Vol. 20, No. 2, pp. 157-165 (2020)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Thermal Requirement and Yield of Mungbean under Different Growing Environments

SARABJOT KAUR SANDHU* AND KARMJIT SINGH

Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana-141004, Punjab

ABSTRACT

The field experiments were conducted to investigate the thermal requirement of mungbean grown under different growing environments at Punjab Agricultural University, Ludhiana. The mungbean varieties ML 2056 and PAU 911 were sown on three different dates (1st July, 15th July and 30th July) with three different row spacing (22.5 cm, 30 cm and 45 cm) during *kharif* 2016 and 2017. Pooled data of two years showed that the crop sown on 1st July took maximum number of days (75 days) followed by 15th July (68 days) and 30th July (62 days) sown crops to attain maturity. Thermal indices viz. growing degree days, heliothermal and photothermal units were calculated for different treatments. The AGDD for mungbean crop from sowing to maturity for 1st July sown crop were 1517.1°C day followed by 15th July (1374.1°C day) and 30th July sown crop (1248.4°C day). The variety ML 2056 accumulated more number of GDD (1428.4°C day) for maturity than variety PAU 911 (1363.3°C day) because the variety ML 2056 took more number of days to reach maturity as compared to PAU 911 variety. The 1st July sown crop accumulated maximum heliothermal and photothermal units as compared to second and third date of sowing in mungbean. The seed yield and yield attributing characteristics were significantly influenced by date of sowing and row spacing in both varieties. Relationship between thermal indices and seed yield indicates linear relationship with significant value of coefficient of determination (R^2=0.66).

Key words: Date of sowing, Mungbean, Phenology, Seed yield, Thermal indices, Varieties

Introduction

Mungbean (*Vigna radiata* L.) is an important conventional pulse crop and commonly known as green gram. It has high nutritive value, and due to this value it has advantage over other pulses. The seed contains 24.2 per cent protein content, 1.3 per cent fat, and 60.4 per cent carbohydrates, calcium (Ca) is 118 and phosphorus (P) is 340 mg per 100 g of seed respectively (Imran *et al*., 2015). Mungbean has originated in India and is a native of India and central Asia. It is grown in these areas since prehistoric period. Mungbean is grown throughout southern Asia including India, Pakistan, Bangladesh, Sri Lanka, China etc. In India green gram is mostly grown in Andhra Pradesh, Maharashtra, Orissa, Rajasthan, Gujarat, Madhya Pradesh, Punjab and Uttar Pradesh etc. Mungbean is a short duration crop and is sensitive to photo thermal regimes. Mungbean has ability to fix atmospheric nitrogen (N_2) in symbiosis with the soil bacteria Rhizobium spp. They can be grown successfully in extreme environments (e.g., high temperatures, low rainfall, and poor soils) with few economic inputs (Das *et al*., 2014). In northern India especially in Punjab, highly

*Corresponding author,
Email: skchahal@pau.edu

profitable crop sequence like rice-wheat dominates the crop scenario, pulses are virtually displaced. But under changing climatic scenario and due to continuous depletion of ground water table in Punjab mungbean can be a better option for bringing some area under crop diversification as it is a short duration crop. Mungbean is a temperature dependent crop and requires temperature in the range of 28-30°C (Singh and Singh, 2011).

