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The Appropriate Sowing Time and Plant Density to Achieve Higher Yield of Cluster Beans

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AN experiment conducted on the guar crop had three main objectives. Choosing the ideal time to sow, determining the appropriate plant density, and examining the effects of various planting dates and plant densities on the yield and yield-related factors of various guar varieties. The field experiment was conducted at the Agricultural Research Station in Bahawalpur in 2019 and 2020. Two guar genotypes (BR-2017 and S-6384) were used in a split-split plot design with three replications to evaluate the three plant densities (D1: 15, D2: 25, and D3: 40 plants/m^2) and six planting dates (from 1st May to 15th July).

The results showed that the early sowing dates (1st May to 1st June) improved the plant height, pod length, clusters per plant, number of pods per cluster, grain per pod, and seed yield. The late planting dates (15th June to 15th July) produced the lowest values of these attributes. The results showed that the yield was not affected by the plant density, but other morphological traits were varied. The study found a significant difference in the yield between the two guar varieties at all the sowing times and plant densities tested. In 2019, BR-2017 had the best yield, and S-6384 had the best yield in 2020.

It is concluded that farmers in Pakistan should sow their guar crop between the 1st of May to the 1st of June. It is important to note that plant density has a marginal effect on yield. In two years, both guar genotypes performed admirably.

Keywords: Guar, Morphological, and yield contributing traits, Plant density, Sowing time.

Introduction

Guar, also known as cluster bean, is an annual legume crop grown primarily in arid and semi-arid regions that grows quickly and uses few inputs (Ashraf et al., 2002). As a significant economic crop, guar is grown for animal feed as fodder, its green pods are consumed as a vegetable, and its gum is used in a wide range of industries (Abidi et al., 2015; Gresta et al., 2017). In Pakistan's arid and semi-arid regions, where the lack of water prevents the cultivation of other warm-season crops, guar is a drought-tolerant crop that is only grown there (Meftahizade et al., 2017). (Gresta et al., 2018) found that the growth time (from planting to harvesting) varied from 90 to 150 days depending on the genotype and environmental conditions. The height of the plants ranged from 30cm to 2m.

Genetic and environmental interactions are the most important components in determining crop yield, but other agronomic factors also play a role. Other agronomic parameters, including the planting date and the seed rate for sowing, also affect the crop yield. Because of fluctuations in the weather, choosing the right time to plant seeds is essential to maximizing crop production

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(Gresta et al., 2013). It has also been discovered through a variety of experiments that early sowing of crops results in a higher yield compared to late sowing. This is due to the fact that early sown crops have more time to finish each phase using the available nutrients (both vegetative and reproductive), resulting in maximum production (Kiss et al., 2018; Korotaeva et al., 2018; de Souza et al., 2018). Because the phenological stages of the crop and the amount of time available for growth are both influenced by the sowing date, it is essential to determine the best sowing date for a given crop by taking into account a variety of environmental factors. This is because the sowing date influences the length of the growing season (Srivastava et al., 2016; Meftahizade et al., 2019a, b).

It has been observed by various scientists that the optimal time for planting varies from region to region and depends on the genotypes being tested as well as the local climate. According to the findings of studies carried out in the Mediterranean region, the optimal time to plant seeds for maximum yield is around the middle of May. (Gresta et al., 2013). The timing of planting and the seed rate are two factors that influence not only the crop stand establishment in the field but also the potential yield (Deka et al., 2015). The optimal time to sow guar can be anywhere between May and June. In addition to this, early sowing results in a notable increase in grain weight in comparison to later sowing (Mahdipour-Afra et al., 2021). According to the findings of Kalyani & Sunitha (2011), when compared to other sowing dates (the first and second fortnights of the months of July and August), the first fortnight of July performed noticeably better than the other sowing dates. In addition, Nandini et al. (2017) reported that the planting date of the 10^{th} of July had resulted in a greater number of pods per plant and grain per pod than any early or late planting date. The evaluation of 22 different guar genotypes also revealed that the gum content varied slightly (from 28.47 percent to 32.89 percent) depending on the ecotype but was not affected by the climate. Additionally, planting during the first two weeks of July resulted in a significantly higher crude gum content than planting at a later date (Kalyani & Sunitha et al., 2011). Furthermore, the optimal plant density with the appropriate geometry of plant depends on the variety, growth habits, and agro-climatic conditions. Lone et al. (2010) and Siddaraju et al. (2010) did research on guar and found that out of three plant spacings (45 x 15, 45 x 30, and 60 x 30cm), the 45 x 15cm plant spacing produced the most grain.

