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Effect of Climate Change on Productivity and Profitability of Chickpea Cultivars under Various Dates of Sowing in Rice Fallows

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Authors' contributions

This work was carried out in collaboration among all authors. Author MR and PM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KCS and TRM managed the analyses of the study. Authors NM, SKS and ST managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out during rabi season of three consecutive years of 2017-18, 2018-19 and 2019-20 at Field Experimental Block, RRTTS, Keonjhar, Odisha to study the effect of heat and thermal unit use of chickpea cultivars under various dates of sowing. The experiment was laid out in a Split plot Design with twelve treatments combinations, four dates of sowing (1st November, 15th November, 30th November and 15th December) kept in main plots, and three varieties of chickpea (JAKI - 9218, JG-14, JG-16) in sub plots with three replications. The results of the experiments revealed that chickpea sown on 15th November registered the maximum mean grain yield of 1040 kg/ha, fetched maximum mean net return of Rs. 26895/- per ha with B:C of 1.89. Growing chickpea variety JAKI 9218 fetched maximum mean net return of Rs. 27850/- per ha with B:C of 1.67. The maximum GDD to reach maturity (2316.3 days) and heliothermal unit was recorded on 1st November while minimum GDD of 1860.5 days was observed on 15th December. Among

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cultivars, JAKI 9218 had higher thermal unit requirement. Photothermal unit from date of emergence to maturity stage accounted higher with 1st November sowing, while lowest PTU were observed with the crop sown on 15th December during both all the years. Variety JAKI 9218 accounted non-significantly higher PTU than JG14 and JG 16 at all the phenological stages of the crop during all the years.

Keywords: Chickpea; sowing dates; climate change; GDD; helio thermal unit; photo thermal unit.

1. INTRODUCTION

In India Chickpea (*Cicer arietinum* L.) is grown as a winter crop during post-monsoon as it requires cool and dry weather conditions for optimum growth. It is grown in area of 9.4 million hectare with annual production of 10.13 million tones and average productivity 10.73 q/ha [1]. In Odisha chickpea is grown in an area of 60 lakh hectares with annual production of 50 thousand tones and average productivity 8.3 q/ha [2]

The selection of appropriate variety with respect to date of sowing and expected temperature rise during the crop growth period is necessary to get an optimum yield under high-temperature stress conditions [3]. Among the climatic parameters temperature, rainfall and light are most important for optimum crop growth and development and thereby it exploits the potentiality of a crop. Among these parameters, temperature is the most important as it plays a vital role in almost all biological processes of crop plants. The growth and yield of chickpea as influenced by different time of sowing as well as temperature has been studied under field conditions through the accumulated heat units by [4].

Photoperiod and temperature are the most important factors affecting chickpea productivity [5]. Plants have a definite temperature requirement before they attain certain phenological stages. High temperature, moisture stress and low humidity during flowering damage the flowering and the foliage, desiccation of pollen and interfere with the pollination resulting in poor grain formation [6]. Higher temperature about 30-35°C has a detrimental effect on the growth of chickpea. During crop growing season, suboptimal photo thermal requirement are known to have profound effect on productivity. Sowing time of chickpea governs the crop phonological development and economic yield, therefore it is an important non-monetary input which has been recognized as the most critical factor in influencing the yield of chickpea [7,8]. To maximize the yield of chickpea the phenology of the cultivar should match well to the resources and constraints of the production environment [9]. The environmental conditions during the reproductive phase have a major impact on grain yield therefore the flowering time is very important. The onset of flowering often determines the entire crop duration [10]. The crop sown at the optimum time has longer growth duration which consequently provides an opportunity to accumulate more grain yield as compared to late sowing and henceforth manifested in higher grain and biological yield [11,12,13,14]. Delay in sowing results in a lower yield, the growth is hampered and the seed development period is shortened [15,16,17]. Studies have shown that early winter sowing (mid-October to mid-November) is the optimum period. Late sowing, after November 18 reduced yield by 28 percent for every 10 days interval delay [18].

