



Thermal Requirement for Phenophases of Pigeonpea Varieties under Rainfed Sub-tropics of Lower Shivalik Hills of Jammu and Kashmir UT

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ABSTRACT

Background: Pigeonpea pulse crop is known to be one of the ancient and an important pulse grown in about all over the Indian sub continent. It is grown in about all agro-climatic zones like plains, hills, deccan plateau, etc. However, in sub tropical areas of Jammu region, pigeonpea is grown by the farmers, but there are not any specific recommendations for the varieties which are well suited particularly for this area. Also, agrometeorological studies for pigeonpea have also not done so far in this area. So, to shift the farmers of lower Shivaliks from their traditional agriculture towards pulses particularly pigeonpea for the better soil health; current research has been conducted for evaluating pigeonpea varieties best suited to this area and also work out its thermal requirements for various phenophases and relationship study.

Methods: The investigation was carried out during *kharif* 2018 to 2020 under AICRP on Pigeonpea at Research Farm of ACRA, Dhiansar, SKUAST-Jammu in *Inceptisols*. The experiments comprised of eight (08) varieties of pigeonpea laid out in RBD with three replications. The thermal requirements for various phenophases worked out along with the relationship studies.

Result: Variety VLA-1 recorded significantly higher grain yield (28.0 q/ha), biological yield (114.52 q/ha), nutrient uptake, yield attributes and agrometeorological parameters viz., accumulated growing degree days (AGDD), accumulated helio-thermal units (AHTU) and accumulated photothermal units (APTU) and was followed by the values obtained with varieties AL-2207 and PA-619. Days to 50% flowering and physiological maturity ranged between 65-77 and 91-112 days, respectively. With respect to the weather relationship study, the grain yield of pigeonpea has very highly significant and positive relationship with AGDD, AHTU and APTU. Accumulated growing degree days at 50% flowering, 50% pod formation and physiological maturity was positively correlated with grain yield with R^2 values of 67, 66 and 65%, respectively.

Key words: GDD, HTU, Pigeonpea, PTU, Relationship, Varieties, Weather factors.

INTRODUCTION

Pigeonpea [*Cajanus cajan* (L.) Millsp] an important pulse crop primarily originated in the Indian sub continent. It is primarily cultivated in tropical and sub-tropical areas between 30°N and 30°S latitude. Pigeon pea is 5th most important pulse crop in the world and 2nd important in India. This pulse crop is hardy in nature and could be grown easily under moisture deficient and adverse climatic conditions successfully. The majority of pulse crop's land is rainfed and thus major reason for its low production and productivity (Gupta *et al.*, 2012 and Gupta *et al.*, 2014). Generally, pulses are considered as environment friendly because of their reduced dependence on fossil fuels. The crop is able to obtain most of its nitrogen requirement from atmosphere through symbiotic relationship (Gupta and Singh, 2012a). For this reason, it has become a very common pulse crop among majority of the population and could be well grown under semi-arid, arid and rainfed conditions. Globally pigeon pea is cultivated over an area of about 5.4 million hectares with the production of 4.49 million tonnes. In India, pigeonpea is mostly cultivated as *kharif* crop mostly under rainfed conditions. In India, area under pigeonpea cultivation is about 4.5 million hectares with production and productivity of 3.1million tonnes and

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831 kg/ha, correspondingly (Anonymous, 2022). Although pigeonpea is primarily grown in practically every Indian state, majority of its land is located in the states encompassing Madhya Pradesh, Maharashtra, Karnataka, Uttar Pradesh and Gujarat. It is one of most crucial pulse crop of Indian rainfed sub-tropical conditions (Van Der Maesen, 1990). Rainfed agriculture makes up around 12% of the Jammu region's total area, which is identified locally

as the *kandi* area. This area is the most stressed ecosystem in region and main cropping sequence utilized by the farming community in Jammu region's *kandi* belt is maize-wheat (Gupta *et al.*, 2014a). Pigeonpea contains high protein, fibre, vitamins, potassium and considerable amounts of zinc, iron and low fat and Na contents thus making them a good source of food and nutrition. It is also known by its English name like red gram and also locally named as *Tur* or *Arhar*. In India majority of the population is vegetarian and thus are dependent on plant-based proteins to fulfil their protein requirements. India being a developing country and having a large population has to face malnutrition because of less availability of nutritious food. Deficiencies mostly faced are related to micronutrients like zinc, iron, calcium, *etc.* (Pandey *et al.*, 2021).

