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Effect of Different Sowing Times and Sowing Densities on the Agronomical and Technological Traits in Gümüşhane Sugar Bean

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Abstract: Locally adapted Landraces are considered as valuable genetic resources, important income sources for local bean producers and consumers' preferences. A limited number of studies have been carried out on different sowing times and densities in landraces of common bean (*Phaseolus vulgaris* L.). To present alternative options for farmers, especially new ones, this study aimed to reveal the effect of different sowing times and densities on the agronomical and technological traits of a common bean known as Şeker fasulye (sugar bean) in Gümüşhane, Türkiye. The study was conducted in a field of farmer in Gümüşhane in three different sowing times (22 May, 6 June, 21 June 2020) and six sowing densities (30×5 cm, 30×10 cm, 30×15 cm, 45×5 cm, 45×10 cm, 45×15 cm) using split-plot design in randomized blocks. The highest grain yield was obtained in sowing densities of 30×10 cm (8.96 t ha^{-1}) and 30×15 cm (8.87 t ha^{-1}) on 22 May. As "a golden rule of plant production", the early sowing time (22 May) is recommended to the farmers. Also, 30×15 cm sowing density is suggested to the producers due to the less seed requirements for the agronomical and technological traits in landrace of common bean (Gümüşhane Sugar Bean).

Keywords: *Phaseolus vulgaris* L., sowing date, sowing norm, technological traits, yield

Farklı Ekim Zamanları ve Ekim Sıklıklarının Gümüşhane Şeker Fasulyesinin Agronomik ve Teknolojik Özellikleri Üzerindeki Etkisi

Öz: *Değerli genetik kaynaklardan olan yerel fasulye çeşitleri, fasulye üreticileri ve tüketicilerin tercihleri için önemli gelir kaynakları olarak kabul edilmektedir. Fasulye (Phaseolus vulgaris L.) yerel çeşitlerinde farklı ekim zamanları ve ekim sıklıkları üzerine sınırlı sayıda çalışma yapılmıştır. Çiftçilere, yeni bir alternatif seçenek sunmak için yapılan bu çalışma, farklı ekim zamanları ve ekim sıklıklarının, Türkiye'de Gümüşhane Şeker Fasulyesi olarak bilinen bir fasulyenin tarımsal ve teknolojik özellikleri üzerindeki etkisini ortaya çıkarmayı amaçlamıştır. Araştırma, üç farklı ekim zamanında (22 Mayıs, 6 Haziran, 21 Haziran 2020) ve altı ekim sıklığında (30×5 cm, 30×10 cm, 30×15 cm, 45×5 cm, 45×10 cm, 45×15 cm); tesadüf bloklarında bölünmüş parseller deneme desenine göre Gümüşhane'de bir çiftçi tarlasında yürütülmüştür. En yüksek tane verimi 22 Mayıs tarihinde 30×10 cm (8,96 t ha^{-1}) ve 30×15 cm (8,87 t ha^{-1}) ekim sıklıklarında elde edilmiştir. "Bitkisel üretimin altın kuralı" olarak çiftçilere erken ekim zamanı (22 Mayıs) önerilmektedir. Ayrıca, Gümüşhane Şeker Fasulyesi'nde gerek tarımsal ve teknolojik özellikler açısından ve gerekse tohum ihtiyacının 30×10 cm ekim normuna göre daha az olması nedeniyle üreticilere 30×15 cm ekim sıklığı tavsiye edilmektedir.*

Anahtar Kelimeler: *Phaseolus vulgaris L., ekim zamanı, ekim normu, teknolojik özellikler, verim*

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is one of the important legumes used directly in nutrition worldwide (Manjeru, 2007). It is consumed for the dried grains and immature grains as well as green pods as vegetable. The cultivation area of beans in Turkey is 97 052 ha, the production is 270 000 t and the grain yield is 2.78 t ha^{-1}. The cultivation area in Gümüşhane is 1 617 ha, the production is 3 441 t and the grain yield is 2.13 kg ha^{-1} (TUIK, 2022).

Bean, originated from America, has a wide cultivation area around the world and is a plant that has a high ability to adapt to warm-temperate climates, but is sensitive to extreme temperatures during the germination period (Sehirali, 1988).

