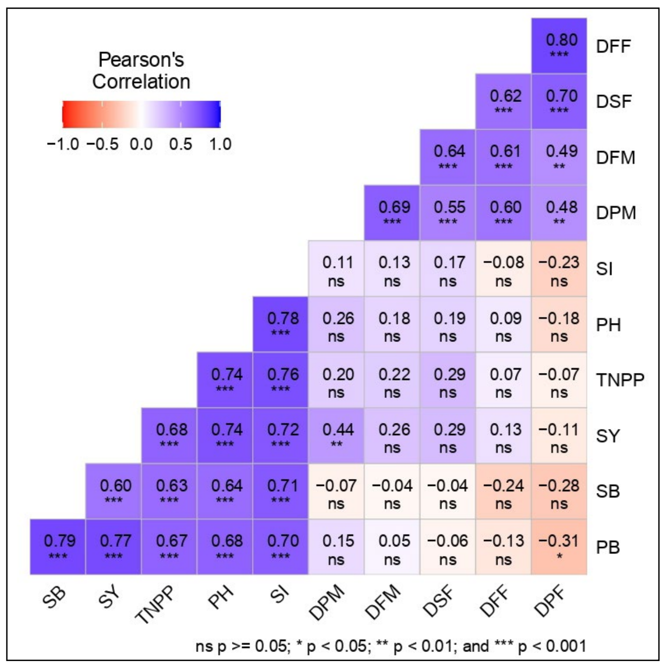

Figure 3: Correlogram indicating the pearson correlation matrix between the phenological parameters and yield and its attributes under late sown conditions

yield demonstrated a positive correlation ($^{***}p<0.001$) with primary branches ($r=0.79^{***}$), secondary branches ($r=0.75^{***}$), plant height ($r=0.75^{***}$) and seed index ($r=0.66^{***}$). Seed index exhibited a significant positive correlation ($^{***}p<0.001$) with plant height ($r=0.76^{***}$), total number of pods $plant^{-1}$ (0.70^{***}), seed yield (0.66^{***}), secondary branches (0.63^{***}), and primary branches (0.60***). The results are in alignment with Kayanet al. (2012) who reported the significant positive correlation between plant height and seed yield in chickpea.

Under late sown conditions significant negative correlation (*p<0.05) was observed between Days to Pod Formation and Primary Branches (-0.31*). Non-significant negative correlation (p>0.05) was observed between Days to Pod Formation and Secondary Branches (-0.28), Seed Yield (-0.11), Total no. of pods plant^{-1} (-0.07), Plant height (-0.18), Seed Index (-0.23), Days to 50% flowering and Primary Branches (-0.13), Secondary Branches (-0.24), Seed index (-0.08), Days to Seed formation and Primary Branches (-0.06), Secondary Branches (-0.04), Days to Field Maturity and Secondary Branches (-0.04), Days to Physiological maturity and Secondary Branches (-0.07).A significant positive correlation (***p<0.001) was observed between Days to Pod Formation and Days to Physiological maturity (0.48**), Days to Field Maturity (0.49**), Days to Seed formation (0.70***), Days to 50% flowering (0.80***), Days to 50% flowering and Days to Physiological maturity (0.60***). The similar results are reported by (Jain et al., 2023). Similarly, the highest positive correlation was observed between Days to Field Maturity (0.61***) and Days to Seed formation (0.62***), Days to Seed formation and Days to Physiological maturity (0.55***), Days to Field Maturity (0.64***). The correlation worked among different characters revealed the significant positive correlation between Days to Physiological maturity and Seed yield (0.44**). In the study when the Seed Index was taken as dependent variable highly correlated trait includes Primary Branches (0.70***), Secondary Branches (0.71***), Seed Yield (0.72***), Total no. of pods plant^{-1} (0.76***), Plant Height (0.78***), The highest correlation between Seed Yield was observed with and Primary Branches (0.77***) and Plant Height (0.74***). The outcomes are consistent with the findings of (Babbar et al., 2012; Vaghela et al., 2015; Shafique et al., 2016; Singh et al., 2023).

4. CONCLUSION

Varied sowing dates significantly influenced chickpea phenology and yield attributes. Temporal differences between normal and late sowings led to distinct genotype responses, impacting critical growth stages. Notably, longer-duration genotypes demonstrated shorter durations under late sowings. Yield attributes varied significantly, with certain genotypes exhibiting substantial reductions under altered sowing timings. DNMRT analysis revealed genotype variability for most traits. Correlation analysis emphasized nuanced associations between phenological stages and yield attributes, highlighting the intricate dynamics of chickpea cultivation.

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