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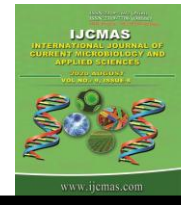

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Growing Degree Days and Heat Use Efficiency Influenced by Dates of Sowing and Irrigation Levels on Rainfed Chickpea

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A field experiment was conducted during *Rabi*, 2016-17 on black soils to find the influence of dates of sowing and irrigation levels on chickpea heat use efficiency and heat units required to reach different phenophases. The chickpea crop required 82 to 97°C days at emergence, whereas to enter the reproductive stage (first flower) crop required 794 to 1073°C days. The growing degree days required by chickpea to reach maturity ranged from 2066 to 2200°C days. The phenophases, emergence, and end pod were not influenced by irrigation levels. Irrigation levels influenced growing degree days at physiological maturity and harvest. Delay in sowing led to a decrease in heat use efficiency.

Introduction

Chickpea is grown under wide agro-climatic conditions ranging from 10 N to 40 N latitudes in the northern hemisphere (Berger *et al.*, 2006) and 27 S and 38 S latitudes in the Southern hemisphere (Imtiaz *et al.*, 2011). Growing regions of chickpea can be broadly divided into two, non-tropical dry areas and semi-arid tropics (Imtiaz *et al.*, 2011).

Chickpea becomes one of the promising rainfed rabi crop on black soils during the winter season in India and Andhra Pradesh in particular. Chickpea cultivation is solely dependent on the soil moisture reserve where planting is late during the recession of the main rainy season to escape the water logging conditions. Shorter cool and dry weather period prevailed between November to February favor the crop growth and development in this region. Delayed sowings force the crop to pass through warmer temperatures during the reproductive phase which is one of the major hindrances to optimum productivity.

Both temperature and moisture supply during the growing period had a strong influence on chickpea. The start of flowering in chickpea is dependent on photothermal conditions which is the main determinant for growth and development (Basu *et al.,* 2009). Flower development is a crucial stage because fluctuations in weather conditions ultimately influence crop production. Optimum sowing date results in timely initiation of flowering by minimizing abiotic stress. The most vital step towards enhancing the yield of chickpea is to ensure that the phenology of the crop is well in line to the resources and constraints of crop growth and development (Summerfield *et al.,* 1990).

Temperature is an important factor controlling crop growth and development by affecting a wide range of physiological processes and altering plant-water relationships (Zinn *et al.,* 2010). Delayed sowings reduce the reproductive period in tropical regions (Ahmed *et al.,* 2011), growing degree days required to physiological maturity (Chaitanya and Chandrika 2006, Sardar, 2009, Mukesh *et al.,* 2010, Sugui and Sugui (2002)) and heat use efficiency (Mukesh *et al.,* 2010). Irrigation delayed flowering and pod development irrespective of the date of sowing (Agrawal and Upadhyay, 2006). The variability in chickpea yield across the date of sowing was explained through temperature variation recorded during different growth stages (Agrawal and Upadhyay, 2006). An adverse effect of temperature can be compensated to some extent by the application of irrigation in late-planted conditions. Moisture stress is one of the main reasons for the timing of the onset of senescence in chickpea. Grain yield is significantly sensitive to water stress during the pod setting to grain development periods irrespective of soil texture (Jalota *et al.,* 2006).

Optimizing sowing dates and deficit irrigation can minimize the exposure to temperature stress. By keeping in view the experiment was planned to study the Growing degree days and Heat use efficiency influenced by dates of sowing and irrigation levels on rainfed chickpea.

Materials and Methods

This study was carried out in Maddipadu village of Prakasam District, Andhra Pradesh, India during *Rabi* 2015-16 and 2016-17. The experimental site is located at an altitude of 11.0 m above MSL, 15 62` N latitude, 80 02` E longitude, and 25 km away from the Bay of Bengal in the Krishna Agro Climatic Zone of Andhra Pradesh.

The experimental site falls under semi-arid climatic conditions as per Thornthwaite’s method of climate classification and Tropical savanna with dry summer as per Koppen’s methods of climate classification.

The results of the soil analysis indicated that the soil was clay in texture (45%), slightly alkaline in reaction (8.1), medium in organic carbon content (0.51 %), low in available nitrogen (201 kg ha^{-1}), high in available phosphorus (95.5 kg ha^{-1}) and potassium (86 kg ha^{-1}).

The chickpea variety, JG 11 (ICVV93954), used for the study is a popular bold seeded variety developed by ICRISAT in partnership with Jawaharlal Nehru Krishi Viswa Vidyalaya (JNKVV), Jabalpur, Madhya Pradesh.