Bean, which is a good alternative to the solving the increasing nutritional problem, contain 17-35% protein (Eroğlu, 2007). Bean is also one of the iron sources that are important for nutrition, excluding meat consumption, and provide 23-30% of the required daily intake (Schwarz et al., 1996). Considering the most important quality characteristics that increase the nutritional value of bean; in addition to its high protein and low fat content, it appears to contain some vitamin and mineral components. It is seen that beans can meet half of the daily vitamin B needs on average in the meal they are consumed, and are also very rich in minerals, especially phosphorus, potassium, calcium and iron. In 100 grams of bean it contains 0.60 mg vitamin B1, 0.10 mg vitamin B2, 80 mg Ca, 400 mg P, 5.0 mg Fe, 1250 mg K (Peksen and Artik, 2005).

Bean, which has a high possibility of being cultivated in all regions of our country, generally show optimum growth and development in hot climates and sandy-loamy soils (Varankaya and Ceyhan, 2012a).

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For Van-Gevas ecological conditions, the most suitable row spacing for dry bean is 50 cm (Uçar, 2021). In beans, the early planting increases the germination rate. However, when temperatures drop below 0˚C after planting, the plant is damaged and thus the problem of crop loss arises (Direk et al., 2002). The most suitable planting time is early May (Uçar, 2020). The biggest problem encountered in dry bean cultivation in Gümüşhane province is the plants rot, and also the sowing wich has to be done twice per season due to heavy rains or even hail after emergence. So, this study was carried out to determine the appropriate sowing time and sowing densities in Gümüşhane conditions to prevent producers from being affected by excessive rainfall in bean cultivation.

MATERIAL AND METHODS

Plant Material

The study was conducted with Gümüşhane Sugar Bean, white colored and long-round shaped seeds as well as geographic sign registration by the Institute of Turkish Patent (TURKPATENT, 2019).

Soil properties of the trial area

The trial was conducted on a farmer land in Gümüşhane province. The trial area is located between 40.4172° north latitude and 39.5910° east longitude; it has an altitude of 1257 meters. The soil analysis of the trial area was carried out by Erzincan Horticultural Research Institute; the results of the analysis were given in Table 1 (Anonymous, 2020a).

Table 1. Soil analysis results of the trial area

Soil texture (%)	Organic matter (%)	pH	Lime (%)	Salt (%)	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
56-clay	1.83	7.89	8.41	0.029	173	1423
Clay-loam	Weak	Slightly alkaline	Calcareous	Salt-free	Sufficient	Excessive

According to Table 1; the trial soil has 56% of clay, and it is called as clay-loam texture. Also, it's not rich in organic compound, it'is slightly alkaline, calcareous, salt-free and has sufficient levels of phosphorus and potassium.

Climatic data of the trial area

Gümüşhane province, where the trial was conducted, constitutes a transition between the Eastern Anatolia Region and the Black Sea Region in terms of climatic characteristics. The climatic data of the trial area were given in Table 2 (Anonymous, 2020b). Accordingly, in terms of monthly average temperature, the average of May 2020 (13.8 °C) was higher than the long-term average (13.6 °C), and similarly, an increase of temperature was observed in June and July. When looking at the monthly average precipitation amounts (Table 2), it was observed that the average of May 2020 (66.1 mm) was higher than the long-term average (40.5 mm), and in other months it was lower than the long-term average (Table 2). When looking at the monthly average relative humidity amounts; it was observed that the average of May 2020 (54.1%) was much lower than the average of many years (93.7%). When evaluated in terms of monthly average relative humidity; in general, there was a decrease of the amount of relative humidity throughout 2020.

According to Table 2, it was observed that the maximum temperature average in June 2020 (33.0 °C) was lower than the long-term average (34.4 °C). When the monthly minimum temperature values of 2020 were compared with many years, it was observed that there is an increase in temperature.

