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Effect of Sowing Time Induced Weather Regimes on Growth and Yield of Chickpea under Irrigated Condition

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

A field experiment conducted to study the effect to find out optimum time of sowing and suitable cultivar for sustainable chickpea production in the region. The study was undertaken to find yield variation with extended sowing date. Five different sowing dates viz., 30th October (44 MW), 15th November (46 MW), 30th November (48 MW), 15th December (50 MW) and 30th December (52 MW) with two chickpea cultivars viz., JAKI 9218 and Vijay were studied. The varieties selected dominated chickpea cultivation in the region. The results revealed that crop sown on 30th October produced higher but statistically equivalent number of pods/plant, number of seeds/plant and grain yield as compared to 15th November sowing. Crop sown on 30th October accumulated higher Growing Degree Days (GDD: 2012 day^{0}C) and Heliothermal Units (HTU: 13515 ^{0}C day hr) closely followed by 15th November sown crop (GDD; 1975-day ^{0}C, HTU: 13130 ^{0}C day hr) during cropping period from vegetative to pod-seed development phase. The number of pods/plant, weight of seed/plant and test weight was higher in cultivar JAKI 9218 than Vijay. Maximum GDD (1888 ^{0}C day) and HTU (12706 ^{0}C day hr) were accumulated by cultivar JAKI 9218 closely followed by Vijay (GDD: 1856 ^{0}C day; HTU: 12449 ^{0}C day hr).

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1. INTRODUCTION

Chickpea is the dominant crop of *rabi* season usually grown under stored residual moisture during first fortnight of October possibly in mungbean/urdbean based crop sequence. On the contrary, chickpea which is largely grown in soybean based crop sequence cannot be seeded during first fortnight of October missing the potential advantage of residual soil moisture under rainfed cultivation many times causing suboptimal initial plant stand. Therefore, sowing time plays an important role in optimal utilization of residual soil profile moisture [1]. In addition to this sowing executed after first fortnight of October mostly requires pre-sowing irrigation for maintaining optimal initial plant stand. By and large variations in the agricultural production are mostly attributed to the effect of seasonal weather conditions on plant growth [2].

Chickpea can thrive under good moisture conditions with day time temperature between 21 to 29^{0}C and night time temperature near 20^{0}C. Chickpea is sensitive to chilling temperatures (<10 ^{0}C), especially at its reproductive phase leading to floral abortion. The exact causes of reproductive failures are not fully understood [3]. According to Wery et al. [4], critical temperature during the reproductive phase, which includes flowering, filling and enlargement of seeds of chickpea, plays an important role in productivity. “Length of crop maturity depends on available heat units and moisture, but is usually in the range of 95-1l0 days depending upon type of chickpea genotypes [5]. Intergovernmental Panel on Climate Change has projected 1.6 to 3.8 °C increase in global average air temperature at the critical stage which may cause considerable yield losses [6]. Keeping this in view, an investigation was undertaken to study the response of different dates of sowing in relation to different cultivars so as to provide wider sowing period to the farmer for the sowing of chickpea especially in soybean based crop sequence.

2. MATERIALS AND METHODS

A field experiment was conducted at AICRP on Chickpea, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (22^0 42' N latitude, 72^0 02' E longitude and at an altitude of 307.42 m above MSL) in Vidarbha region of Maharashtra, in factorial randomized block design with 10 treatments comprising combinations of 5 dates of sowing *viz.*, 30th October (44 MW) sowing (considered as normal growing condition), 15th November (46 MW) and 30th November (48 MW) and 15th December (50 MW) and 30th December (52 MW) and two cultivars *viz.*, Vijay and JAKI 9218, replicated three times. The soil of experimental field was Inceptisol, almost neutral in reaction (pH 8.07), low in organic carbon (0.45%), medium in available phosphorus (18.89 kg ha^{-1}) and medium in available potassium (344 kg ha^{-1}). Chickpea crop was sown at row spacing of 30 cm. Recommended basal dose of nitrogen (25 kg N ha^{-1}), phosphorus (50 kg P_2O_5 ha^{-1}) and potassium (30 K_2O kg ha^{-1}) was applied through urea, di-ammonium phosphate and muriate of potash. Meteorological data *viz,* rainfall, relative humidity, maximum and minimum temperature, bright sunshine hrs and day length were recorded from Agro-meteorological observatory of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, India.