The thermal units approach is widely used for quantifying the thermal relation of crops [19] and it has been further modified to include photothermal units and heliothermal units [12]. This photothermal unit concept provides a reliable index for the progress of the crop that can be used to predict the yield of any crop. This concept has been used by several workers to compare the performance of different varieties at several dates in different crops [20,21] . Growing Degree Days and Heat Use Efficiency based on temperature are very useful in predicting the growth and yield of chickpea. Another important aspect is the utilization of heat in terms of dry matter. The efficiency of conversion of heat energy into dry matter depends upon genetic factors, sowing time and type of crop [12]. However, the growing degree day (GDD) concept may mislead as to the minimum and maximum temperatures are being considered for calculating GDD which are the events occurring at a particular point of time in a day. As the planting is delayed beyond optimum date/ideal time the chickpea yields go down.

Information from photothermal units can be used to predict the yield of any crop. According to [22] timely and early sowing allowed the higher accumulation of heat sum and photothermal units which in turn resulted in better growth and yield of the crop. The optimum sowing date results in flowering of the crop when the risk of cold temperatures is low, as extremely low temperatures can kill chickpea plants [23]. Too early sowing can expose the crop to more rain events which can increase the risk of Ascochyta disease, increase in crop biomass, lodging, and also soil moisture deficit during grain fill. Late sowing can result in shorter plants due to the harvesting difficulties [24]. Crops require specific thermal time as they go through different growth stages, and these have to do with mean ambient temperatures [25,26,27,28].

Optimum sowing time of chickpea varies from one cultivar to another and also from one region to another due to the variation of agro-ecological conditions [29,30]. So a field experiment was conducted at RRTTS, Keonjhar, Odisha to study the productivity and profitability of Chickpea cultivars under various dates of sowing, the effect of Growing Degree Days (GDD) on dry matter production, heat use efficiency and yield response of chickpea genotypes to Helio-Thermal Units (HTU).

2. MATERIALS AND METHODS

A field experiment was carried out during *rabi* season of three consecutive years of 2017-18, 2018-19 and 2019-20 on loamy sand soil at Field Experimental Block, Regional Research and Technology Transfer Station, Keonjhar, Odisha state (India). Geographically, the experimental site is situated at 14°.0' to 14°.1' N latitude and 75°.40' to 75°.42' E longitude at an altitude of 650 meters above mean sea level. The normal rainfall of experimental site was 1331.2 mm (75 rainy days) with maximum temperature being recorded in the month of April (39.2°C) and minimum temperature (9.3°C) during January (Table 1). The soil of the experimental field was having pH 8, electrical conductivity-0.15dS/m, organic carbon (0.50%) and N(107 kg/ha) and K (78 kg/ ha) status was low whereas P (21 kg/ha) status was medium.. The experiment was laid out in a Split plot Design with twelve treatments combinations, four dates of sowing (1st November, 15th November, 30th November and 15th December) kept in main plots, and three varieties of chickpea (JAKI - 9218, JG-14, JG-16) in sub plots with three replications. The crop was sown with a row spacing of 30 cm as per the dates of sowings. N and P_2O_5 were applied through urea and single SSP and given as basal just below the seed at the time of sowing. All recommended package of practices were followed for cultivation.

Growing degree days at different phenological stages were calculated by summation of daily mean temperature above base temperature for a corresponding period from sowing, as suggested by [31] taking a base temperature of 5°C

$$GDD = \Sigma \frac{(Tmax + T\,min)}{2} - T\,base$$

Where, Tmax, Tmin and are maximum, minimum temperature.

T base is base temperature was taken as 100 C.

Heat use efficiency was calculated as:

$$HUE = \frac{Total\ dry\ matter\ (g\ m2)}{GDD}$$

The index helio thermal unit (HTU) serves to be effective in taking into account and expressing the effect of varying ambient temperature on the duration between the phenological events for comparing the crop response to the ambient temperature between phenological stages. Helio thermal unit was calculated using the formula given by [32].

HTU = GDD x Cumulative Sun Shine Hours (from sowing to physiological maturity)

Helio-thermal use efficiency was calculated by using the formula:

$$HTUE\ (kg/HTU) = \frac{Yield\ (kg)}{HTU}$$

Thermal indices during different phenophases of chickpea as affected by various treatments

3. RESULTS AND DISCUSSION

Data pertaining to plant height, number of branches per plant, number of pods per plant and number of seeds per pod as influenced by sowing time and cultivars are presented in Table 2. Both early and delay sowing affected the chickpea plant growth, yield and grain quality. Sowing chickpea on15th of November resulted in significantly taller plants as compared to delayed sowing. Significantly taller plants were recorded in JAKI 9218 than all other cultivars.