Weather parameters, most significantly environmental factors influenced growth as well as development of pigeonpea crop under rainfed conditions. Environmental factors like maximum and minimum temperature and sun shine hours influenced the occurrence of various phenophases and yield of pigeonpea crop. These factors interact with one another and influence the growth and development of pigeonpea and thus may assist the weather-based control of this crop under rainfed conditions. Idea behind growing degree days is that the temperature in range between base temperature and optimal temperature has linear relationship with amount of time needed to reach phenological stage (Monteith, 1981; Gupta *et al.*, 2014b). The in-built property of pigeonpea pulse to tolerate adverse conditions has made this crop to perform well even under prolonged dry spells and droughts and also minimizes their effects (Saileela *et al.*, 2019). Pigeonpea offer an excellent scope for its expansion in the non-traditional areas and new niches (Bansal *et al.*, 2024). The newly developed high yielding varieties with wider adaptability can be grown in new areas based on the local cropping situation requirements (Kumar *et al.*, 2016; Kumar *et al.*, 2021). Current examination is predicated on adaptability and study of weather interactions of extra early varieties of pigeonpea under rainfed conditions of Jammu.

MATERIALS AND METHODS

Field experiments performed during *kharif* 2018 to 2020 under AICRP on Pigeonpea (Volunteer centre) at Research Farm of Advanced Centre for Rainfed Agriculture (ACRA), Rakh Dhiansar under Sher-e-Kashmir University of Agricultural Science and Technology (SKUAST) of Jammu, JandK (UT) (32°39'N 74° 53'E, elevation of 332 m AMSL). Soil of experimental site was *Inceptisols* and categorized under alluvial group possessing a sandy loam texture, low organic carbon (2.3 g/kg), moderate potash, medium phosphorus, low accessible nitrogen and a pH of 6.62. Research was mainly performed to examine impact of several extra early varieties on phenology and yield of pigeonpea and their relationship with weather parameters under rainfed conditions in sub-tropics of Jammu. The study

comprised of eight (08) varieties of pigeonpea; viz., V₁: VLA-1, V₂: PAU-881, V₃: Manak, V₄: AL-2207, V₅: PA-619, V₆: Pusa-2018, V₇: Pusa-2018-3 and V₈: Pusa-2018-2 developed via randomized block design (RBD) and replicated thrice. The region's climate is classified as subtropical, with hot, dry summers, cold, dry winters and humid *monsoons*. The *monsoon* rainfall generally commences on 27th June $\pm$ 10 days and ceases in mid of September in lower hills/plains of *Shivalik* hills in sub tropical area of JandK region. The Meteorological Observatory, "Advanced Centre for Rainfed Agriculture (ACRA)", Rakh Dhiansar, Samba, J and K UT, roughly 100 meters from the experimental location, is where the weather data was acquired. Plot size was 6.0 $\times$ 4.0 m. During the *kharif* seasons of 2018, 2019 and 2020, the crop was planted at the beginning of the *monsoon* and harvested when the corresponding types reached physiological maturity. Fertilizer dose was applied as per the package of practices of SKUAST-Jammu. Rest all the other agronomic practices were carried out throughout the crop growing season. As needed, additional field operations encompassing roguing, weeding and plant protection measures has been carried out.

Field data was collected for harvest index, biological yield, grain yield and different crop phenological stages. Attainment of various phenophases adjudged by the manual inspection of ten (10) tagged plants at 2-3 days interval.