The timing of when the seeds are planted has a significant influence on the yield of guar. As a result of the changes in climate, choosing the right date to start sowing is essential if one wishes to obtain a high yield. The purpose of the research is to determine the optimal planting date as well as the optimal plant density in order to maximize guar production.

Materials and Methods

Site description, cultural practices, and experimental design

In the research area of the Agricultural Research Station in Bahawalpur, which is located in southern Punjab, Pakistan, a series of field experiments were carried out for two consecutive years (2019 and 2020). In the experiment, we used two different genotypes of guar (BR-2017 and S-6384), both of which have distinct morphological characteristics. We investigated the effects of three factors in this study, including genotype, sowing date, and plant density. The split-split plot design in RCBD is the experimental design that was used for the experiment. The genotype (V) in the main plot and the sowing date (SD) were assigned to the subplot, while the plant density (D) was assigned to the sub-sub plot factor. Two guar genotypes (V1: BR-2017 and V2: S-6384), three plant densities (D1: 15, D2: 25, and D3: 40 plants/m^2), and six sowing dates (SD1: May 3, SD2: May 18, SD3: June 1, SD4: June 15, SD5: July 2, SD6: July 15, 2019, SD1: May 1, SD2: May 15, SD3: June 2, SD4: June 17, SD5: July 1, SD6: July 15, 2020) were included.

Each plot was comprised of four rows that were a total length of 3.9m, and the distance between each row was kept constant at 0.3m. The nitrogen fertilizer (150kg N ha^{-1}) was applied in the form of urea, which contains 46 percent nitrogen. The fertilizer was applied in two divided doses: one dose was given when the plant had four leaves, and the other dose was given when the pods were forming. In contrast to the absence of a significant pest epidemic on the plants, disease epidemics have been observed and sprayed with fungicides in accordance with recommendations in order to control the disease throughout both growing seasons. Manual weeding was used to keep the weed population under control, and the field was irrigated three times at three different stages of growth. The first irrigation was at the four-leaf stage, the second irrigation was at the flowering stage, and the third was when there was a fifty-percent chance of pod formation.

Morphological traits of varieties

BR-2017: BR-2017 is a variety that has been approved and has morphological characteristics that are unique and distinctive. It is a single-stemmed variety (not a single branch), and the plant height can range anywhere from 80 to 200cm. The pods are clustered and arranged in clusters in such a way that there is no space between clusters. This variety has the potential to bear pods all the way up to the tip of the stem. After 30–35 days from the time of planting, the plant will begin to flower, and it will reach full maturity in 120–130 days. This variety produces pods that are 4-6cm in length and contain 6–9 seeds each.

S-6384: In comparison to BR-2017, the advanced line known as S-6384 possesses distinctively distinct morphological characteristics. The typical plant will reach a height of 60 to 120cm and will have 5 to 8 branches. The fact that it is a line that matures quickly is one of its distinguishing characteristics (90-100 days). After 25–30 days from the time of planting, flowers will begin to appear. It has a pod length that is about average (4-5cm), and each pod contains between 6 and 8 seeds. It has clusters on all of its branches, but there are spaces in between each of the clusters.

Morphological data

Daily observations revealed the onset of flowering as well as physiologic maturation. The number of days from sowing to flowering, 50%, and the number of days until physiological maturity, 80%, (the pods turning brown is a sign that the plant has reached its physiological maturity) were both recorded. At the point in time when the plants had reached their physiological maturity, ten plants were chosen at random from each plot. The height of the plants (measured from the bottom to the top) and the length of the pod, in cm, were both recorded.

Yield and yield contributing data

During the physiological maturation process, data was recorded from ten plants that were chosen at random. The characteristics that contribute to yield were recorded from randomly selected plants. These characteristics include the number of clusters per plant, the number of pods per cluster, and the number of seeds per pod. After harvesting, threshing, wind pumping, and finally weighing each plot, we were able to calculate the seed yield per plot in kilograms.

