Vol. 23, No. 1, pp. 71-78 (2023)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Effect of Weather on Phenology, Growth and Yield of Cluster bean under Two Crop Row Orientations

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ABSTRACT

A field investigation on phenology, growth and seed yield attributes as affected by crop row orientation among three cluster bean varieties was carried out during the *Kharif* season 2020-21 at the Research area, Department of Agricultural Meteorology, Research Farm, Chaudhary Charan Singh Haryana Agricultural University, Hisar. The treatment consisted of two crop row orientations D_1 (East-West) and D_2 (North-South) and three cultivars/varieties V_1 (HG 365), V_2 (HG 563) and V_3 (HG 2-20) which were replicated thrice. These eighteen plots were evaluated in factorial randomized block design. The North-South crop row orientation had a higher seed yield owing to its greater number of pods per plant as compared to the East-West crop row orientation. The cultivar HG 2-20 similarly had a higher seed yield due to more pods/plant. There was no difference between crop row orientations in the occurrence of phenophases but variety HG 2-20 had a longer reproductive phase i.e., it entered the flowering stage earlier and matured later. The leaf area index (LAI) of cluster bean increased up until around 65 DAS and then started decreasing while dry matter accumulation kept on increasing up until maturity. The correlational analysis of yield attributes and weather parameters and agrometeorological indices showed that negative correlation with temperature especially with night time and relative humidity, especially evening RH. However, crops planted in North-South row orientation were less affected. Cluster bean crop was significantly positively correlated with sunshine duration and heat units as well.

Key words: Cluster bean, Crop phenology, Crop-weather relationship, Crop row orientation

Introduction

Cluster bean, also known as guar (*Cyamopsis tetragonoloba*), is a legume plant grown for its gum, vegetable, fodder, and green manure properties. It is a member of the Leguminosae family. Since ancient times, cluster beans have been farmed throughout India. Numerous wild cousins of the cluster bean may be found in Africa, indicating that this is where it most likely first appeared (Mudgil *et al.,* 2011). Cluster bean may have been domesticated extremely early in Africa and Arabia before migrating to the Indian subcontinent.

India accounts for 80% of global production and is the leading grower and producer of cluster beans. Guar farming covered 40,60,010 ha in India, and in 2016–17 it produced 18,05,220 tonnes, yielding 445 kg/ha on average (Yogi *et al.,* 2017). In Haryana, the area, production, and yield of guar seed were 2,72,500 ha, 2,26,700 tonnes, and 817 kg/ha, respectively (Haryana Government, 2019). The acreage, production, and average yield of guar in

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Rajasthan were 34,32,392 ha, 12,65,141 tonnes, and 369 kg/ha, respectively, in the 2017–18 fiscal year (Rajasthan Agricultural Statistics, 2020). Guar gum is another important product that India sends to other nations, and it comes in many different varieties. Our country exported 3.82 lakh tonnes of guar gum to the world which was worth of Rs. 3,261.60 crores/ USD 456.96 million during the year 2019-20 (APEDA, 2021).

The natural hydrocolloid found in guar is soluble in cold water and forms thick solutions at low concentrations. The endosperm (35-42%), the germ (43-47%), and the seed coat (14-17%) make up the guar seed. The spherical endosperm's commercial by-product, galactomannan gum, makes up 19 to 43% of the entire seed (Mudgil *et al.,* 2011). Guar is a great crop for developing soil since it is nitrogen fixing, just like other legumes are. When crop wastes and nitrogen-fixing bacteria are combined in root nodules, the yield of future crops is increased (Pathak, 2015). In guar, genotypic differences in pod yield per plant and pod length have a significant positive direct impact on plant seed yield (Nampelli, 2016).

A tropical plant that enjoys warm weather is the cluster bean. At the time of seeding, the crop needs temperatures between 30 and 35°C for healthy germination, and between 32 and 38°C for good vegetative growth. However, excessive temperatures might induce premature flower drop when the crop is in the flowering stage. Cluster beans are capable of withstanding temperatures as high as 45–46°C. It is a photosensitive and indeterminate crop (Meena, 2014).