The formula provided by Nuttonson (1955) has been employed to compute growing degree days (GDD) or heat units (HU):

$$\text{GDD (}^{\circ}\text{C days)} = \frac{\sum (\text{T max} - \text{T min})}{2} - \text{T}_b$$

Here, T max, maximum temperature ($^{\circ}\text{C}$) during a day; T min, minimum temperature ($^{\circ}\text{C}$) during a day; T_b, base temperature (8°C) for pigeonpea crop under sub tropical conditions.

The photothermal unit (PTU), which is represented in degrees Celsius per day, was computed by multiplying GDD by the maximum number of sunshine hours (Nuttonson, 1956).

$$\text{Photo thermal units (PTU)} = \Sigma \text{GDD} \times \text{maximum day length (}^{\circ}\text{C day hrs)}$$

GDD and actual bright sunshine hours were multiplied to determine the helio-thermal unit (HTU), which was then expressed as $^{\circ}\text{C}$ day hour (Rajput, 1980).

$$\text{Helio thermal units (HTU)} = \Sigma \text{GDD} \times \text{bright (actual) sun shine hrs (}^{\circ}\text{C day hrs)}$$

According to a randomized block design, variety-wise data collected for several crop metrics was statistically analyzed (Cochran and Cox, 1963).

RESULTS AND DISCUSSION

Crop phenology

Data about crop phenophases, viz., flowering, physiological maturity, as well as duration of reproductive phase noted

as per the procedures (Table 1). Significant variations in occurrence of phenophases in pigeonpea varieties noticed in Jammu's sub-tropical rainfed environment. A considerable and notable difference observed for days taken to physiological maturity among the varieties of pigeonpea. Critical difference in duration of reproductive phase in pigeonpea varieties was also significant. Variety VLA-1 (T_1) recorded significantly superior values of days to 50 percent flowering (77.4 days), physiological maturity (147.8 days) and duration of reproductive stage (70.4 days), however minimum days to accomplish these stages recorded in variety PAU-881. A notable variation in occurrence of phenophases may result from the genetic differences between types as well as from how they react to changes in air and canopy temperature over time frame needed to achieve that specific phenophase. Under sub-tropical instances in Jammu, Gupta *et al.* (2017) discovered comparable findings. Additionally, a variety's inability to adapt to higher temperatures is determined by its genetic composition and temperature tolerance limit during different phenophases (Gupta *et al.*, 2020).

Yield

Pigeonpea varieties had a major impact on various growth parameters and yield characteristics and higher values

observed in VLA-1 variety which was followed by variety AL-2207 and the minimum values noted in PAU-881 variety. Grain, stover and biological yield of pigeonpea varieties affected significantly (Table 2). Variety PAU-881 recorded statistically superior grain, stover and biological yield to the tune of 28.0, 86.5 and 114.5 q/ha, respectively and followed by variety AL 2207; whereas minimum values of the same observed in PAU-881 variety. Pigeonpea varieties' differences in grain, stover and biological yields may result from their distinctive genetic compositions and yielding capacities, which are primarily in charge of how their different growth and yield parameters emerge in a particular environment (Sujathamma *et al.*, 2025). Jatti, (2013) and Tripathi, (2003) similarly revealed similar findings. Gupta *et al.* (2021) also examined the noteworthy performance of various wheat types in Jammu's subtropical climate.

Relationship of grain yield with agro-meteorological indices

Grain yield with AGDD

Fig 1, 2 and 3 show relationship between grain yield and "accumulated growing degree days (AGDD)" at 50% flowering, 50% pod formation and physiological maturity. Grain yield and AGDD had a strong linear connection that

Table 1: Occurrence of phenophases stages in pigeonpea varieties under rainfed conditions (pooled data of 3 years).

