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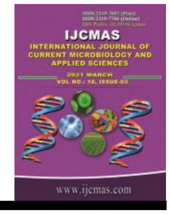

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Effect of Different Photothermal Regimes on Morpho-physiological Traits in Chickpea (*Cicer arietinum* L.)

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A B S T R A C T

A field experiment was conducted to study the photothermal requirement of chickpea cultivars during rabi season of 2018-19 and 2019-20 at Regional Agricultural Research Station, Nandyal. The experiment was laid out in factorial RBD with three replications consisted three sowing dates 1st fortnight of October, November and December and fifteen genotypes *viz.*, NBeG 47, NBeG 49, JG 11, Jaki, NBeG 452, NBeG 738, NBeG 776, NBeG 779, NBeG 857, NBeG 119, NBeG 399, NBeG 440, NBeG 458, Vihar and KAK2.The genotypes were evaluated for various morpho-phenological and heat units accumulation under different dates of sowing. A significant genotypic variability was recorded in plant height, number of branches, phenological stages and photothermal indices *viz.*, growing degree days (GDD), heliothermal units, photothermal units and heat use efficiency. Results revealed that duration of phenological stages and thermal unit from sowing to maturity decreased with successive delay in sowing. Crop sown during November produced significantly higher seed yield as compared to October and December sowings. Among the desi genotypes NBeG 779 and in kabuli genotypes NBeG 440 exhibited significantly higher seed yield.

Keywords

Chickpea, Sowing dates, Photothermal unit, Yield attributes

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Introduction

Chickpea (*Cicer arietinum* L.) or Bengalgram is the third most important grain legume cum pulse crop in the world, whereas in India chickpea is important pulse crop placed in first position with an area of 9.55 million hectares producing 9.94 million tones with an average productivity of 1041 kg ha^{-1} (*www.indiastat.com*, 2020). The major chickpea-growing states in India are Madhya Pradesh, Uttar Pradesh, Rajasthan, Andhra Pradesh, Haryana and Maharashtra, which constitute 85 per cent area with 89 per cent production. Andhra Pradesh is one of the major chickpea producing states in India. In terms of area and production chickpea occupies 5^{th} position, with an area of 4.78 lakh hectares producing 2.42 lakh tones with an average productivity of 508 kg ha^{-1} (*www.indiastat.com*, 2020).

Among pulses, chickpea is preferred to food legumes in some regions because of its multiple uses. Chickpea is considered to be unique because of its high level of protein content that accounts for almost 40% of its weight. Moreover, the grain chickpea legume crop has potential health benefits, which include reducing cardiovascular, diabetic, and cancer risks. Chickpea is a highly nutritious and an inexpensive source of protein that is estimated at 24% and ranges from 15% to 30% depending on variety and environmental conditions.

Temperature is an important factor controlling plant growth and development in chickpea. Daily seasonal temperature above optimum becomes a limiting factor for crop production when they coincide with critical stages of development. IPCC (2007) has projected 1.6 to 3.8^{o}C increase in global average air temperature at the critical stage may cause considerable yield losses. Moreover, the rise in temperature is reported to be a greater during the *rabi* season and thus, crops grown in the *rabi* season like chickpea are more vulnerable. Photoperiod is another major environmental factor determining time to flower initiation and first flower appearance in plants. In chickpea, photoperiod sensitivity, expressed as delayed to flower under short days (SD) as compared to long days (LD), may change with the growth stage of the crop. Agro-climatic factors that influence crop phenology may also have a major effect on crop growth rate and the partitioning of dry matter. It is therefore useful to integrate phenological and growth responses.

Optimum date of sowing provides favourable environmental conditions for growth, development and yield of crops through optimum utilization of available natural resources. The objective of the investigation is to study the influence of photoperiod and temperature on various growth attributes, dry matter partitioning and yield in chickpea genotypes in scarce rainfall zone of Andhra Pradesh

Materials and Methods

A field experiment was conducted to study the photothermal requirement of chickpea cultivars during rabi season of 2018-19 and 2019-20 at Regional Agricultural Research Station, Nandyal. The experiment was laid out in factorial RBD with three replications consisted of fifteen genotypes *viz*., Desi- NBeG 47, NBeG 49, JG 11, Jaki, NBeG 452, NBeG 738, NBeG 776, NBeG 779, NBeG 857 and kabuli- NBeG 119, NBeG 399, NBeG 440, NBeG 458, Vihar and KAK2 as factor one and three sowing dates 1^{st} FN of October, 1^{st} FN of November and 1^{st} FN of December as factor two.