Guar, like virtually all other crops, depends on favourable climatic conditions for a higher yield. In several other legumes, including pigeon pea, high photosynthetically active radiation during the late vegetative and pod-filling phase is likewise linked to enhanced seed output (Patel *et al*., 2000). This study was conducted to find out the effect of weather parameters and crop row orientation on the growth, development and yield of cluster bean crop.

Materials and Methods

Study location climate

The experiment was carried out at the Research farm, Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar during the Kharif season 2020-21 this sub-tropical location has co-ordinates of longitude 75°.46′ E, latitude 29°1′ N and at an altitude of 215.2 meters altitude. This

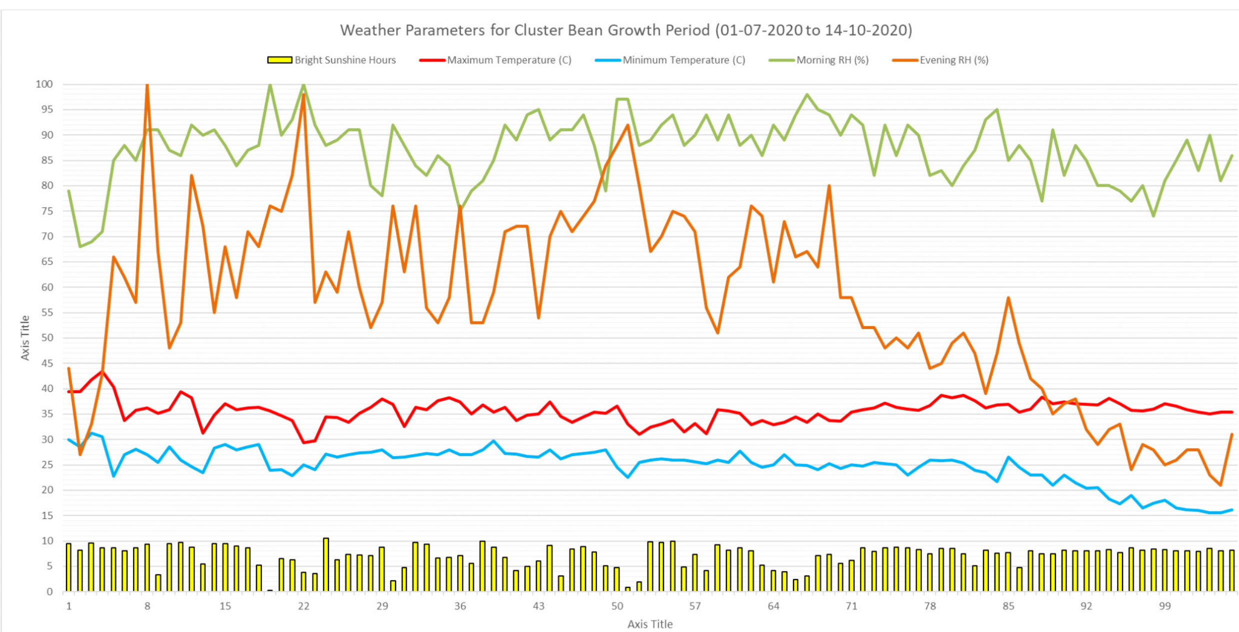

Fig. 1. Weather parameters for the experimental duration

region is a component of the deposit Ghaggar-Yamuna plain and its southern and western parts mark a gradual transition to the desert. The climate of Hisar is a semi-arid climatic zone monsoonal climate. The ratio varies from 25 to 100%. South-west monsoon brings rain typically from the initial week of July to mid-September. the average annual precipitation is 460 millimetres. Approximately three quarters of annual precipitation is received by South-west monsoon. From October to the end of the next June, the weather remains principally dry, aside from some showers received due to western disturbances.

Soil characteristics of the experimental sites

The soil of the experimental area of the Department of Agricultural Meteorology, CCS HAU, Hisar is sandy loam in texture. There was no variation in soil fertility over the experimental space. The soil is moderately coloured and well-drained. The N, P and K contents within the soil area are low, low to medium and medium to high respectively. The soils have decent contents of iron, Cu, Zn and Mn to offer to the crops.

