Eco. Env. & Cons. 28 (November Suppl. Issue) : 2022; pp. (S336-S341)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i07s.055

Assessment of Growing Degree Days and Heat use Efficiency in Pigeonpea Varieties under Different Sowing Windows in Western Maharashtra, India

D. Nagaraju[1], S.B. Kharbade[2], J.D. Jadhav[3], R. Balasubramanian[3], A.A. Shaikh[4] and V.A. Sthool[5]

Department of Agricultural Meteorology, College of Agriculture - Pune, MPKV-Rahuri, M.S., India
[1]College of Agriculture - Pune, MPKV-Rahuri, M.S., India
[2]College of Agriculture, Nandurbar, M.S., India
[3]ZARS, Solapur, MPKV, Rahuri, M.S., India
[4]Agricultural Meteorology Division, IMD, Pune, M.S., India
[5]Oilseeds Research Station, Jalgaon, M.S., India
[6]Department of Agricultural Meteorology, College of Agriculture, Pune, M.S., India

(Received 25 March, 2022; Accepted 10 May, 2022)

ABSTRACT

Pigeonpea is an important source of high quality dietary protein and is mostly consumed as dehusked splits or dhal. For production of pigeonpea agrometeorological indices plays an important role in growth and development of the crop. Comprehensive assessment of agrometeorological studies on crop growth and development at local and regional scales can be highly beneficial. In this aspect, an experiment was laid out in split plot design with three replications. The treatment comprised of four varieties *viz.,* Vipula, Rajeshwari (Phule T 0012), BDN 711 and ICPH 2740 as main plot and four sowing windows *viz*., 24th, 26th MW, 28th and 30th MW as sub plot treatments. Higher GDD was observed in 24th MW sowing window in var. ICPH 2740 (2747.6 and 2700.6 ^{0}C) and var. Vipula (2539.4 and 2507.5 ^{0}C) this was followed var. BDN 711 and Rajeshwari during 2017-18 and 2018-19, respectively. Higher heat use efficiency (1.1441 and 1.0480 g/GDD) at branching to flower initiation was observed under 24th MW sowing window in var. ICPH 2740 this was followed var. Vipula, BDN 711 and Rajeshwari during 2017-18 and 2018-19, respectively.

Key words: *Pigeonpea, Agrometeorological indices, Heat use efficiency, GDD*

Introduction

Pigeonpea (*Cajanus cajan* (L.) Millspaugh) is one of the major pulse crop of the tropics and subtropics. It is the second most important pulse crop of India, after chickpea (Nene *et al.*, 1990). Pigeonpea is grown on an area of 4.43 m ha and production of 4.25 m tonnes the productivity is 960 kg ha^{-1} in India (Anonymous, 2019). All of these cultivated types of pigeonpea fall into two group's *viz*., *Cajanus cajan* (L.) var. Bicolour and *C. indicus* (L.) var. flavus.

Pigeonpea is very sensitive to low radiation at pod development, therefore flowering during the monsoon and cloudy weather, leads to poor pod formation (Saniya *et al.,* 2019). Low day and night temperature during reproductive phase favored higher crop production (Nanda *et al.,* 2010). Crop phenology is one of the important aspects since the biomass

([1]Ph. D. Scholar, [2]Associate Dean, [3]Agrometeorologist, [4]Scientist- E, [5]Retired Groundnut Agronomist, [6]Associate Prof.)

production and seed yields are known to depend greatly on prevailing environmental conditions during various phenophase. All biological processes of crops respond to temperature and all responses can be summarized in terms of three cardinal temperatures: a base or minimum, an optimum and a maximum temperature. Air temperature based meteorological indices viz., growing degree days (GDD) and heat use efficiency (HUE) are used to describe changes in phenology and growth parameters (Prakash *et al.,* 2015).