The soil of the experimental field is black cotton soil, with P^{H} 8.3 and EC 0.26 dS^{-m}. The data collected from the experiment was subjected to statistical analysis as described by Gomez and Gomez (1984).

Observations recorded

Morphological characters: The observations on plant height and the number of primary and secondary branches were recorded as per the standard procedure in five tagged plants in the plot. Phenological parameter viz., days to flower initiation, days to fifty per cent flowering, days to pod initiation and days to maturity were recorded randomly in the plot and was expressed in days.

Thermal indices: The growing degree days (GDD), heliothermal units (HTU), photothermal units (PTU) and heat use efficiency (HUE) were calculated by using phenological data and weather data are as follows

Growing Degree Days (GDD) (Monteith, 1984)

Growing Degree Days (GDD) is an arithmetic accumulation of daily mean temperature above certain threshold temperature (base temperature) and is calculated using the formula.

$$GDD = \frac{(Tmax + Tmin)}{2} - \text{Base temperature}$$

Heliothermal units (HTU)

Heliothermal units (HTU) are the product of GDD and corresponding actual sunshine hours for that day were computed on daily basis as:

HTU (°C day hr) = GDD × Actual sunshine hours

Photothermal units (PTU)

Photothermal units (PTU) are the product of GDD and corresponding day length for that day were computed on daily basis as follows:

PTU (°C day hr) = GDD × Day length

Where, day length refers to maximum possible sunshine hours.

Heat use efficiency (HUE) (Monteith, 1984)

Heat use efficiency (HUE) for seed was obtained as under:

$$\text{Thermal use efficiency (HUE)} = \frac{\text{Seed yield (Kg ha}^{-1}\text{)}}{\text{Growing degree days (}^{0}\text{Cday)}}$$

Results and Discussion

Morphological parameters like plant height, number of primary and secondary branches, phenology and physiological maturity significantly differed due to different dates of sowing, genotypes and their interactions. Plant height is an important morphological character controlled genetically but the environmental factors also influence these characters.

Significant variability for plant height (Table 1) among the genotypes, dates of sowing and their interactions were recorded. Among the varieties, phenotypic variability for plant height ranges from 34.73 cm (NBeG 452) to 50.12 cm (NBeG 47). Similar result in chickpea was reported by Kiran and Chimmad (2015). Among the desi varieties, NBeG 47 recorded highest plant height (50.12 cm) followed by NBeG 779 (43.88 cm) respectively whereas lowest plant height of (34.73) cm was recorded by NBeG 452. Among the Kabuli's NBeG-399 recorded plant height of (42.06 cm) which is at par with NBeG-458 (42.03). Similarly the increase in plant height was attributed to the increased duration of the crop *i.e.* growing period, which is evident by the number of days taken for maturity was higher in these sowing dates was reported by Saim and Ufuk (2003).

Secondary branches per plant differed significantly due to different dates of sowing (Table 1). Among the genotypes, phenotypic variability for secondary branches ranges from 4.76 (NBeG 440) to 9.79 (NBeG-776). Among the desi genotypes, NBeG 776 (9.79) recorded more number of secondary branches followed by NBeG-779 (9.73) and NBeG 49 (9.64) respectively whereas in kabuli genotypes more number of secondary branches was recorded by NBeG-119 (7.85) followed by Vihar (6.89). Similar result in chickpea was reported by Kiran and Chimmad (2018). All the dates of sowing showed significant variability throughout the crop growth stages. Among the three dates of sowing October 1st FN sowing (8.80) exhibited more number of secondary branches followed by November 1st FN sowing (7.54) whereas lowest number of secondary branches was recorded in December 1stFN (5.65). Similar variability for secondary branches with respective delayed sowing in chickpea was reported by Rathod and Chimmad (2016).