Experimental details

Crop row orientation and the effect of weather on phenology, growth and yield of cluster bean gained attention in recent times. Three cluster bean varieties that are commonly grown under Hisar conditions: HG 365: V1, HG 563: V2, HG 2-20: V3 were grown under two crop row orientations: D1: East-West and D2: North-South. The treatments were all replicated three times under a factorial randomized block design. Weather data of T_{min}, T_{max}, RH_m, RH_e and Bright Sunshine Hours were taken from the agrometeorological observatory situated at the farm.

The following phenological observations of (a) germination, (b) 50% flowering, (c) 50% pod formation and (d) maturity were recorded by visual observations at frequent intervals.

Three plants were uprooted and leaves separated from plants were taken for dry matter and were used for determining leaf area index and dry matter at 15 days' intervals starting from 20 days after sowing of the crop. The green leaf area (cm^2) was measured using a leaf area meter (LI-3000 Area meter, LI-COR Biosciences, Nebraska, USA). The leaf area was used to compute the leaf area index.

The crop was harvested at maturity and seed yield parameters were recorded on a per plant basis. The total seed yield per plot was weighted and then it was used to calculate seed yield in kg/ha. The average number of seeds per pod and pods per plant were also recorded. Finally test weight (per 1000-seeds) was measured for each treatment.

Growing degree days, photothermal units, heliothermal units and heat use efficiency were calculated for each phenological stage of the crop namely, vegetative, flowering and pod formation.

Results and Discussion

Crop phenology

The days taken for the occurrence of phenological phases of cluster bean cultivars under two crop row orientations have been shown in Table 1. There was no significant difference between crop

Table 1. Phenophase occurrence (days) in cluster bean varieties under two crop row orientations

Treatments	Germination	Flowering	Pod formation	Maturity
E-W	4.56	39.33	55.67	99.67
N-S	4.44	39.00	55.67	99.44
S E (m±)	0.21	0.14	0.14	0.57
C D at 5%	NS	NS	NS	NS
HG 365	4.33	41.17	57.33	98.83
HG 563	4.50	38.83	55.67	96.83
HG 2-20	4.67	37.50	54.00	103.00
S E (m±)	0.12	0.43	0.24	0.59
C D at 5%	NS	1.71	0.95	2.36

row orientations in the occurrence of phenophases. The variety HG 2-20 was found to be having a significantly longer reproductive phase i.e., it arrived at the flowering stage at the earliest but matured last (103 DAS). Variety HG 365 (98.83 DAS) stood between HG 2-20 (103 DAS) and HG 563 (96.83 DAS) in terms of maturity but it started flowering latter (41.17 DAS) as compared to HG 563 (38.83 DAS) and HG 2-20 (37.5 DAS).

There wasn't any significant difference in the germination dates of any of the three varieties (4.5 DAS average). The difference in the occurrence of phenophases between the varieties increased as the crop matured but took a slight dip for the pod formation stage. This indicates phenophase occurrence to be a factor of plant genetics and is influenced minimally by changes in crop row orientation. These findings are very similar to what has been observed by other researchers such as Punia *et al.* (2009) and Panchta *et al.* (2015).

Crop growth parameters

The observations for crop growth parameters were taken at a regular interval instead of being taken at phenophases as cluster bean shows indeterminate growing habit, the observations for leaf area index (LAI) are shown in Table 2. The leaf area index of the crop under all cultivars and both crop row orientations kept on increasing with the progression of the crop but it has shown a decreasing trend in later stages (80 DAS) as is shown by many other plants of similar growing habits.

Initially (20 and 35 DAS) there was no significant difference between the two crop row orientations but later on (from 50 DAS) the plants in rows of North-South orientation had a significantly higher LAI as compared to those plants sown East-West. HG 2-20 had the highest LAI at 65 DAS. In the case of different cluster bean varieties HG 2-20 had a higher LAI as compared to HG 563 and HG 365 varieties. This difference became more pronounced after pod formation phenophase.