Treatments/Varieties	Days to 50% flowering	Days to 50% pod formation	Days to physiological maturity	Duration of reproductive phase
V ₁ : VLA-1	77.4	111.9	147.8	70.4
V ₂ : PAU-881	65.1	92.1	116.7	51.6
V ₃ : Manak	69.2	96.9	124.1	54.9
V ₄ : AL-2207	65.6	91.0	119.6	54.0
V ₅ : PA-619	74.2	103.2	134.2	59.9
V ₆ : Pusa-2018	66.3	93.1	117.6	51.3
V ₇ : Pusa-2018-3	70.4	96.4	118.6	48.2
V ₈ : Pusa-2018-2	67.7	97.3	139.6	71.9
Mean	69.5	97.8	127.3	57.8
CD (5%)	5.8	8.3	5.7	4.4

Table 2: Growth parameters, yield attributes and yield of pigeonpea varieties under rainfed conditions (pooled data of 3 years).

Treatments/ Varieties	Plant height (cm)	Primary branches/ Plant	Pods/ Plant	Grain yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest index (%)	100 Seed weight (g)
V ₁ : VLA-1	179.5	18.7	124.9	28.00	86.5	114.52	24.5	10.2
V ₂ : PAU-881	167.0	14.0	103.1	21.04	58.0	79.05	26.7	8.0
V ₃ : Manak	175.6	13.6	91.0	20.38	54.5	74.88	27.2	7.2
V ₄ : AL-2207	183.5	18.0	112.9	26.15	77.9	104.09	25.2	9.5
V ₅ : PA-619	153.6	15.5	110.8	25.21	73.2	98.38	25.6	8.3
V ₆ : Pusa-2018	164.8	14.6	102.5	22.00	59.8	81.84	26.9	7.2
V ₇ : Pusa-2018-3	160.1	15.4	104.2	22.78	64.1	86.84	26.2	8.2
V ₈ : Pusa-2018-2	191.0	14.0	101.2	22.09	58.9	80.94	27.4	6.9
CD (5%)	11.9	2.9	13.2	2.06	6.98	7.8	NS	0.78

explained 67, 66 and 65% of the variability, accordingly. Gupta *et al.* (2020a) and Kaur *et al.* (2016) also noted great substantial correlation between “accumulated growing degree days (AGDD)” and grain yield.

Grain yield with AHTU

“Accumulated Helio Thermal Units (AHTU)” at 50% flowering, 50% pod formation and physiological maturity is related to grain yield (Fig 4, 5 and 6). It showed solid

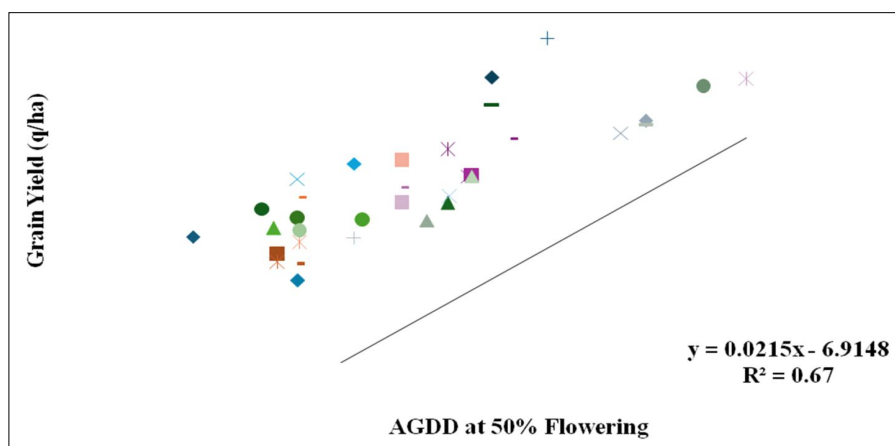


Fig 1: Relationship between AGDD at 50% flowering and grain yield of pigeonpea varieties.

