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RESEARCH PAPER

Growth and yield of chickpea genotypes under changing weather scenario in the Northern Dry Zone of Karnataka

M. P. NIVEDITHA , S. B. PATIL, S. B. KALAGHATAGI AND V. H. ASHVATHAMA

Department of Agronomy, College of Agriculture, Vijayapur
University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
E-mails: patilsb13617@uasd.in, neethump97@gmail.com

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Abstract : A field experiment was conducted to study the influence of weather scenarios created by adjusting sowing dates on the growth and yield of chickpea genotypes at the Regional Agricultural Research Station, Vijayapura, Karnataka, during *Rabi,* 2020-21. The experiment was laid out in a split-plot design comprised of twelve treatment combinations, including four sowing dates *viz.,* 1st fortnight of October, 2nd fortnight of October, 1st fortnight of November and 2nd fortnight of November and three genotypes *viz.,* JG-11, BGD-111-1 and JG-14. The sowing of chickpea during 1st fortnight of October recorded a significantly higher seed yield (1913 kg ha^{-1}), haulm yield (2304 kg ha^{-1}), harvest index (45.12%) and better growth and yield attributes than later sown crop, but it was statistically on par with 2nd fortnight of October sowing for most of the parameters. Among the genotypes, JG-11 recorded a significantly higher seed yield of (1848 kg ha^{-1}) followed by BGD-111-1 (1748 kg ha^{-1}) and JG-14 (1521 kg ha^{-1}). Interactions of sowing dates and genotypes influenced the growth, yield and economics of chickpea. In the treatment interaction, the genotype JG-11 sown during the 1st fortnight of October recorded significantly higher seed yield (2168 kg ha^{-1}), net returns (₹ 69,699 ha^{-1}) and benefit-cost ratio (3.51) over other interactions. However, it was on par with BGD-111-1 sown at the same period and JG-11 sown during the 2nd fortnight of October. The plant height was maximum with the sowing of JG-14 in the 1st fortnight of October. Therefore, we conclude that early sowing is better for getting the higher productivity of chickpea with JG-11 and BGD-111-1 genotypes. The genotype JG-14 is heat tolerant and well suited for delayed sowing upto the 2nd fortnight of November.

Key words: Canopy spread, Economics, Genotypes, Seed yield, Sowing date

Introduction

Chickpea (*Cicer arietinum* L.) is a cool-season legume crop that belongs to the Fabaceae family. It is an important source of protein for millions of people in developing countries, particularly in South Asia. It is one of the essential semi-arid tropical legume crops grown in several countries world wide as a food source. In India, it is grown over an area of 10.17 million hectares with a productivity of 1116 kg ha^{-1} and production of about 11.35 million tonnes (Anon., 2020). Chickpea is grown after the rainy season on conserved soil moisture during winter in the tropics. Crop production in an environment is a function of many variables, out of which weather is the most critical factor determining the success or failure of a crop. Among weather variables, temperature and rainfall are the most important factors affecting crops' growth, productivity, and adaptability. The unusual weather during the reproductive period of a crop adversely affects crop productivity. Although the climate is the least manageable part of environmental resources, a better understanding of the climatic resources and their interactions with agricultural parameters can help to increase crop productivity under changing climate scenarios.