These results show that North-South crop row orientation possibly due to its increased light penetration in the lower layers of the plant canopy causes slightly increased growth of leaves than East-West crop row orientation. These results are in agreement with the research done by Tsubo *et al.* (2001) on beans and Lungaria *et al.* (2006) on wheat. The variety HG 2-20 showed a slightly higher LAI in later stages of crop growth but that can be attributed to its longer crop duration especially its longer reproductive phenophase. The dry matter of cluster bean plants in grams of different cultivars sown in two crop row orientations has been shown in Table 2. These results were similar yet enlarged in critical difference as compared to those seen in LAI. Again, the East-West crop row orientation had a lower dry matter (81.21 g/plant) production as compared to North-South (82.57 g/plant) crop row

Table 2. Leaf area index and dry matter of cluster bean varieties at various growth stages under two crop row orientations

Treatments	Leaf area index					Dry Matter					
	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	20 DAS	35 DAS	50 DAS	65 DAS	80 DAS	95 DAS
E-W	0.23	0.71	2.12	3.25	3.23	4.02	10.74	17.56	32.96	58.89	81.21
N-S	0.26	0.76	2.36	3.65	3.54	4.19	11.43	18.34	35.72	60.34	82.57
S E (m±)	0.032	0.056	0.012	0.05	0.038	0.098	0.049	0.15	0.062	0.15	0.15
C D at 5%	NS	NS	0.081	0.33	0.25	NS	0.32	NS	0.40	0.99	0.95
HG 365	0.23	0.67	2.18	3.28	3.26	4.08	10.79	17.42	33.87	59.17	81.15
HG 563	0.22	0.69	2.33	3.22	3.17	3.93	11.04	17.97	33.92	57.83	80.55
HG 2-20	0.28	0.85	2.21	3.86	3.81	4.30	11.43	18.47	35.23	61.85	83.97
S E (m±)	0.028	0.051	0.17	0.023	0.052	0.092	0.046	0.129	0.229	0.177	0.30
C D at 5%	NS	NS	NS	0.093	0.21	NS	0.19	0.52	0.92	0.71	1.22

*DAS = Days after Sowing

orientation. This difference increased with the progression of crop growth. Varieties HG 365 (81.55 g/plant) and HG 563 (80.55 g/plant) were found to be statistically at par. However, they accumulated significantly less dry matter than HG 2-20 (83.97 g/plant) and the difference only increased with crop growth.

This means that the dry matter is a major factor of LAI as leaves too have weight and a higher LAI means more dry matter if all other things remain equal. Higher dry matter accumulation by crop sown in North-South oriented rows as compared to East-West can also be attributed to increased light penetration into the lower canopy of the plant. This result is contrary to a study done by Pathan *et al.* (2006) as he used to grow wheat and barley which are of determinate type growing pattern as opposed to indeterminate growth pattern shown by cluster bean where the crop continuously grows and the shading effect of upper plant canopy on the lower canopy is an important factor throughout the life cycle of the plant. In the case of cultivars here again HG 2-20 performed better as compared to the other two older cultivars which display its superiority as a denser and more branching cultivar if other requirements are well met.

Seed yield and its attributes

The North-South crop row orientation produced significantly higher seed yield (1667 kg/ha) as compared to East-West (1542 kg/ha) crop row orientation (Table 3) much like the observations in another indeterminate type crop, mustard (even though it is of *Rabi* season) as seen by Goyal *et al.* (2015). HG 365 produced the least seed yield (1463 kg/ha and HG 2-20 yielded the maximum seed yield (1762 kg/ha).

There was no significant difference between the number of seeds that a pod bore in the case of either crop row orientation. Although North-South (7.24) planted rows had more seeds per pod as compared to East-West (6.73) planted crop this was not significant. The seeds per pod were also similar for HG 365 (7.03), HG 563 (6.90) and HG 2-20 varieties with only minor variations (Table 3).

Plants of treatments sown in North-South orientated crop rows had more pods (41.11) as compared to those sown with East-West (37.89) row orientation (Table 4). HG 2-20 produced the maximum pods per plant (42.67) followed by HG 563 (40) and the least in the case of HG 365 (35.83).

Differently sown crop in rows yielded no significant difference in the test weight of cluster bean seeds (Table 3). However, HG 365 had slightly smaller seeds with lower test weight (25.34 g) as compared to HG 563 (26.18 g) and HG 2-20 (26.33 g).