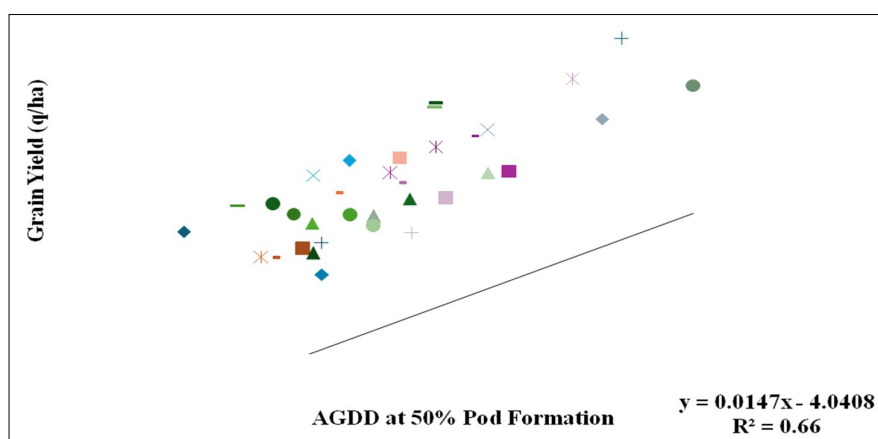


Fig 2: Relationship between AGDD at 50% pod formation and grain yield of pigeonpea varieties.

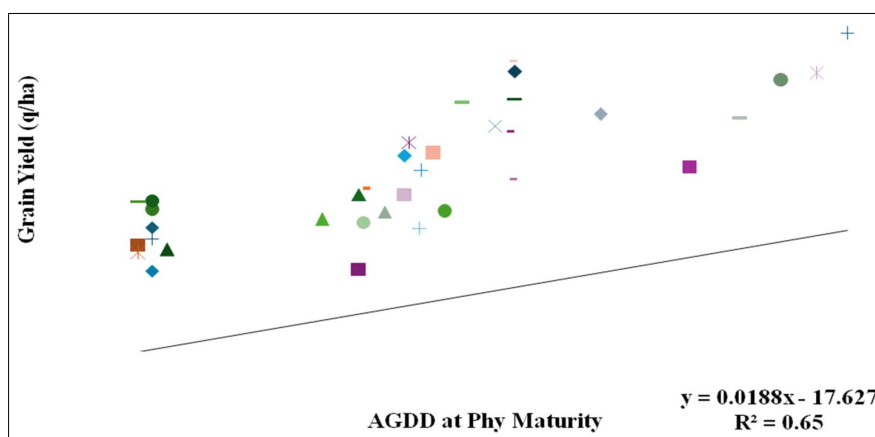


Fig 3: Relationship between AGDD at physiological maturity and grain yield of pigeonpea varieties.

connection between AHTU and grain yield, described 66, 65 and 69% of variability, respectively. It is clear from the data that weather parameter *i.e.*, actual bright sunshine hour had a very prominent role in grain yield of pigeonpea crop.

Grain yield with APTU

“Accrued photo thermal units (APTU)” at 50 % flowering, 50 % pod formation and physiological maturity are related to grain yield (Fig 7, 8 and 9). There was a solid connection between

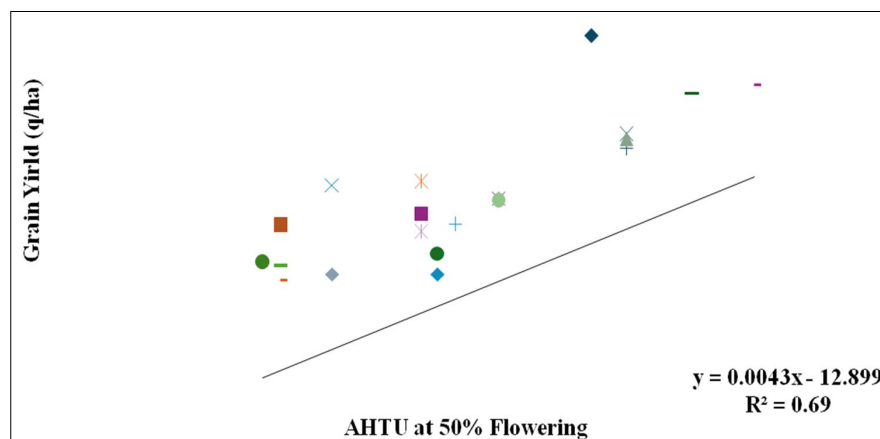


Fig 4: Relationship between AHTU at 50% flowering and grain yield of pigeonpea varieties.