Climate change has become a significant challenge to chickpea production and productivity. The temperature increases day by day, the rainfall pattern is also disturbed and the rainy season is extended. Thus, a predicted moderate increase in air temperature under future climate change scenarios might be critical for the chickpea crop (Bahuguna *et al*., 2012). The temperature change reduces the winter season and affects crop growth and development, especially in chickpea, which is photo-thermosensitive. Lower temperatures, shorter photoperiods and optimal soil moisture, individually or in combinations help to extend the growth period, while higher temperatures, longer photoperiods and moisture stress conditions are known to shorten all developmental phases, thereby reducing the crop duration. Several researchers are engaged in understanding the impact of temperature on the growth and yield of crops and identifying suitable management options to sustain productivity. Sowing time is the single most important factor among the various agronomic practices for optimizing the yields in climate change . The changing weather scenarios resulting from different sowing dates influence crop growth and development to various temperatures, solar radiation, and daylength. It has been proved to be one of the non-monetary inputs for better yields in chickpea. In India, mid-October to mid-November is ideal for sowing chickpea crop. Any deviation from this period causes a remarkable reduction in yield. The effect of sowing dates on crop growth and development is also genotype-dependent. Optimum sowing time for a genotype ensures better harmony among soil, plant, and atmospheric systems. Delay in sowing causes early maturity of the genotype resulting in a drastic yield reduction. But, it may not be the case in heat-tolerant genotypes.

Sowing time and genotype are two important factors that can affect the growth and yield of chickpea. The most vital step towards enhancing the yield of chickpea is to ensure that the phenology of the crop is well in line with the resources and constraints of the production environment. One method to enhance grain yield in chickpea would be to change the sowing time by using existing genotypes resistant to biotic and abiotic stress. A quantitative understanding of the response of phenological development to environmental factors would help to predict optimum sowing dates for better yield in a future climate change situations. It is required to determine optimum sowing time and genotypes under different weather scenarios and evaluate their subsequent effect on chickpea productivity. Therefore, we planned the present study to know how chickpea genotypes perform in changing weather scenarios and determine the optimized conditions for maximum chickpea productivity in the Northern Dry Zone of Karnataka.

Material and methods

A field experiment was conducted at the Regional Agricultural Research Station, Vijayapura, Karnataka, during *Rabi* 2020-21 on medium-deep black soil having pH 8.33 and EC 0.24 dS m^{-1}. The soil was medium in organic carbon (0.51 %), low in available nitrogen (168 kg ha^{-1}), medium in available phosphorus (31 kg ha^{-1}) and high in available potassium (357.7 kg ha^{-1}). During the cropping period (October 2020 to February 2021), a rainfall of 126.8 mm was received on 7 rainy days. The highest maximum air temperature was recorded in February 2021 (31.7 ^{0}C) and the lowest maximum air temperature was recorded in December 2020 (29.8 ^{0}C). Similarly, the lowest minimum temperature was recorded in December 2020 (13.4 ^{0}C) and the highest in October 2020 (20.7 ^{0}C). The highest morning time relative humidity (RH-I) was recorded in October 2020 (91 %) and the lowest in February 2021 (64 %). Similarly, the highest afternoon relative humidity (RH-II) was recorded in October 2020 (59 %) and the lowest in February 2021 (25 %). During the crop growing period, the highest wind velocity was recorded in October 2020 (5.0 km hr^{-1}) and the lowest in December 2020 (3.6 km hr^{-1}). The weather data during the cropping period is depicted in Fig 1.

The experiment was laid out in a split-plot design with three replications having twelve treatment combinations. The experiment comprised two factors *viz.*, four sowing dates (1st fortnight of October, 2nd fortnight of October, 1st fortnight of November and 2nd fortnight of November) in main plots and three genotypes , (JG-11, BGD-111-1 and JG-14) in subplots. The plots were laid out as per the plan of the layout of the experiment. Sowing was done as per the treatments by hand