The experiment was conducted in strip plot design replicated thrice in with three sowing windows as main plots viz., D_1: 2nd Fortnight of October, D_2: 1st Fortnight of November and D_3: 2nd Fortnight of November and eight irrigation levels of water with one control *i.e.*, I_1 = No irrigation, I_2 = Irrigation with aerial water spray at pod filling stage (70-75 DAS) @ 5,000 L ha^{-1}, I_3 = Irrigation with aerial water spray at pod filling stage (70-75 DAS) @ 10, 000 L ha^{-1}, I_4 = Irrigation with aerial water spray at pod filling stage (70-75 DAS) @ 15, 000 L ha^{-1}, I_5 = Irrigation with aerial water spray at pod filling stage (70-75 DAS) @ 20, 000 L ha^{-1}, I_6 = Irrigation with aerial water spray at maximum vegetative stage (30-35 DAS) followed by pod filling stage (70-75 DAS) @ 5, 000 L ha^{-1}, I_7 = Irrigation with aerial water spray at maximum vegetative stage (30-35 DAS) followed by pod filling stage (70-75 DAS) @ 10, 000 L ha^{-1}, I_8 = Irrigation with aerial water spray at maximum vegetative stage (30-35 DAS) followed by pod filling stage (70-75 DAS) @ 15, 000 L ha^{-1}, I_9 = Irrigation with aerial water spray at maximum vegetative stage (30-35 DAS) followed by pod filling stage (70-75 DAS) @ 20, 000 L ha^{-1}.

This study was carried out with specific objectives of heat use efficiency and no heat units required reaching each phenophases under the above main and sub-plot treatments. During the crop growth period, 36.1 mm of rainfall was recorded in 2015-16, and 262.8 mm received in 2016-17 against normal rainfall of 441 mm.

The distribution of rainfall was highly in uneven is 2015-16 but cool and dry weather favored crop growth. Recommended package and practices were followed for crop management. Crop phenophases were recorded and growing degree-days (GDD) were determined as per Nuttonson (1955).

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

Where, Tmax and Tmin are the daily maximum and minimum temperature (^{o} C). The base temperature was taken 5 ^{o} C for the analysis.

The HUE was worked using the formula and units for heat use efficiency is The HUE was worked using the formula and units for heat use efficiency is kg ha^{-1} ^{o} C^{-1} day^{-1}.

$$\text{Heat use efficiency (HUE)} = \frac{\text{Seed yield}}{\text{Growing degree days}} \quad \text{X } 100$$

Results and Discussion

The data on growing degree days required to reach different phenophases during *rabi* 2015-16 crop season presented in Table-1.

Among different dates of sowing, crop sown during the 2nd fortnight of October recorded the highest growing degree days to reach maturity followed by 1st fortnight of November whereas the lowest was recorded with the 2nd fortnight of November. The chickpea crop required 84 to 97 C days at emergence, whereas to enter the reproductive stage (first flower) crop required 794 to 1073 C days. The growing degree days required by chickpea to reach maturity ranged from 2066 to 2188 C days. The phenophases, emergence, and end pod were not influenced by irrigation levels. The response to irrigation levels was noticed with I_8 and I_9 treatments at the first flower and first pod stage and I_9 treatment at first seed-stage during 2015-16 and superior to the rest of the treatments. Irrigation levels influenced growing degree days at physiological maturity and harvest. Higher heat units were registered with I_5, I_9, I_4, and I_8 treatments in descending order.

The perusal of data presented in Table-2 indicates a similar response to the dates of sowing in accumulation of growing degree days at different phenophases as in the 2015-16 crop season. The chickpea crop required 82 to 94 C days at emergence, whereas to enter the reproductive stage (first flower) crop required 782 to 1064 C days. The growing degree days required by chickpea to reach maturity ranged from 2122 to 2200 C days. The phenophases, emergence, and end pod were not influenced by irrigation levels during 2016-17 also. Unlike the response to irrigation levels in the first year, I_9 treatment registered higher growing degree days at the first flower, first pod, first seed, physiological maturity, and at harvest over other irrigation levels, Which was closely followed by I^5 and I^8 treatments at physiological maturity and harvest.

