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PHOTOTHERMAL INDICES OF SUPER EARLY AND MID EARLY PIGEONPEA (*Cajanus cajan* (L.) Millsp) GENOTYPES UNDER DELAYED *KHARIF* SOWING

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ABSTRACT

Ten genotypes of pigeonpea *viz.,* ICPL 20338, ICPL 11255, ICPL 20325, ICPL 88039 (super early genotypes) and AKTE 12-04, WRG 121, TRG 111, KRG 33, WRG 93, PRG 176 (mid early genotypes) were grown on the sandy loam soils of dryland farm, S.V. Agricultural College, ANGRAU, Tirupati in late *kharif*, 2019-20. The pigeonpea genotypes were sown on 24th August, 2019. Photothermal indices accumulated for different phenological events *viz.,* days to initiation of flowering, 50 per cent flowering and maturity were carried out. The accumulation of GDD, PTU, HTU were higher in AKTE 12-04 during days to initiation of flowering and maturity whereas during days to 50% flowering, WRG 93 accumulated highest. HUE was higher in ICPL 20325 and was on par with WRG 121. Though they matured earlier, the accumulated dry matter was more during 50% flowering to maturity. This showed the significant differences in using the heat available to the plants.

KEY WORDS: Pigeonpea Growing Degree Days (GDD), Photo Thermal Units (PTU), Helio Thermal Units (HTU) and Heat Use Efficiency (HUE).

INTRODUCTION

Legumes are economically important and widely grown throughout the world. They ranked next to cereals as a source of carbohydrates, proteins, fiber, certain minerals and B-complex vitamins. Whereas, nutritionally, legumes are 2 to 3 times richer in protein than cereal grains. Legumes play a vital role in providing protein to the growing population. The nutritional composition of pigeonpea in protein, fat, crude fiber, Nitrogen free extract, ash, P_2O_5, Ca and Fe is 22.9 per cent, 3.8 per cent, 5 per cent, 64.15 per cent, 4.15 per cent, 366 mg, 296 mg and 6.7 mg per 100 g, respectively (Salunkhe *et al.*, 2013). Pigeonpea is widely cultivated in India in an area of 4.44 million hectare with production and average productivity of 4.3 million tonnes and 967 kg ha^{-1} respectively. In Andhra Pradesh, it is cultivated in 0.28 million hectares with a production and productivity of 0.119 million tonnes and 430 kg ha^{-1} respectively (INDIASTAT, 2017). Pigeonpea is primarily grown in *kharif* season and mostly under rainfed condition.

As pigeonpea is short day species and sensitive to photoperiod, the plant enters into reproductive phase under favourable short day conditions whereas the late sowing causes considerable reduction in yield. Pigeonpea is restricted to adaptation due to its photoperiod sensitivity. The linear association of earliness with photo insensitivity furnishes an opportunity to develop cultivars that are widely adapted and it is possible through selection of earliness (Srivastava and Saxena, 2019). Based on these, International Crop Research Institute for Semi-Arid Tropics (ICRISAT) have developed early maturing pigeonpea germplasm and called it as "super early" that matures in 90 days. Extra short duration genotypes escape terminal drought and therefore have shown good adaptation to environments with a short growing season. Under this situation, timely sowing during *kharif* is affected due to frequent delay of South West Monsoon. Hence, contingent crop plan for *kharif* has become a prerequisite. Redgram is highly economical contingent crop recommended if rains received after 1st fortnight of August to 1st fortnight of September. The research priority of identification of photo insensitive varieties under late sowing is scanty and hence the super early genotypes developed by ICRISAT and mid early genotypes developed by Regional Agricultural Research Station (RARS), Tirupati were tested for photo insensitivity.

MATERIAL AND METHODS

The experiment was conducted in sandy loam soils of dryland farm, S.V. Agricultural College, Tirupati, Acharya N.G Ranga Agricultural University, in late *kharif*

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season, 2019-20 represented by latitude, longitude and altitude of 13.5° N, 79.5° E and 182.9 m above the mean sea level in the Southern agro-climatic zone of Andhra Pradesh respectively. The experiment was laid out in a randomized block design with ten genotypes and replicated thrice. Based on visual observations, different phenological events *viz.,* days to initiation of flowering, days to 50 per cent flowering and days to maturity were observed. Daily data on meteorological parameters were collected from meteorological observatory, S.V. Agricultural College farm, Tirupati.