Temperature is the most important environmental factor affecting crop growth, linked both directly and indirectly to other indicators such as soil temperature, day length (photoperiod) and solar radiation. Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat units system (Pandey *et al*., 2010). So this, GDD concept expresses the time in terms of temperature, as crops have basic requirement for temperature to complete a specific phenophases. The application of GDD has vastly improved the description and prediction of phenology as compared to other approaches, such as time of year or number of days. Temperature based agrometeorological or thermal indices such as growing degree day (GDD), heliothermal unit (HTU) and photothermal unit (PTU) are very useful for predicting the growth and yield of crops. Accumulated growing degree days (AGDD), accumulated photothermal units (APTU) and accumulated heliothermal units (AHTU) can be quite useful in predicting phenology of the crop. GDD requirement indicates the thermal status for the onset of a particular phenophase in the crop. Requirement of cumulative GDD is regulated by the ambient temperature as well as change in physiological stage of crop regulated by hormonal activities (Nath *et al*., 1999). The climate change and agriculture are interrelated and affect each other. The climate change has deleterious effects on crop production in terms of period of maturity and yield. From the last few years, the change in climate has been observed which may adversely affect the phenology and production efficiency of crops (Swaminathan and Kesavan, 2012). Although many dynamic crop simulation models have been used for assessing the phenology of the crop but the lacking point in the same is the requirement of large input data (Bemal *et al.,* 2009; Kumar *et al.,* 2009). However, this problem can be resolved by using simplified growth and yield prediction models, needing lesser input data. Agro-climatic models based on thermal indices can be quite helpful to fulfill these needs. Accumulated growing degree days (AGDD), accumulated photothermal units (APTU) and accumulated heliothermal units (AHTU) can be quite useful in predicting phenology of the crop.

Sowing time is important factor for obtaining the optimum yield from mungbean (Samanta *et al*., 1999). So it's important to determine the optimum sowing time for mungbean. The optimum time of sowing ensures complete harmony between the vegetative and reproductive phases on one hand and the climatic rhythm on the other hand and helps in realizing the potential yield of the crop (Singh and Dhingra, 1993). The temperature based agrometeorological indices provide a reliable prediction for crop development and yield. Knowledge of accumulated GDD may project developmental stages of a crop as well as its approximate date of harvest (Roy *et al*., 2005). The present study was planned to investigate the effect of sowing time and planting geometry on phenology, seed yield and thermal indices of two mungbean varieties.

Material and Methods

An experiment was conducted during *kharif* 2016 and 2017 at the Research Farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana (30°54′N latitude and 75°48′E longitude and at an altitude of 247 meter above mean sea level) with three different dates of sowing (1st July, 15th July and 30th July), three different row spacing (22.5 cm, 30 cm and 45 cm), two mungbean varieties (ML 2056 and PAU 911) under split plot design having three replications for each treatment. The number of days taken by crop for various phenological stages i.e. emergence, flower initiation, pod initiation and maturity under different growing environments were observed.

Thermal indices viz. growing degree days, heliothermal units and photo thermal units were calculated by using following formulae:

Growing degree days (GDD)

GDD were calculated by simple arithmetic accumulation of daily mean temperature above the base temperature of 10°C for mungbean crop. The growing degree days for each phenophases were calculated as:

$$\text{Growing degree days } (^{o}\text{C day}) = \frac{(\text{Tmax} + \text{Tmin})}{2} - \text{Tb}$$

$$\text{Accumulated growing degree days } (^{o}\text{C day}) = \sum_{i=1}^{n} \frac{T_{\max} + T_{\min}}{2} - T_b$$

Where,

T_{max} = Daily maximum temperature (°C)

T_{min} = Daily minimum temperature (°C)

T_b = Base temperature (10°C)

Heliothermal units (HTU)

The HTU is the product of GDD and bright sunshine hours for that day. The HTU was determined by using the following formula:

Heliothermal Units (°C days hr) = GDD × Bright Sunshine hours

Accumulated Heliothermal Units (°C days hr) =

$$\sum_{i=1}^{n} (\text{GDD} \times \text{Bright Sunshine hours})$$

Photothermal units (PTU)

The PTU for a day represent the product of GDD and day length for that day. The PTU was determined by using the following formula:

Photothermal Units (°C days hr) = GDD × Day length

Accumulated Photothermal Units (°C days hr) =

$$\sum_{i=1}^{n} (\text{GDD} \times \text{Day length})$$

Seed yield and yield attributing characteristics viz. number of pods per plant, number of seeds per pod, 1000 grain weight (g) were recorded during both years at the time of harvesting. Relationship was developed between seed yield and accumulated heat units to know interaction between heat units and seed yield.