Table.1 Growing degree days (°C day) required to reach different phenophases as influenced by different dates of sowing and irrigation levels during *Rabi* 2015-16

Treatment	Emergence	First flower	First Pod	First Seed	End pod	Physiological maturity	Harvest
Dates of sowing							
2nd Fortnight of October	97	1073	1201	1334	1464	2025	2188
1st Fortnight of November	85	920	1050	1254	1412	1976	2142
2nd Fortnight of November	84	794	930	1260	1420	1891	2066
Mean	89	929	1060	1283	1432	1964	2132
Irrigation levels as aerial water spray (L ha^{-1})							
I_1= No irrigation	89	923	1055	1288	1432	1952	2120
I_2= Irrigation at 75 DAS @ 5,000	89	923	1055	1288	1432	1952	2120
I_3= Irrigation at 75 DAS @ 10, 000	89	923	1055	1288	1432	1952	2120
I_4= Irrigation at 75 DAS @ 15, 000	89	923	1055	1288	1432	1973	2141
I_5= Irrigation at 75 DAS @ 20, 000	89	923	1055	1288	1432	1994	2163
I_6= Irrigation at 35 and 75 DAS @ 5, 000	89	923	1055	1288	1432	1952	2120
I_7= Irrigation at 35 and 75 DAS @ 10, 000	89	923	1055	1288	1432	1952	2120
I_8= Irrigation at 35 and 75 DAS @ 15, 000	89	942	1068	1288	1432	1965	2133
I_9= Irrigation at 35 and 75 DAS @ 20, 000	89	960	1088	1307	1432	1987	2155
Mean	**89**	**929**	**1060**	**1283**	**1432**	**1964**	**2132**

Table.2 Growing degree days (°C day) required to reach different phenophases as influenced by different dates of sowing and irrigation levels during *Rabi* 2016-17

Treatment	Emergence	First flower	First Pod	First Seed	End pod	Physiological maturity	Harvest
Dates of sowing							
2nd Fortnight of October	94	1064	1195	1327	1452	2029	2200
1st Fortnight of November	82	914	1041	1284	1417	1983	2161
2nd Fortnight of November	88	782	924	1268	1439	1936	2122
Mean	88	920	1053	1293	1436	1983	2161
Irrigation levels as aerial water spray (L ha^{-1})							
I_1= No irrigation	88	918	1052	1291	1436	1973	2150
I_2= Irrigation at 75 DAS @ 5,000	88	918	1052	1291	1436	1973	2150
I_3= Irrigation at 75 DAS @ 10, 000	88	918	1052	1291	1436	1973	2150
I_4= Irrigation at 75 DAS @ 15, 000	88	918	1052	1291	1436	1973	2150
I_5= Irrigation at 75 DAS @ 20, 000	88	918	1052	1291	1436	1995	2175
I_6= Irrigation at 35 and 75 DAS @ 5, 000	88	918	1052	1291	1436	1973	2150
I_7= Irrigation at 35 and 75 DAS @ 10, 000	88	918	1052	1291	1436	1973	2150
I_8= Irrigation at 35 and 75 DAS @ 15, 000	88	918	1052	1291	1436	1995	2175
I_9= Irrigation at 35 and 75 DAS @ 20, 000	88	937	1065	1311	1436	2017	2199
Mean	88	920	1053	1293	1436	1983	2161

Fig.1 Heat use efficiency (kg ha^{-1} °C^{-1} day^{-1}) as influenced by different dates of sowing and irrigation levels during 2015-16

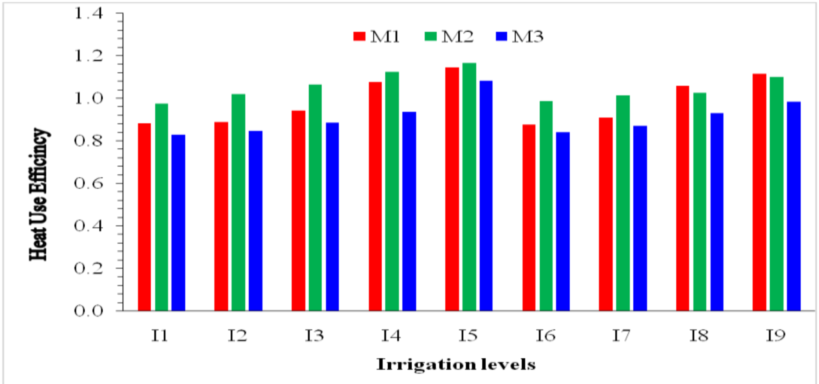
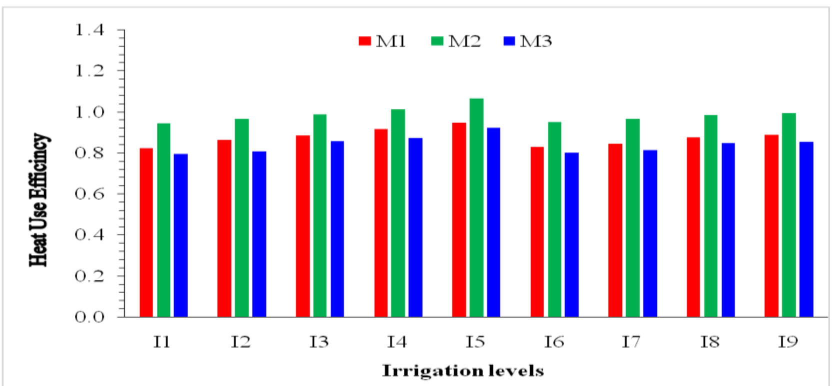