Statistical analysis

The main plot (genotype), the sub-plot (sowing date), and the sub-sub plot (plant density), as well as the effect of interaction with experimental factors, were all calculated by using analysis of variance (ANOVA) with split-split plots analysis with Statistix 10 software. Before beginning the analysis of variance, a univariate procedure was carried out in order to guarantee that the residuals would have a normal distribution. The test of least significant difference (LSD) was applied at a probability level of five percent in order to determine the mean comparisons of the characteristics that were measured.

Results and Discussion

The results of the analysis of variance showed that the effect of the interaction of planting date with plant density was significant in both study years for plant height, pod length, clusters per plant, pods per cluster, and seed yield. On the other hand, the number of flowering days up to 50 percent, the number of days until maturation, and the number of grains in the pods showed a significant relationship in the second year of the study, which was in the year 2020. The sowing dates and plant densities for both years were significant for all traits, with the exception of the maturity date, the number of pods per cluster in 2019, and the seed yield in 2020. Also, in the first year of 2019, the effect of the three-way interaction between cultivar, sowing date, and plant density was significant for all traits except pod length and the number of clusters each plant made (Tables 1, 2).

Morphological parameters

It is widely accepted that the height of a plant plays a significant role in determining the degree to which genetic and environmental factors influence the plant's ability to successfully compete for solar radiation (Ncube et al., 2012). The results of the comparison showed that planting seeds on May 3, 2019, and June

2, 2020, resulted in the tallest plants. However, plant height decreased as planting was delayed in 2019. In the second year, 2020, it was found that there were significant differences between plant densities of 15, 25, and 40 plants/m^2, whereas in the first year, 2019, there was found to be no significant difference between plant densities of 25 and 40 plants/m^2. In contrast to the branched variety S-6384, the unbranched BR-2017 variety has the genetic potential to achieve the maximum plant height in every single growing season (Table 3). Previous research (Mahdipour-Afra et al., 2021; Honnaiah et al., 2021) showed that when late sowing and higher plant density were used together, plant height decreased by a large amount.

TABLE 1. Analysis of variance on morphological traits affected by sowing date, plant density and variety in 2019 and 2020

S.O.V		Plant height		Days to 50% flowering		Days to maturity		Pod length	
	Df	2019	2020	2019	2020	2019	2020	2019	2020
R	2								
V	1	19.1**	533.70**	402.87**	2.59*	183.64**	6302.5**	7.05*	8161.1**
SD	5	41.31**	197.89**	26.73**	113.01**	55.27**	394.17**	4.74*	43.48**
V x SD	5	0.91ns	32.10**	29.17**	243.34**	3.31*	29.49**	1.99*	10.81**
D	2	4.25**	440.95**	2.16*	33.78**	0.25ns	225.25**	4.33*	6.44*
V x D	2	1.37*	37.56**	0.17ns	13.49**	2.49*	25.25**	0.79ns	15.78**
SD x D	10	1.70*	37.36**	0.59ns	33.09**	0.94ns	13.58**	1.88*	12.04**
V x SD x D	10	1.31*	9.32**	1.13*	50.01**	34.21**	14.57**	0.37ns	7.97*
Error	48								
CV (%)		4.72	4.92	1.51	1.76	0.88	1.56	4.62	5.95

*, ** and ns indicate significant at the P< 0.05, 0.01 levels and not significant, respectively.
R: replication, SD: sowing date, D: density, V: variety

TABLE 2. Analysis of variance on seed yield and yield contributing traits affected by sowing date, plant density and variety in 2019 and 2020

S.O.V		Clusters/plant		Pods/cluster		Grains/pod		Seed yield	
	Df	2019	2020	2019	2020	2019	2020	2019	2020
R	2								
V	1	11.19**	0.79ns	4.71*	83.77**	22.13**	1824.27**	1.85*	266.39**
SD	5	2.55*	22.37**	1.22*	3.69*	10.54**	209.26**	27.44**	16.24**
V x SD	5	3.72*	92.94**	1.65*	3.14*	9.71*	217.49**	0.59ns	2.43*
D	2	7.79*	12.81**	0.44ns	5.18*	1.58*	190.65**	1.97*	0.42ns
V x D	2	5.32*	5.72*	2.31*	3.38*	1.51*	221.69**	0.26ns	14.82**
SD x D	10	2.02*	5.96*	1.04*	1.41*	0.73ns	116.23**	1.04*	24.76**
V x SD x D	10	0.34ns	4.68*	2.31*	3.60*	1.05*	150.82**	2.14*	5.05*
Error	48								
CV (%)		19.88	10.01	13.48	13.58	3.93	3.28	0.97	7.27

*,** and ns indicate significance at p < 0.05, 0.01, and not significant, respectively.
R: replication, SD: sowing date, D: density, V: variety.

