International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 1645-1649
Received: 15-08-2025
Accepted: 19-09-2025

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Effect of thermal regimes on phenology, biomass, yield and yield attribute of chickpea different varieties

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i9q.3935

Abstract
The present investigation was conducted at research farm of Department of Agricultural Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *rabi* season 2024. The experiment was laid out in split plot design with three replication and four sowing dates viz. D_1 (42thSMW) D_2 (43th SMW), D_3 (44th SMW), D_4 (45th SMW) and four varieties (V_1) BDNG-797, (V_2) Digvijay, (V_3) Phule Vikram and (V_4) Jaki-9218 sown. Observations were recorded on the crop phenology, crop characteristics like biomass. The effect of thermal stress on yield and yield attributes were observed.
The best sowing date of chickpea was observed during 43nd SMW (22th to 28th October). Among the four varieties, Phule Vikram performed better throughout the crop growth phases and recorded higher yield. Dry matter accumulation of plant was maximum in second date of sowing (43nd SMW) and there after the rate of biomass accumulation declined and minimum was recorded under D_4 (45th SMW) sowing. The yield attributing characters like seed yield (kg ha^{-1}), straw yield (kg ha^{-1}), Biological yield (kg ha^{-1}), etc. found highest in D_2 sowing followed by D_1, D_3 and D_4. In case of varieties, Phule Vikram found superior over BDNG-797, Digvijay and Jaki-9219. High temperature stress during reproductive growth stages in chickpea crop reduces yield attributes.

Keywords: Biomass, crop growth rate, relative growth rate and yield attributes of chickpea

Introduction
In India, chickpea cultivation typically occurs during the *rabi* season, where the crop benefits from cool and dry weather conditions (Ali *et al.*, 2018; Devi *et al.*, 2023) [2, 6]. As it is predominantly grown under rainfed conditions, conserved soil moisture plays a crucial role in supporting its growth. However, the optimal sowing time for chickpea can differ significantly between varieties and regions due to diverse agro-ecological conditions. According to research by Yadav *et al.* (1999) [14], varying planting dates expose the crop's vegetative and reproductive stages to different temperatures, solar radiation, and day lengths, underscoring the need for tailored sowing strategies to optimize growth and development (Aslam *et al.*, 2010) [3].
According to the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)chickpea seeds contain on average 21.1% protein, 64% total carbohydrates (47% starch, 6% soluble sugar), 5% fat, 6% crude fiber and 3% ash. High mineral content has been reported for phosphorus (340 mg per 100 g), calcium (190 mg per 100 g) and magnesium (140 mg per 100g), iron (7 mg per 100 g) and zinc (3 mg per 100 g).
The strategic selection of improved cultivars and optimal sowing times is pivotal in maximizing chickpea yields under specific agro-climatic conditions. Notably, the sowing date is a critical non-monetary input that significantly influences crop productivity (Getachew & Abraham, 2021) [9]. Research has shown that sub-optimal thermal requirements during the growing season can profoundly impact yields. Furthermore, the concept of thermal use efficiency has been employed by various studies to compare the performance of different chickpea varieties and sowing dates, highlighting its utility in agricultural research (Rao *et al.*, 1999; Aggarwal *et al.*, 1999; Mrudula *et al.*, 2012) [1, 12].
One of the most important agronomic factors influencing chickpea productivity is the sowing date. The pattern of moisture availability during plant growth, temperature, and photoperiod are

the environmental factors that determine the best sowing date (Devasirvatham and Tan.2018) [5]. The best time to sow chickpeas is determined by the interaction of the environment and the available varietal germplasm. Choosing an optimum sowing time can be a trade-off between increasing yield potential and reducing disease levels. However, due to erratic weather patterns, such as a lack of or excess rainfall, changes in temperature patterns, and rainfed farming, sowing at the optimal time is not always possible in central India's black soils (Neenu *et al*., 2017) [11].

The growth and productivity of chickpea, that beloved legume, are subject to a complex interplay of numerous environmental and genetic factors. In this intricate dance, the timing of sowing emerges as a singular force, holding the power to sway the yield of chickpea crops (Chakrabarti *et al*., 2013) [4]. However, this optimal sowing time is not a static concept, for it varies not only from one variety to another but also across different regions, shaped by the diverse tapestry of agro-ecological conditions that paint the landscape (Gadde *et al*., 2025) [8]. It is within this dynamic realm that farmers must navigate, seeking the perfect balance between the variety's needs and the unique rhythms of their local environment. Different planting dates subject the vegetative and reproductive stages of the plant to various temperature, solar radiation and day length (Yadav *et al*., 1999) [14].