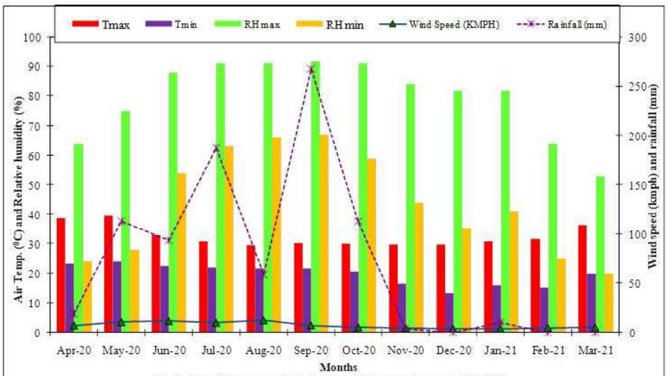

Fig.1 : Monthly meteorological data of the cropping period 2020-21

dibbling with 1-2 seeds at each hill. The crop was sown by gap-filling was done to maintain the optimum plant population. Hand weeding was done at 25 days after sowing (DAS) to avoid crop weed competition. One intercultural operation was carried out at 45 DAS to conserve the soil moisture and provide favourable conditions for plant growth. The crop was considered mature when 95% of pods had obtained their mature colour. The plants of the net plot area were harvested by cutting the plants to the ground level and then allowing for sun drying. After complete sun drying, the crop was threshed manually, seeds were cleaned and grain and stalk yield were expressed in kilogram per hectare. The harvest index (HI) was calculated by using the formula suggested by Donald (1962).

$$HI = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

The economics of each treatment was calculated based on prevailing market prices of the corresponding year. The yield was further computed for gross and net returns as well as benefit-cost (BC) ratio to assess the profitability. The benefit-cost ratio was worked out by dividing the gross returns by the total cost of cultivation of respective treatments.

The data collected from the experiment at different growth stages and harvest were subjected to statistical analysis as per the split-plot design described by Gomez and Gomez (1984). Summary tables for treatment effect have been prepared and furnished with standard error of means (S.Em±) and critical difference (C.D.) at 5 per cent level of probability (p=0.05) has also given where the treatment differences were significant. A simple correlation between growth parameters, i.e., plant height, primary branches and secondary branches and yield parameters, *i.e.,* seed weight per plant, 100-seed weight, haulm yield on the development of chickpea, was estimated to know the correlation between these growth and yield parameters and chickpea seed yield. The statistical analysis tool, the OPSTAT was used for correlation coefficient (r) calculation. The significance (probability) of the correlation coefficient was determined from the t-statistic at 5% and 1% probability.

Results and discussion

Growth and yield contributing characters

Effect of sowing dates

The sowing dates significantly influenced the growth parameters of chickpea recorded at various growth stages (Table 1). The sowing in the 1st fortnight of October recorded significantly greater plant height (45.53 cm) than other sowing dates . However, the lower plant height (34.87 cm) was recorded from the 2nd fortnight of November sowing. The reason for increased plant height in early sowing may be the enhanced vegetative development of the crop due to favourable weather conditions (Pezeshkpur *et al*., 2005). The number of primary (6.51) and secondary (11.46) branches were significantly maximum during the 1st fortnight of October and significantly minimum number of primary (4.97) and secondary (9.46) branches during the 2nd fortnight of November sowing. Similar

Table 1. Growth parameters of chickpea genotypes as influenced by different weather scenarios

Treatments	Plant height (cm)	Primary branches	Secondary branches	Canopy spread (cm^2) First-flower stage	Canopy spread (cm^2) At harvest
Date of sowing (D)					
D_1: 1st fortnight October	45.53	6.51	11.46	629.17	307.07
D_2: 2nd fortnight October	39.66	6.12	10.70	587.50	283.49
D_3: 1st fortnight November	36.75	5.76	10.36	549.22	254.34
D_4: 2nd fortnight November	34.87	4.97	9.46	507.20	229.91
S.Em±	0.91	0.11	0.04	3.56	5.35
C.D. (p=0.05)	3.16	0.39	0.13	12.32	18.53
Genotype (G)					
G_1: JG-11	37.38	6.89	10.28	561.30	265.62
G_2: BGD-111-1	38.17	5.79	11.38	601.49	297.78
G_3: JG-14	42.05	4.84	9.82	542.02	242.71
S.Em±	0.76	0.08	0.08	2.91	3.18
C.D. (p=0.05)	2.28	0.24	0.23	8.73	9.54
Interactions (D×G)					
D_1G_1	41.55	7.77	11.17	612.43	309.33
D_1G_2	42.30	6.40	12.51	667.20	342.71
D_1G_3	52.73	5.37	10.70	607.87	269.17
D_2G_1	38.27	7.30	10.33	573.09	271.80
D_2G_2	39.66	6.03	11.60	621.67	32260
D_2G_3	41.04	5.03	10.17	567.73	256.07
D_3G_1	35.90	6.90	10.13	547.07	250.09
D_3G_2	36.20	5.73	11.43	577.6	286.53
D_3G_3	38.16	4.63	9.50	523.00	226.40
D_4G_1	33.82	5.60	9.50	512.63	231.27
D_4G_2	34.54	5.00	9.97	539.50	239.27
D_4G_3	36.26	4.32	8.90	469.47	219.20
S.Em±	1.52	0.16	0.15	5.83	6.37
C.D. (p=0.05)	4.56	0.48	0.45	17.47	19.08