Fig.2 Heat use efficiency (kg ha^{-1} °C^{-1} day^{-1}) as influenced by different dates of sowing and irrigation levels during 2016-17



T_1=No irrigation
T_2=Irrigation with aerial water spray at pod filling stage (70-75 DAS) @ 5, 000 L ha^{-1}
T_3=Irrigation with aerial water spray at pod filling stage (70-75 DAS) @ 10, 000 L ha^{-1}
T_4=Irrigation with aerial water spray at pod filling stage (70-75 DAS) @ 15, 000 L ha^{-1}
T_5=Irrigation with aerial water spray at pod filling stage (70-75 DAS) @ 20, 000 L ha^{-1}
T_6=Irrigation with aerial water spray at maximum vegetative (35-40 DAS) and pod filling stages (70-75 DAS) @ 5, 000 L ha^{-1}
T_7=Irrigation with aerial water spray at maximum vegetative (35-40 DAS) and Pod filling stages (70-75 DAS) @ 10, 000 L ha^{-1}
T_8=Irrigation with aerial water spray at maximum vegetative (35-40 DAS) and pod filling stages (70-75 DAS) @ 15, 000 L ha^{-1}
T_9=Irrigation with aerial water spray at Maximum vegetative (35-40 DAS) and Pod filling stages (70-75 DAS) @ 20, 000 L ha^{-1}

It was revealed from the present investigation that, growing degree days required for a crop to attain maturity in two seasons differed considerably. The emergence of the crop required a range of 82 to 97 C days. Application of deficit irrigation of 15, 000 L ha^{-1} in I^8 treatment and 20, 000 L ha^{-1} in I^5 and I^9 treatments influenced crop to accumulate more heat units to reach the next phenophase. Application of irrigation at maximum vegetative stage and pod filling stage had prolonged crop duration than application in the pod filling stage alone in I^4 and I^5 treatments. This might be due to deficit irrigation relieved part of stress accumulated in the vegetative stage and irrigation at pod filling further favored the extension of crop duration. Early sowing required more heat units to reach maturity than late sowing. These findings are in accordance with those of Gan *et al.,* (2002); Agrawal and Upadhyay (2009). Chickpea cultivar JG-11 needed 782 to 1073 C days to flower at Maddipadu village of Prakasam district. These findings are in agreement with those of Rajin *et al.,* (2003) who concluded that chickpea phenological phases depend on accumulated thermal time and which varies with genotype. Heat use efficiency of chickpea during the 2015-16 crop season as influenced by dates of sowing and irrigation levels is presented in Fig-1. Heat use efficiency of chickpea was affected by the time of sowing and also irrigation levels.

Maximum heat use efficiency was recorded in the 1st fortnight of November sowing with 1.05 kg ha^{-1} C^{-1} day^{-1} followed by the 2nd fortnight of October sowing with 0.99 kg ha^{-1} C^{-1} day^{-1}. Among irrigation levels, the highest heat use efficiency of 1.13 kg ha^{-1} C^{-1} day^{-1} was recorded with I_5 treatment followed by I_9 treatment (1.07 kg ha^{-1} C^{-1} day^{-1}) whereas, the lowest was observed in I1 treatment with 0.89 kg ha^{-1} C^{-1} day^{-1}.

The data on heat use efficiency during 2016-17 as presented in Fig-2 indicated that the highest heat use efficiency of 0.98 kg ha^{-1} C^{-1} day^{-1} was recorded with 1st fortnight of November sowing followed by 2nd fortnight of October sowing with 0.87 kg ha^{-1} C^{-1} day^{-1}. Among different irrigation levels, the highest heat use efficiency was recorded in I_5 treatment followed by I_4 treatment, whereas the lowest was recorded with I_1 treatment (0.85 kg ha^{-1} C^{-1} day^{-1}).

It was revealed from the present investigation that heat use efficiency of was influenced by dates of sowing and irrigation levels. Delay in sowing led to decrease in heat use efficiency. These findings were in agreement with those of Venkatachalapathi and Reddy (2013); Agrawal *et al.*, (2002).

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