Materials and Methods

The experiment was conducted during the *rabi* season of 2024-25 at research farm of the Department of Agricultural Meteorology station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. Geographically Parbhani is situated at 19 knot 16' north latitude and 76 knot 47' east longitude and at 409 m altitudes above sea level and has a semi-arid climate. Agro-climatically Parbhani comes under assured rainfall zone which is also known as Central Maharashtra Plateau Zone, characterized as hot and dry in summer, cold in winter. Most part of the precipitation received from the South-West monsoon.

In the present investigation four varieties of chickpea and four sowing dates which provide the different thermal regime for chickpea crop varieties and comprising total sixteen treatment combinations were tried. Three replications were used in the split plot design of the experiment. The gross plot size was 5.4 m x 4.8 m and the net plot size was 4.5 m x 4.2 m, and were distributed randomly to each replication.

In order to record the observations, five plants were randomly selected across the date of sowing and replication for each variety, from each net plot for identification of phenological events. The day of which, five of them attained particular phenological stage was recorded for attaining that stage. The different phenological phases from emergence to maturity with number of days required to attained the specific phases were recorded. The plants were selected from the net plot and kept for oven drying by separating its leaf, stem and pods. After drying weight of leaf, stem, and pods was taken separately at each phenological stage of the crop.

At maturity, growth parameters and yield attributes were assessed from randomly chosen plants in each plot to gather accurate production data.

Results and Discussion

The statistical analysis shows that sowing dates significantly influence on the total dry matter accumulation in chickpea crop. The second sowing date D_2 (33.73 g plant^{-1}) is significantly superior over all date of sowing across all phenological stages due to efficient translocation of photo assimilates. In contrast, the fourth sowing date D_4 (28.25 g plant^{-1}) has the lowest dry matter accumulation, likely due to thermal stress during later growth stages impact on photosynthesis, biomass production, seed set and grain yield in crop growth stages was reduced which ultimately affected the total dry matter production. Similar results were observed by Thombre *et.al* (2019) [13] reported that the D_2 (28th October) sowing date accumulated highest dry matter due to favorable weather condition *i.e.* solar radiation, bright sun shine hours and relative humidity etc. during crop growing period than other sowing dates.

As shown in Table No. 4.1, the variety Phule Vikram (V_3) exhibited the highest dry matter accumulation (33.34 g plant^{-1}) and significantly superior over other variety across the growth stage, followed by V_1 (32.42 g plant^{-1}). In contrast, V_4 (29.24g plant^{-1}) had the lowest dry matter accumulation. This variation might be attributed to the genetic characteristics of the varieties and their response to temperature, highlighting the importance of selecting suitable varieties for specific growing conditions.

The data on chickpea varieties under different thermal conditions are summarized in Table No. 4.2 shown that the Phule Vikram variety (V_3), the crop growth rate (CGR) was highest at the P_5 (1.12 g day^{-1} plant^{-1}) stage under the D_2 sowing date, followed by D_1, D_3 and D_4. this trend was similar for all rest four varieties. The crop growth rate (CGR) of chickpea was at its lowest during the early initial growth stage, particularly around the seedling stage. From this point onward, CGR gradually increased, reaching its peak at the pod formation stage. A slight decline was noted from the grain/ seed formation stage (P_6) to the maturity stage (P_8), with a more noticeable reduction by the harvest stage (P_8) across all sowing dates. This similar pattern slow initial growth, a rapid rise toward pod formation, and a gradual decline thereafter was consistently observed across all chickpea varieties.

The drop in CGR at maturity is likely due to natural senescence processes such as leaf drying, leaf drop, and stem desiccation. The highest CGR was recorded between stages P_5 and P_6, after which a decline occurred, likely resulting from increased leaf shedding and reduced photosynthetic activity.

The relative growth rate (RGR) data for different chickpea varieties under varying thermal regimes are presented in Table No.4.3 for the Phule Vikram variety (V_3), the highest RGR was noted between the P_2 (0.09 g day^{-1}plant^{-1}) and P_4 (0.13g day^{-1}plant^{-1}) stages under the D_2 sowing date, followed by D_1, D_3 and D_4. this trend was similar for BDNG-797, Digvijay and Jaki-9218. From the seedling stage (P_2) to the flowering stage (P_4), RGR gradually increased. After flowering, however, a steady decline in RGR was observed until the crop reached maturity (P_8). The highest RGR was consistently recorded at the flowering stage (P_4) across all sowing dates and varieties. The decrease in RGR at the harvest stage can be attributed to natural senescence processes such as leaf drop, stem drying, and the shedding of lower leaves. The sharp reduction in RGR following the reproductive phase likely reflects the plant's shift in resource allocation toward grain development, which increases the assimilate demand.