The progress in terms of growth is estimated by integrating a developmental rate, which is usually a function of temperature and photoperiod. Besides, heat use efficiency, *i.e*. efficiency of utilization of heat in terms of dry matter production or grain yield is another important aspect which has practical utility. Efficiency of heat energy conversion for dry matter production depends on genetic factors, crop and the growing environment. Several phenological models have been prepared to predict the duration required to attain different phenophases by using growing degree days (GDD), photothermal units (PTU) and other crop thermal units (Esfandiary *et al*., 2009). GDD and PTU are good estimators of growth stages in different crops like pigeonpea, sorghum (Prakash *et al*., 2017) and wheat (Pandey *et al*., 2010), and finally to predict the yield in view of different climatic changes. So, a detailed study of crop phenological events in pigeonpea would provide a base for understanding different growth and developmental processes as related to weather parameters.

Materials and Methods

Location of the experimental site

The field experiment was conducted for two consecutive years at Department of Agricultural Meteorology farm, College of Agriculture, Pune during *kharif*, 2017 and 2018. The geographical location of the site (Pune) was 18° 32′N, latitude; 73°51E, longitude and 559 m above mean sea level (MSL). The average annual rainfall of Pune is 675 mm.

Weather conditions during experimental period

Weekly mean meteorological data during the crop growth period (24^{th} to 2^{nd} MW) of *Kharif* 2017 and 2018 recorded in class 'A' observatory situated in the adjoining of field. The recorded weather data was briefly described as below:

The weekly maximum temperature experienced during 2017-18 was 33.4 ^{0}C and lowest maximum temperature was 27.1 ^{0}C. The highest minimum temperature experienced was 23.9 ^{0}C and the lowest was 10.3 ^{0}C. The total rainfall was 909.1 mm and maximum amount of rainfall 135.1 mm in a week. The weekly maximum temperature experienced during 2018-19 was 33.8 ^{0}C and lowest maximum temperature was 26.2 ^{0}C. The highest minimum temperature experienced was 24.6^{0}C and the lowest was 8.7 ^{0}C. The total rainfall was 420.3 mm and maximum amount of rainfall 90.8 mm in a week.

Experimental details

The experiment was conducted in a split plot design with three replications and sixteen treatment combinations of different varieties and sowing windows. The treatment comprised of four varieties *viz.*, Vipula, Rajeshwari (Phule T 0012), BDN 711 and ICPH 2740 as main plot and four sowing windows *viz*., 24^{th}, 26^{th} MW, 28th and 30^{th} MW as sub plot treatments. Inter row spacing was 45 cm and plant to plant spacing was 20 cm. Gross plot size was 4.0 × 4.5 square metres and net plot size was 3.6 × 4.0 square metres. The seed rate @ 18 kg ha^{-1} for all varieties. Urea and DAP were used as source of N and P, and applied as per recommended dose i.e., 25 kg N and 50 kg per hectare. All other practices were followed as per recommanadations of MPKV-Rahuri.

Agro-meteorological observations

Growing degree days (GDD)

Temperature is a major environmental factor that determines rate of plant development. The temperature required and range of optimum temperature varies with sowing dates and available soil moisture. Thermal response of sowing dates can be quantified by using the heat unit or thermal time concept. All agro-climatic indices namely growing degree days, heilo-thermal unit and photo-thermal units were calculated following Singh *et al.* (1990) and Nuttonson (1955).

$$GDD = \sum_{i=1}^{n} \frac{T_{max} + T_{min}}{2} - T_b$$

where $\sum_{i=1}$ = Period in days from sowing date till the last date of harvesting

GDD = Growing degree days

$T_{max.}$ = Daily maximum temperature of day i (^{0}C)
$T_{min.}$ = Daily minimum temperature of day i (^{0}C)
Tb = Base temperature (^{0}C)

In present study, the base temperature of pigeonpea was taken as 10 ^{0}C.