Table 1. Monthly meteorological data for the year 2017, 2018 and 2019 against normal at RRTTS, Keonjhar, Odisha

Month	Total Rainfall (mm)				Mean max. temp (°C)				Mean min temp (°C)				Mean RH max (%)				Mean RH min (%)				Cumulative BSH		
	N	2017	2018	2019	N	2017	2018	2019	N	2017	2018	2019	N	2017	2018	2019	N	2017	2018	2019	2017	2018	2019
Jan	30.4	0	0	0.1	26.6	26.4	26.5	26.5	11.8	11.3	9.3	10.1	75.6	83.5	75.7	64.6	47.8	45.3	19.7	53.6	36.4	37.7	38.2
Feb	20.6	0	0	61.7	29.6	31.4	31.3	31.3	15.0	15.2	15.8	14.4	68.3	77.6	65.3	66.3	42.3	40.2	16.5	43.1	112.5	110.1	109.5
Mar	34.8	27.4	21.1	55.7	33.6	33.4	34.8	34.8	18.6	18.6	19.3	18.3	76.9	71.7	75.9	77.8	39.7	42.1	14.1	53.6	130.6	132.2	131.2
Apr	69.4	8.4	61.1	37.7	36.8	39.2	35.2	35.2	22.0	23.5	21.4	22.4	74.5	75.6	72.5	64.7	23.4	15.6	21.2	34.8	144.6	142.6	142.5
May	100.9	140.0	43.2	178.5	37.1	38.0	36.3	36.3	23.5	23.9	23.0	24.2	71.2	75.9	67.3	69.3	41.2	20.2	53.2	40.3	103.6	105.2	101.5
Jun	208.6	234.0	145.0	143.2	33.4	34.4	34.1	34.1	23.8	24.8	24.4	24.8	76.8	75.3	73.3	75.4	58.9	36.1	61.8	56.5	163.9	165.3	161.6
July	268.3	273.1	314.3	204.6	30.2	29.3	30.1	30.1	23.4	23.8	23.9	24.1	87.1	85.0	87.7	83.1	68.3	56.4	83.1	71.0	74.7	75.6	73.7
Aug	273.1	296.1	263.0	332.3	30.0	31.0	30.3	30.3	22.9	24.0	23.4	24.0	89.8	85.9	88.6	87.0	79.0	58.9	82.2	81.0	24.4	26.1	21.2
Sept	191.1	151.0	294.1	326.8	30.3	32.0	30.3	30.3	22.4	24.0	22.8	23.3	90.2	86.5	87.7	93.4	75.7	60.6	81.6	84.0	66.8	81.4	54.2
Oct	103.4	183.9	103.0	137.5	30.0	30.7	29.9	29.9	19.7	21.3	19.1	21.0	79.6	82.9	73.0	89.0	66.8	61.7	57.9	81.0	85.7	119.6	76.1
Nov	20.7	15.9	0	1.7	28.2	26.9	28.7	28.7	15.3	15.5	15.9	16.3	81.7	80.4	73.4	88.1	65.6	43.5	60.7	71.3	53.7	54.1	52.8
Dec	9.9	0	85.9	7.4	26.0	26.1	23.9	23.9	11.4	11.3	11.6	12.7	76.5	75.0	67.3	85.1	67.4	33.6	63.2	66.7	18.3	19.7	16.9

Table 2. Mean growth and yield attributing characters of Chickpea

Treatments	Plant height	No of branches/plant		No of pods/plant	No of seeds/pod
		Primary	Secondary		
D1 (1 st Nov)	32.0	3.2	11.8	63.7	1.6
D2 (15th Nov)	32.4	3.4	12.1	71.1	1.9
D3(30th Nov)	31.7	3.1	10.9	58.8	1.5
D4 (15th Dec)	30.6	2.9	10.3	52.1	1.3
Sem(±)	0.79	0.26	0.75	1.16	0.03
CD(0.05)	1.98	0.63	0.89	4.39	0.10
V1(JAKI 9218)	32.7	3.3	12.0	70.1	1.8
V2(JG 14)	31.6	3.1	11.6	67.8	1.5
V3(JG 16)	30.9	2.9	10.9	60.4	1.4
Sem(±)	0.81	0.25	0.79	1.3	0.03
CD(0.05)	1.78	0.59	0.84	4.5	0.15