results were reported by Sharma *et al.* (1989); Mansur *et al.* (2010) and Kiran *et al.* (2015). At first flower and harvest, canopy spread was more significant in the 1st fortnight of October (629.17 and 307.07 cm^2, respectively) sowing and with the delay in sowing, canopy spread of the plant decreases. As a result, minimum canopy spread at the first flower and harvest (507.20 and 229.91 cm^2, respectively) stages was recorded in the 2nd fortnight of November.

The yield parameters of chickpea were also influenced due to various sowing dates (Table 2). The number of pods per plant was significantly maximum under the 1st fortnight of October (40.31), which was on par with the 2nd fortnight of October (38.38). The minimum number of pods (35.30) was recorded under the 2nd fortnight of November. Delay in sowing time beyond the optimum, especially in the northern dry zone of Karnataka, was found to decrease the number of pods per plant. However, the sowing dates failed to influence the number of seeds per pod and 100-seed weight. Because 100-seed weight is an inherent conservative character, which was not usually affected by environmental changes unless the change was extreme. These results were closely associated with findings of Chaitanya and Chandrika (2006) and Ahmed *et al.* (2011); they mentioned that sowing time does not differ significantly for the number of seeds per pod and 100-seed weight. The data on seed weight per plant showed a decreasing trend concerning sowing dates. Generally, early sowing was favoured by higher seed weight per plant than delayed sowing. Under the 1st fortnight of October, a significantly higher seed weight (9.3 g $plant^{-1}$) was recorded, followed by the 2nd fortnight of October (8.77 g $plant^{-1}$). However, delayed sowing in the 2nd fortnight of November recorded a significantly lower seed weight per plant (7.88 g $plant^{-1}$). The reduction in seed weight per plant under the 2nd fortnight of November is attributed to decreased pollen fertility and variation in flower to pod ratio (Kiran and Chimmad, 2018). Heat stress coincides with the reproductive phase of chickpea under delayed sowings. However, chickpea being sensitive to fluctuating temperatures, reproductive efficiency reduction impacts yield and yield associated traits.

Effect of genotypes

The genotype JG-14 recorded significantly higher plant height (42.05 cm) (Table 1). However, lower plant height (37.38 cm) was observed with the genotype JG-11. Genotypic variation in the plant height exists during the normal sown and late sown conditions, and it was significantly affected by high temperature. The cause of plant height reduction might be due to a rapid rise in temperature as well as depletion of soil moisture. The significantly higher number of primary branches (6.89) was recorded by the genotype JG-11, while JG-14 recorded the minimum (4.84) number of primary branches per plant. The higher number of secondary branches per plant was recorded by the genotype BGD-111-1 (11.38), while JG-14 was recorded a

Table 2. Yield parameters of chickpea genotypes as influenced by different weather scenarios