GDD is the arithmetic accumulation of daily mean temperature above certain threshold temperature. Base temperature for pigeonpea is 10°C (Singh *et al.,* 2016).

$$GDD = \sum \frac{T_{max} + T_{min}}{2} - T_b$$

where, T_{min} = minimum temperature (°C), T_{max}= maximum temperature and T_b = Base temperature = 10°C.

The photothermal units for each day represent the product of GDD and the day length. The accumulated PTU for each phenophase was determined by following formula given by Hundal *et al.* (2003).

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

where, day length refers to maximum possible sunshine hours.

The heliothermal units for a given day represent the product of GDD and the actual bright sun shine hour. The sum of the HTU for the duration of each phenophase was determined by using the formula (Billore *et al.,* 1996).

Accumulated HTU (°C day hr) = GDD × No. of bright sunshine hours

Heat Use Efficiency (HUE) for economic yield (grain yield, kg/ha) was calculated using the following formula (Aggarwal *et al.*, 2016).

$$HUE = \frac{\text{Grain yield / Unit area}}{GDD}$$

Five plants from each treatment were selected and tagged for periodic phenological observations. Whenever more than three plants from each treatment attained a particular stage, the date was considered as the one for attainment of that stage.

RESULTS AND DISCUSSIONS

Phenological stages of the crop

The data pertaining to phenology of the crop was presented in Table 1. It was observed that number of days taken to attain any phenological stage varied with genotype. Among super early genotypes, ICPL 11255 attained flower initiation within 47 days after sowing (DAS) whereas ICPL 88039 took maximum of 82 DAS. Among mid early genotypes, AKTE 12-04 required maximum of 94 days to attain flower initiation and WRG 121 required minimum days (87 DAS) comparatively. Similar results were presented by Vales *et al*. (2012) in redgram. Among super early genotypes, ICPL 88039 attained 50 per cent flowering within maximum days of 90 whereas ICPL 11255 attained 50 per cent flowering within less number of days *i.e.,* 75. Among mid early genotypes, WRG 93 (109 DAS) required more days for 50 per cent flowering whereas WRG 121 required less days for 50 per cent flowering *i.e.,* 95 DAS. These results were in conformity with Meena *et al.* (2016). It was observed that ICPL 11255 attained maturity within less number of days *i.e.,* 107 days whereas ICPL 20325 took more days *i.e.,* 141 days among super early genotypes however, among mid early genotypes, AKTE 12-04 took 154 DAS to mature which was longer and PRG 176 took short duration of 145 DAS comparatively. Similarly, Hanumanthappa *et al.* (2020) portrayed that, the redgram variety ICP-14944 matured uniformly within short duration (133.17 days) whereas PRIL-B-155 taken long duration (167.66 days).

Photo thermal indices

The data pertaining to photo thermal indices were depicted in Table 1.

Growing degree days

During days to initiation of flowering, between super early determinate genotypes ICPL 20338 accumulated more GDD of 1408.8°C day than ICPL 11255. Between super early indeterminate genotypes, ICPL 88039 required more accumulated GDD of 2250.3°C day than ICPL 20325. Among mid early genotypes, AKTE 12-04 and WRG 93 accumulated highest GDD of 2553.1 °C day whereas WRG 121 accumulated less amount of GDD *i.e.,* 2376.6°C day. During days to 50% flowering, between super early determinate genotypes ICPL 20338 accumulated highest GDD of 2145.1°C day than ICPL