Results and Discussion

Crop phenology

The number of days taken by crop during both seasons for various phenological stages i.e. emergence, flower initiation, pod initiation and maturity under different growing environments were recorded for both growing years and pooled data of both years is presented in Table 1. The number of days taken for maturity were significantly different for different treatments and it was observed that the crop sown on 1st July

Table 1. Number of days taken for different phenological stages in mungbean under different growing environments (pooled data of 2016 and 2017)

Treatments	Emergence	Flower initiation	Pod initiation	Maturity
		Sowing time		
01st July	7.0	40.0	45.0	75.0
15th July	5.0	32.0	37.0	68.0
30th July	5.0	29.0	32.0	62.0
		Varieties		
ML2056	6.0	36.0	39.0	70.0
PAU 911	5.0	32.0	35.0	67.0
		Row spacing		
22.5 cm	6.0	35.0	38.0	68.0
30.0 cm	6.0	34.0	37.0	69.0
45.0 cm	6.0	34.0	37.0	67.0

took highest number of days (75 days) followed by 15th July (68 days) and 30th July (62 days) sown crops to reach maturity. This may be due to the reason that the early sown crop took more number of days to complete its vegetative and reproductive phases. Singh *et al*. (2010) observed 50 per cent flowering with delayed sowings in mungbean. The variety ML 2056 took more number of days (70) to reach maturity than PAU 911 (67 days). This was due to the reason that ML 2056 variety was a long duration variety as compared with PAU 911 variety. The days taken for various phenological stages did not show much variability with respect to spacing (22.5 cm, 30 cm and 45 cm).

Thermal Indices

The duration of particular growth stages of crop shows direct relationship with temperature and this duration may be predicted through summation of mean daily air temperature, because the duration of each growth phase determines the accumulation and partitioning of dry matter in different organs as well as crop responses to external environmental factors. The temperature, soil moisture, relative humidity and bright sunshine hours are the important weather elements that influence the crop life cycle during summer season. The growing degree days in mungbean are useful in explaining the relationships between growth duration and temperature. Growing degree days can be the best index to predict the various phenophases. The GDD for different phenological stages i.e. emergence, flower initiation, pod initiation and maturity during both seasons varied with different dates of sowing, varieties and row spacings. The accumulated growing degree days (AGDD) taken from emergence to maturity for different treatments are presented in Table 2. Among different dates of sowing, the AGDD for mungbean crop from sowing to maturity for 1st July sown crop were 1517.1°C day followed by 15th July (1374.1°C day) and 30th July sown crop (1248.4°C day). The AGDD decreased with successive delay in sowing. The early sown crop had accumulated maximum number of GDDs at all the phenological stages as compared to late sown crop. The thermal units consumed by the crop reduce progressively in case of delayed sowing. The requirement of heat units i.e. GDD decreased for different phenological stages with delay in sowing was reported by several researchers (Sandhu *et al.,*1999, Paul and Sarkar 2000, Pandey *et al.,* 2010).

Among varieties ML 2056 accumulated more number of GDD (1428.4°C days) for maturity than PAU 911 (1363.3°C days) because ML 2056 took more number of days to reach maturity as compared to PAU 911. Singh *et al.* (2010) observed that genotypes are known to show differential response with respect to AGDD, HTU and PTU. Among different row spacing treatment

Table 2. Accumulated growing degree days (°C days) for different phenological stages under different growing environments (pooled data of 2016 and 2017)

Treatments	Emergence	Flower initiation	Pod initiation	Maturity
		Date of sowing		
01st July	140.6	859.3	940.3	1517.1
15th July	130.3	686.3	773.1	1374.1
30th July	126.9	590.4	649.6	1248.4
		Varieties		
ML 2056	140.6	757.1	819.7	1428.4
PAU 911	126.9	679.3	728.7	1363.3
		Row spacing		
22.5 cm	140.6	728.7	802.0	1374.1
30.0 cm	140.6	748.3	777.0	1412.1
45.0 cm	140.6	748.3	779.0	1363.1