Treatments	No. of pods/plant	No. of seeds/pod	Seed weight/plant (g)	100 seed weight (g)
Date of sowing (D)				
D_1: 1st fortnight October	40.31	1.12	9.30	23.74
D_2: 2nd fortnight October	38.38	1.09	8.77	23.17
D_3: 1st fortnight November	38.11	1.08	8.48	22.21
D_4: 2nd fortnight November	35.30	1.03	7.88	22.15
S.Em±	0.56	0.04	0.10	0.43
C.D. (p=0.05)	1.94	NS	0.33	NS
Genotype (G)				
G_1: JG-11	39.08	1.08	9.32	22.07
G_2: BGD-111-1	38.09	1.09	8.48	22.92
G_3: JG-14	36.90	1.07	8.02	23.46
S.Em±	0.12	0.03	0.07	0.39
C.D. (p=0.05)	0.37	NS	0.20	NS
Interactions (D×G)				
D_1G_1	41.33	1.10	10.11	22.14
D_1G_2	40.13	1.20	9.11	23.97
D_1G_3	39.47	1.07	8.68	25.10
D_2G_1	39.07	1.17	9.62	22.27
D_2G_2	38.33	1.07	8.67	23.23
D_2G_3	37.75	1.03	8.03	24.01
D_3G_1	39.33	1.03	9.32	22.15
D_3G_2	38.30	1.03	8.26	22.30
D_3G_3	36.70	1.17	7.87	22.17
D_4G_1	36.60	1.03	8.21	21.72
D_4G_2	35.60	1.07	7.90	22.16
D_4G_3	33.70	1.00	7.52	22.57
S.Em±	0.25	0.07	0.13	0.78
C.D. (p=0.05)	0.74	NS	0.40	NS

NS: Not significant

minimum number of secondary branches per plant (9.81). The genotype BGD-111-1 has a greater canopy spread at first flower and harvest (601.49 and 297.78 cm^2, respectively), followed by JG-11 (561.3 and 265.62 cm^2, respectively). The lower canopy cover in JG-14 (542.02 and 242.71 cm^2, respectively) due to the erect and compact nature of genotype and also differential behaviour in branching was noticed by Chaitanya and Chandrika (2006) and Patil (2013).

The highest number of pods per plant (39.08) was recorded in JG-11 (Table 2). The lowest number of pods (36.90) were found in JG-14. The variation in the number of pods per plant was found due to the variation in branch production and genetic variations. Similar findings were also observed by Hussain *et al*. (2008). The genotypes differed significantly in respect of seed weight per plant. The higher seed weight per plant (9.32 g) was produced by JG-11, which was 9.01 per cent and 13.95 per cent higher than that of BGD-111-1 (8.48 g) and JG-14 (8.02 g). The genotypes were failed to influence the number of seeds per pod and 100-seed weight.

Interaction effect

The genotype JG-14 sown in 1st fortnight of October recorded a greater plant height (52.73 cm), followed by the genotype BGD 111-1 sown in 1st fortnight of October (42.3 cm) and the genotype JG-14 sown in 2nd fortnight of October (41.04 cm) (Table 1). The lower plant height (33.82 cm) was recorded from the interaction of the 2nd fortnight of November with the genotype JG-11. The reason for increased plant height in early sowing may be the enhanced vegetative development of crops due to favourable weather conditions. Similar results were reported by Singh *et al*. (2004); Mahse *et al*. (2006) and Kabir *et al*. (2009). The genotype JG-11 sown in the 1st fortnight of October recorded a significantly higher number of primary branches (7.77).

In comparison, JG-14 under the 2nd fortnight of November was recorded with a significantly minimum number of primary branches (4.32), which was on par with the genotype JG-14 sown in the 1st fortnight of November(4.63). The genotype BGD-111-1 sown in the 1st fortnight of October recorded a significantly higher number (12.51) of secondary branches. In contrast, the genotype JG-14 sown in the 2nd fortnight of November recorded a significantly minimum number of secondary branches (8.9). The maximum canopy spread was found in BGD-111-1 under the 1st fortnight of October (667.20 and 342.71, respectively), and a significantly minimum was recorded at 2nd fortnight of November by JG-14 genotype at both first flower (469.47) and full maturity stage (219.20). It was reported earlier that chickpea variety with great canopy growth used more water rapidly until the soil profile was depleted and water deficit before the first flower decreased the canopy cover. The canopy spread showed a significant positive correlation with seed yield per hectare.