TABLE 3. mean comparison of morphological traits affected by sowing date, plant density and variety in 2019 and 2020

Sowing date	Plant height		Days to 50% flowering		Days to maturity		Pod length	
	2019	2020	2019	2020	2019	2020	2019	2020
SD1	161.0a	136.56b	49.50a	47.05b	130.28a	127.17a	5.35a	5.50a
SD2	152.1ab	102.00c	49.50a	43.33c	120.56b	108.11e	4.93ab	4.44c
SD3	136.8bc	149.67a	45.55b	47.27b	121.50b	125.00b	4.52bc	4.96b
SD4	131.0c	85.28e	43.83c	42.22d	112.83c	111.39d	4.01c	4.32c
SD5	74.1d	145.72a	43.66c	48.88a	111.72c	116.89c	4.62bc	4.39c
SD6	64.3d	93.22d	43.11c	43.05c	102.89d	103.39f	4.32bc	4.03d
Density								
D1	117.6b	141.86a	46.05a	45.83a	116.67a	120.03a	4.70a	4.64a
D2	121.3a	111.22b	45.77a	45.66a	116.39a	114.86b	4.62ab	4.71a
D3	120.6a	103.14c	45.75a	44.41b	116.83a	111.08c	4.55b	4.48b
Variety								
V1	134.07a	131.56a	48.72a	45.53a	129.98a	128.20a	5.00a	5.01a
V2	105.74b	105.93b	43.00b	45.07a	103.28b	102.44b	4.25a	4.21b

Means within a column followed by the same letter do not significantly different from each other ($P< 0.05$; LSD test).

SD: sowing date (SD1: MAY 3, SD2: MAY18, SD3: JUNE 1, SD4: JUNE 15, SD5: JULY 2, SD6: JULY 15 in 2019 and SD1: MAY 1, SD2: MAY15, SD3: JUNE 2, SD4: JUNE 17, SD5: JULY 1, SD6: JULY 15 in 2020); D: density (D1: 15, D2: 25, and D3: 40 plants m-2) and V: variety (V1: BR-2017, V2: S-6384).

Early-sown plants appear to have more time to absorb soil moisture and nutrients, ensure proper plant growth, use radiation more efficiently, and develop more photosynthesis than late-sown plants, according to the findings of the majority of the researchers who investigated this phenomenon (Mahdipour-Afra et al., 2021; Hussain et al., 2022). When comparing May sowing to June sowing, early sowing dates produce the greatest plant height, and Gresta et al. (2013) found similar results.The findings of Khalil et al. (2010) and Honnaiah et al. (2021) demonstrated that delayed sowing results in a reduction in plant height. This is due to the fact that the growth period of plants is affected by a rise in temperature, photosynthetic disturbance, reduced photosynthetic production, and the flexibility of the stem cell wall. These factors all contribute to a shorter growth period (Candan et al., 2018). When compared to S-6384, the results show that BR-2017 had a significantly higher plant height during both years of the study as well as throughout all of the sowing periods. Both genetic variations and morphological characteristics can be responsible for the difference in plant height that can be observed between the two varieties (Santonoceto et al., 2019; Mahdipour-Afra et al., 2021).

There was not a significant difference in plant density at 50% of flowering; however, there was a significant difference in the number of maturation days between the first year (2019) and the second year (2020). Although both guar varieties require the same number of days up to fifty percent of their flowering days, S-6384 matures in one hundred and BR-2017 matures in one hundred thirty days, making it an early maturing variety. BR-2017 requires 50% more flowering days than S-6384 (Table 3). It is widely accepted that the date of sowing is a crucial component in the process of shifting the plants' seasonal stage from flowering days to 50 percent of flowering and maturation days (Deka et al., 2015). In the current investigation, the differences in the phenomenological characteristics of plants that occurred during the sowing date treatment may be related to genetic characteristics as well as abiotic factors such as variations in temperature and humidity. Variations in flowering and ripening have also been observed in areas where cluster beans are grown, which is because this crop is photosensitive (Ali et al., 2004). Previous research (Lilley et al., 2017) has shown that planting late in the spring decreases the number of spring canola seedlings and makes them mature a few days before they bloom.