AGDD requirement for different phenological stages was comparatively higher (1412.1°C days) in 30 cm spacing as compared to 22.5 cm (1374.1°C days) and 45 cm (1363.1°C days) spacing. Singh and Singh (2015) observed that mungbean sown in 30 cm spacing accumulated lesser number of growing degree days as compared to 22.5 cm spacing. The variation in phenology of mungbean varieties was also reported by Taleei *et al.* (1999).

The accumulated heliothermal units (AHTUs) required for attaining different phenological stages under different growing environments (dates of sowing, different varieties and different row spacing) were worked out. The accumulated heliothermal units (AHTU) taken from emergence stage to maturity for different treatments are presented in Table 3. For different dates of sowing, the AHTU requirement for 1st July sown crop was highest (9750°C day hrs) followed by 15th July (8620°C day hrs) and 30th July (7632°C day hrs) sown crop. This was due to the reason that early sown crop took more number of days to attain maturity. Kingra and Kaur (2012) revealed that earlier sown crop availed higher heliothermal units during all the seasons and with delay in sowing the accumulation of heliothermal units decreased. Among the varieties ML 2056 accumulated significantly higher HTU (9008°C day hrs) than PAU 911 (8320°C day hrs) because ML 2056 takes more number of days to reach maturity and complete its reproductive phase as compared with PAU 911. However Under different row spacings AHTU requirement for different phenological stages was moderately higher (8643°C day hrs) in 30 cm spacing as compared to 22.5 cm (8595°C day hrs) and 45 cm (8451°C day hrs) spacing.

The accumulated photothermal units (APTU) taken from emergence to physiological maturity stage for different treatments are given in Table 4. For different dates of sowing the APTU requirement for 1st July sown crop was highest (20289°C day hrs) followed by 15th July (18690°C day hrs) and 30th July (17400°C day hrs) sown crop. Singh and Singh (2015) observed that the mungbean crop sown on 1st July required higher thermal indices viz. accumulated growing degree days (AGDD), accumulated photothermal units (APTU) and accumulated heliothermal units (AHTU) to complete various phenological stages as compared to all other sowing times. Gill *et al.* (2018) also observed that accumulated photothermal units decreased with delay in sowing of mungbean under Punjab conditions. Among the varieties ML 2056 accumulated higher APTU (19169°C day hrs) than PAU 911 (18425°C day hrs) because the variety ML 2056 took more number of days to reach physiological maturity and complete its reproductive phase.

Table 3. Accumulated heliothermal units (°C days hr) for various phenological stages under different growing environments (pooled data of 2016 and 2017)

Treatments	Emergence	Flower initiation	Pod initiation	Maturity
		Sowing time		
01st July	775	5200	5529	9750
15th July	695	4150	4625	8620
30th July	690	3600	3900	7632
		Varieties		
ML 2056	840	4565	4900	9008
PAU 911	835	4129	4450	8320
		Row spacing		
22.5 cm	840	4300	4680	8595
30.0 cm	840	4345	4712	8643
45.0 cm	840	4395	4690	8451

However, among the different row spacing, crop accumulated maximum photothermal units (18865°C day hrs) when sown under 30 cm spacing as compared to mungbean sown under 22.5 cm (18740°C day hrs) and 45 cm (18769°C day hrs) spacing. Singh and Singh (2015) concluded that sowing time and planting geometry affect the growth, phenology and thermal indices of mungbean varieties. The days taken to attain phenological stages and thermal indices were higher in case of 1st July sowing as compared to other sowing times.

