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Ascertaining Weather Indices to Exploit the Yield Potential of Chickpea (*Cicer arietinum* L.) at Scarce Rainfall Zone of Andhra Pradesh

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A B S T R A C T

Field experiments were conducted during *rabi* season of 2018-19 and 2019-20 at ANGRAU, Regional Agricultural Research Station, Nandyal, to study the weather related information on chickpea (*Cicer arietinum* L.) growth and yield under crop residue incorporation, varied time of sowing and irrigation stages. Results revealed that the mean values of weather indices like accumulated growing degree day, helio thermal units, photo thermal units at different phenophases and thermal use efficiency were influenced by times of sowing but not with crop residues incorporation and irrigation. Time of sowing also did not influence the days to reach different phenophases from emergence to harvest significantly. However, the first and second dates of sowing recorded more number of days to reach 50 per cent flowering, physiological maturity and harvest stage. Growing degree days, helio thermal units, photo thermal units, at flowering, physiological maturity and harvesting maturity of crop found to be highest in October second fortnight sown crop and goes on decreased with delay in sowing with fortnight interval, up to December first fort night. The drymatter and seed yield were higher with November first fortnight sown crop drymatter production (4719 kg ha^{-1}), seed yield (1660 kg ha^{-1}). The study concludes that maximum seed yield of chickpea can be achieved when chickpea was sown during November 1st FN, with incorporation of foxtail millet crop residue with two irrigations, one at pre flowering and another at pod development stage, attributed to record the higher thermal use efficiency (TUE) (dry matter 2.25 kg ha^{-1} ^{0}C day and seed 0.77 kg ha^{-1} ^{0}C day) under SRZ of Andhra Pradesh.

Keywords

Chickpea, Phenophases, GDD, PTU, HTU and TUE

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Introduction

Chickpea is a drought tolerant, photoperiod sensitive C_3 plant originated in Turkish Kurdistan (Lev *et al.*, 2000). In sub-tropical region like India, the climate is temperate with kharif rainfall mostly from June-September. Chickpea is conventionally grown during winter, based on available residual soil moisture on deep clayey soils. Therefore, the crop faces high temperature and water stress towards maturity which result in low and variable yields.

Chickpea is a thermo-sensitive winter season crop. The most important factors affecting chickpea are temperature and photoperiod (Summerfield *et al*., 1980; Sandhu and Hodges, 1971; Kiran and Chimmad, 2015). In the view of recent climate change situation, the weather parameters are highly influencing the crop productivity wherein, there is an increase in day temperature and drastic reduction in the night temperature and photo periods are expecting in future days.

Time of sowing is an important agronomic factor affecting the productivity of most of the arable crops, owing to changes in environmental conditions to which phenological stages of crops are exposed. Under late sown conditions, the growth of chickpea is affected resulting in low yield. Variable seed yields are a deterrent to growing chickpea (*Cicer arietinum* L.) as they are mostly grown on residual soil moisture and often experience water stress during their terminal growth in major chickpea growing countries.

Determining the moisture basis for yield variation may help to determine best management practices to maximize yield, which may help to identify other areas as potential production sites. Dixith *et al*., (1993) reported that earlier or late sowing of chickpea caused drastic reduction in yield and net profit compared with timely sowing. Mohammed *et al.,* (2017) concluded that when sowing time for chickpea is delayed the residual soil moisture available to support the crop growth might be depleted onwards, which could expose the crop for terminal drought and finally reduce the grain yield, on other hand, sowing too early may expose the crop to water logging which also a major problem for chickpea production particularly in vertisols. So it is appropriate to find optimum time of sowing for different farming situations under double cropping system to improve yields and net returns.

Materials and Methods

Field experiments were carried out for two consecutive *kharif* and *rabi* seasons of 2018-19 and 2019-20 at R.A.R.S. Farm, Nandyal, Andhra Pradesh. The treatments comprised of three crop residue incorporations *viz.*, foxtail millet (C_1), greengram (C_2) and fallow (C_3) as main plot treatments and four times of sowing *viz.* October 2^{nd} FN (D_1), November 1^{st} FN (D_2), November 2^{nd} FN (D_3) and December 1^{st} FN (D_4) as sub plot treatments and three irrigation schedules as sub- sub plots with irrigation at pre-flowering stage (I_1), irrigation at pod development stage (I_2) and irrigation at pre-flowering and pod development stage (I_3) During *kharif* season, foxtail millet and greengram crops were raised as bulk crops in respective main plots and crop residues were incorporated after harvest of economic parts viz., panicles of foxtail millet and pods of greengram. Experimental design was split-split plot, with three replications.

