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Effects of weather parameters on growth, development and yield of pigeon pea varieties

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Abstract
A research trial named "Effects of weather parameters on growth, development and yield of pigeon pea varieties" was conducted at Farm of AICRP on Agrometeorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *kharif* season 2021. The research field was laid out in split-plot design with three replications and four varieties *viz*. dates of sowing D_1 (25^{th} MW), D_2 (26^{th} MW), D_3 (27^{th}MW), D_4 (28^{th} MW) and varieties V_1 (BDN-711), V_2 (BSMR-736) and V_3 (BDN-716) sown with the spacing of 90 x 20 cm^2 using 12 treatments and 36 plots to study the crop weather relationship. The Gross plot size was 5.4 x 5.0 m^2 with a net plot size of one treatment was 4.5 x 4.2 m^2. The correlation was worked between the different weather parameters and seed yield of different varieties.

Keywords: Weather parameters, growth, development, yield, pigeon pea varieties

Introduction
Pigeon pea (*Cajanus cajan* (L.) Millsp.) is cultivated in the semi-arid areas of tropics and subtropics. Pigeon pea is a long duration pulse crop mainly being cultivated in poor soils under rainfed condition and the crop has capacity to thrive well under low input and adverse condition (Kumar and Paslawar 2017) [7]. The crop owes its popularity to the fact that being a leguminous plant; it is capable of fixing atmospheric nitrogen and thereby restores nitrogen content in the soil. Its deep root system helps in extracting nutrients and moisture from deeper soil layers thus making it suitable for rainfed condition.
Weather plays a major role in determining the success of agricultural pursuits. Most field crops are dependent solely upon weather to provide life sustaining water and energy. Growing Degree Days (GDD) and temperature are two significant spatially dynamic climatic variables that have a significant impact on forest development (Bourque *et al*. 2000) [2]. The length of each phenophase affects how quickly dry matter accumulates and is distributed throughout the plant, as well as how the crop reacts to external and environmental influences (Dalton, 1967) [3].

Materials and Methods
Field experiment was conducted at Farm of AICRP on Agrometeorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *kharif* season 2021 to find out the effects of dates of sowing on pigeon pea varieties, effects of weather parameters on growth and development of pigeon pea and effect of varied weather condition. The research field was laid out in split-plot design with three replications and four varieties *viz*. dates of sowing D_1 (25^{th} MW), D_2 (26^{th} MW), D_3 (27^{th} MW), D_4 (28^{th} MW) and varieties V_1 (BDN-711), V_2 (BSMR-736) and V_3 (BDN-716) sown with the spacing of 90 x 20 cm^2 using 12 treatments and 36 plots to study the crop weather relationship. The Gross plot size was 5.4 x 5.0 m^2 with a net plot size of one treatment was 4.5 x 4.2 m^2. Five plants in plot were selected for biometric observations.

Growing Degree Days (GDD)
Growing Degree Days is defined as "the sum over the growing season of a crop of the difference between the daily temperature and a reference temperature". GDD was expressed in terms of °C day. The Growing Degree Days (GDD) was worked out by considering the base temperature of 10 °C (Patel *et al.* 1999) [9].
The total Growing Degree Days (GDD) for different phenophases were determined by the following formula-

$$\text{Accumulated GDD } (^{o}\text{C day}) = \sum_{ds}^{dh}[(T_{max} + T_{min}) / 2] - Tb$$

Where,
GDD = Growing degree days
T_{max} = Daily maximum temperature (°C)
T_{min} = Daily minimum temperature (°C)
Tb = Base temperature (10 °C)
ds = Date of sowing
dh = Date of harvest

Helio Thermal Units (HTU)

The HTU may be defined as "the accumulated product of GDD and Bright sun shine hours between the developmental thresholds for each day" and HTU was expressed in terms of ^{o}C day hrs.

The HTU is the product of GDD and mean daily hours of bright sun shine. The sum of HTU for each phenophase was worked out by following equation which was given by Nagamani *et al.* (2015) [8].

Accumulated HTU (^{o}C day hrs) = GDD x BSS

Where,
HTU = Helio Thermal Units
GDD = Growing Degree days
BSS = Bright Sun Shine Hours

Photo Thermal Unit (PTU)

PTU may be defined as "the product of growing degree days and the day length" expressed in terms of ^{o}C day hrs. PTU was computed by using following formula. This was proposed by Gudadhe *et al*. (2013) [5].