Seed yield and yield attributing characteristics

The mungbean was harvested when the grains in the pods were fully ripened and yield and yield contributing characteristics were recorded in mungbean under different growing environments during both growing years and pooled data of these parameters is presented in Table 5. The yield attributing characters viz. number of pods per plant and 1000 grain weight (g) were significantly higher under second date of sowing

Table 4. Accumulated photothermal unit (°C days hr) for different phenological stages under different growing environments (pooled data of 2016 and 2017)

Treatments	Emergence	Flower initiation	Pod initiation	Maturity
		Sowing time		
01st July	2295	12179	12908	20289
15th July	2190	9800	10729	18690
30th July	2110	8259	9100	17400
		Varieties		
ML 2056	2112	10560	11490	19169
PAU 911	2086	9658	10655	18425
		Row spacing		
22.5 cm	2112	10415	10924	18740
30.0 cm	2112	9956	10895	18865
45.0 cm	2112	10212	10915	18769

Table 5. Seed yield and yield attributing characteristics of mungbean under different growing environments (pooled data of 2016 and 2017)

Treatments	Number of pods per plant	Number of seeds per pod	1000 grain weight (g)	Seed yield (q/ha)
01st July	30.0^{b}	9.8	37.6^{b}	8.94^{b}
15th July	32.5^{a}	10.1	39.6^{a}	9.85^{a}
30th July	28.6^{c}	9.2	35.4^{c}	8.41^{c}
$LSD_{0.05}$	1.14	NS	0.18	0.37
ML 2056	34.2^{a}	11.5^{a}	39.0	10.37^{a}
PAU 911	27.6^{b}	9.45^{b}	34.7	8.41^{b}
$LSD_{0.05}$	3.01	0.45	NS	0.48
22.5 cm	30.8	10.4	37.9	9.12^{b}
30.0 cm	31.4	10.2	38.8	9.75^{a}
45.0 cm	28.9	10.0	36.7	8.49^{c}
$LSD_{0.05}$	NS	NS	NS	0.32

followed by first and third date of sowing. This may be due to the reason that during 15th July sowing prevailing weather conditions favoured mungbean crop so all the yield contributing parameters were higher than the other two dates of sowing. These results are in accordance with those reported by Fraz *et al.* (2006). The seed yield showed significant differences for different dates of sowing. The highest seed yield (9.85 q/ha) was observed in 15th July sown crop followed by 1st July (8.94 q/ha) sown crop and 30th July (8.41 q/ha) sown mungbean crop. This was due to the reason that yield attributing characteristics were higher in 15th July sowing. The results are in accordance with Sugui and Sugui (2002) who revealed that sowing time has great effect on yield and various yield components. However, when seed yield of both varieties was compared, it was observed that variety ML-2056 gave significantly higher yield (10.37 q/ha) as compared to PAU 911(8.41 q/ha).

The number of pods per plant, number of seeds per pod and 1000 grain weight was maximum in 30 cm row spacing followed by 22.5 cm row spacing and 45 cm row spacing. These results are in accordance with those reported by Abbas (2000). The highest seed yield of 9.75 q/ha was observed in 30 cm row spacing followed by grain yield of 9.12 q/ha and 8.49 q/ha in 22.5 cm and 45 cm row spacing respectively. Results of this research are in corroboration with findings of Fraz *et al.* (2006) and Rachaputi *et al.* (2015).

Relationship between thermal indices and seed yield

It has been observed that thermal indices play significant role in grain yield of any crop. Different researchers worked on this aspect and they found that grain yield of crop was positively correlated with GDD (Al-Karaki 2012). Similarly, Amrawat *et al*. (2013) revealed that long growth duration provides an opportunity to plant for accumulation of maximum biomass. In this experiment, relationships were developed between different thermal indices and seed yield to know the effect of heat units on seed yield of mungbean. The linear regression equation was developed between the thermal indices and seed yield to find out the extent of variability in seed yield due to different thermal indices. It was observed that the thermal indices (GDD, HTU and PTU) were able to explain the variability in seed yield of mungbean by about 66, 63 and 55 per cent respectively (Fig. 1, 2 and 3). Jain and Sandhu (2018) also developed relationships between different heat units and seed yield. They revealed that the thermal indices (GDD, HTU and PTU) were able to explain the variability of seed yield by about 66, 61 and 63 percent respectively.