Sowing dates significantly impacted seed yield, with D_2 (1574.11 kg ha^{-1}) outperforming the other dates. The yields for D_1, D_3, and D_4 were 1357.75 kg ha^{-1}, 1220.04 kg ha^{-1}, and 1086.36 kg ha^{-1}, respectively. The four chickpea varieties significantly affected seed yield. Phule Vikram recorded the highest yield (1474.68 kg ha^{-1}), followed by BDNG-797 (1372.68 kg ha^{-1}), Digvijay (1259.9 kg ha^{-1}), and Jaki-9218 (1131.0 kg ha^{-1}). The variation in yield is likely due to the genetic differences among the varieties and their response to similar environmental conditions.

The sowing dates shows significant impact on straw yield. The sowing date D_2 was found significantly superior over other treatments with straw yield of 2324.71 kg ha^{-1}. It is followed by D_1 and D_3 sowings with straw yield of 2186.14 and 2058.70 kg ha^{-1} respectively. The lowest straw yield was recorded in D_4 sowing date *i.e.* 1755.74 kg ha^{-1}. The chickpea varieties were show significant impact on straw yield. Among the varieties, variety Phule Vikram (2282.49 kg ha^{-1}) had significantly superior over Digvijay, Jaki-9218 and BDNG-797 is at par with Phule Vikram. Jaki-9218 had the lowest straw yield (1844.50 kg ha^{-1}). It due to because of its varietal traits, which allow it to respond and produce a greater amount of seed under the same prevailing meteorological conditions.

Table 1: Effect of different thermal regime on total dry matter (g plant^{-1}) chickpea crop.

Effect of different thermal regime on total dry matter (g) of chickpea crop. (Phenological stage wise)							
Sowing dates/Varieties	**Seedling stage**	**Branching Stage**	**Flowering Stage**	**Pod formation Stage**	**Grain formation Stage**	**pod containing full size grain formation**	**Maturity stage**
D_1: (42th SMW)	1.97	9.86	23.86	29.78	30.92	36.73	37.65
D_2: (43th SMW)	2.12	10.35	24.49	31.21	32.13	38.82	39.48
D_3: (44th SMW)	1.66	9.66	20.83	28.34	29.55	34.71	35.96
D_4: (45th SMW)	1.53	9.12	20.14	26.08	27	31.59	32.67
S.E.	0.059	0.10	0.271	0.140	0.15	0.14	0.28
C.D.@ 5%	0.2	0.37	0.930	0.48	0.51	0.48	0.98
G. Mean	1.82	9.75	22.33	28.85	29.9	35.46	36.44
Varieties							
V_1: BDNG-797	1.94	10.46	23.85	29.62	30.23	36.09	37.17
V_2: DIGVIJAY	1.63	9.06	21.67	28.47	28.88	34.18	35.27
V_3: PHULE VIKRAM	2.23	12.15	24.83	30.38	32.08	39.34	40.09
V_4: JAKI-9218	1.48	7.32	18.96	26.94	28.42	32.24	33.24
S.E.	0.078	0.16	0.255	0.103	0.326	0.14	0.23
C.D.@ 5%	0.229	0.49	0.744	0.564	0.952	0.42	0.67
D X V Interaction							
S.E.	0.157	0.336	0.510	0.387	0.652	0.29	0.458
C.D.@ 5%	NS	NS	NS	NS	NS	NS	NS
G. Mean	1.82	9.75	22.33	28.85	29.90	35.46	36.66

Table 2: Impact of different thermal regimes on Crop Growth Rate (CGR) (g /day/plant) of different chickpea varieties.

Variety	**Treatments**	**Seedling stage**	**Branching stage**	**Flowering stage**	**Pod formation stage**	**Grain formation stage**	**Pod containing full size grain stage**	**Maturity stage**
V1: BDNG-797	D1V1	0.09	0.13	0.39	1.16	0.68	0.59	0.41
	D2V1	0.11	0.15	0.40	1.19	0.69	0.65	0.42
	D3V1	0.09	0.12	0.38	0.97	0.60	0.49	0.37
	D4V1	0.08	0.11	0.36	0.94	0.52	0.47	0.29
	MEAN	0.09	0.13	0.38	1.07	0.62	0.55	0.37
V2: DIGVIJAY	D1V2	0.09	0.12	0.42	1.0	0.65	0.62	0.42
	D2V2	0.09	0.11	0.44	1.09	0.78	0.64	0.44
	D3V2	0.09	0.13	0.40	0.92	0.61	0.53	0.39
	D4V2	0.08	0.10	0.38	0.82	0.58	0.47	0.36
	MEAN	0.09	0.12	0.41	1.0	0.66	0.57	0.40
V3: PHULE VIKRAM	D1V3	0.1	0.14	0.44	1.16	0.74	0.60	0.42
	D2V3	0.12	0.15	0.47	1.19	0.80	0.61	0.46
	D3V3	0.09	0.12	0.4	1.12	0.66	0.58	0.41
	D4V3	0.08	0.11	0.36	1.08	0.60	0.52	0.38
	MEAN	0.10	0.13	0.42	1.14	0.70	0.58	0.42
V4: JAKI-9218	D1V4	0.07	0.12	0.39	1.08	0.62	0.59	0.35
	D2V4	0.08	0.12	0.41	1.11	0.65	0.61	0.38
	D3V4	0.06	0.11	0.38	0.95	0.6	0.48	0.31
	D4V4	0.05	0.1	0.35	0.87	0.58	0.44	0.29
	MEAN	0.07	0.11	0.38	1.00	0.61	0.53	0.33