The site was situated at an altitude of 216 m above mean sea level at 15^{o}29’19’’ N latitude and 78^{o} 29’11’’ E longitude, mostly under rainfed conditions, categorized in the Scarce rainfall Agro-climatic Zone of Andhra Pradesh. The meteorological data of maximum and minimum temperature, rainfall, rainy days, morning and evening relative humidity and wind speed were recorded from meteorological observatory, Regional Agricultural Research station, Nandyal near the experimental site, during the period of crop growth. Soil of the site was medium in fertility and slightly saline in reaction having pH 8.42, electrical conductivity 0.24 dSm^{-1}, organic carbon 0.32% with available nitrogen, phosphorus and potassium of N, 143, 53 and 451 kg/ha, respectively. Sowing of seeds was done in rows, 30 cm apart with 10 cm between plants. An amount of 20 kg nitrogen and 50 kg P_2O_5 per hectare was applied through urea and single SSP in basal. Sowing was done in four intervals as D_1 on October 2^{nd} fortnight, D_2 on November 1^{st} fortnight, D_3 on November 2^{nd} fortnight, D_4 on December 1^{st} fortnight, in respective treatment plots. Healthy and matured seeds NBeG-3 chickpea desi variety having high germination percentage was used for sowing. Seed rate @ 50 kg ha^{-1} was adopted and sown in the open furrows made with the help of hand hoe. The seeds were dropped to a depth of 5 cm and covered thoroughly. The phonological development of the crop was monitored at 2- 3 days interval to decide the duration taken to reach different physiological stages, where 50% of plumule emergence was considered as days to emergence, 50 % plants with one flower at any node was considered as days flowering, 95 % of pods had obtained their mature colour was considered as physiological maturity and harvest stage was when all ground parts attains matured straw colour (Soltani *et al.*, 2006). Agrometeorological indices like Growing Degree Days (GDD), Heliothermal Units (HTU), Photothermal Units (PTU) and Thermal use efficiency (TUE) were computed by adopting the procedure laid out by Rajput (1980).

Growing degree days

The growing degree-days (GDD) were determined as (Nuttonson, 1955)

GDD =

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

Where, Tmax and Tmin are the daily maximum and minimum temperature (^{0}C). Base temperature of 5 ^{O}C was adopted for calculation.

Helio thermal units

The helio thermal units for a given day represent the product of GDD and the actual hours of bright sun shine for that day. The sum of the HTU for the duration of each phenophase was determined by using the formula.

Accumulated HTU (°C day hour) = GDD × Duration of sunshine hours

Photo thermal units

The photo thermal units for each day represent the product of GDD and the day length. The accumulated PTU for each phenophase was determined by the following formula.

Accumulated PTU (°C day hour) = GDD × Day length

Thermal Use Efficiency (TUE)

The TUE was worked using the formula and a unit for heat use efficiency is kg ha^{-1} per degree day.

Thermal use efficiency (TUE) =

$$\frac{\text{Seed yield/dry matter}}{\text{Growing degree days}}$$

Five randomly selected plants outside the net plot area collected at 30, 60 DAS and at harvest were used for estimation of dry matter production. These samples were air dried and then oven dried at 60°C to a constant weight and expressed in kg ha^{-1}. The seed yield obtained from net plot area was threshed, cleaned and sundried and expressed as kg ha^{-1}.

Results and Discussion

Results pertaining to effect of crop residue incorporation, time of sowing and irrigation stages on days to reach different phenophases, accumulated GDD, HTU, PTU, TUE and seed yield were presented in table number 1 to 5 and Fig. 1. Results shown yearly variations in all weather indices studied.

Days to reach different phenophases

Response of chickpea to crop residue incorporation, time of sowing and irrigation to reach different phenophases (days) during *rabi* 2018-19 and 2019-20 is presented in Table 1. The results indicated that crop residue incorporation did not influence significantly the days to reach different phenophases from emergence to harvest. However, during both the years of study seedling emergence was slightly delayed in crop residue incorporated plots compared to fallow. Thereafter, 50 per cent flowering, physiological maturity and harvest was relatively faster in crop residue incorporated plots then in fallow plots.