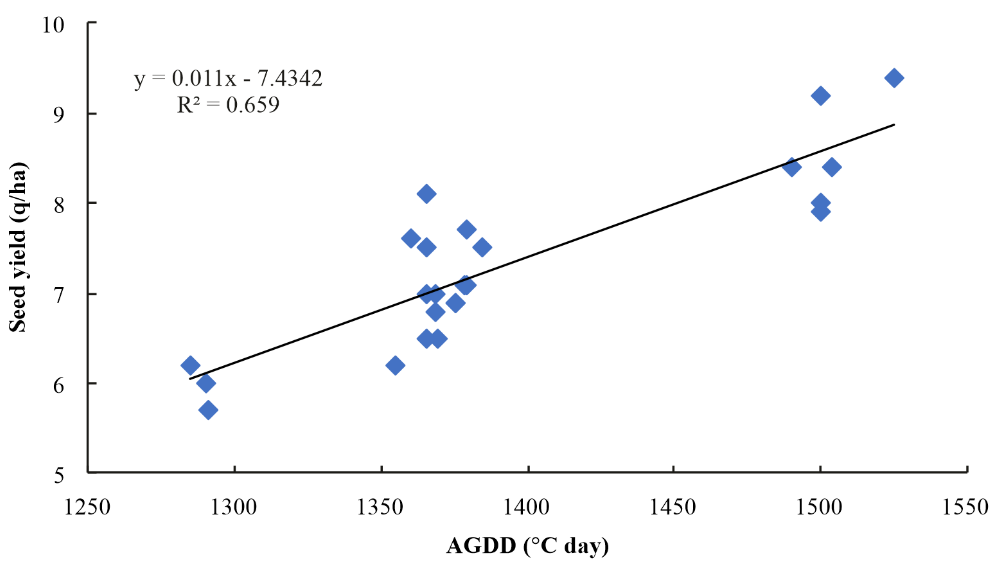

Fig. 1. Relationship between AGDD and seed yield of mungbean

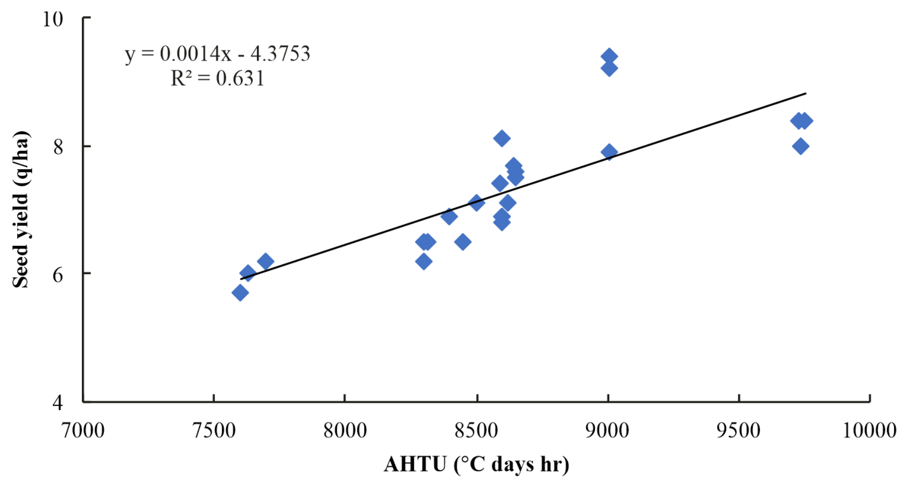

Fig. 2. Relationship between AHTU and seed yield of mungbean

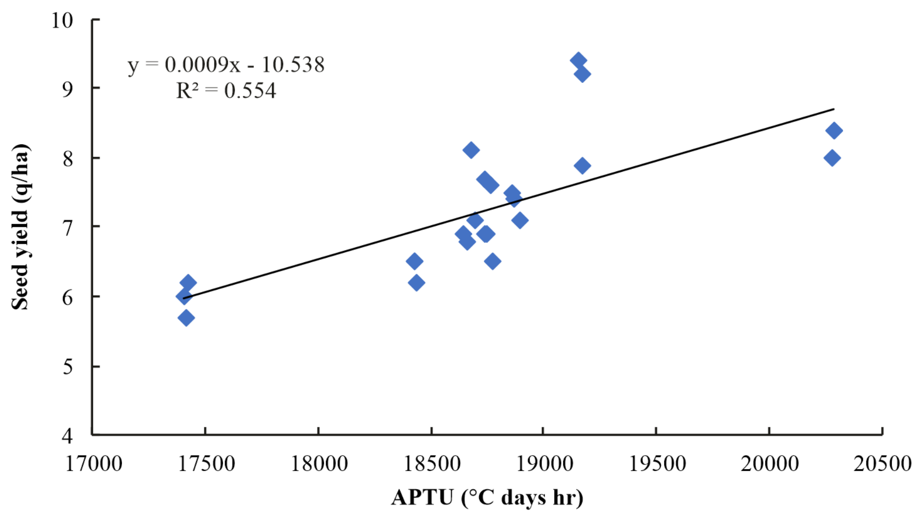

Fig. 3. Relationship between APTU and seed yield of mungbean

Conclusion

From the present investigation, it can be concluded that sowing time and planting geometry affect the growth, phenology and thermal indices of mungbean varieties. The days taken to attain different phenological stages and thermal indices were higher in case of 1st July sowing as compared to other sowing times. The early sown mungbean took more days to mature and thus acquired more heat throughout its growing period. The seed yield was maximum in 15th July sowing. In 30th July sowing, GDD, HTU and PTU values were reduced as the crop duration reduced with delay in sowing. The early sown mungbean crop performed better in terms of accumulation and utilization of heat units whereas, timely sown mungbean gave higher yield due to lower incidence of mungbean yellow mosaic virus.

References

Abbas, S. 2000. *Effect of various levels of phosphorus on growth and yield of two mungbean cultivars.* M.Sc. Thesis, Deptt Agron Univ Agri Faisalabad.