The higher number of pods per plant was recorded from the genotype JG-11 (Table 2) under the 1st fortnight of October sowing (41.33), which was statistically followed by the genotype

BGD-111-1 (40.13) under the 1st fortnight of October. The lowest pods per plant were found in JG-14 (33.7) under the 2nd fortnight of November, which indicated that in delayed sowing conditions, all the genotypes showed poor pod formation. Prasad *et al.* (2012) reported that sowing dates and genotypes interaction was highly significant for seed yield. The seed weight per plant of the studied chickpea genotype was found significant for the interaction effect. The highest seed weight per plant was in JG-11 under the 1st fortnight of October (10.11 g) and the lowest seed weight per plant was in JG-14 under the 2nd fortnight of November (7.52 g), which was at par with BGD-111-1 under the 2nd fortnight of November (7.9 g). Similar findings were also reported by Kabir *et al.* (2009) and Kiran *et al.* (2015). They observed that sowing at 44th MSW temperature regimes produces higher yield under maximum and minimum temperature compared to other temperature regimes and the genotypes JG-11 recorded significantly higher yield (28.32 q ha^{-1}) due to higher primary branches (9.1), took less number of days to flower initiation (156) and recorded higher yield. But, the genotype JG-14 is thermotolerant and recorded optimum yield under the 44th MSW temperature regime compared to other genotypes.

Yield and economics

Effect of sowing dates

Different sowing dates had a profound influence on the grain yield. Significantly superior grain yield (1913 kg ha^{-1}) was obtained when the crop was sown on the 1st fortnight of October than later sowing date of 2nd fortnight of October (1775 kg ha^{-1}), 1st fortnight of November (1622 kg ha^{-1}) and 2nd fortnight of November (1512 kg ha^{-1}) and we observed that with each consecutive 15 days delay in sowing from 1st fortnight of October caused a reduction in seed yield by 15.20 per cent in the 1st fortnight of November (1622 kg ha^{-1}) and 20.96 per cent in the 2nd fortnight of November (1512 kg ha^{-1}) sowings (Table 3). The decrease in seed yield per hectare with delay in sowing occurred mainly due to the lower biomass build-up, less translocation of photosynthates towards reproductive parts and the overall shorter life span and reduced seed filling time and sink strength (pods number). High temperatures and long days accelerated rapid maturity and lowered the seed yield in delayed sowing (Mondal *et al.,* 2011). The haulm yield (kg ha^{-1}) was also significantly higher with early sowing in the 1st fortnight of October and the reduction in haulm yield with delay in sowing in the 2nd fortnight of November occurred mainly due to the decrease in growth attributes in terms of plant height and the number of branches per plant. The decrease in the haulm yield was a tune of 10.12 per cent and 4.94 per cent with the delayed sowings on the 2nd fortnight of November and the 1st fortnight of November, respectively, over the 1st fortnight of October sowing. The higher harvest index of 45.12 per cent was recorded in the 1st fortnight of October, which generally decreased with successive delays in sowings. The lowest harvest index values were recorded in the 2nd fortnight of

Table 3. Yield and economics of chickpea genotypes as influenced by different weather scenarios