Table 2. Climatic data for Gümüşhane province in 2020

Months	Monthly Maximum Temperature (°C)		Monthly Minimum Temperature (°C)		Monthly Mean Temperature (°C)		Monthly Total Precipitation (mm)		Monthly Mean Relative Humidity (%)	
	2020	Long term	2020	Long term	2020	Long term	2020	Long term	2020	Long term
May	30.9	34.4	2.1	- 2.8	13.8	13.6	66.1	40.5	54.1	93.7
June	33.0	36.2	8.1	1.8	19.1	17.2	31.5	51.7	50.9	92.9
July	39.3	41.0	12.4	4.5	22.2	20.2	15.6	26.6	52.6	90.7
August	37.0	41.1	8.8	4.9	20.2	20.2	4.4	25.7	49.9	91.6
September	37.1	37.1	10.4	- 1.0	20.4	16.6	4.8	23.2	47.2	93.8
October	28.7	32.0	3.8	- 4.8	15.1	11.4	10.5	49.1	30.3	95.1

Trial setup and agronomical procedures

The study was conducted according to the split-plot trial design in randomized blocks design, with three replications. While the sowing times (22 May, 6 June and 21 June in 2020) were taken as the main plots, sowing densities (30 × 5 cm, 30 × 10 cm, 30 × 15 cm, 45 × 5 cm, 45 × 10 cm, 45 × 15 cm) were placed in sub-plots. The trial plots were 5 m long and consisted with 4 rows (2 m between main plots and 0.5 m between sub-plots). Between the blocks, 2 m distance was left. The sowing depth was used as 5-6 cm. Before the sowing, organomineral fertilizer containing 8.20.0 (NPK) was applied at 24 kg of pure nitrogen and 60 kg of P_2O_5 per ha as top fertilization after sowing, while after the first hoeing, 21% of pure nitrogen at 50 kg per ha in the form of nitrogen-containing ammonium sulfate was applied. The first irrigation was done as soon as the top fertilizer was applied, and the next ones were given as needed. Harvest was made when the pods reached harvest maturity, and the middle two rows were harvested by removing 50 cm away from the edges of the rows.

Investigated traits

The following agricultural and technological traits were studied according to Technical Instruction of Seed Registration and Certification Center Directorate of the Ministry of Agriculture and Forestry on the Agricultural Values Measurement Trials (Anonymous, 2001).

Agricultural traits

Days to flowering time

It was determined by taking the number of days from the seed emergence date to the date of anthesis was observed in at least 50% of the plants.

Days to physiological maturity time

It was determined by taking the number of days between the seed emergence date and the date when the pods in the middle of the plant crown turned yellow.

Plant height

The vertical distance was measured in cm between the soil surface and the top point of the plant during the harvest period, on 5 randomly selected plants in the middle two rows of each plot.

First pod height

During the harvest period, the vertical distance between the soil surface and the first pod was measured in cm on 5 randomly selected plants in the middle two rows of each plot.

Number of pods per plant

At harvest, the mean number of pods per plant was determined by counting pods on 5 randomly selected plants within the middle two rows.

Number of grains per pod

In the plants randomly determined in the plot and pods were counted; it was obtained by dividing the number of grains by the number of pods.

100-Grain weight

After harvest, the grains were dried, they were determined by taking the weight mean of 100-grains randomly selected from the product taken from each plot in four repetitions.

Grain yield

Grain yield was determined as t ha^{-1} by removing 50 cm from the edge of each plot and converting the grain mass obtained from the two rows in the middle into plot.

Technological traits

Water absorption capacity

It was calculated as grain g^{-1} with the formula of [(Wet weight-Dry weight)/100]. Dry weight (g); 100 dried beans were determined by counting and weighing. Wet weight (g); after the dry weight of 100 seeds was taken, water was added and left for 16 hours and then drained. Then, it was dried with paper towel and weighed to obtain the wet weight.

Water uptake index

It was calculated with the formula of [Swelling Capacity/(Dry Weight/100)].

Swelling capacity

It was calculated as mL $grain^{-1}$ with the formula of [(Wet Volume-100)-(Dry Volume-50)]-[(Dry Volume-50)/100×No of Unswollen Grains]/(100-No of Unswollen Grains). Dry volume (mL); 100 dry bean samples were placed in a graduated cylinder and the result was determined as dry volume. Wet volume (mL); a certain amount of pure water was added to 100 dried bean samples, left for 16 hours, then dried with a paper towel and placed in a graduated cylinder, and the result was determined as the wet volume.