Table 1. Photothermal indices of pigeonpea genotypes during phenological stages

Genotypes	Days to Initiation of Flowering				Days to 50% of Flowering				Days to Maturity				
	DAS	GDD	PTU	HTU	DAS	GDD	PTU	HTU	DAS	GDD	PTU	HTU	HUE
Super early determinate genotypes													
ICPL 20338	50	1408.8	17483.2	9557.3	78	2145.1	26083.8	10972.8	108	2895.2	35784.7	14502.8	0.15
ICPL 11255	47	1322.3	16462.4	8822.8	75	2065.1	25173.6	10666.9	107	2872.7	35535.3	14334.0	0.15
Mean	**48.5**	**1365.6**	**16972.8**	**9190.1**	**76.5**	**2105.1**	**25628.7**	**10819.9**	**107.5**	**2884.0**	**35660.0**	**14418.4**	**0.15**
Super early indeterminate genotypes													
ICPL 20325	79	2172.8	26399.5	11141.8	87	2376.6	28756.3	12489.2	141	3691.8	48694.2	19359.4	0.54
ICPL 88039	82	2250.3	27296.1	11794.9	90	2452.5	29626.2	12684.9	140	3644.3	47995.4	18317.6	0.45
Mean	**80.5**	**2211.6**	**26847.8**	**11468.4**	**88.5**	**2414.6**	**29191.3**	**12587.1**	**140.5**	**3668.1**	**48344.8**	**18838.5**	**0.50**
Mid early genotypes													
AKTE 12-04	94	2553.1	30764.3	13457.8	105	2824.1	34933.5	14252.0	154	4001.7	52301.6	21915.5	0.33
WRG 121	87	2376.6	28708.7	12489.2	95	2577.1	31027.7	13566.1	150	3906.9	51493.6	21011.6	0.53
TRG 111	89	2426.3	29915.7	12512.9	97	2626.8	31574.1	13678.3	148	3857.5	47717.3	20585.5	0.50
KRG 33	92	2502.8	30208.8	13014.6	103	2775.5	34360.1	14127.9	146	3809.6	47200.9	20235.2	0.39
WRG 93	94	2553.1	30764.3	13457.8	109	2919.7	36058.3	14735.1	147	3832.6	47447.6	20435.3	0.36
PRG 176	90	2452.5	29613.9	12684.9	99	2676.4	32143.0	13835.9	145	3785.4	46939.0	19994.7	0.29
Mean	**91**	**2477.4**	**29996.0**	**12936.2**	**101.3**	**2733.3**	**33349.5**	**14032.6**	**148.3**	**3865.6**	**48850.0**	**20696.3**	**0.40**
Grand mean	**80.04**	**2201.84**	**26761.71**	**11893.40**	**93.80**	**2543.86**	**30973.65**	**13100.91**	**138.60**	**3629.77**	**46110.95**	**19119.17**	**0.37**
SD	16.61	434.36	5083.55	1511.69	10.69	268.99	3449.88	1309.24	16.01	384.90	5497.62	2483.00	0.14
CV (5%)	20.66	19.73	18.99	12.71	11.45	10.57	11.13	9.99	11.55	10.60	11.92	12.99	36.91

DAS : days after sowing; GDD : ^{o}C day; PTU, HTU : ^{o}C day hour; HUE : kg ha^{-1}^{o}C day^{-1}

11255. Between super early indeterminate genotypes, ICPL 88039 accumulated more GDD of 2452.5°C day than ICPL 20325. Among mid early genotypes, WRG 93 accumulated highest GDD of 2919.7°C day followed by AKTE 12-.04 with 2824.1°C day whereas less amount of GDD was accumulated in WRG 121 *i.e.,* 2577.1°C day. The results were in conformity with findings of Ram *et al*. (2014). During days to maturity, between super early determinate genotypes, ICPL 20338 accumulated more GDD of 2895.2°C day compared to ICPL 11255. Between super early indeterminate genotypes, ICPL 20325 accumulated highest GDD of 3691.8°C day than ICPL 88039. Among mid early genotypes, AKTE 12-04 accumulated highest GDD of 4001.7°C day whereas less amount of GDD was accumulated in PRG 176 (3785.4°C day). The accumulated temperature during each phenological stage is more which leads to accumulation of maximum GDD. Similarly, Rajbongshi *et al*. (2014) have depicted that higher GDD was accumulated upto physiological maturity in pigeonpea variety, BC (local) compared to ICPL 88039 in different sowings and seasons.