Table.1 Effect of temperature and photoperiod on growth and phenology of chickpea genotypes at different dates of sowing

Treatments	Plant height (cm)	Secondary branches	Days to 50 % flowering	Days to physiological maturity
Genotypes (G)				
G1 : NBeG 47	50.12	7.43	39.6	90.8
G2 : NBeG 49	38.22	9.64	38.7	89.1
G3 : JG 11	34.92	9.25	37.8	88.9
G4 : Jaki	37.98	7.33	40.8	91.7
G5 : NBeG 452	34.73	7.77	37.8	88.1
G6 : NBeG 738	39.22	8.31	37.8	89.3
G7 : NBeG 776	43.51	9.79	38.1	90.8
G8 : NBeG 779	43.88	9.73	37.6	89.0
G9 : NBeG 857	37.27	8.62	38.1	92.2
G10 : NBeG 119	40.02	7.85	36.4	90.1
G11 : NBeG 399	42.06	5.30	42.3	99.8
G12 : NBeG 440	40.87	4.76	40.3	102.0
G13 : NBeG 458	42.03	5.83	41.5	102.1
G14 : Vihar	40.27	6.89	43.1	105.3
G15 : KAK2	41.52	5.35	42.7	103.6
SE(m)	0.64	0.40	0.16	0.35
CD (P=0.05)	1.80	1.13	0.47	0.98
Dates of Sowing (D)				
D1:1st FN of October	39.50	7.54	41.7	101.0
D2:1st FN of November	40.46	8.80	39.4	94.3
D3: 1st FN of December	41.37	5.65	37.5	87.3
SE(m)	0.28	0.17	0.07	0.15
CD (P=0.05)	0.80	0.53	0.21	0.44
Interactions (VXD)				
SE(m)	1.10	0.68	0.29	0.60
CD (P=0.05)	NS	2.03	0.82	1.70

NS- Non Significant

Table.2 Effect of temperature and photoperiod on photothermal indices, heat use efficiency (HUE kg/ha/°C) and yield (Kg/ha) in chickpea genotypes at different dates of sowing

Treatments	Growing degree days (GDD) °C	Helio-thermal units (HTU °C day hrs)	Photo-thermal units (PTU °C day hrs)	Heat use efficiency (HUE kg/ha/°C)	Yield (Kg/ha)
Genotypes (G)					
G1 : NBeG 47	1910	14432	21613	0.74	1498
G2 : NBeG 49	1911	14452	21028	0.76	1548
G3 : JG 11	1894	14311	21562	0.83	1659
G4 : Jaki	1981	15076	22594	0.74	1572
G5 : NBeG 452	1852	13950	21099	0.84	1635
G6 : NBeG 738	1913	14468	21797	0.80	1634
G7 : NBeG 776	1896	14345	21782	0.85	1722
G8 : NBeG 779	1845	13884	21996	0.93	1811
G9 : NBeG 857	1930	14604	21721	0.83	1704
G10 : NBeG 119	1818	13657	20683	0.76	1465
G11 : NBeG 399	2022	15506	23034	0.68	1463
G12 : NBeG 440	2059	15801	23395	0.77	1662
G13 : NBeG 458	2114	16299	24105	0.65	1465
G14 : Vihar	2180	16961	24848	0.61	1411
G15 : KAK2	2154	16725	24543	0.60	1380
SE(m)	5.6	48.6	65.4	0.02	39.9
CD (P=0.05)	15.8	136.9	184.2	0.05	112.4
Dates of Sowing (D)					
D1:1st FN of October	2112	15080	24176	0.63	1400
D2:1st FN of November	1954	14551	22103	0.88	1831
D3: 1st FN of December	1830	14262	20880	0.78	1494
SE(m)	2.51	21.75	29.27	0.009	17.86
CD (P=0.05)	7.08	61.24	82.40	0.025	50.29
Interactions (VXD)					
SE(m)	9.7	84.2	113.3	0.03	69.1
CD (P=0.05)	27.4	237.1	319.1	0.09	194.7

Phenological parameters

Phenological parameters (Table 1) like days to fifty per cent flowering and days to physiological maturity are differed significantly with respect to genotypes, dates of sowing and their interactions. The number of days taken for 50 per cent flowering differs significantly among the genotypes and also at different dates of sowing and their interactions. Among kabuli genotypes, Vihar took significantly maximum number of days (43.1 days) for 50 per cent flowering followed by, KAK-2 (42.7 days) and NBeG-399 (42.3), where as minimum number of days (36.4 days) was recorded in NBeG-119. Among the desi genotypes Jaki recorded maximum number of days (40.8 days) followed by NBeG-47 (39.6 days) and minimum number of days recorded by NBeG-779 (37.6 days).