Heat use efficiency (HUE)

Heat use efficiency (HUE) for seed and total dry matter are calculated by the formula:

$$\text{HUE (kg/ha/}^0\text{C day)} = \frac{\text{Total dry matter (kg/ha)}}{\Sigma \text{ GDD (}^o\text{C day)}}$$

Results and Discussion

Agrometeorological studies

Growing degree day (GDD)

It was evident from the data (Table 1 and 2) that accumulated growing degree days (GDD) varied considerably from sowing to physiological maturity of the crop. Different pigeonpea varieties responded differently in terms of accumulated GDD. Higher GDD was observed under 24th MW sowing window in var. ICPH 2740 (2747.6 and 2700.6) this was followed by Vipula (2539.4 and 2507.5), BDN 711 (2515.8 and 2482.7), and the lower GDD was observed in var. Rajeshawari (2430.5 and 2381.9), during 2017-18 and 2018-19, respectively, from sowing to physiological maturity.

The linear relationship between growing degree day and pod yield was graphically presented in Figure 1 and 2. In this results found that yield were increased of all varieties with the increase in heat units in both the years. The highest yields were found in ICPH 2740 because of longer duration of the crop *i.e.*, higher the heat units productivity was also

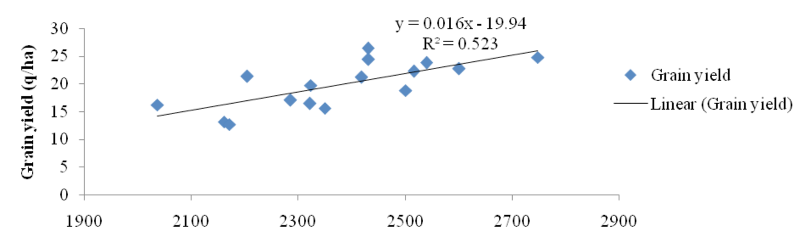

Fig. 1: Grain yield (q/ha) as influenced by growing degree days, during 2017-18

Table 1. Cumulative growing degree days (GDD) (^{0} Days) as influenced by different sowing windows and varieties in pigeonpea during 2017-18

Treatments		Cumulative growing degree days (GDD) (^{0} Days)					
		P_1	P_2	P_3	P_4	P_5	P_6
Vipula	D_1: 24th MW	140.0	614.3	1865.5	2074.3	2265.7	2539.4
	D_2: 26th MW	127.6	585.5	1837.3	2000.3	2152.4	2418.6
	D_3: 28th MW	140.8	581.3	1750.8	1890.1	2031.6	2285.7
	D_4: 30th MW	148.5	566.6	1696.0	1827.6	1957.3	2161.2
Rajeshwari	D_1: 24th MW	140.0	645.5	1743.8	1962.5	2164.4	2430.5
	D_2- 26th MW	126.2	615.8	1835.9	1998.9	2151.0	2430.8
	D_3: 28th MW	140.8	612.4	1563.8	1754.1	1947.3	2204.9
	D_4: 30th MW	148.5	597.5	1555.8	1696.0	1840.7	2036.8
BDN 711	D_1: 24th MW	140.0	614.3	1848.4	2058.5	2254.3	2515.8
	D_2: 26th MW	126.2	566.7	1765.0	1933.7	2085.2	2323.1
	D_3: 28th MW	140.8	559.0	1803.2	1938.1	2085.3	2321.8
	D_4: 30th MW	148.5	566.6	1685.3	1814.2	1957.3	2170.9
ICPH 2740	D_1: 24th MW	140.0	659.9	1996.0	2206.3	2406.4	2747.6
	D_2: 26th MW	126.2	631.6	1924.3	2084.4	2284.1	2600.6
	D_3: 28th MW	140.8	628.0	1877.9	2016.9	2204.6	2500.8
	D_4: 30th MW	148.5	612.5	1800.2	1930.5	2109.5	2349.4

Note: P_1: Sowing to germination, P_2: Germination to branching, P_3: Branching to flower initiation, P_4: Flower initiation to 50% flowering, P_5: 50% flowering to pod initiation, P_6: Pod initiation to maturity more.

In general, the GDD values decreased when the sowing was delayed. This might be due to early maturity of crops under delayed sown condition because of higher temperature.