Table 3. Yield, Cost and Return analysis of maize based intercropping systems at North Central Plateau Zone of Odisha

Treatment	Chickpea yield(kg/ha)				Gross Return (Rs./ha)				Net Return (Rs./ha)				B:C			
	2017	**2018**	**2019**	**Mean**	**2017**	**2018**	**2019**	**Mean**	**2017**	**2018**	**2019**	**Mean**	**2017**	**2018**	**2019**	**Mean**
D1 (1 st Nov)	904	949	917	923	54240	52200	50435	52292	22240	20200	18435	20292	1.70	1.63	1.58	1.67
D2 (15th Nov)	1028	1071	1020	1040	61660	58924	56100	58895	29660	26924	24100	26895	1.93	1.84	1.75	**1.89**
D3(30th Nov)	837	871	848	852	50213	47889	46640	48247	18213	15889	14640	16247	1.57	1.50	1.46	1.54
D4 (15th Dec)	732	788	747	756	43907	43330	41085	42774	11907	11330	9085	10774	1.37	1.35	1.28	1.36
Sem(±)	34	40	29	34	-	-			-	-			-	-		-
CD(0.05)	116	138	100	118	-	-			-	-			-	-		-
V1(JAKI 9218)	1046	1089	1035	1057	62735	59891	56925	59850	30735	27891	24925	27850	1.96	1.87	1.78	1.92
V2(JG 14)	843	880	868	864	50585	48386	47740	48904	18585	16386	15740	16904	1.58	1.51	1.49	1.55
V3(JG 16)	737	791	745	757	44195	43481	40975	42884	12195	11481	8975	10884	1.38	1.36	1.28	1.37
Sem(±)	23.7	26.2	16.2	21	-	-		-	-	-		-	-	-		-
CD(0.05)	71.2	78.6	48.5	64	-	-		-	-	-		-	-	-		-

Table 4. Thermal indices during different phenophases of chickpea as affected by various treatments

Treatments	Thermal indices indices	Emergence	Vegetative	50% flowering	Podding	Maturity
Sowing dates	**Days taken**	**7**	**111**	**126**	**151**	**167**
D_1 (1 st Nov)	GDD	107.7	1355.8	1616.8	1919.5	2316.3
	PTU	1160.4	14733.6	17602.7	20897.3	25388.8
	HTU	874.1	11086.3	13235.9	15721.6	19175.6
D_2 (15th Nov)	Days taken	8	103	119	139	156
	GDD	118.7	1219.4	1465.6	1737.17	2043.9
	PTU	1291.1	13262.8	15967.7	18909.4	22265.2
	HTU	968.9	10058.7	12015.6	14228.9	16754.4
D_3 (30th Nov)	Days taken	9	98	113	127	148
	GDD	119.3	1017.6	1304.6	1493.5	1866.8
	PTU	1298.1	12128.3	14209.6	16308.1	20559.4
	HTU	971.6	9123.5	10684.6	12268.1	15464.5
D_4 (15th Dec)	Days taken	10	94	110	121	142
	GDD	115.3	1011.7	1300.6	1489.6	1860.5
	PTU	1291.5	12122.4	14201.8	16303.2	20454.6
	HTU	969.3	9121.8	10682.2	12262.4	15460.8
Genotypes	Days taken	8	105	120	141	160
V1(JAKI 9218)	GDD	118.7	1238.3	1454.6	1739.8	2102.1
	PTU	1279.5	13483.9	15831.6	18953.5	22946.2
	HTU	963.8	10144.2	11909.4	14459.8	17863.1
V2(JG 14)	Days taken	7	101	116	136	155
	GDD	115.6	12155.8	1454.7	1695.1	2082.5
	PTU	1246.8	13249.3	15830.8	18461.5	22675.7
	HTU	938.6	998.3	11810.7	13889.1	17265.2
V3(JG 16)	Days taken	6	85	109	135	154
	GDD	118.7	1219.5	1456.4	1687.9	2015.7
	PTU	1268.6	13258.7	15845.4	18352.7	22620.7
	HTU	956.5	9734.3	11918.5	13808.5	17058.6