Time of sowing also did not influence the days to reach different phenophases from emergence to harvest significantly. However, the first and second dates of sowing recorded more number of days to reach 50 per cent flowering, physiological maturity and harvest stage. It was observed that during both the years, gradual delay in time of sowing from October month to December month decreased the days to reach different phenophases. This might be due to exposing of late sown crop with increased temperatures in their later growth stages.

The interaction between crop residue incorporation, time of sowing and irrigation levels either at two level or three level interaction was not significant in altering the duration of phenophases, during the both the years of study.

In the present investigation, delay in sowing from October second fortnight to December first fort night, reduced the number of days to attain physiological maturity and harvesting maturity of crop. These results are in accordance with the results reported by Agarwal and Upadyaya (2016). It is mainly due to increasing temperature at reproductive phase those of which had profound effect on phenology of chickpea.

Growing degree days (GDD)

The accumulated growing degree days attained by chickpea at different phenophases under different treatments were calculated and presented in Table 2.

The GDD were influenced by time of sowing only but not with crop residues and irrigation during both the years of study. Accumulated GDD values from sowing to emergence were higher in October 2nd FN sowing i.e same 140^{o}C day, during 2018-19 and 2019-20 respectively followed by November 1st FN sowing and gradually reduced with delay in sowing upto December 1st FN sowing i.e. 81.5 and 80.6 ^{o}C day, during 2018-19 and 2019-20, respectively.

Growing degree days (GDD) value at flowering, physiological maturity and harvesting maturity of crop found to be highest in 1st growing environments and goes on decreasing with 2nd 3rd and fourth growing environments, due to shorter phonological stages with delay in sowing. Sunil Kumar and Martin Luther, (2018) and Sada Kumar *et al.*, (2018) were also reported similar line of results.

Table.1 Days to reach different phenophases of chickpea as influenced by crop residue incorporation, time of sowing and Irrigation

Treatment	Emergence *		Fifty % flowering		Physiological maturity		Harvest	
	***Rabi*, 2018**	***Rabi*, 2019**	***Rabi*, 2018**	***Rabi*, 2019**	***Rabi*, 2018**	***Rabi*, 2019**	***Rabi*, 2018**	***Rabi*, 2019**
Crop residue incorporation								
C_1: Foxtail millet	5.2	5.3	39.1	41.3	94	96	101	104.
C_2: Greengram	4.7	5.2	39.0	41.1	95	96	100	105
C_3: Fallow	4.3	4.7	38.3	40.3	94	96	100	103
SEm ±	-	-	1.11	0.35	0.7	0.9	0.7	0.9
CD (P=0.05)	-	--	NS	NS	NS	NS	NS	NS
Time of sowing								
D_1: October 2^{nd} FN	5.3	5.5	40.7	42.2	97	98	104	107
D_2: November 1^{st} FN	4.9	4.8	40.5	41.9	95	97	104	105
D_3: November 2^{nd} FN	4.7	4.6	37.4	41.2	95	98	99	101
$D_{4:}$ December 1^{st} FN	4.7	4.6	36.3	40.1	90	95	94	97
SEm ±	-	-	2.62	0.96	1.2	1.2	3.6	3.3
CD (P=0.05)	-	-	NS	NS	NS	NS	NS	NS
Time of irrigation								
I_1: Irrigation at pre-flowering stage	-	-	38.6	39.5	95	95	100	102
I_2: Irrigation at pod development stage	-	-	38.6	39.4	94	96	101	102
I_3: Irrigation at pre-flowering and pod development stage		-	39.6	39.2	95	95	101	103
SEm ±	-	-	1.25	0.52	0.7	0.5	1.1	1.2
CD (P=0.05)	-	-	NS	NS	NS	NS	NS	NS

*Statistically not analysed

Table.2 Accumulated Growing degree days (^{0}C day) at different phenophases of chickpea as influenced by crop residue incorporation, time of sowing and irrigation