Mishra and Chand (2009) reported that crop sown early took more number of degree-days ranges from 2813.8 to 3043.8 °C than delayed sowing (2482.7 to 2654.6 °C). Shortening of growing season in pigeonpea gradually related to reduction in growing degree days. The similar results were reported by Patel *et al.* (1999) and Gowda *et al.* (2013).

Heat use efficiency (HUE) (g/GDD)

Table 2. Cumulative growing degree days (GDD) (^{0} Days) as influenced by different sowing windows and varieties in pigeonpea during 2018-19

Treatments		Cumulative growing degree days (GDD) (^{0} Days)					
		P_1	P_2	P_3	P_4	P_5	P_6
Vipula	D_1: 24th MW	143.8	599.9	1781.5	2000.1	2207.4	2507.5
	D_2: 26th MW	127.6	566.9	1772.3	1958.1	2152.6	2407.5
	D_3: 28th MW	131.4	556.5	1712.5	1876.3	2042.6	2278.9
	D_4: 30th MW	149.8	550.7	1774.7	1911.7	2043.5	2227.7
Rajeshwari	D_1: 24th MW	143.8	614.3	1648.3	1867.9	2095.3	2381.9
	D_2- 26th MW	143.3	582.8	1569.7	1773.2	1981.8	2260.2
	D_3: 28th MW	131.4	570.8	1758.5	1948.8	2142.0	2163.3
	D_4: 30th MW	149.8	565.4	1468.1	1660.8	1814.4	2008.4
BDN 711	D_1: 24th MW	143.8	585.8	1763.8	1983.5	2191.2	2482.7
	D_2: 26th MW	127.6	551.4	1755.2	1945.4	2138.6	2385.3
	D_3: 28th MW	131.4	541.9	1755.5	1917.1	2086.8	2309.5
	D_4: 30th MW	149.8	610.8	1830.3	1966.7	2111.5	2312.5
ICPH 2740	D_1: 24th MW	143.8	627.2	1900.7	2124.2	2370.1	2700.6
	D_2: 26th MW	127.6	597.7	1885.5	2078.2	2305.9	2649.7
	D_3: 28th MW	131.4	584.0	1868.7	2037.5	2229.9	2500.9
	D_4: 30th MW	149.8	610.8	1899.3	2048.7	2208.1	2423.9

Note: P_1: Sowing to germination, P_2: Germination to branching, P_3: Branching to flower initiation, P_4: Flower initiation to 50% flowering, P_5: 50% flowering to pod initiation, P_6: Pod initiation to maturity

Table 3. Heat use efficiency as influenced by different sowing windows and varieties in pigeonpea during 2017-18.

Treatments		Heat use efficiency (g/GDD)				
		P_1	P_2	P_3	P_4	P_5
Vipula	D_1: 24th MW	0.3352	0.9704	0.7817	0.4825	0.6742
	D_2: 26th MW	0.3052	0.9518	0.6180	0.4225	0.6391
	D_3: 28th MW	0.2478	0.9404	0.6180	0.4125	0.6742
	D_4: 30th MW	0.2013	0.9404	0.6180	0.3900	0.6742
Rajeshwari	D_1: 24th MW	0.4020	1.0428	0.6659	0.5709	0.8259
	D_2- 26th MW	0.3521	1.0332	0.7031	0.5477	0.7533
	D_3: 28th MW	0.3052	0.8993	0.7941	0.4943	0.8566
	D_4: 30th MW	0.2780	0.9897	0.8713	0.4564	0.9379
BDN 711	D_1: 24th MW	0.3926	0.9520	0.6398	0.5317	0.6760
	D_2: 26th MW	0.3629	0.9323	0.5364	0.3788	0.7099
	D_3: 28th MW	0.3278	0.9410	0.5860	0.3720	0.6885
	D_4: 30th MW	0.2806	0.9755	0.6189	0.3157	0.7189
ICPH 2740	D_1: 24th MW	0.4688	1.1441	0.8004	0.5284	0.7414
	D_2: 26th MW	0.4288	1.1402	0.7481	0.4917	0.7179
	D_3: 28th MW	0.3501	1.0683	0.8004	0.4890	0.7414
	D_4: 30th MW	0.0261	0.0789	0.7853	1.0263	0.6776