Swelling index

It was calculated as percent with the formula of [(Wet Volume-100)/(Dry Volume-50)].

Protein ratio

It was determined as percent by the Kjeldahl method according to AOAC (2003).

Cooking time

100 dried bean samples soaked for 12 hours and were placed in boiling water; by checking every 5 minutes. The cooking time was determined in min when the white dot inside disappeared, the skin peeled and the grain was divided in two.

Data analysis

The data obtained from the trial were analyzed according to the split-plot trial design in randomized blocks (sowing time in the main plots and sowing density in the sub-plots) by JMP 7 (2007) package program. Comparisons of the means related to the statistically significant traits were done by LSD test.

RESULTS AND DISCUSSION

Days to flowering time (DFT)

DFT in Gümüşhane Sugar Bean at different sowing times and sowing densities showed significant differences for sowing time (p<0.01) and sowing densities (p<0.05) (Table 3). Means of DFT in Gümüşhane Sugar Bean at different sowing times and sowing norms were given in Table 4. The longest DFT for sowing time was observed on 21 June (38.97 days). According to the sowing densities, the longest DFT (38.27 days) was from the 30×10 cm sowing norm; the shortest was observed in 30×5 cm (37.96 days) and 45×5 cm (37.91 days) sowing norms. Şener and Kaya (2022) stated that the flowering period in beans varies between 35.60-71.20 days. Serengul (2019) determined the DFT as 34.00-37.50 days in her study, which is similar to our study. Differences among the DFTs in beans may be caused by sowing time, climatic conditions, soil characteristics, irrigation regime and seed type. In a study, it was stated that heat and moisture stress affected the DFT in beans, and as the day length decreased, the crop growth and DFT of the plant was prolonged (Ulker, 2008). The reason why the sowing time × sowing density interaction was not significant in terms of DFT (Table 3) is due to the fact that sowing times do not have significant effects on sowing densities for DFT in Gümüşhane Sugar Bean. It is thought that the increase of average temperatures in June (Table 2), during the vegetation period when the study was conducted, caused the DFT of the crops extention

Days to physiological maturity time (DPMT)

The variation sources such as sowing time (p<0.05), sowing density (p<0.01) and sowing time × sowing density interaction (p<0.05) showed statistically significant differences (Table 3). Means of DPMT in Gümüşhane Sugar Bean at different sowing times and sowing densities were given in Table 4. When evaluated according to the mean of the sowing densities, the longest DPMT was obtained from 21 June sowing with 121.45 days (Table 4). Also, DPMT varied between 119.33 days (30×15 cm) and 121.67 days (45×10 cm) depending on the mean of sowing time; while maturation took longer in the 45×10 cm and 45×15 cm sowing densities, the plants matured in a shorter time in the other sowing densities (Table 4).

Table 3. Mean squares related to agricultural and technological traits in Gümüşhane Sugar Bean at different sowing times and sowing densities

Variation sources	Df	Mean Squares for Agricultural Traits							
		DFT	DPMT	PH	FPH	NPP	NGP	HGW	GY
Sowing time (ST)	2	10.632**	19.907*	5.979**	0.207*	85.630**	16.074**	6.352*	13.659**
Replication	2	0.019	0.963	0.007	0.030	1.185	0.296	1.241	0.003
Error 1	4	0.052	1.407	0.008	0.020	0.574	0.130	0.769	0.004
Sowing density (SD)	5	0.182*	10.374**	0.229**	0.138**	8.152**	1.674**	1.319**	17.232**
ST×SD	10	0.070	4.485*	0.022	0.161**	1.941*	1.207**	0.163	0.110**
Error 2	30	0.050	1.660	0.027	0.024	0.689	0.274	0.181	0.005
CV (%)		0.58	1.07	0.32	1.19	11.52	10.55	1.00	1.00