Treatment	Emergence *		Fifty % flowering		Physiological maturity		Harvest		
	***Rabi*, 2018**	***Rabi*, 2019**	***Rabi*, 2018**	***Rabi*, 2019**	***Rabi*, 2018**	***Rabi*, 2019**	***Rabi*, 2018**	***Rabi*, 2019**	**Pooled**
Crop residue incorporation									
C_1: Foxtail millet	101	101	820	825	1952	1955	2073	2075	2074
C_2: Greengram	101	102	820	826	1953	1954	2073	2076	2074
C_3: Fallow	101	101	818	821	1951	1954	2071	2074	2072
SEm ±	-	-	1.3	0.9	2.3	1.0	2.2	0.9	0.9
CD (P=0.05)	-	-	NS	NS	NS	NS	NS	NS	NS
Time of sowing									
D_1: October 2nd FN	140	140	910	924	2072	2092	2172	2192	2182
D_2: November 1st FN	92	92	877	855	2017	1992	2117	2092	2105
D_3: November 2nd FN	91	88	807	839	1929	1974	2029	2074	2051
$D_{4:}$ December 1st FN	82	81	720	706	1827	1818	1927	1918	1922
SEm ±	-	-	12.6	11.5	16.3	10.4	16.4	10.3	11.5
CD (P=0.05)	-	-	37	34	46	31	46	31	35
Time of irrigation									
I_1: Irrigation at pre-flowering stage	-	-	818	821	1951	1952	1961	1962	1962
I_2: Irrigation at pod development stage	-	-	819	823	1951	1953	1961	1963	1962
I_3: Irrigation at pre-flowering and pod development stage	-	-	828	824	1960	1956	1969	1966	1968
SEm ±	-	-	3.3	1.0	14.2	2.4	14.3	2.3	3.4
CD (P=0.05)	-	-	NS	NS	NS	NS	NS	NS	NS

*Statistically not analysed

Table.3 Accumulated Helio thermal units (^{0}C day hrs) at different phenophases of chickpea as influenced by crop residue incorporation, time of sowing and irrigation

Treatment	Emergence*		Fifty % flowering		Physiological maturity		Harvest		
	***Rabi*, 2018**	***Rabi*, 2019**	***Rabi*, 2018**	***Rabi*, 2019**	***Rabi*, 2018**	***Rabi*, 2019**	***Rabi*, 2018**	***Rabi*, 2019**	**Pooled**
Crop residue incorporation									
C_1: Foxtail millet	748	628	6031	5607	15325	14586	16125	16185	16155
C_2: Greengram	751	629	6037	5606	15322	14586	16122	1618	16154
C_3: Fallow	754	626	6041	5602	15321	14580	16120	16181	16149
SEm ±	-	-	2.4	2.3	2.3	2.1	2.3	2.1	3.6
CD (P=0.05)	-	-	NS	NS	NS	NS	NS	NS	NS
Time of sowing									
D_1: October 2nd FN	1331	899	7726	6817	19548	17801	20399	18652	19526
D_2: November 1st FN	819	572	6704	6445	16637	16046	17488	16897	17191
D_3: November 2nd FN	625	625	5150	5588	13777	14469	14628	15320	14974
$D_{4:}$ December 1st FN	423	348	4760	5101	13213	12689	14063	13540	13801
SEm ±	-	-	7.8	6.3	11.6	9.3	11.6	9.3	11.2
CD (P=0.05)	-	-	23	19	35	28	35	28	33
Time of irrigation									
I_1: Irrigation at pre-flowering stage	-	-	6026	5609	15308	14575	16108	15375	15741
I_2: Irrigation at pod development stage	-	-	6020	5614	15307	14583	16108	15385	15745
I_3: Irrigation at pre-flowering and pod development stage	-	-	6062	5621	15316	14596	16117	15397	15758
SEm ±	-	-	16.7	3.3	7.2	6.5	7.1	6.6	5.5
CD (P=0.05)	-	-	50	NS	NS	NS	NS	NS	NS

*Statistically not analysed

Table.4 Accumulated Photo thermal units (^{0}C day hrs) at different phenophases of chickpea as influenced by crop residue incorporation, time of sowing and irrigation