Conclusively, the North-South crop row orientation produced better seed yield as compared to the East-West crop row orientation mostly due to increased pods per plant. Crop row orientation, however, didn't cause any variation in the number of seeds per pod and test weight (1000-seeds) of cluster bean as those factors appear to be maximally affected by plant genetics itself. This probably is due

Table 3. Seed yield and its attributes of cluster bean varieties under two crop row orientations

Treatments	Seed yield (kg/ha)	Seeds per pod	Pods per plant	Test weight (g)
E-W	1542	6.73	37.89	25.97
N-S	1667	7.24	41.11	25.93
S E (m±)	14	0.25	0.96	0.11
C D at 5%	43	NS	3.08	NS
HG 365	1463	7.03	35.83	25.34
HG 563	1588	6.90	40.00	26.18
HG 2-20	1762	7.03	42.67	26.33
S E (m±)	17	0.31	1.18	0.14
C D at 5%	53	NS	3.77	0.44

to increased light penetration in the middle and lower level of the plant which were not getting adequate sunshine in East-West crop row orientation where the arrangement of rows causes a shading effect of one row over the other. This increased light penetration was also observed by Borger *et al.,* (2010) at Western Australia which is almost the same latitude as in the case of Hisar.

Agrometeorological indices

There was no significant difference between crop row orientations in respect of growing degree days GDD (Table 4). The variety HG 2-20 was found to be consumed more GDD in total (2079.22 °C days). Variety HG 365 (2011.22 °C days) stood in between HG 2-20 and HG 563 (1971.87 °C days) in respect of GDD for maturity. At the pod formation stage all varieties had statistically different GDD (1191.67 for HG 365, 1159.83 for HG 563 and 1127.03 °C days for HG 2-20) GDD. In the earlier phase, i.e., flowering HG 2-20 had a lower GDD of (784.9 °C days) as compared to HG 563 (814.08 °C days) and HG 365 (865.3 °C days).

The cultivar HG 2-20 accumulated more GDD as compared to HG 365 and HG 563, this was due to its longer growth duration.

There was no significant difference between crop row orientations in accumulated photo thermal units (PTU) at any of the phenophases of cluster bean (Table 4). The variety HG 2-20 was found to be having a significantly longer reproductive phase and accumulated more PTU in total (27036.83°C day hours). Variety HG 365 (26245.02°C day hours) stood in between HG 2-20 and HG 563 (25781.2°C day hours) in terms of total PTU at maturity.

There was no significant difference between crop row orientations in respect of accumulated helio thermal units (HTU) (Table 4). The variety HG 2-20 accumulated more HTU in total (15016.18°C day hours) and variety HG 365 (14461.76°C day hours) stood in between HG 2-20 and HG 563 (14134.76°C day hours) in terms of total HTU at maturity.

The North-South crop row orientation (0.31) had a higher HUE than that of the East-West crop row orientation (0.29) at the flowering stage (Table 5). Later at pod formation (0.34 and 0.35) and maturity

Table 5. Heat use efficiency (kg/ha/°C days) of cluster bean cultivars at different phenophases under both crop row orientations

Treatments	Flowering	Pod formation	Maturity
E-W	0.29	0.34	0.89
N-S	0.31	0.35	0.91
S E (m±)	0.001	0.003	0.003
C D at 5%	NS	NS	NS
HG 365	0.28	0.33	0.90
HG 563	0.30	0.34	0.91
HG 2-20	0.32	0.36	0.90
S E (m±)	NS	0.003	0.005
C D at 5%	0.02	0.01	NS

Table 4. Heat unit requirements of cluster bean cultivars at different phenophases under two crop row orientations

	Growing degree days (°C days)			Photo thermal units (°C day hours)			Helio thermal units (°C day hours)		
Treatments	Flowe-ring	Pod formation	Matu-rity	Flowe-ring	Pod formation	Matu-rity	Flowe-ring	Pod formation	Matu-rity
E-W	825.1	1159.5	2020.9	11326.1	15728.9	26355.7	6138.8	8289.7	14539.1
N-S	817.8	1159.5	2020.7	11229.1	15728.9	26352.9	6087.3	8289.7	14536.0
S E (m±)	2.99	2.65	8.85	39.56	34.83	103.30	22.92	32.51	71.50
C D at 5%	NS	NS	57.96	NS	NS	NS	NS	NS	468.39
HG 365	865.3	1191.7	2011.3	11912.2	16145.0	26245.1	6454.9	8533.7	14461.8
HG 563	814.1	1159.8	1971.9	11179.9	15733.4	25781.2	6062.7	8328.3	14134.8
HG 2-20	784.9	1127.1	2079.2	10789.1	15308.4	27036.8	5821.5	8007.1	15016.2
S E (m±)	9.21	4.58	7.55	104.77	59.50	88.12	70.068	42.29	62.40
C D at 5%	37.12	18.45	30.42	422.38	239.90	355.26	282.49	170.49	251.59