Variation sources	Df	Mean Squares for Technological Traits					
		WAC	WUI	SC	SI	PR	CT
Sowing time (ST)	2	0.011	0.059	0.003**	745.658*	1.717	1.685
Replication	2	0.001	0.002	0.000	8.526	0.208	0.685
Error 1	4	0.002	0.012	0.000	46.849	0.766	1.463
Sowing density (SD)	5	0.000	0.003	0.000	22.469	0.649**	1.130*
ST×SD	10	0.000	0.002	0.000	36.621	0.345	1.241*
Error 2	30	0.000	0.001	0.000	20.110	0.171	0.426
CV (%)		2.86	3.60	1.87	30.09	8.84	1.95

*, ** indicate significant differences at the probability levels of 0.05 and 0.01, respectively. Df: degree of freedom, CV: variation of coefficient, DFT: days to flowering time, DPMT: days to physiological maturity time, PH: plant height, FPH: first pod height, NPP: no of pods per plant, NGP: no of grains per pod, HGW: 100-grain weight, GY: grain yield, WAC: water absorption capacity, WUI: water uptake index, SC: swelling capacity, SI: swelling index, PR: protein ratio, CT: cooking time.

The significant interaction (Table 3) is due to the fact that physiological dormancy times increase as day length decreases in different sowing densities (Table 4). In the vegetation period when the study was carried out, the day length in the first sowing time (22 May) and second sowing time (6 June) was longer than the third sowing time (21 June), as well as the lower average rainfall and relative humidity in June and July (Table 2). Therefore, it is thought that late sowing time may caused the extension of physiological maturity time. Peksen (2005) determined the DPMT as 99.17-120.00 days, which is similar to our study. Karabacak (2018) determined this time as 116.00-137.66 days in his study, and Deniz (2008) determined the DPMT as 114-137 days in his study. Differences among the DPMTs in bean may be due to the ability of the genotypes used to adapt to environmental conditions, sowing time, and sowing densities (distance between rows and intrarows).

Table 4. Mean values of agricultural traits in Gümüşhane Sugar Bean at different sowing times and sowing densities

Sowing density (SD)	DFT (days)				DPMT (days)				PH (cm)			
	Sowing time (ST)				Sowing time				Sowing time			
	22 May	6 June	21 June	Mean	22 May	6 June	21 June	Mean	22 May	6 June	21 June	Mean
30 × 5 cm	37.53	37.53	38.80	37.96^{c}	117.00^{f}	120.67^{bcd}	120.67^{bcd}	119.45^{b}	51.23	51.30	50.23	50.92^{bc}
30×10 cm	38.00	37.87	38.93	38.27^{a}	118.33^{ef}	119.33^{cde}	121.33^{bc}	119.66^{b}	51.27	51.10	50.23	50.87^{c}
30×15 cm	37.73	37.60	39.00	38.11^{abc}	118.67^{def}	119.33^{cde}	120.00^{b-e}	119.33^{b}	51.27	51.27	50.23	50.92^{bc}
45 × 5 cm	37.53	37.40	38.80	37.91^{c}	120.67^{bcd}	118.00^{ef}	120.67^{bcd}	119.78^{b}	51.40	51.30	50.37	51.02^{bc}
45×10 cm	37.60	37.53	39.00	38.04^{bc}	121.00^{bc}	120.00^{b-e}	124.00^{a}	121.67^{a}	51.70	51.47	50.77	51.31^{a}
45×15 cm	38.00	37.40	39.27	38.22^{ab}	121.33^{bc}	121.33^{bc}	122.00^{ab}	121.55^{a}	51.50	51.33	50.27	51.03^{b}
Mean	37.73^{b*}	37.56^{b}	38.97^{a}	38.09	119.50^{b}	119.78^{b}	121.45^{a}	120.24	51.39^{a}	51.29^{b}	50.35^{c}	51.01
$LSD_{(ST)}$	0.21				1.10				0.08			
$LSD_{(SD)}$	0.21				1.24				0.16			
$LSD_{(ST×SD)}$	ns				2.15				ns			