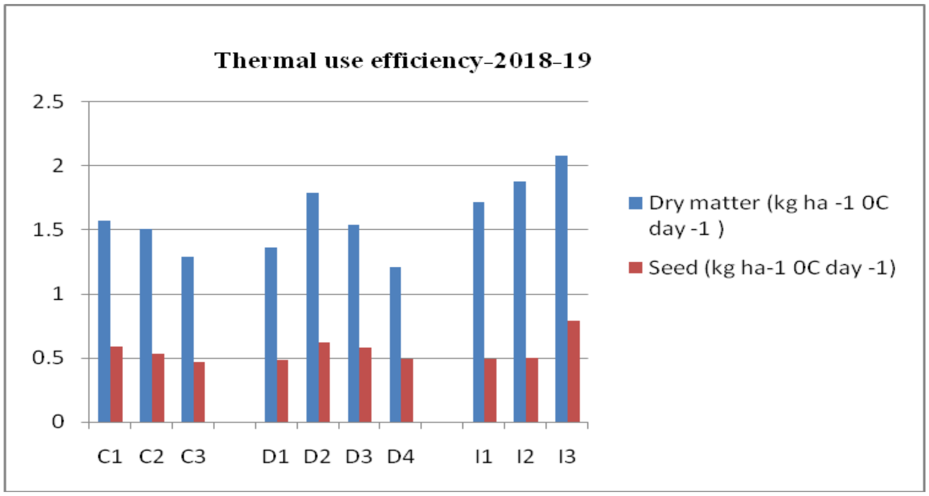
Treatment	Emergence*		Fifty % flowering		Physiological maturity		Harvest		
	Rabi, 2018	*Rabi*, 2019	*Rabi*, 2018	*Rabi*, 2019	*Rabi*, 2018	*Rabi*, 2019	*Rabi*, 2018	*Rabi*, 2019	Pooled
Crop residue incorporation									
C_1: Foxtail millet	1101	989	9557	9359	19800	19749	20986	20978	20982
C_2: Greengram	1101	988	9556	9356	19797	19747	20982	20977	20979
C_3: Fallow	1099	986	9547	9355	19795	19741	20980	20974	20977
SEm ±	-	-	4.5	3.3	3.4	2.6	3.3	2.8	5.2
CD (P=0.05)	-	-	NS	NS	NS	NS	NS	NS	NS
Time of sowing									
D_1: October 2nd FN	1461	1161	10692	9880	22350	22169	23804	22169	22986
D_2: November 1st FN	1182	1045	9709	9596	21923	21529	23611	22529	23070
D_3: November 2nd FN	1041	1015	9638	9083	21769	21060	23211	21873	22541
D_4: December 1st FN	908	910	8462	8594	20475	19989	22256	21042	21649
SEm ±	-	-	5.7	6.2	12.5	6.7	12.1	11.5	12
CD (P=0.05)	-	-	17	18	38	20	37	35	37
Time of irrigation									
I_1: Irrigation at pre-flowering stage	-	-	9712	9422	19866	19850	21786	21007	21396
I_2: Irrigation at pod development stage	-	-	9711	9416	19859	19852	21782	21009	21396
I_3: Irrigation at pre-flowering and pod development stage	-	-	9716	9418	19861	19849	21787	21007	21397
SEm ±	-	-	12.6	6.2	5.9	3.4	7.4	11.7	4.5
CD (P=0.05)	-	-	NS	NS	NS	NS	NS	NS	NS