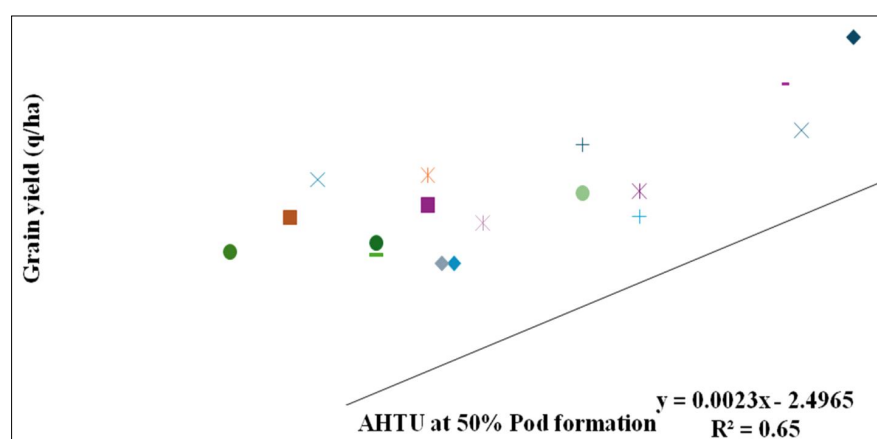


Fig 5: Relationship between AHTU at 50% pod formation and grain yield of pigeonpea varieties.

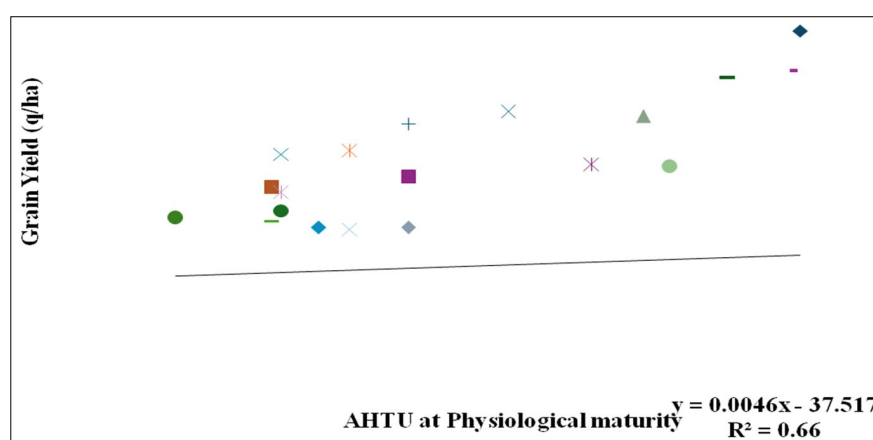


Fig 6: Relationship between AHTU at physiological maturity and grain yield of pigeonpea hybrids.