The Agro-meteorological indices growing degree days (GDD), heliothermal units (HTU), were calculated using following formula:

GDD= (Max. temperature + Min. temperature / 2) -- Threshhold temperature

Threshold temperature of 5°C was considered for chickpea crop [7].

Heat unit concept has been applied to correlate phenological development in crop. The summation of daily mean temperature for days required to a phenophase namely, emergence, vegetative, flowering, pod to seed development were considered for growing degree days with base temperature (T_b) of 5^{0}C. It is based on the concept that real time to attain a phenological stage is linearly related to temperature in the range between base temperature (T_b) and optimum temperature [10]. The accumulated Heliothermal Unit (HTU) for each phenophase was determined by the following formula:

Accumulated HTU (°C day hr) = n Σ [(Accumulated GDD) x mean bright sunshine hours)]

3. RESULTS AND DISCUSSION

3.1 Seed Yield

The results indicated that the significantly higher ancillary parameters like number of pods/plant, grain weight/plant and grain yield (1913 kg/ha) were obtained with the crop sown on 30th October which was statistically on par with 15th November sowing, but significantly higher than recorded in the late sowing dates (Table 1). It might be due to higher GDD and HTU accumulated to attain physiological maturity phase in these sowing dates (Tables 3 & 4). Favourable weather conditions for growth and development of the 30th October and 15th November sown crop resulted in higher dry matter accumulation. The reduction in seed yield continues with further delayed sowing (30th November, 15th December and 30th December) which was due to the shorter reproductive period and the reduction in seed yield perhaps due to unfavourable temperature conditions during reproductive period. The detrimental effect of heat at a later stage of crop development in delayed sowing had an adverse effect on grain yield. Wardlaw and Wringley [12] reported 3 to 4% decrease in grain yield for each 1°C rise in ambient temperature above 15°C during grain filling. The interaction effect between date of sowing and cultivars was found to be significant (Table 1a) and cultivar sown at 30th October showed superiority over remaining sowing dates except 15th November sowing with respect to grain yield of chickpea. This indicated that sowing of chickpea can be extended up to 15th November without any significant loss in grain yield. In terms of economics significantly higher gross returns, net returns and BCR were recorded with 30th October and 15th November sown chickpea over further delayed sowings.

3.2 Crop Phenology

The calendar for different phenophases of chickpea observed during the experimentation period revealed (Table 1) that the crop availed maximum number of days for vegetative phase compared to the completion of other phases in all dates of sowing. The number of days required to attain different phenological stages decreased with delay in sowing from 30th October (44 MW) to 30th December (52 MW). The crop sown early (44 MW) took 101 days from sowing to maturity, while late sown crop (52 MW) took 85 days for maturity. Delay in sowing (30th November, 15th December and 30th December) required lesser number of days as compared to early sowing for vegetative, flowering and pod-seed development phases. The number of days taken from sowing to pod-seed development was highest in early sown crop and decreased consistently with subsequent sowing. During late sowing, the duration of crop growth decreased because of forced maturity due to high temperatures. The crop duration reduced with delay in sowing on account of shorter vegetative and reproductive phases. It is well known that shorter days and lower temperature under delayed sowing in the initial stages of crop growth reduces photosynthesis and other physiological activities of the plant". (24) The cultivar JAKI 9218 recorded longest vegetative period (37) over Vijay (35). The cultivar Vijay flowered earlier (44) in comparison to JAKI 9218 (46) cultivar. The number of days required to complete each phenophase with cultivars did not vary much, the cultivar JAKI 9218 showed more days to pod and seed development (95) compared to Vijay (93).

3.3 Effect of Temperature

Mean temperatures prevailed during vegetative and reproductive stage are presented in (Table 3). Data shows that chickpea crop sown under different sowing dates got exposed to various thermal regimes during vegetative and reproductive phase of the crop. It was noted that 30th October and 15th November sown crop experienced higher mean temperature during vegetative phase and further delayed sowing showed decreased T_{max} and T_{min}. However, during reproductive phase, later sowing dates i.e., 30th November and 15th December recorded higher T_{max} and however no change with T_{min} was observed excepting at 30th December where both T_{max} and T_{min} increased as compared to early sowing dates (30th October and 15th November). During pod to seed development phase mean T_{max} of 29.3^{0}C and 30.3^{0}C and, mean T_{min} of 13.3^{0}C and 14.3^{0}C were recorded with October 30th (44 MW) and November 15th (46 MW) sown chickpea, respectively. Sowing on 15th November onwards decreased the days to pod to seed development, however with increased $T_{max.}$ Devasirvatham [13] reported that sowing time may vary in different locations depending on the temperature experienced at different crop developmental stages. Temperature, therefore the most important for growth that governs yield and high temperature during reproductive phase of chickpea is a major cause of yield loss. Suneeta Patra et al. [14] observed that the performance of high yielding chickpea under different temperature condition revealed that 25 to 30^{0}C temperature was optimum for better seed yield in chickpea. Similar results are obtained from the present study also.