Photo thermal units

The evaluation of the results during all the phenological phases indicated that there was significant difference among three different groups of genotypes. During days to initiation of flowering, ICPL 20338 accumulated more PTU of 17483.2°C day hour compared to ICPL 11255 of super early determinate genotypes whereas between super early indeterminate genotypes, ICPL 88039 accumulated highest PTU of 27296.1°C day hour. Among mid early genotypes, AKTE 12-04 along with WRG 93 accumulated highest PTU of 30764.3°C day hour followed by KRG 33 (30208.8°C day hour) whereas WRG 121 accumulated less amount of PTU *i.e.,* 28708.7°C day hour. During days to 50% flowering, between super early determinate genotypes, ICPL 20338 accumulated highest PTU of 26083.8°C day hour. Comparatively, between super early genotypes, ICPL 88039 accumulated highest PTU of 29626.2°C day hour. Above mentioned genotypes accumulated more GDD and day length, higher PTU was accumulated. Among mid early genotypes, during days to 50% of flowering WRG 93 accumulated highest PTU of 36058.3°C day hour followed by AKTE 12-04 (34933.5°C day hour) whereas WRG 121 accumulated less amount of PTU *i.e.,* 31027.7°C day hour. During days to maturity, between super early determinate genotypes, ICPL 20338 accumulated highest PTU of 14502.8°C day hour compared to ICPL 11255. Between super early indeterminate genotypes ICPL 20325 accumulated highest PTU of 48694.2°C day hour. Among mid early genotypes, AKTE 12-04 accumulated highest PTU of 52301.6°C day hour followed by WRG 121 (51493.6°C day hour) whereas less amount of PTU was accumulated in PRG 176 *i.e.* 46939.0°C day hour. Similarly, Sidhu *et al.* (2017) indicated that significant difference of accumulated PTU was observed among cultivars at flower initiation, 50% flowering, pod initiation and physiological maturity.

Helio thermal units

During days to initiation of flowering, between super early determinate genotypes ICPL 20338 accumulated highest HTU of 9557.3°C day hour than ICPL 11255. Between super early indeterminate genotypes, ICPL 88039 accumulated highest HTU of 11141.8°C day hour. Among mid early genotypes, AKTE 12-04 along with WRG 93 accumulated highest HTU of 13457.8°C day hour followed by KRG 33 with13014.6°C day hour whereas WRG 121 accumulated less amount of HTU *i.e.,* 12489.2°C day hour. During days to 50% flowering between super early determinate genotypes, ICPL 20338 accumulated more HTU of 10666.9°C day hour. Between super early indeterminate genotypes ICPL 88039 accumulated HTU of 12684.9°C day hour. Comparatively among mid early genotypes, during days to 50% of flowering, WRG 93 accumulated highest HTU of 14735.7°C day hour followed by AKTE 12-04 (14252.0°C day hour) whereas less amount of HTU was accumulated in WRG 121 *i.e.,* 13566.1°C day hour. During days to maturity, between super early determinate genotypes, ICPL20338 accumulated highest HTU of 14502.8°C day hour. Between super early indeterminate genotypes, ICPL 20325 accumulated highest HTU of 19359.4. Among mid early genotypes, AKTE 12-04 accumulated highest HTU of 21915.5°C day hour whereas less amount of HTU was accumulated by PRG 176 *i.e.* 19994.7°C day hour. The genotypes showed more HTU due to accumulation of more GDD and bright sunshine hours during each phenological stage. Bhalerao *et al.* (2018) in pigeonpea have also found that the total HTU accumulated was high in pigeonpea variety BSMR-853 compared to BDN-711.

Heat use efficiency

Comparatively between super early determinate genotypes, both ICPL 20338 and ICPL 11255 recorded