(0.89 and 0.91) phenological phases the difference was non-significant. The cultivar HG 2-20 (0.32 and 0.36) had a higher HUE at the flowering and pod formation stage as compared to HG 365 (0.28 and 0.33) and HG 563 (0.30 and 0.34). This was due to the highest LAI and dry matter produced by this variety. Cluster bean, being a longer duration crop than mungbean or urdbean (100 days compared to 70-80) accumulated more growing degree days as well as photothermal and heliothermal units that these crops (Sandhu and Singh, 2020).

Crop weather relationship/Correlation analysis

The cluster bean crop was negatively influenced by minimum and average temperature and evening relative humidity and average relative humidity. While BSS had a positive correlation with the seed yield and pods/plant of cluster bean. The number of pods per plant was found to be significantly influenced by weather parameters except for morning relative humidity (RH) and maximum temperature (Table 6). The agrometeorological indices: GDD, HTU, and PTU are significantly associated with seed yield and the number of pods per plant. While HUE did not show any significant association with seed yield and its attributes.

Table 6. Relationship of cluster bean seed yield and its attributes with weather parameters and agro-meteorological indices

	Seed yield (kg/ha)	Seeds/ Pod	Pods/ plant	Test weight (g)
T_{max}	0.058	0.59*	0.093	0.16
T_{min}	-0.52*	0.11	-0.54*	-0.19
T_{avg}	-0.53*	-0.083	-0.55*	0.19
Rh_{mor}	0.13	0.35	0.25	0.043
Rh_{eve}	-0.48*	0.14	-0.52*	-0.18
Rh_{avg}	-0.44	0.17	-0.49*	-0.16
BSS	0.44	-0.16	0.48*	0.16
GDD	0.51*	0.076	0.52*	0.13
HUE	0.27	0.42	-0.014	-0.018
HTU	0.51*	0.079	0.52*	-0.13
PTU	0.51*	-0.077	0.52*	0.13

*Significant at 5% level of significance

This is different from what Meena (2014) observed where he found that cluster bean crop yield is non-significantly positively correlated with weather parameters (rainfall and temperature). When the whole of the data of cluster bean was pooled and analysed, we see that cluster bean crop was negatively influenced by minimum and average temperature and average and evening relative humidity. This can be well understood as the impact of these weather parameters on flowering in cluster bean crop which impacted the number of pods per plant which in turn impacted total seed yield. The bright sunshine duration and agrometeorological indices GDD, HTU, PTU and HUE had a positive impact on crop growth. Similar findings were observed by Ramakrishna *et al.* (1999) in the case of pigeon pea and by Kumar (2006) in soybean crops.

Conclusions

Based on the abovementioned results following conclusions are drawn:

- North-South crop row orientation cluster bean varieties yielded better than East-West crop row orientation due to higher HUE in the north-south sown crop.
- HG 2-20 produced the highest seed yield followed by HG 563 and HG 365 due to higher thermal indices and HUE observed in this crop row orientation.
- Cluster bean seed yield and pods/plant were significantly influenced by weather and thermal indices.

Conflict of Interest

The authors declare that they have no known conflict of interest.

Acknowledgement

The authors gratefully acknowledge the Head, Department of Agricultural Meteorology, Hisar for providing facilities to conduct field experiment. The contents and views expressed in this research paper/ article are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

References

APEDA (The Agricultural and Processed Food Products Export Development Authority), 2021, New Delhi. http://apeda.gov.in/apedawebsite/SubHead_Products/Guargum.htm

Borger, C.P., Hashem, A. and Pathan, S. 2010. Manipulating crop row orientation to suppress weeds and increase crop yield. *Weed Sci.* **58**(2): 174-178.