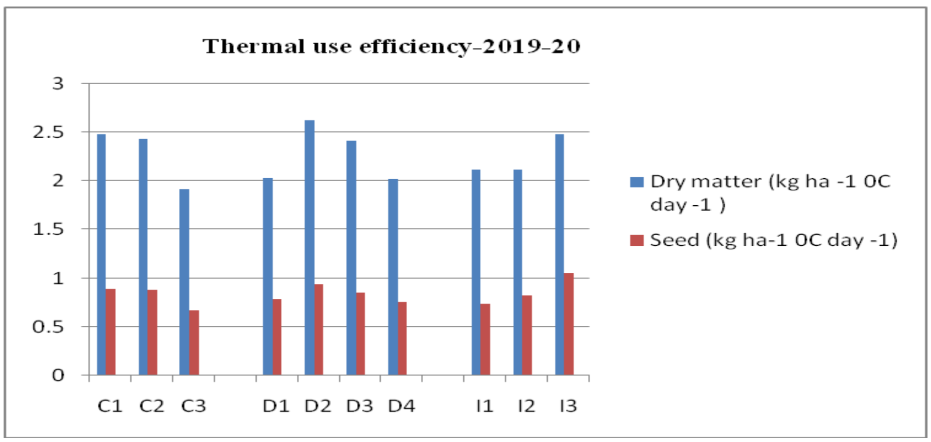
*Statistically not analysed

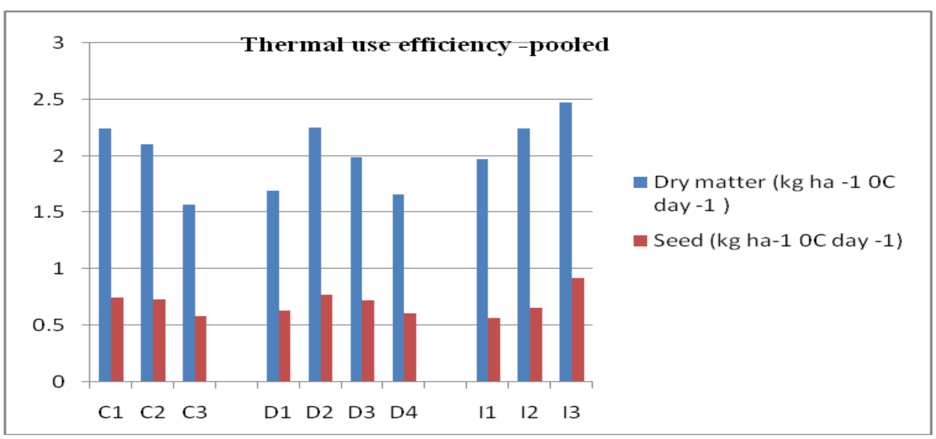
Table.5 Seed yield and harvest index of chickpea as influenced by crop residue incorporation, time of sowing and irrigation

Treatments	Seed yield (kg^{-1})			Harvest Index (%)		
	rabi, 2018	*rabi*, 2019	Pooled	*rabi*, 2018	*rabi*, 2019	Pooled
Crop residue incorporation						
C_1: Foxtail millet	1229	1867	1546	46.72	44.31	45.53
C_2: Greengram	1142	1828	1474	48.11	45.56	46.84
C_3: Fallow	974	1447	1216	47.03	45.67	46.37
SEm ±	40.4	34.4	39	0.6	0.5	0.6
CD (P=0.05)	158	135	115	NS	NS	NS
Time of sowing						
D_1: October 2^{nd} FN	1044	1700	1380	47.77	45.37	46.57
D_2: November 1^{st} FN	1702	1957	1660	4470	43.50	44.21
D_3: November 2^{nd} FN	1180	1770	1472	46.63	45.73	46.26
$D_{4:}$ December 1^{st} FN	935	1429	1167	47.03	44.84	45.92
SEm ±	22.3	31.8	31	0.3	0.2	0.2
CD (P=0.05)	66	95	92	1.1	0.6	0.6
Time of Irrigation						
I_1: Irrigation at pre-flowering stage	801	1445	1117	47.55	45.04	46.31
I_2: Irrigation at pod development stage	985	1633	1300	47.11	45.10	46.10
I_3: Irrigation at pre-flowering and pod development stage	1557	2064	1819	47.14	45.41	46.29
SEm ±	27.4	31.7	34	0.2	0.3	0.3
CD (P=0.05)	78	90	101	NS	NS	NS
Interaction						
C x D						
SEm ±	38.5	55.2	22.5	0.6	0.6	0.9
CD (P=0.05)	115	164	96	NS	NS	NS
C x I						
SEm ±	47.4	55.0	38.2	0.9	0.5	0.6
CD (P=0.05)	NS	NS	NS	NS	NS	NS
D x I						
SEm ±	54.8	63.5	52.5	0.3	1.0	0.9
CD (P=0.05)	NS	NS	NS	NS	NS	NS
C x D x I						
SEm ±	94.9	110.0	75.4	0.9	0.6	0.5
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Fig.1 Thermal use efficiency (TUE) of chickpea at harvest as influenced by crop residue incorporation, time of sowing and irrigation







Helio thermal units (HTU)

Accumulated HTU valves were higher with October II fortnight sowing (D_1) and followed the same trend as of GDD from sowing to emergence, emergence to 50 per cent flowering and 50 per cent flowering to physiological maturity (Table 3). The HTU were influenced by time of sowing only but not with crop residues and irrigation, during both the years of study. The values of HTU were lower with late sown chickpea at each phenophase which indicates that crop facing suboptimal conditions which leads to lower yields. The interaction between crop residue incorporation, time of sowing and irrigation levels either at two level or three level interaction was not significant in altering the HTU of phenophases, during the both the years of study. These results are in close to the findings of Shamsi *et al.*, (2011).