Note: P_1: Germination to branching, P_2: Branching to flower initiation, P_3: Flower initiation to 50% flowering, P_4: 50% flowering to pod initiation, P_5: Pod initiation to maturity

Table 4. Heat use efficiency as influenced by different sowing windows and varieties in pigeonpea during 2018-19.

Treatments		Heat use efficiency (g/GDD)				
		P_1	P_2	P_3	P_4	P_5
Vipula	D_1: 24th MW	0.1271	0.9576	0.6956	0.3366	0.8241
	D_2: 26th MW	0.1238	0.8191	0.6509	0.3173	0.6463
	D_3: 28th MW	0.1188	0.8191	0.6509	0.3073	0.6463
	D_4: 30th MW	0.0989	0.8390	0.5921	0.2789	0.5692
Rajeshwari	D_1: 24th MW	0.1308	0.9852	0.7360	0.4131	0.8257
	D_2- 26th MW	0.1160	0.8565	0.7433	0.3746	0.7239
	D_3: 28th MW	0.1079	0.8405	0.6292	0.3624	0.7443
	D_4: 30th MW	0.1115	0.8124	0.6121	0.3262	0.7530
BDN 711	D_1: 24th MW	0.1229	0.9506	0.5458	0.2797	0.7002
	D_2: 26th MW	0.1139	0.7910	0.4406	0.2775	0.6075
	D_3: 28th MW	0.1125	0.8711	0.4989	0.2602	0.6676
	D_4: 30th MW	0.0852	0.8002	0.4434	0.2398	0.5166
ICPH 2740	D_1: 24th MW	0.1306	1.0480	0.7387	0.4991	0.9169
	D_2: 26th MW	0.1272	0.8503	0.7304	0.4477	0.6456
	D_3: 28th MW	0.1256	0.8994	0.7028	0.4453	0.7865
	D_4: 30th MW	0.1148	0.8331	0.7071	0.4312	0.7108

Note: P_1: Germination to branching, P_2: Branching to flower initiation, P_3: Flower initiation to 50% flowering, P_4: 50% flowering to pod initiation, P_5: Pod initiation to maturity

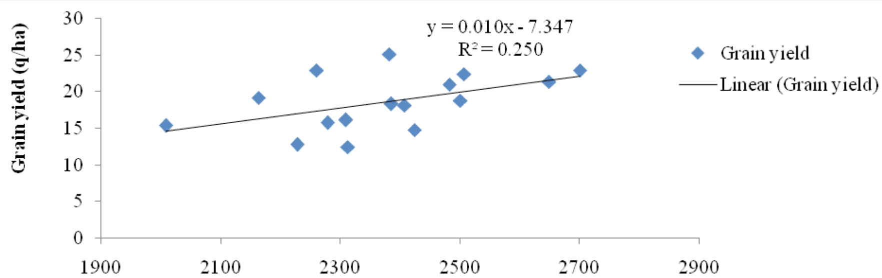

Fig. 2: Grain yield (q/ha) as influenced by growing degree days, during 2018-19

Different pigeonpea varieties responded differently in terms of heat use efficiency (g/GDD) at different phenophases. The highest heat use efficiency was observed in 24th MW sowing window (D_1) in all the varieties during 2017-18 and 2018-19. Heat use efficiency (HUE) for different genotypes varied considerably at different growth stages (Table 3 and 4).