Table 3: Impact of different thermal regimes on Relative Growth Rate (RGR) (g/day/plant) of different chickpea varieties.

Variety	Treatments	Seedling stage (P2)	Branching stage (P3)	Flowering stage (P4)	Pod formation stage (P5)	Grain formation stage(P6)	full size grain stage(P7)	Maturity stage(P8)
V1: BDNG-797	D1V1	0.067	0.091	0.102	0.068	0.0508	0.018	0.008
	D2V1	0.069	0.094	0.118	0.078	0.0519	0.025	0.010
	D3V1	0.056	0.084	0.0988	0.062	0.0497	0.021	0.006
	D4V1	0.053	0.0741	0.0975	0.058	0.0495	0.018	0.004
	MEAN	0.06	0.09	0.10	0.07	0.05	0.02	0.01
V2: DIGVIJAY	D1V2	0.0302	0.063	0.081	0.044	0.019	0.011	0.008
	D2V2	0.0314	0.068	0.083	0.048	0.021	0.013	0.009
	D3V2	0.0291	0.058	0.078	0.043	0.018	0.01	0.006
	D4V2	0.0289	0.052	0.074	0.038	0.014	0.009	0.005
	MEAN	0.03	0.06	0.08	0.04	0.02	0.01	0.01
V3: PHULE VIKRAM	D1V3	0.0938	0.10431	0.1255	0.1109	0.0672	0.0428	0.0059
	D2V3	0.0948	0.1085	0.1387	0.1124	0.0684	0.0468	0.0062
	D3V3	0.0936	0.1039	0.1293	0.1089	0.0591	0.0392	0.0048
	D4V3	0.0832	0.0941	0.1103	0.1064	0.0589	0.0275	0.0034
	MEAN	0.09	0.10	0.13	0.11	0.06	0.04	0.01
V4: Jaki-9218	D1V4	0.0671	0.0837	0.0912	0.0712	0.0453	0.0218	0.00076
	D2V4	0.0685	0.0842	0.1014	0.0814	0.0485	0.0228	0.00085
	D3V4	0.0645	0.0821	0.0992	0.0692	0.0363	0.0172	0.00056
	D4V4	0.0603	0.0818	0.0879	0.0579	0.0319	0.0158	0.00045
	MEAN	0.07	0.08	0.09	0.07	0.04	0.02	0.00

Table 4: Effect of different thermal regimes on yield and yield attributing characters of chickpea crop.

Effect of different thermal regime on yield and yield attribute of chickpea			
Treatment	**Seed Yield Kg ha^{-1}**	**Straw Yield kg ha-1**	**Biological Yield Kg ha-1**
Date of sowing			
D_1: (42th SMW)	1357.75	2186.14	3543.9
D_2: (43th SMW)	1574.11	2324.71	3898.83
D_3: (44th SMW)	1220.04	2058.7	3278.75
D_4: (45th SMW)	1086.36	1755.74	2842.1
S.E.	16.95	93.51	107.83
C.D.@ 5%	58.661	323.6	373.15
G. Mean	1239.36	2052.01	3766.2
Varieties			
V_1: BDNG-797	1372.68	2141.20	3513.88
V_2: DIGVIJAY	1259.9	2057.12	3317.02
V_3: PHULE VIKRAM	1474.68	2282.49	3757.17
V4: JAKI-9218	1131.00	1844.5	2975.51
S.E.	17.71	67.58	73.26
C.D.@ 5%	51.72	197.28	213.86
D X V Interaction			
S.E.	13.89	135.17	30.65
C.D.@ 5%	NS	NS	NS
G. Mean	1309.56	2081.33	3390.89

Conclusions

Crop Growth Rate (CGR) was initially lowest upto (seedling stage) then gradually increased and peak at Pod Formation and declined toward harvest. Among the various sowing schedules, crops sown during D_2 (43th SMW) exhibited significantly greater total dry matter production, grain yield, and straw yield compared D_1, D_3 and D_4. Among the tested varieties, 'Phule Vikram' outperformed others in terms of total dry matter, seed yield, and straw yield.

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