Sowing density (SD)	FPH (cm)				NPP (pcs)				NGP (pcs)			
	Sowing time				Sowing time				Sowing time			
	22 May	6 June	21 June	Mean	22 May	6 June	21 June	Mean	22 May	6 June	21 June	Mean
30 × 5 cm	13.10^{bcd}	12.93^{de}	12.67^{f}	12.90^{c}	9.33	4.33	4.33	6.00^{d}	6.00^{a}	5.67^{ab}	2.33^{g}	4.67^{b}
30×10 cm	12.60^{f}	13.23^{abc}	13.10^{bcd}	12.98^{bc}	8.67	6.33	5.00	6.67^{cd}	5.67^{ab}	5.00^{bcd}	3.67^{f}	4.78^{b}
30×15 cm	12.80^{ef}	13.37^{a}	13.20^{abc}	13.12^{ab}	10.67	6.67	5.67	7.67^{b}	5.00^{bcd}	5.00^{bcd}	4.33^{def}	4.78^{b}
45 × 5 cm	13.33^{ab}	13.20^{abc}	13.10^{bcd}	13.21^{a}	9.00	4.67	7.00	6.89^{bc}	5.67^{ab}	4.67^{cde}	3.67^{f}	4.67^{b}
45×10 cm	13.40^{a}	13.20^{abc}	12.93^{de}	13.18^{a}	9.33	6.00	6.33	7.22^{bc}	5.67^{ab}	5.67^{ab}	4.00^{ef}	5.11^{b}
45×15 cm	13.10^{bcd}	13.33^{ab}	13.03^{cde}	13.16^{a}	11.33	7.67	7.33	8.78^{a}	6.00^{a}	6.00^{a}	5.33^{abc}	5.78^{a}
Mean	13.06^{b}	13.21^{a}	13.01^{b}	13.09	9.72^{a}	5.94^{b}	5.94^{b}	7.20	5.67^{a}	5.33^{b}	3.89^{c}	4.96
$LSD_{(ST)}$	0.13				0.70				0.33			
$LSD_{(SD)}$	0.15				0.80				0.50			
$LSD_{(ST×SD)}$	0.26				1.38				0.87			

Sowing density (SD)	HGW (g)				GY (t ha^{-1})			
	Sowing time				Sowing time			
	22 May	6 June	21 June	Mean	22 May	6 June	21 June	Mean
30 × 5 cm	42.00	42.67	41.50	42.06^{b}	8.85^{a}	7.30^{c}	6.85^{d}	7.67^{b}
30×10 cm	41.67	42.67	41.50	41.94^{b}	8.96^{a}	7.40^{bc}	6.90^{d}	7.76^{a}
30×15 cm	42.67	43.33	41.50	42.50^{a}	8.87^{a}	7.46^{b}	6.92^{d}	7.75^{a}
45 × 5 cm	42.33	43.33	42.17	42.61^{a}	5.95^{e}	4.99^{f}	4.59^{g}	5.18^{c}
45×10 cm	42.67	43.33	42.50	42.83^{a}	5.95^{e}	5.02^{f}	4.63^{g}	5.20^{c}
45×15 cm	42.67	43.33	42.50	42.83^{a}	6.02^{e}	5.03^{f}	4.61^{g}	5.22^{c}
Mean	42.33^{ab}	43.11^{a}	41.94^{b}	42.46	7.43^{a}	6.20^{b}	5.75^{c}	6.46
$LSD_{(ST)}$	0.81				0.06			
$LSD_{(SD)}$	0.41				0.07			
$LSD_{(ST×SD)}$	ns				0.12			

***** Values within the same letter group are not different at the 0.05 significance level. ns: non-significant, LSD: least significant difference, DFT: days to flowering time, DPMT: days to physiological maturity time, PH: plant height, FPH: first pod height, NPP: no of pods per plant, NGP: no of grains per pod, HGW: 100-grain weight, GY: grain yield.