Days to 50% flowering in chickpea was significantly reduced with faster accumulation of both photo-thermal and thermal units. This is similar to the results of Trudgill *et al.*, (2005) in which they reported that rapid development results from a small overall degree day increase in diverse plant species with short generation times. All the dates of sowing showed significant variability throughout the crop growth stages. Among the three dates of sowing October 1^{st} FN sowing recorded (41.7 days), followed by November 1^{st} FN sowing (39.4 days) and December 1^{st} FN sowing (37.5 days).

The results observed from (Table 1) indicated that genotypes, dates of sowing and their interactions differed significantly with respect to days to physiological maturity. Among the kabuli genotypes, Vihar took significantly maximum number of days (105.3 days) for physiological maturity followed by, KAK-2 (103.6 days), where as minimum number of days (90.1 days) was recorded in NBeG 119. Similar results were reported by Purushothaman *et al.*, (2014). Among the desi genotypes NBeG 857 took significantly maximum number of days (92.2 days) for physiological maturity followed by, Jaki (91.7 days) and minimum number of days (88.1days) was recorded in NBeG 452. These results are in agreement with Berger *et al.*, (2011) and Suresh Mhaske *et al*, (2019).

The days taken to attain different phenological stages and total duration were differed significantly by changing the date of sowing. Among the three dates of sowing October 1^{st} FN sowing recorded (101.0 days), followed by November 1^{st} FN sowing (94.3 days) and December 1^{st} FN sowing (87.3 days). The crop sown on October 1^{st} FN taken highest number of days to attain different growth stages i.e from start of flowering to physiological maturity followed by November 1^{st} FN and December 1^{st} FN during both the crop season. In the present study higher temperature and long photoperiod shorten the developmental growth phases and high rainfall at early sown crop have extended growth phase with poor growth was observed.

Photothermal indices

GDD significantly varied among the varieties, from sowing to physiological maturity, accumulated Growing degree days (GDD) ranges from 1818 ^{o}day to 2180 ^{o}day across all the three dates of sowing whereas among the dates of sowing, GDD ranges from 1830 ^{o}day to 2112 ^{o}day (Table 2). Under late sown conditions, lower GDD was required by the crop to attain maturity. However, when dates of sowing were advanced, higher GDD was needed by the chickpea crop to attain maturity. Similar results were reported by Kiran and Chimmad (2018). Heat use efficiency (HUE) ranges from 0.60 kg/ha/^{o}C day to 0.93 kg/ha/^{o}C day at physiological maturity, across the three dates of sowing, HUE ranges from 0.63 kg/ha/^{o}C day (D1) to 0.88 kg/ha/^{o}C day (D2).

Variability for grain yield ranges from 1380 kg.ha^{-1} to 1811 kg.ha^{-1}. Among the desi genotypes, NBeG-779 (1811 kg.ha^{-1}) recorded significantly higher yield followed by NBeG-776 (1722 kg.ha^{-1}) and was at par with NBeG-857 (1704 kg.ha^{-1}) and lowest was recorded in NBeG-47 (1498 kg.ha^{-1}). Among kabuli genotypes NBeG-440 (1662 kg.ha^{-1}) recorded higher yield followed by NBeG-458 and NBeG-119 (1465 kg.ha^{-1}) whereas lowest grain yield were recorded by KAK-2 (1380 kg.ha^{-1}). Under delayed sowings chickpea reproductive phase suffers considerably due to high temperatures (35/18 °C, day/night), under such thermal conditions, grain yield is reduced to 33% compared to that of normal conditions such as 30/10°C day/night (Summerfield *et al.*, 1984).

In conclusion the genotype NBeG 779 recorded higher physiological efficiency and yield and its components compared to other desi genotypes like NBeG 47, NBeG 49, JG 11, Jaki, NBeG 452, NBeG 738, NBeG 776, NBeG 857 and in kabuli genotypes NBeG 440 recorded higher physiological efficiency and yield compared to NBeG 119, NBeG 399,, NBeG 458, Vihar and

KAK2. Among the three dates of sowing, November 1st FN sowing found favourable interms of higher accumulation of GDD specially at grain filling stage and recorded higher HUE and yield compared to December 1st FN sowing and October 1st FN sowing.

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