Al-Karaki, G.N. 2012. Phenological development-yield relationships in durum wheat cultivars under late-Season high temperature stress in a semiarid environment. In Pro: *Int. Scholar. Res. Net. Agron*. Pp: 1-7.

Amrawat, T., Solanki, N.S., Sharma, S.K., Jajoria, D.K. and Dotaniya, M.L. 2013. Phenology growth and yield of wheat in relation to agrometeorological indices under different sowing dates. *African. J. Agric. Res*. **8**(49): 6366 -6374.

Bemal, S., Singh, D. and Singh, S. 2009. Assessing Seasonal climatic variability impact on rice productivity in Haryana. *J. Agrometeorol.* **11**(*Spl Issue*): 64-66.

Das, S., Das, S.S. and Ghosh, P. 2014. A comparative analysis of genetic diversity across certain mung bean and urd bean cultivars of West Bengal, using ISSR markers. *Asian J. Plant Sci. Res*. **4**: 56 - 61.

Fraz, R.A., Iqbal, J. and Bakhsh, H.A. 2006. Effect of sowing dates and planting patterns on growth and yield of mungbean (*Vigna radiata* L.) cv. M-6. *Int. J. Agri. Bio.* **3**: 363-65.

Gill, K.K., Sandhu, S.S. and Bhatt, Kavita. 2018. Performance of moong under different methods and dates of sowing. *J. Agri. Phy.* **18**(1): 82-87.

Imran, Hussain, I., Khattak, I., Rehman, A.U., Ahamad, F., Zada, H. and Naveed, S. 2015. Roots nodulation, yield and yield contributing parameters of mungbean cultivars as influenced by different phosphorous level in Swat, Pakistan. *Pure. and App. Bio*. **4**: 557-67.