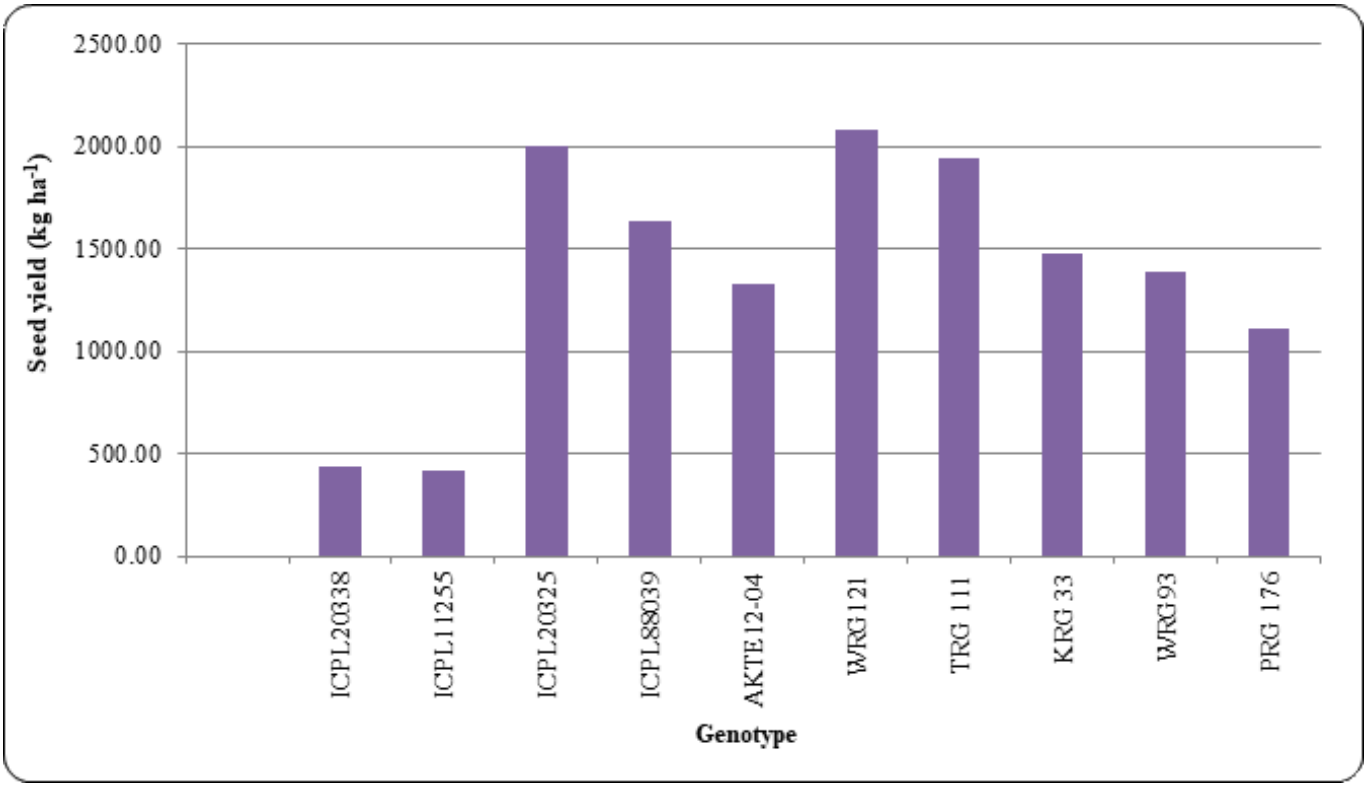

Fig. 1. Seed yield (kg ha^{-1}) of pigeonpea genotypes.

HUE of 0.15 kg ha^{-1} ^{o}C day^{-1}. Between super early indeterminate genotypes, ICPL 20325 has recorded higher HUE of 0.54 kg ha^{-1} ^{o}C day^{-1} compared to ICPL 88039. Similar, results were presented by Rajbongshi *et al*. (2014). Among mid early genotypes, the HUE was higher in WRG 121 (0.53 kg ha^{-1} ^{o}C day^{-1}) followed by TRG 111 (0.50 kg ha^{-1}^{o}C day^{-1}) and lower in PRG 176 with 0.29 kg ha^{-1} ^{o}C day^{-1}. Singh *et al*., 2016 have shown similar results. Due to accumulation of more drymatter during 50% flowering to maturity stage, the above depicted genotypes have shown highest HUE.

Seed Yield (kg ha^{-1})

Compared to ICPL 11255, more seed yield was recorded by ICPL 20338 (436 kg ha^{-1}) of super early determinate genotypes. Between super early indeterminate genotypes, ICPL 20325 recorded more seed yield of 2000 kg ha^{-1}. Among mid early genotypes, WRG 121 recorded more seed yield of 2083 kg ha^{-1} followed by TRG 111 (1944 kg ha^{-1}) and less seed yield was recorded by PRG 176 (1111 kg ha^{-1}). As the above mentioned genotypes are early indeterminate type, these can produce second flush of flowers which can escape from rainfall. Similarly, under delayed sowing, redgram variety 'ICP 8863' (Maruthi) performed better than 'TTB 7' and 'WRP 1' (Reddy *et al*., 2012) and reduction of 23 per cent was observed in delayed sowing (15-30 days) compared to normal sowing.

CONCLUSION

Photothermal indices analyzed at each phenological stage helped in knowing the suitable genotype for delayed *kharif* sowing. The pigeonpea genotypes WRG 121, ICPL 20325, TRG 111, ICPL 88039 matured earlier but they took more accumulation in between days to 50% flowering and maturity and resulted in yielding higher seed yield of 2083 kg ha^{-1}, 2000 kg ha^{-1} 1944 kg ha^{-1} and 1638 kg ha^{-1}, respectively.

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