Table 1. Effect of sowing dates and cultivars of chickpea on yield and economics

Treatment	Grain yield (kg/ha)				% decrease in yield	COC (Rs/ha)	GMR (Rs/ha)	NMR (Rs/ha)	BCR
	2011-12	2012-13	2013-14	Pooled					
Factor A. Sowing date									
30 Oct	2315	1846	1579	1913	--	24307	60748	36423	2.50
15 Nov	2267	1810	1586	1887	1.36	24322	59923	35606	2.46
30 Nov	1428	1097	905	1143	40.25	23947	36301	12346	1.52
15 Dec	837	667	1180	895	53.21	24777	28406	3630	1.15
30 Dec	520	415	847	594	68.95	24117	18860	-5254	0.78
CD at 5%	163	170	190	80	--	--	1990	1990	--
Factor B. Cultivar									
Vijay	1400	1100	1211	1237	--	24252	39275	15013	1.62
JAKI-9218	1547	1234	1227	1336	--	24335	42418	18087	1.74
CD at 5%	120.68	NS	NS	NS	--	--	NS	NS	--
Interaction	251	228	225	113	--	--	--	--	--

Table 1 a. Interaction effect of date of sowing and cultivar on grain yield of chickpea

Date of sowing / Cultivars	30 October	15 November	30 November	15 December	30 December	Mean
Vijay	1771	1744	1060	864	745	1237
JAKI-9218	2055	2031	1226	925	444	1336
Mean	1913	1887	1143	895	594	
CD at 5%	113					

(Pooled of 3 years); (It indicates significant difference at 15 Nov between the varieties)

Table 2. Effect of sowing dates and cultivars of chickpea on yield attributes

Treatment	Plant height (cm)	No. of branches /plant	No. of pods/ plant	Weight of grain /plant (g)	100-grain weight (g)	Harvest Index (%)
Factor A. Sowing date						
30 Oct	44.26	12.17	51.63	6.93	19.72	42.64
15 Nov	43.03	12.20	51.43	6.80	19.52	41.91
30 Nov	39.28	10.12	40.73	4.47	19.11	38.86
15 Dec	34.33	8.07	37.43	3.70	18.51	33.16
30 Dec	31.68	7.19	22.10	2.73	17.24	32.46
CD at 5%	1.87	0.36	1.83	0.32	0.47	4.73
Factor B. Cultivar						
Vijay	37.77	19.30	29.30	16.67	11.00	37.77
JAKI-9218	39.10	16.99	30.90	17.93	17.00	39.10
CD at 5%	1.90	0.40	1.90	0.39	0.50	4.80

(Mean of 3 years)

3.4 Growing Degree Days (GDD)

The number of accumulated growing degree days required for attaining different phenophases under different sowing dates and chickpea cultivars are presented (Table 4). The heat unit or GDD was proposed to explain the relationship between growth duration and temperature. This concept assumes a direct and linear relationship between growth and temperature [7]. The accumulated heat units (GDD) to reach various growth stages varied among the sowing dates. Heat units requirement for various phenological stages from vegetative to pod-seed development decreased with successive delay in sowing. The early sown crop on 30th October (44 MW) utilized maximum heat units followed by 15th November (46 MW) sowing for attaining various

Table 3. Effect of mean T_{max}, T_{min}, accumulated GDD (^{0}C day) and HTU (^{0}C day hr) for days to vegetative, days to 50% flowering, days to pod-grain development phase (Mean of 3 years)