Yield and yield contributing characteristics

During the course of this research experiment, it was discovered that the planting date as well as the planting density had a significant impact on the number of clusters that were produced by each plant. As a direct consequence of this, the number of clusters produced by each plant after early seeding was greater than it was at later sowing (Table 4). The temperature was optimal for plant growth and development at the beginning of the planting process, particularly for reproductive processes such as pollination, fertilization, and pod production. Therefore, comparable outcomes were seen in the earlier rounds of study tests (Akhilesh et al., 2013). The results of this study's experiments revealed that early and late planting both had an effect on the total number of pods produced by a cluster. In the 2019 study year, significant differences were found between the treatments administered on May 3, 18, and June 15; in the 2020 study year, these same differences were found between the treatments administered on June 17, July 1, and July 15. The results of the investigations comparing the two years' plant densities did not disclose any significant variations. However, in comparison to the branching variety S-6384, BR-2017 produced a greater number of pods within each cluster (Table 4). This is because it has been shown that planting seeds early gives plants more time to grow and better growing conditions. It also helps plants use water, nutrients, and sunlight more efficiently.

Lower plant densities reduce the amount of competition between plants and provide better conditions for the use of moisture, nutrients, space, and light for better plant growth. As a result, plants produce more flowers and pods per plant (Henry & Kackar, 2001). This is because better growing conditions and better roots of plants occur at the time of early sowing. On the other hand, it has been noted that the planting of early crops results in an increase in the number of grains per pod due to prolonged periods of vegetative and reproductive growth (Table 4). Ali et al. (2004) found results that were quite similar to these, and they indicated that early sowing (in May) greatly boosted pod productivity in comparison to later sowing. The timing of planting also has an effect on seed yield, with the best results occurring on June 3, 2019, and May 3, 2020. There wasn't a strong link between crop density and seed yield, but yields went up a lot in 2020, with S-6384 reaching its highest point (Table 4).

Conclusion

- On the other hand, the number of flowering days up to 50 percent, the number of days until maturation, and the number of grains in the pods showed a significant relationship in the second year of the study, which was in the year 2020.
- When compared to S-6384, the results show that BR-2017 had a significantly higher plant height during both years of the study as well as throughout all of the sowing periods.
- Although both guar varieties require the same number of days up to fifty percent of their flowering days, S-6384 matures in one hundred and BR-2017 matures in one hundred thirty days, making it an early maturing variety.
- In this study, the differences in the phenomenological traits of plants that happened during the sowing date treatment may have been caused by both genetic factors and environmental factors like changes in temperature and humidity.

TABLE 4. mean comparison of seed yield and yield contributing traits affected by sowing date, plant density and variety in 2019 and 2020

Sowing date	Clusters/plant		Pods/cluster		Grains/pod		Seed yield (kg/plot)	
	2019	2020	2019	2020	2019	2020	2019	2020
SD1	30.66abc	41.33a	5.55ab	6.83a	6.72a	5.94a	3.98b	3.19a
SD2	26.55c	34.77b	5.72a	6.55a	5.49b	5.05c	3.07b	2.79b
SD3	33.00ab	32.55c	5.00ab	6.66a	4.67cd	5.57b	3.42a	3.07a
SD4	28.38bc	32.88bc	3.83b	6.16ab	4.47d	4.85d	3.19ab	2.48c
SD5	33.72a	33.66bc	4.72ab	6.77a	5.34bc	4.85d	2.50c	3.17a
SD6	28.83abc	32.88bc	4.83ab	5.61b	4.69cd	4.08e	1.96d	2.76b
Density								
D1	32.80a	36.72a	4.91a	6.66a	5.18a	5.28a	2.85a	2.88a
D2	30.52a	34.75b	4.88a	6.58a	5.23a	5.27a	2.85a	2.92a
D3	27.25b	32.58c	5.02a	6.05b	5.27a	4.61b	2.86a	2.93a
Variety								
V1	36.68a	34.94a	5.72a	7.35a	6.36a	6.13a	2.98a	2.72b
V2	23.70a	34.42a	4.16a	5.51b	4.10b	3.98b	2.73a	3.10a

Means within a column followed by the same letter do not significantly different from each other ($P < 0.05$; LSD test). SD: sowing date (SD1: MAY 3, SD2: MAY18, SD3: JUNE 1, SD4: JUNE 15, SD5: JULY 2, SD6: JULY 15 in 2019 and SD1: MAY 1, SD2: MAY15, SD3: JUNE 2, SD4: JUNE 17, SD5: JULY 1, SD6: JULY 15 in 2020); D: density (D1: 15, D2: 25, and D3: 40 plants m-2) and V: variety (V1: BR-2017, V2: S-6384).