Treatments	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio (₹ ha^{-1})
Date of sowing (D)							
D_1: 1st fortnight October	1913	2304	45.12	27873	86,105	58,232	3.09
D_2: 2nd fortnight October	1775	2249	43.92	27873	79,861	51,988	2.87
D_3: 1st fortnight November	1622	2190	42.30	27873	72,982	45,109	2.62
D_4: 2nd fortnight November	1512	2067	42.27	27123	68,045	40,922	2.51
S.Em±	65	26	0.54	-	-	-	-
C.D. (p=0.05)	227	90	1.87	-	-	-	-
Genotype (G)							
G_1: JG-11	1848	2129	46.26	27686	83,148	55,463	3.00
G_2: BGD-111-1	1748	2206	43.93	27686	78,667	50,981	2.84
G_3: JG-14	1521	2273	40.02	27686	68,430	40,744	2.48
S.Em±	39	18	0.30	-	-	-	-
C.D. (p=0.05)	118	53	0.89	-	-	-	-
Interactions (D×G)							
D_1G_1	2168	2247	49.11	27873	97,572	69,699	3.51
D_1G_2	2017	2352	46.09	27873	90,749	62,876	3.25
D_1G_3	1555	2313	40.15	27873	69,995	42,122	2.52
D_2G_1	1964	2205	47.11	27873	88,395	60,522	3.17
D_2G_2	1827	2267	44.40	27873	82,195	54,322	2.95
D_2G_3	1533	2275	40.26	27873	68,993	41,120	2.48
D_3G_1	1722	2085	45.09	27873	77,509	49,636	2.77
D_3G_2	1645	2211	42.23	27873	74,030	46,157	2.66
D_3G_3	1498	2274	39.50	27873	67,409	39,536	2.42
D_4G_1	1536	1978	43.71	27123	69,117	41,994	2.55
D_4G_2	1504	1993	43.01	27123	67,694	40,571	2.50
D_4G_3	1496	2230	40.17	27123	67,324	40,201	2.49
S.Em±	79	36	0.59	-	3,544	3,413	0.13
C.D. (p=0.05)	236	107	1.77	-	10,626	10,232	0.38

Table 4. Correlation between growth and yield attributing characters with seed yield of chickpea

	Seed yield	Haulm yield	Seed weight/plant	100 seed weight	Plant height	Primary branches	Secondary branches
Seed yield	1						
Haulm yield	0.33^{NS}	1					
Seed weight/plant	0.89**	0.17^{NS}	1				
100 seed weight	-0.02^{NS}	0.66*	-0.01^{NS}	1			
Plant height	0.17^{NS}	0.68*	0.27^{NS}	0.86**	1		
Primary branches	0.89**	0.03^{NS}	0.97**	-0.17^{NS}	0.08^{NS}	1	
Secondary branches	0.67*	0.49^{NS}	0.53^{NS}	0.40^{NS}	0.39^{NS}	0.52^{NS}	1

*Significant at 5% level of significance; ** Significant at 1% level of significance; NS: Not significant

November (42.27 %). A higher harvest index in earlier sown crops is due to more grains per plant and better translocation of photosynthates to reproductive parts. Similarly, Kabir *et al.* (2009) obtained the maximum harvest index was recorded on 22nd November (49.0%) sowing , which was statistically at par with 2nd December (44.0%) and 12 December (43.0%) sowing, and the lowest harvest index was observed on 1st January (34.0%) sowing and also Ali *et al.* (2018) found that the BARI Chola-9 sown on 20th November produced maximum harvest index than later sowings.

The chickpea sowing at 1st fortnight of October performed better than other sowing windows, which recorded significantly higher gross returns (₹ 86,105 ha^{-1}), net returns (₹ 58,232 ha^{-1}) and BC ratio (3.09). The gross and net returns were reduced by 20.97 per cent and 27.51 per cent in late sowing (2nd fortnight of November) compared to early sowing (1st fortnight of October) of chickpea.