Treatment	Emergence					Days to vegetative phase					Days to 50% flowering phase					Days for pod to grain development phase				
	Days	T_{max}	T_{min}	GDD	HTU	Days	T_{max}	T_{min}	GDD	HTU	Days	T_{max}	T_{min}	GDD	HTU	Days	T_{max}	T_{min}	GDD	HTU
Factor A. Sowing dates																				
D_1-30 October	7	32.3	16.3	165	1068	40.5	31.3	14.3	866	6122	49.5	30.1	11.5	1105	7961	101.7	29.3	13.3	2012	13515
D_2-15 November	7	28.1	11.9	155	1132	40.5	30.4	13.2	826	6068	48.3	29.0	12.1	1040	7230	100.7	30.3	14.3	1975	13130
D_3-30 November	8	28.3	14.7	146	1197	36.0	29.6	12.2	749	5127	46.0	27.8	10.7	959	6427	94.7	31.5	14.3	1923	12856
D_4-15 December	8	26.2	11.0	157	1136	32.5	28.8	12.1	606	4046	42.5	29.2	14.0	889	5599	89.7	32.2	14.7	1727	11649
D_5-30 December	8	26.9	14.7	168	1075	32.5	28.7	12.8	622	3610	42.5	30.7	13.5	899	5318	85.8	34.0	16.5	1725	11737
Factor B. Cultivars																				
V_1-Vijay	8	30.6	13.7	162	1074	35.6	29.7	12.9	719	4893	44.8	29.4	12.4	958	6360	93.3	31.3	14.6	1856	12449
V_2-JAKI 9218	7	26.1	13.7	162	1074	37.2	29.8	12.9	749	5096	46.7	29.3	12.4	999	6654	95.7	31.6	14.6	1888	12706

phenological stages and hence availed higher total heat units (GDD: 2012 and 1975 ^{0}C day) for pod to seed development phase. With progressive decrease in the number of days for reaching maturity, last sowing on 30th December (52 MW) availed the minimum GDD (1725 ^{0}C day). This describes clearly the effect of temperature on phenological stage. Every crop needs a specific amount of GDD to enter its reproductive phase from vegetative phase. Early sowing resulted in absorbing sufficient GDD in relatively more time. While late sown crop experienced higher temperature during later stage in less time. The shortened crop growth period (85-94 days) under late sown condition was due to the sudden drop in temperature during early vegetative phase and sharp rise in temperature during pod-seed development phase which hastened reproductive phase and maturity (Table 3). Pandey et al. [9] also reported lower consumption of heat units under delayed sowing. Amid the cultivars JAKI-9218 utilized maximum heat units (GDD: 1888 ^{0}C days) closely followed by cultivar Vijay (GDD: 1856 days ^{0}C). The differential behaviors to heat unit requirements and days required to reach the various phenological phases could be ascribed solely to their genetic makeup.

3.5 Heliothermal Units (HTU)

Heliothermal units (HTU) required to attain different phonological stages of chickpea are shown in Table 4. Early sown crop on 30th October (44 MW) and 15th November (46 MW) accumulated 13515 and 13130 °C days hr heliothermal units, respectively, from sowing to pod-seed development phase while for late sowing on 30th November (12856 ^{0}C day hr), 15th December (11649 ^{0}C day) and 30th December (11737 ^{0}C day) HTU decreased. HTU decreased with delay in sowing as the late sown crop suffered from high temperature later in the growing season. Late sowing compelled the plants to complete their life cycle with a short period of time resulting in decreased HTU. It was reported that HTU for different phenological stages decreased with delay in sowing as reported by Masoni et al. [15]. Among cultivars JAKI 9218 recorded more HTU (12706 ^{0}C day hr) over Vijay (12449 ^{0}C day hr). Sowing on 30th October and 15th November was found to be most suitable in harnessing the prevailing weather conditions in the region.

3.6 Correlation between Agro-Climatic Indices and Yield

The performance of high yielding chickpea under different temperature condition revealed that 25 to 30^{0}C temperature was optimum for better seed yield in chickpea. Though there was no perfect association between T_{max} and T_{min} at 50% flowering with yield, but strong linear regression was obtained between yield, and T_{max} at vegetative stage (R^2=0.761), T_{min} at pod to seed development phase (R^2=0.472), GDD and HTU values at vegetative phase (R^2=0.544; 0.496), 50% flowering (R^2=0.603; 0.643) and pod to seed development phase (R^2=0.762; 0.519).

4. CONCLUSION

Under irrigated condition sowing of *desi* chickpea cultivar (Vijay and JAKI 9218) can be extend up to 15th November without significant loss in grain yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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