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Reference

Abidi, N., Liyanage, S., Auld, D., Norman, L., Grover, K., Augadi, S., et al. (2015) "*Challenges and Opportunities for Increasing Guar Production in the United States to Support Unconventional Oil and Gas Production*". Chapter 12: Challenges and Opportunities for Increasing Guar Production in the United States to Support Unconventional Oil and Gas Production, pp. 207-225.

Akhilesh, S., Yudhvir, S., Munish, S., Viveka, K. (2013) Optimum sowing dates and varieties for seed productivity of pole Frenchbean (*Phaseolus vulgaris* L.) under north western Himalayas. *African Journal of Agricultural Research*, **8**(48), 6196-6201.

Ali, Z., Zahid, M.S., Zia-ul-Hassan, M., Bashir, M. (2004) Sowing dates effects on growth, development and yield of guar (*Cyamopsis tetragonoloba* L.) under rainfed conditions of Pothowar region [Pakistan]. *Journal of Agricultural Research (Pakistan),* **42**(1), 33-40.

Ashraf, M.Y., Akhtar, K., Sarwar, G., Ashraf, M. (2002) Evaluation of arid and semi-arid ecotypes of guar (*Cyamopsis tetragonoloba* L.) for salinity (NaCl) tolerance. *Journal of arid environments*, **52**(4), 473-482.

Candan, N., Cakmak, I., Ozturk, L. (2018) Zinc-biofortified seeds improved seedling growth under zinc deficiency and drought stress in durum wheat. *Journal of Plant Nutrition and Soil Science*, **181**(3), 388-395.

de Souza, L.C., da Luz, L.M., da Silva Martins, J.T., de Oliveira Neto, C.F., Palheta, J.G., de Oliveira, T.B., et al. (2018) Osmoregulators in Hymenaea courbaril and Hymenaea stigonocarpa under water stress and rehydration. *Journal of Forestry Research*, **29**(6), 1475-1479. .

Deka, K.K., Das, M.R., Bora, P., Mazumder, N. (2015) Effect of sowing dates and spacing on growth and yield of cluster bean (*Cyamopsis tetragonoloba* L.) in subtropical climate of Assam, India. *Indian*

Journal of Agricultural Research, **49**(3), 250-254.

Gresta, F., Sortino, O., Santonoceto, C., Issi, L., Formantici, C., Galante, Y.M. (2013) Effects of sowing times on seed yield, protein and galactomannans content of four varieties of guar (*Cyamopsis tetragonoloba* L.) in a Mediterranean environment. *Industrial Crops and Products*, **41**, 46-52. .

Gresta, F., Ceravolo, G., Presti, V. L., D'Agata, A., Rao, R., Chiofalo, B. (2017) Seed yield, galactomannan content and quality traits of different guar (*Cyamopsis tetragonoloba* L.) genotypes. *Industrial Crops and Products*, **107**, 122-129.

Gresta, F., Avola, G., Cannavò, S., Santonoceto, C. (2018) Morphological, biological, productive and qualitative characterization of 68 guar (*Cyamopsis tetragonoloba* L.) Taub. genotypes. *Industrial Crops and Products*, **114**, 98-107.

Henry, A., Kackar, N.L. (2001) Studies on phenotypic stability in cluster bean under late sown conditions. *Current Agriculture*, **25**(1-2), 103-105.

Honnaiah, P.A., Sridhara, S., Gopakkali, P., Ramesh, N., Mahmoud, E.A., Abdelmohsen, S.A., et al. (2021) Influence of sowing windows and genotypes on growth, radiation interception, conversion efficiency and yield of guar. *Saudi Journal of Biological Sciences*, **28**(6), 3453-3460.

Hussain, I., Ali, M., Ghoneim, A.M., Shahzad, K., Farooq, O., Iqbal, S., et al. (2022) Improvement in growth and yield attributes of cluster bean through optimization of sowing time and plant spacing under climate change scenario. *Saudi Journal of Biological Sciences*, **29**(2), 781-792.