Jain, Gourav and Sandhu, Sarabjot Kaur. 2018. Agroclimatic indices and yield of mustard under different thermal regimes. *J. Agri. Phy.* **18**(2): 232-239.

Kingra, P.K. and Kaur, P. 2012. Effect of dates of sowing on thermal utilization and heat use efficiency of groundnut cultivars in central Punjab. *J. Agri. Phy.* **12**(1): 54-62.

Kumar, K., Singh, S. and Singh, D. 2009. Winter Season's Climatic variability and impact analysis on wheat productivity in Western Agroclimatic zone of Haryana. *J. Agrometeorol.* **11** (Spl Issue): 50-53.

Nath, R., Chakraborty, P.K. and Chakraborty, A. 1999. Requirement of growing degree days, photothermal unit and heliothermal unit for different phenophase of sesame (*Sesamum indicum* L.) at different sowing dates. *Indian Agric*. **4**: 127-34.

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 crop growing environment. *Ind. J. Agric. Sci.* **80**: 136- 40.

Paul, N.K. and Sarkar, D.K. 2000. Accumulated heat units and phenology relationship in wheat as influenced by sowing dates. *Bangladesh J. Bot*. **29**: 49-54.

Rachaputi, R.C.N., Chauhan, Y., Douglas, C., Martin, W., Krosch, S., Agius, P. and King, K. 2015. Physiological basis of yield variation in response to row spacing andplant density of mungbean grown in subtropical environments. *Field. Crop. Res.* **183**: 14-22.

Roy, S., Meena, R.L., Sharma, K.C., Kumar, V., Chattopadhyay, C., Khan, S.A. and Chakravarthy, N.V.K. 2005. Thermal requirement of oilseed Brassica cultivars at different phenological stages under varying environmental conditions. *Indian J. Agric. Sci*. **75**: 17-21.

Samanta, S.C., Rashid, M.H., Biswas, P. and Hasan, M.A. 1999. Performance of five cultivars of mungbean under different dates of sowing. *Bangla J. Agric. Res.* **24**: 521-27.

Sandhu, I.S., Sharma, A.R. and Sur, H.S. 1999. Yield performance and heat unit requirement of wheat varieties as affected by sowing dates under rainfed conditions. *Ind. J. Agri. Sci.* **69**: 175-79.

Singh, D.P. and Singh, B.B. 2011. Breeding for tolerance to abiotic stresses in Mungbean. *J. Food Legumes* **24**: 83-90.

Singh, T. and Dhingra, K.K. 1993. Response of mung (*Vigna radiata* L.) cultivars to time of sowing under south-western region of Punjab. *J. Res. Punjab Agric. Univ.* **30**: 157-159.

Singh, H. and Singh, G. 2015. Growth, phenology and thermal indices of mungbean as influenced by sowing time, varieties and planting geometry. *Ind. J. Agric. Res*. **49**(5): 472-75.

Singh, G., Sekhon, H.S., Ram, H., Gill, K.K. and Sharma, P. 2010. Effect of date of sowing on nodulation, growth, thermal requirement and grain yield of *kharif* mungbean genotypes. *J. Food Legume* **23**: 132-34.

Sugui, F.P. and Sugui, C.C. 2002. Response of chickpea to dates of sowing in Ilocos Norte, Philippines. *Int. Chickpea Pigeonpea Newsletters* **9**: 13.

Swaminathan, M.S. and Kesavan, P.C. 2012. Agricultural research in era of climate change. *Agric. Res.* **1**: 3-11.

Taleei A.R., Khoda-Bandeh, N. and Gholamie, B. 1999. Effects of sowing date on grain yield, yield components and percentage of protein in green gram cultivars. *Iran J. Agri. Sci.* **29**(4): 751-758.

Received: October 16, 2020; Accepted: December 30, 2020