PTU (^{o}C day hrs) = GDD x Day length

Where,
PTU = Photo Thermal Units
GDD = Growing Degree days

Photo Thermal Index (PTI)

PTI may be defined as "the ratio of total accumulation of GDD to the no. of days taken between two phenophases" and expressed in terms of ^{o}C day. PTI was computed by using following formula. This was proposed by Gowda *et al*. (2013) [4].

$$\text{PTI } (^{o}\text{C day}) = \frac{\text{Total accumulation of GDD}}{\text{No. of days taken between two phenophases}}$$

Heat Use Efficiency (HUE)

HUE may be defined as "the ratio of biological yield i.e, total dry matter to the total accumulated heat unit i.e, GDD" and expressed in terms of kg ha^{-1} °C day^{-1}. HUE was computed by using following formula. This was proposed by Kumar *et al*. (2008) [6].

$$\text{HUE (kg ha}^{-1}\,^{o}\text{C day}^{-1}) = \frac{\text{Biological yield (total dry matter)}}{\text{Accumulated heat units (GDD)}}$$

Results and Discussion

Growing Degree Days (GDD)

The Growing Degree Days (GDD) for the pigeon pea crop under various planting dates and types are reported in Table 1. According to the data in Table 1, the mean heat unit requirement from the germination to maturity stage (P_1 to P_7) in D_1 (25th SMW), the mean heat load was recorded to be 617.57 °C day, and in D_2 (26th SMW), D_3 (27th SMW) and D_4 (28th MW) it was 609, 597.86 and 591.86 °C day respectively. It showed that the average heat load dropped from D_1 to D_4, which can be related to the delayed sowing. Date of sowing D_1 (25th SMW) showed a higher heat load (i.e. 617.57 °C day) than the other treatments, this may be because the higher air temperature was present at the time of planting. Due to the influence of temperature and delayed sowing during the crop growing season, the lowest (i.e. 591.86 °C day) heat unit necessary for achieving various phenophases in D_4 (27th SMW) date of sowing. Gowda *et al*. (2012) [4] and Nagamani *et al*. (2015) [8] reported similar findings.

The data shown in Table 1 exhibited that average heat unit demand of variety BDN-711 found as 576.43 °C day and average heat unit demand of varieties BSMR-736 and BDN-716 found to be same i.e. 631.86 °C day.

Helio Thermal Unit (HTU)

From germination to maturity, the Helio Thermal Unit (HTU) for the pigeon pea crop under various dates of sowings and varieties are reported in Table 2.

According to the data in Table 2, the mean HTU requirement from the germination to maturity stage (P_1 to P_7) in D_1 (25th SMW), the mean HTU was recorded to be 3787.86 °C day hrs, and in D_2 (26th SMW), D_3 (27th SMW) and D_4 (28th MW) it was 3374.14, 3318.57 and 3263.43 °C day respectively. It showed that the average HTU decreased from D_1 to D_4, which can be related to the delayed sowing. The HTU unit was found to be highest (3387. 86 °C Day hrs) in the D_1 (25th SMW) and lowest (3263.43 °C) in the D_4 (28th SMW) date of sowing as compared to other dates of sowing. The total HTU recorded in D_1, D_2, D_3 and D_4 date of sowing was 23715, 23619, 23230 and 22844 °C Day hrs, respectively. It may be due to the variation in dates of sowings. Nagamani *et al*. (2015) [8] reported the similar findings. The data shown in Table 2 exhibited that average HTU of variety BDN-711 found as 3180 °C day hrs and average heat unit demand of varieties BSMR-736 and BDN-716 found to be same i.e. 3491.57 °C day hrs.

Photo Thermal Units (PTU)

According to the data in Table 3, the mean PTU requirement from the germination to maturity stage (P_1 to P_7) in D_1 (25th SMW), the mean PTU was recorded to be 7716.71 °C day hour, and in D_2 (26th SMW), D_3 (27th SMW) and D_4 (28th MW) it was 7612.43, 7472.29 and 7397.29 °C day hour respectively. It showed that the average PTU decreased from D_1 to D_4, which can be related to the delayed sowing. The PTU unit was found to be highest (7716.71°C day hour) in the D_1 (25th SMW) and lowest (7397.29 °C day hour) in the D_4 (28th SMW) date of sowing as compared to other dates of sowing. The total PTU recorded in D_1, D_2, D_3 and D_4 date of sowing was 54017, 53287, 52306 and 51781 °C day hour, respectively. It may be due to the variation in dates of sowings. Similar results were reported by Bhalerao *et al*. (2020) [1]. The data shown in Table 3. exhibited that average

PTU of variety BDN-711 found as 7204.86 °C day hour and average heat unit demand of varieties BSMR-736 and BDN-716 found to be same i.e. 7894.29 °C day hour.