Kalyani, D.L., Sunitha, N. (2011) Response of cluster bean [*Cyamopsis tetragonoloba* L.) varieties to different times of sowing-a review. *Agricultural Reviews*, **32**(3), 209-215.

Khalil, S. K., Wahab, A., Rehman, A., Muhammad, F., Wahab, S., Khan, A. Z., et al. (2010). Density and planting date influence phenological development assimilate partitioning and dry matter production of faba bean. *Pakistan Journal of Botany*, **42**(6), 3831-3838.

Kiss, T., Balla, K., Bányai, J., Veisz, O., Karsai, I. (2018) Associations between plant density and yield components using different sowing times in wheat (*Triticum aestivum* L.). *Cereal research communications*, **46**(2), 211-220.

Korotaeva, N.E., Ivanova, M.V., Suvorova, G.G., Borovskii, G.B. (2018) The impact of the environmental factors on the photosynthetic activity of common pine (*Pinus sylvestris*) in spring and in autumn in the region of Eastern Siberia. *Journal of Forestry Research*, **29**(6), 1465-1473.

Lilley, J., Flohr, B., Whish, J., Kirkegaard, J. (2017) Optimal flowering periods for canola in eastern Australia. In: *Proceedings of the 18th Australian Society of Agronomy Conference,* Ballarat, Australia.

Lone, B.A., Badrul, H., Ansar-ul-Haq, S., Khan, M.H. (2010) Effect of seed rate, row spacing and fertility levels on relative economics of soybean (*Glycine max* L.) under temperate conditions. *African journal of agricultural research*, **5**(5), 322-324.

Mahdipour-Afra, M., AghaAlikhani, M., Abbasi, S., Mokhtassi-Bidgoli, A. (2021) Growth, yield and quality of two guar (*Cyamopsis tetragonoloba* L.) ecotypes affected by sowing date and planting density in a semi-arid area. *Plos one*, **16**(9), e0257692. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0257692

Meftahizade, H., Hamidoghli, Y., Assareh, M.H., Dakheli, M.J. (2017) Effect of sowing date and irrigation regimes on yield components, protein and galactomannan content of guar (*Cyamopsis tetragonoloba* L.) in Iran climate. *Australian Journal of Crop Science*, **11**(11), 1481-1487.

Meftahizadeh, H., Ghorbanpour, M., Asareh, M.H. (2019a) Changes in phenological attributes, yield and phytochemical compositions of guar (*Cyamopsis tetragonoloba* L.) landaraces under various irrigation regimes and planting dates. *Scientia Horticulturae*, **256**, 108577. https://doi.org/10.1016/j.scienta.2019.108577.

Meftahizadeh, H., Ghorbanpour, M., Asareh, M.H. (2019b) Comparison of morphological and phytochemical characteristics in guar (*Cyamopsis tetragonoloba* L.) landraces and cultivars under different sowing dates in an arid environment. *Industrial Crops and Products*, **140**, 111606. https://doi.org/10.1016/j.indcrop.2019.111606.

Nandini, K.M., Sridhara, S., Patil, S., Kumar, K. (2017) Effect of planting density and different genotypes on growth, yield and quality of Guar. *International Journal of Pure & Applied Bioscience*, **5**(1), 320-328.

Ncube, B., Finnie, J.F., Van Staden, J. (2012) Quality from the field: The impact of environmental factors as quality determinants in medicinal plants. *South African Journal of Botany*, **82**, 11-20.

Santonoceto, C., Mauceri, A., Lupini, A., Gresta, F., Chiera, E., Sunseri, F., et al. (2019) Morpho-agronomic characterization and genetic variability assessment of a guar germplasm collection by a novel SSR panel. *Industrial Crops and Products*, **138**, 111568. https://doi.org/10.1016/j.indcrop.2019.111568

Siddaraju, R., Narayanaswamy, S., Prasad, S.R. (2010) Studies on growth, seed yield and yield attributes as influenced by varieties and row spacings in cluster bean (*Cyamopsis tetragonoloba* L.). *Mysore Journal of Agricultural Sciences*, **44**(1), 16-21.

Srivastava, A. K., Mboh, C. M., Gaiser, T., Webber, H., Ewert, F. (2016) Effect of sowing date distributions on simulation of maize yields at regional scale–A case study in Central Ghana, West Africa. *Agricultural Systems*, **147**, 10-23.