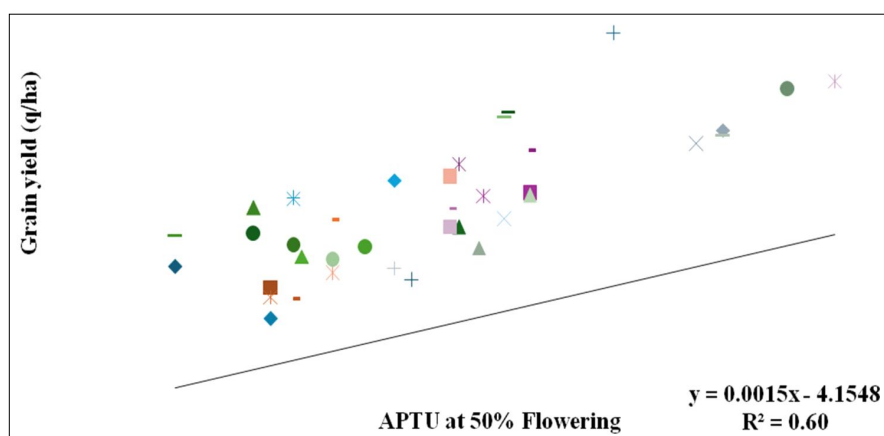


Fig 7: Relationship between APTU at 50% flowering and grain yield of pigeonpea varieties.

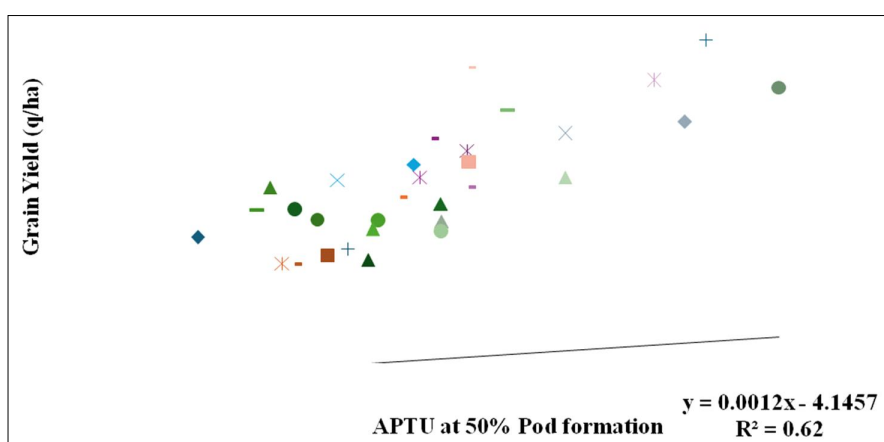


Fig 8: Relationship between APTU at 50% pod formation and grain yield of pigeonpea varieties.

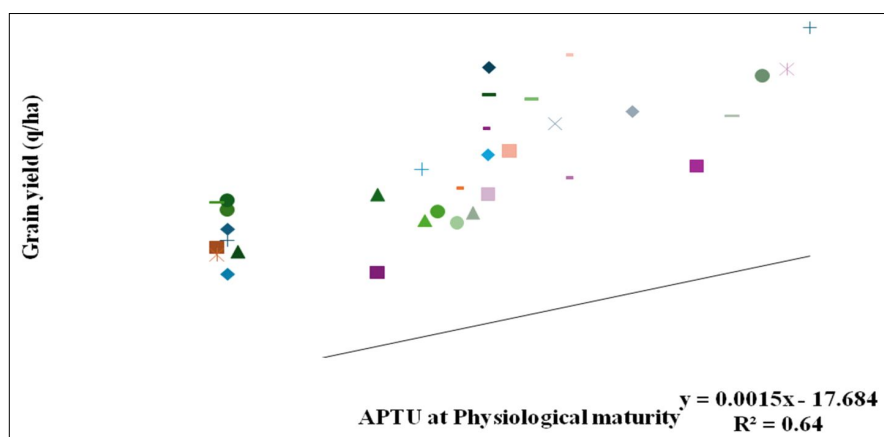


Fig 9: Relationship between APTU at physiological maturity and grain yield of pigeonpea varieties.

APTU and grain yield, representing roughly 60, 62 and 64% of variability, respectively.

CONCLUSION

Pigeonpea can be grown well under rainfed conditions of the plains in lower *Shivalik* hills of Jammu and Kashmir UT. Pigeonpea crop is highly significantly correlated with various environmental factors and agro-meteorological indices.

Conflict of interest

I am submitting it on behalf of all the authors that there is no conflict of interest among the authors of the manuscript.

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