Govt. of Haryana. 2019. *Crop wise area, average yield and production of major crops in Haryana for the year 2013-14 to 2017-18 (Anticipated) and target of 2018-19 pp. 58.* http://agriharyana.gov.in/assets/images/whatsnew/Five_Year_AYP_Targeted_2016-17__N__Ek_Patti.pdf.,

Govt. of Rajasthan. 2020. *Rajasthan agricultural statistics at a glance 2018-19 pp. 108.* https://agriculture.rajasthan.gov.in/content/dam/agriculture/Agriculture%20Department/agriculturalstatistics/rajasthan_agriculture_statistics_at_a_glance_2018-19.

Goyal, A., Das, D.K., Sehgal, V.K., Vashisth, A., Mukherjee, J., Pradhan, S. and Singh, J. 2015. Relationship of thermal indices with biophysical parameters and seed yield of oilseed Brassica cultivars sown in two different row directions. *Journal of Agricultural Physics* **15**(1): 38-44.

Kumar, A. 2006. Study of crop weather relationship in soybean and evaluation of cropgro-soybean model under varying environment at Anand (Doctoral dissertation, Anand Agricultural University, Anand).

Lunagaria, M.M. and Shekh, A.M. 2006. Radiation interception, light extinction coefficient and leaf area index of wheat (*Triticum aestivum* L.) crop as influenced by row orientation and row spacing. *Journal of Agricultural Science* **2**(2): 43-54.

Meena, H.S. 2014. Performance of cluster bean varieties at varied crop geometry (Doctoral dissertation, Acharya N.G. Ranga Agricultural University. Rajendranagar, Hyderabad).

Monem, R., Mirtaheri, S.M. and Ahmadi, A. 2012. Investigation of row orientation and planting date on yield and yield components of mung bean. *Annals of Biological Research* **3**(4): 1764-1767.

Mudgil, D., Barak, S. and Khatkar, B.S. 2011. Guar gum: processing, properties and food applications — A Review. *JFST* **51**(3): 409–418.

Nampelli, P. 2016. Studies on identification of morphological and physiological traits in relation to yield and quality of seed guar (Cyamopsis tetragonoloba (L.) Taub.) cultivars under rainfed condition, (Doctoral dissertation, Dr. Y.S.R. Horticultural University, Mahabubnagar)

Panchta, R. and Pahuja, S.K. 2016. Evaluation of cluster bean genotypes in summer for yield and its contributing traits under Haryana conditions. *For. Res. Pap.* **42**(1):62-64.

Patel, N.R., Mehta, A.N. and Shekh, A.M. 2000. Weather factors influencing phenology and yield of pigeonpea (*Cajanus cajan* (L.) Milli sp.). *Journal of Agrometeorology* **2**(1): 21-29.

Pathak, R. 2015. *Cluster bean: Physiology, Genetics and Cultivation*. Pp. 329. Springer, Singapore.

Pathan, S., Hashem, A. and Borger, C. 2006. Crop row orientation induced photo-sensory effect on the competitive interactions of crops and weeds. Pp. 24-28. In *Proceedings of the 15th Australian Weeds Conference, Adelaide, Australia*.

Punia, A., Yadav, R., Arora, P. and Chaudhury, A. 2009. Molecular and morphophysiological characterization of superior cluster bean (*Cymopsis tetragonoloba* L.) varieties. *JCSB* **12**(3): 143.

Ramakrishna, Y., Vijaya Kumar, P. and Ramana Rao, B.V. 1999. *Crop-weather relationship studies in dryland agriculture. Fifty Years of Dryland Agriculture Research in India.* Central Research Institute for Dryland Agriculture, India. pp.211-226.

Sandhu, S.K. and Singh, K. 2020. Thermal requirement and yield of mungbean under different growing environments. *Journal of Agricultural Physics* **20**(2): 157-165

Tsubo, M., Walker, S. and Mukhala, E. 2001. Comparisons of radiation use efficiency of mono-/inter-cropping systems with different row orientations. *Field Crops Research* **71**(1): 17-29.

Yogi, R.K., Kumar, A. and Singh, A.K. 2020. Lac, Plant Resins and Gums Statistics: At a Glance, ICAR-Indian Institute of Natural Resins and Gums, Ranchi (Jharkhand), India. Bul.

Received: March 22, 2023; Accepted: June 10, 2023