Table 1: Phenological stage-wise GDD (ºC day) required by Pigeon pea under varying dates of sowing and variety during *Kharif* 2021

	Phenological stages								
Date of sowing	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**Total**	**Mean**
D_1 (25th SMW)	146	741	120	2376	192	140	608	4323	617.57
D_2 (26th SMW)	127	733	122	2358	153	148	622	4263	609.00
D_3 (27th SMW)	126	728	116	2219	159	172	665	4185	597.86
D_4 (28th SMW)	122	724	136	2197	161	172	631	4143	591.86
Variety	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**Total**	**Mean**
V_1 (BDN-711)	131	526	128	2407	152	150	541	4035	576.43
V_2 (BSMR-736)	131	937	119	2168	180	166	722	4423	631.86
V_3 (BDN-716)	131	937	119	2168	180	166	722	4423	631.86

P_1 – Sowing to Germination	P_5 – 50% Flowering to 50% pod Formation
P_2 – Germination to Seedling	P_6 – 50% Pod formation to Grain formation
P_3 – Seedling to Branching	P_7 – Maturity Stage
P_4 – Branching to 50% Flowering	

Table 2: Phenological stage-wise Helio Thermal Unit (ºC day hrs) required by Pigeon pea under varying dates of sowing and variety during *Kharif* 2021

Phenological stages									
Date of sowing	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**Total**	**Mean**
D_1 (25th SMW)	931	3500	391	12773	1692	1036	3392	23715	3387.86
D_2 (26th SMW)	496	3521	483	13446	1238	862	3573	23619	3374.14
D_3 (27th SMW)	526	3441	223	13435	949	942	3714	23230	3318.57
D_4 (28th SMW)	338	3238	492	13373	945	1051	3407	22844	3263.43
Varieties	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**Total**	**Mean**
V_1 (BDN-711)	573	2429	470	13506	1226	942	3116	22262	3180.29
V_2 (BSMR-736)	573	4421	325	13007	1185	1003	3927	24441	3491.57
V_3 (BDN-716)	573	4421	325	13007	1185	1003	3927	24441	3491.57

P_1 – Sowing to Germination	P_5 – 50% Flowering to 50% pod Formation
P_2 – Germination to Seedling	P_6 – 50% Pod formation to Grain formation
P_3 – Seedling to Branching	P_7 – Maturity Stage
P_4 – Branching to 50% Flowering	

Table 3: Phenological stage-wise PTU (ºC day hour) required by Pigeon pea under varying dates of sowing and variety during *Kharif* 2021

	Phenological stages								
Date of sowing	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**Total**	**Mean**
D_1 (25th SMW)	1828	9259	1496	29697	2396	1745	7596	54017	7716.71
D_2 (26th SMW)	1589	9158	1525	29473	1908	1854	7780	53287	7612.43
D_3 (27th SMW)	1580	9095	1452	27735	1983	2144	8317	52306	7472.29
D_4 (28th SMW)	1529	9046	1695	27464	2011	2148	7888	51781	7397.29
Variety	**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**Total**	**Mean**
V_1 (BDN-711)	1631	6572	1600	30089	1901	1874	6767	50434	7204.86
V_2 (BSMR-736)	1631	11707	1484	27095	2248	2071	9024	55260	7894.29
V_3 (BDN-716)	1631	11707	1484	27095	2248	2071	9024	55260	7894.29

P_1 – Sowing to Germination	P_5 – 50% Flowering to 50% pod Formation
P_2 – Germination to Seedling	P_6 – 50% Pod formation to Grain formation
P_3 – Seedling to Branching	P_7 – Maturity Stage
P_4 – Branching to 50% Flowering	

Heat Use Efficiency (HUE)

The Heat Use Efficiency (HUE) of pigeon pea during different dates of sowing was exhibited in Table 4. HUE of pigeon pea in D_1, D_2, D_3 and D_4 dates of sowing was recorded 0.22, 0.20, 0.18 and 0.18 Kg ha^{-1} °C day^{-1} hour, respectively. It might be due to the different growing period of different dates of sowing of crop. Rajbongshi *et al*. (2016) [10] also concluded the same results.

Table 4: HUE (Kg ha^{-1} °C day^{-1} hour) of Pigeon pea under varying dates of sowing during *Kharif 2021*

	Particulars	D_1 (25th SMW)	D_2 (26th SMW)	D_3 (27th SMW)	D_4 (28th SMW)
Sr. No.	**Yield (Kg ha^{-1})**	950.89	870.11	733.89	732.89
	Phenophases	**GDD (°C day)**			
1	P_1	146	127	126	122
2	P_2	741	733	728	724
3	P_3	120	122	116	136
4	P_4	2376	2358	2219	2197
5	P_5	192	153	159	161
6	P_6	140	148	172	172
7	P_7	608	622	665	631
Accumulated GDD (°C day)		4323	4263	4185	4143
HUE (Kg ha^{-1} °C day^{-1} hour)		0.22	0.20	0.18	0.18

Conclusion

The meteorological variables rainfall, rainy days, minimum temperature, RH-I, RH-II and wind speed only exhibited significant positive link with seed yield during branching to 50% flowering (P_4) stage of variety BDN-711 and BSMR-736.

The meteorological variables maximum temperature, minimum temperature and RH-I exhibited significant correlation with seed yield during branching to 50% flowering (P_4) stage of variety BDN-716.

The branching to 50% flowering (P_4) stage of the pigeon pea recorded greater levels of GDD, HTU, and PTU among all the important growth stages or phenophases.

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