Chickpea sown on 15th of November produced significantly highest number of pods per plant(71.1) as well as number of seeds per pod (1.9) than early and delayed sowing. Delayed sowing gradually decreased the number of seeds of chickpea. The lowest number of pods per plant (52,1) and seeds per pod (1.3) was recorded from December 15 as the temperature during grain filling stage might be the possible reason of a lower number of pods per plant and seeds per pod of chickpea with delayed sowing. Maximum number of pods (70.1) and seeds per pod (1.8) was recorded in JAKI 9218 and least number of pods per plant(60.4) and seeds per pod (1.4) was obtained by the cultivar JG 16.

Chickpea sown on 15th November registered the maximum mean grain yield of 1040 kg/ha followed by 1st Nov sowing (923 kg/ ha)(Table 3). Studies have shown that early winter sowing (mid-October to mid-November) is the optimum period. Late sowing, after November 18 reduced yield by 28 per cent for every 10 day interval delay. Maximum yield in November15 sowing was a result of a favourable climatic condition which provided the suitable vegetative and reproductive growth stages for chickpea plant. November 15 sowing increased seeds weight and seed yield of chickpea compared to early and late sowing and this result was due to the moderate tem regime during the grain filling stages [33]. Among the chickpea varieties, JAKI 9218 produced the maximum yield of 1057 kg /ha followed by JG 14 (864 kg/ha).

Sowing chickpea on 15th November fetched maximum mean net return of Rs. 26895/- per ha with B:C of 1.89 followed by 1st Nov sowing which fetched mean net return of Rs. 24100/- per ha with B:C of 1.67. Growing chickpea variety JAKI 9218 fetched maximum mean net return of Rs. 27850/- per ha with B:C of 1.67. Chickpea variety JAKI 9218 should be sown on or around 15th November for higher income.

Days taken to vegetative stage was recorded maximum (111 days) and minimum (94 days) when crop was sown on 1st November and 15th December, respectively. Delay in sowing by one and half month reduced the vegetative phase by 17 days over 1st November sowing and 9 days over 15th November sowing (Table 4). These findings are in confirmation with [34] and [35]. The maximum GDD to reach maturity (2316.3 days) was recorded on 1st November followed by 2043.9 days on 15th November while minimum GDD 1860.5 days was observed on 15th December which indicated that the crop exposed sub-optimal thermal regime with delay in sowing [36].

The requirement of Heliothermal unit to attain different phenophases could be seen in Table 4. Heliothermal unit from sowing to maturity ranged between 15460.80 to 19175.60°days hr. Heliothermal unit was recorded highest in 1st November followed by 15th November due to higher growing degree days [37] while lowest value was recorded at 15th December. Among cultivars, JAKI 9218 had higher thermal unit requirement due to comparatively longer duration of maturity followed by JG 14 and JG 16. The varietal differences of chickpea for phasic duration and thermal units was also reported by [35].

Photothermal unit from date of emergence to maturity stage accounted higher with 1st November than 15th November sowing, while lowest PTU were observed with the crop sown on 15th December during both all the years this was also reported by [38]. The photothermal unit ranged from 20454.6 to 25388.8°days hrs. Variety JAKI 9218 accounted non-significantly higher PTU than JG14 and JG 16 at all the phenological stages of the crop during all the years. PTU increased as the sowings were delayed for all the varieties. (Table 4).

4. CONCLUSION

A general trend was observed that early and delay in sowing dates decreased the average yield and quality of chickpea. Both early and delayed sowing affected the chickpea plant growth, yield and grain quality .Maximum results were obtained when chickpea var JAKI 9218 was sown on November 15. Therefore we can conclude that the chickpea variety JAKI 9218 should be sown on or around 15th November for higher income in the North Central Plateau Zone of Odisha.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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