Higher heat use efficiency (1.1441 and 1.0480 g/GDD) at branching to flower initiation stage was observed under 24th MW sowing window (D_1) in var. ICPH 2740 (V_4) during both the year 2017-18 and 2018-19, respectively. This was followed by var. Rajeshwari (1.0428 and 0.9852), Vipula (0.9704 and 9576). The var. BDN 711 observed the lowest heat use efficiency values (0.9520 and 0.9506 g/GDD) at branching to flower initiation stage during 2017-18 and 2018-19.

With delayed sowing window, heat use efficiency reduced significantly in pigeonpea. This was due to increase in the temperature during delayed plantings which accelerated the growth of the crop. The similar results were reported by Rajbongshi *et al*. (2017).

Conclusions

Amongst all the pigeon pea cultivars, var. ICPH 2740 found significantly superior under extended sowing windows followed by var. Rajeshwari (Phule T 0012), Vipula and BDN 711. Sowing during 24th MW sowing window was observed to be the most suitable and optimum for pigeonpea considering the yield attributes and yield of the crop.

References

Anonynous, 2019. Pulses revolution from food to nutritional security. Min Agri. & FW (DAC&FW), GOI.

Esfandiary, F., Aghaie, G. and Mehr, A.D. 2009. Wheat yield prediction through agro meteorological indices for Ardebil District. *Internat. J. of Bio. Life Sci.* 1 : 48-51.

Gowda, T. P., Halikatti, S. I., Venkatesh, H., Hiremath S. M. and Aravindkumar, B. N. 2013. Phenology, thermal time and phasic development of pigeonpea (*Cajanus cajan* L. Millisp.) grown under intercropping system. *J. Agromet.* 15 : (Spl. Issue.-II):129-134.

Mishra, A. and Chand, M. 2009. Effect of weather on phenology and yield of pigeonpea (*Cajanus cajan*) in central plain zone of Uttar Pradesh. *Current Adv. Agri. Sci.* 1(1) : 11-13.

Nanda, M. K., Chowdhury, S., Madan, S. and Saha, G. 2010. Studies on yield limiting meteorological factors for production of rabi pigeonpea in West Bengol. *J. Agromet.* 12(1) : 64-68.

Nene, Y. L., Susan, D. H. and Sheila, V. K. 1990. The Pigeonpea. C.A.B. *Int., Wallingford for ICRISAT*, Patancheru, India. p. 490.

Pandey, I. B., Pandey, R. K, Dwivedi, D. K. and Singh, R. S. 2010. Phenology, heat unit requirement and yield of wheat (*Triticum aestivum*) varieties under different crop growing environment. *Indian J. Agri. Sci.* 80: 136-140.

Patel, H. R., Shekh, A. M., Bapuji Rao, B., Chaudhari, G. B and Khushu, M. K. 1999, An assessment of phenology, thermal time and phasic development model of pigeonpea (*Cajanus cajan* L. Millsp.) cv. GT-100. *J. Agromet.* 1 (2) : 149-154.

Prakash, V., Niwas, R., Khichar, M.L., Sharma, D., Manmohan and Singh, B. 2015. Agrometeorological indices and intercepted photosynthetically active radiation in cotton crop under different environments. *J. Cotton Res. and Dev.* 29: 268-272.

Prakash, V., Mishra J. S, Kumar, R., Kumar, R., Kumar, S., Dwivedi, S. K., Rao, K. K. and Bhatt, B. P. 2017. Thermal utilization and heat use efficiency of sorghum cultivars in middle Indo-Gangetic Plains. *J. Agromet.* 19 : 29-33.

Rajbongshi, R, Neog P., Sarma, P. K., Sarmah K., Sarma, M. K., Sarma, D. and Hazarika, M. 2017. Thermal indices in relation to crop phenology and seed yield of pigeon pea (*C. cajan* L. Millsp.) grown in the north bank plains zone of Assam. *Mausam*. 67(2) : 397-404.

Saniya, N. L, Harsh, M. H, Abhishek, O. G and Altamash M. S. 2019. Study of price trends of *arhar* (Tur) Daal with special reference to Akola district markets. *J. of Emerging Tech. and Innovative Res.* 6(2) : 302-305.