Photo thermal units (PTU)

The PTU values were influenced by time of sowing only but not with crop residues, irrigation or by their interaction, during both the years of study. Accumulated PTU valves were calculated and presented in Table 4 and results showed that the values were also higher with October 2^{nd} fortnight sowing (D_1) and followed the same trend of GDD and HTU from sowing to emergence, emergence to 50 per cent flowering and 50 per cent flowering to physiological maturity. The values of PTU are lower with late sown chickpea at each phenophase which indicated that crop facing suboptimal conditions which leads to lower yields. The quantified PTU units were relatively lower during *rabi* 2019-20 due to cloudy weather and continuous rains.

Seed yield

Seed yield obtained were presented in Tabe.5 and pooled data indicated that foxtail millet crop residue incorporation recorded higher chickpea seed yield (1546 kg ha^{-1}) followed by greengram crop residue incorporation (1474 kg ha^{-1}). Fallow or no crop residue incorporation treatment recorded lowest seed yields (1216 kg ha^{-1}).

Pooled analysis of seed yield also indicated significant differences in time of sowing and irrigation as that observed in individual years. The pooled yield of 1660 kg ha^{-1} was recorded with crop sown during November first fortnight (D_2) of followed by that of November second fortnight (D_3) sowing treatment. Seed yields followed increased trend up to November sowings and decreased beyond November month. The response to irrigation levels also followed similar trend as in case of individual years.

Chickpea GDD, and heat units are positively related and first sown crop (D_1) recorded higher values compared to rest of times of sowing crop. But seed yield was less than D_2 sown chickpea crop because of higher GDD for sowing to emergence and comparable number of GDD for emergence to 50 per cent flowering stage than D_2. More over during second year an amount of 74.8 mm of rainfall received in eight rainy days from 44 to 46 meteorological weeks, which coincided with germination to vegetative stage of October second fortnight(D_1) sown crop. Whereas November first fortnight sown (D_2) crop utilised the favourable weather condition and recorded highest yields. These results are also in concurrence with the findings of Sunil Kumar and Martin Luther, (2018).

Harvest index

Harvest index of chickpea was presented in Table 5. An insight in to the data indicated that there was no significant difference due to crop residue incorporation and irrigation as well as their interactions but statistically significant values were achieved with different times of sowing. Highest harvest index was recorded with October 2nd FN sowing, during both the years of study, which was followed by November 2nd FN, December, 1st FN and November 1st FN in order of decent. The harvest index values were in contrast to seed yields. The November 1st FN resulted in highest seed yield recorded lowest harvest index. This showed that, still there was a possibility for yield increase with best performed time of sowing, when partitioning ability was increased towards sink.

Thermal use efficiency (TUE)

Data on thermal use efficiency of different treatments was presented in Fig. 1 showed that crop residue incorporation, time of sowing and irrigations were significantly influenced the thermal use efficiency, in both years of study and on pooled basis, but all interactions were failed to differ significantly. Both dry matter and seed (kg ha^{-1} per degree day) producing efficiency values were significantly higher with November 1st FN sowing followed by November 2nd FN sowing, first time sowing (D_1) and fourth time of sowing (D_4) in order of decent, during both years of investigation and on pooled basis.

Crop growing ecological condition was the prime factor to utilise the heat energy for growth, development and harvest of economic yields. Thermal use efficiency was maximum when chickpea sown in of November 1st FN with high degree relation with increase in yields, during both years of study and on pooled basis and found to be optimum time of sowing for chickpea in rabi season under double cropping system in vertisols of Andhra Pradesh. These results are in close to the findings of Shamsi *et al.,* (2011). When the crop was raised during November first fortnight, growth is more advanced than average development of chickpea crop.

In conclusion, the assessment of weather indices and seed yield of chickpea showed that, maximum seed yield of chickpea can be achieved when chickpea was sown during November 1st FN, with incorporation of foxtail millet crop residue with two irrigations, one at pre flowering and another at pod development stage under double cropping system in vertisols of Andhra Pradesh.

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