Effect of genotypes

There was a statistically significant variation in seed yield due to genotypes. Among the genotypes, JG-11 recorded a significantly higher seed yield (1848 kg ha^{-1}) with an increase of 5.41 per cent and 17.7 per cent over the genotype BGD-111-1 (1748 kg ha^{-1}) and JG-14 (1521 kg ha^{-1}). Among the yield components, the number of pods per plant, 100-seeds weight and seed yield per plant were more closely related to seed yield. This increase in yield was mainly due to a significantly higher number of branches and canopy spread in JG-11 (Patil, 2013) and total dry matter production (Patil *et al.,* 2021) at all crop growth stages. Chaitanya and Chandrika (2006) and Shamsi (2010) reported the varietal differences in the seed yield of chickpea. The haulm yield (kg ha^{-1}) showed significant variation due to the genotypes (Table 3), where significantly the higher haulm yield (2273 kg ha^{-1}) was found in JG-14 while JG-11 gave a lower haulm yield (2129 kg ha^{-1}). This result indicated that JG-14 produced a higher total dry matter than JG-11, which ultimately resulted in higher production of haulm yield. The harvest index was found higher in JG-11 (46.26 %). The lowest harvest index (40.02 %) was found in JG-14. Kumari *et al.* (2012) also found variation in the harvest index with the genotypes. However, a significant variation in net returns, gross returns and BC ratio was observed due to cultivars. Among all the genotypes, JG-11 recorded significantly higher gross returns (₹ 83148 ha^{-1}), net returns (₹ 55463 ha^{-1}) and BC ratio (3.00) than that of BGD-111-1 and JG-14.

Interaction effect

The sowing during the 1st fortnight of October with JG-11 genotype (2168 kg ha^{-1}) recorded a significantly higher seed yield, which was at par with BGD-111-1 (2017 kg ha^{-1}) under the 1st fortnight of October and JG-11 (1964 kg ha^{-1}) under the 2nd fortnight of October (Table 3). The genotypes JG-11 and BGD-111-1 perform better when sowing in the 1st fortnight of October. This may be due to variables like primary branches, number of pods per plant, which facilitated higher grain weight. Genotypes are different in their yield potential depending on many complex physiological processes taking place in different parts of the plant controlled by both the plant's genetic makeup and the environment (Tigga *et al*., 2017). A significant interaction was found due to sowing time and genotype, which influenced the plant height, the number of pods per plant, pod weight, grain and haulm yield indicating the genotype performed better at different planting periods (Egbe *et al*., 2013). The highest harvest index was recorded from the genotype JG-11 under the 1st fortnight of October (49.11%), followed by the JG-11 genotype under the 2nd fortnight of October (47.11%), BGD-111-1 genotype under the 1st fortnight of October (46.09). The harvest index was decreased as the sowing time varies irrespective of genotypes. The lowest harvest index (39.5%) was recorded from JG-14 under the 1st fortnight of November sowing. The results are in agreement with Alamin and Abdalla (2020), who observed that the harvest index varied significantly with the combination of sowing dates and genotypes.The increased harvest index resulted in the increased crop yield, probably due to more partitioning of dry matter to reproductive parts. The overall poor yield of the chickpea genotypes might result from the higher evaporation rate and depletion of soil moisture over time as there was no rainfall during the growing season (Kabir *et al*., 2009). Among the interactions, the JG-11 genotype sown during the 1st fortnight of October recorded significantly higher gross returns (₹ 97,572 ha^{-1}), net returns (₹ 69,699 ha^{-1}) and BC ratio (3.51).

Correlation between growth and yield attributing characters with seed yield

The result given in Table 4 indicated that the seed yield has been non significantly negative correlated with 100- seed weight (r=0.02), and it was positively correlated with seed weight per plant (r=0.89), primary branches (r=0.89), secondary branches (r=0.67), plant height (r=0.17) and haulm yield (r=0.33).

Conclusion

Based on the results, it could be concluded that the JG-11 and BGD-111-1 genotype performed better in early sown conditions (1st fortnight of October and 2nd fortnight of October), whereas for the delayed sowing at the 2nd fortnight of November, the genotype JG-14 was performed better than JG-11 and BGD-111-1. Therefore, we summarize that the chickpea genotype JG-14 is heat tolerant and well suited for delayed sowing upto the 2nd fortnight of November.

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