Plant height (PH)

Sowing time (p<0.01) and sowing density (p<0.01) showed significant differences for PH while there were no statistically significant differences for sowing time × sowing density interaction (Table 3). Thus, as the mean of the sowing densities, the longest PH was observed in the 22 May sowing time (51.39 cm); the shortest PH (50.35 cm) was found in 21 June sowing time. As the mean of sowing times, the longest PH (51.31 cm) was in the 45×10 sowing norm; the shortest was observed in the 30×10 cm (50.87 cm) sowing norm (Table 4). Bean is a crop with high water and nutrient requirements and require regular and sufficient irrigation, at least 300-400 mm during the growth period (Caliskan et al., 2018). It is thought that during the vegetation period when the study was conducted, the amount of precipitation and humidity level in May were higher than in June, and the weather conditions were hotter and drier in June (Table 2), causing the plants to experience water stress and the growth rate to slow down slightly. Kahraman (2014) determined the mean PH as 76.07-91.12 cm; Peksen (2005) determined the mean plant height as 46.83 cm; and Cinar (2015) determined the mean PH as 46.4-40.8 cm. So, differences between plant heights in bean; it may be caused by sowing time, soil moisture, irrigation patterns and environmental factors.

First Pod Height (FPH)

Variation sources such as sowing time (p<0.05), sowing density (p<0.01) and sowing time × sowing density interaction (p<0.01) showed significant differences for FPH (Table 3). In Gümüşhane Sugar Bean, FPHs of 22 May sowing time (13.06 cm) and 21 June sowing time (13.01 cm) were shorter than on 6 June (13.21 cm). FPHs varied between 12.90 cm (30×5 cm) and 13.21 cm (45×5 cm) depending on sowing densities (Table 4). The significant interaction may be due to the fact that the FPH increases as the distance between rows increases in different sowing densities. Obtained from different bean genotypes used by Kahraman (2008) in a similar climate (in Konya) showed the lowest FPH was 6.40 cm in 30 June sowing time, and the highest was from 1 May sowing time with 15.07 cm. A study reported that factors such as the genotypes, sowing density, fertilization and environmental conditions had significant effects on the FPH (Peksen, 2005). According to Kahraman (2014), the lowest FPH with 6.40 cm in 30 June sowing time, and the highest with 15.07 cm in 1 May sowing time. Akgündüz (2016) reported the FPH as 6.63-9.22 cm, depending on the sowing time. Differences of FPH in bean may be caused by sowing time, distance between rows and intrarows (sowing densities), soil structure, fertilization and irrigation.

Number of Pods per Plant (NPP)

All variation sources (sowing time, p<0.01; sowing norm, p<0.01 and sowing time × sowing norm interaction, p<0.05) showed statistically significant differences (Table 3). NPP in Gümüşhane Sugar Bean was higher on 22 May sowing time (9.72 pcs) compared to 6 June sowing time (5.94 pcs) and 21 June (5.94 pcs). It varied between 6.00 pcs (30×5 cm) and 8.78 pcs (45×15 cm) depending on the sowing densities (Table 4). Caliskan et al. (2018), reported that drought occurring in the generative period, one of the most important development periods of legumes, negatively affects pod formation. During the vegetation period when the study was conducted, it is thought that the high average temperature and low humidity in July (Table 2) negatively affected flowering and therefore reduced the number of pods. According to Kacar et al. (2004), the lowest NPP with 10.84 pcs, and the highest NPP with 12.74 pcs. Canci et al. (2019) reported the mean NPP with 5-65 pcs. Also, Ceyhan et al. (2009) stated the wide range of the NPP as 12.3-32.0 pcs. Konuk et al. (2021) determined the NPP as 18.88-27.25 pcs. So, broad differences among the studies on the NPP; it may be caused by differences in sowing time, sowing densities, climatic conditions, soil characteristics, irrigation patterns and genotypes.

Number of Grains per Pod (NGP)

Statistically significant differences (p<0.01) were found for sowing time, sowing density and sowing time × sowing density interaction (Table 3). The NGP in Gümüşhane Sugar Bean was highest in 22 May sowing time (5.67 pcs); the lowest was found in 21 June sowing time (3.89 pcs). It varied between 4.67 pcs (30×5 cm) and 5.78 pcs (45×15 cm) depending on the sowing densities (Table 4). The significant interaction is due to the decrease in the NGP as day length increases in different sowing densities. In addition, the significant interaction was from the first sowing time (May 22) at the 30×5 cm and 45×15 cm sowing densities in the upper groups for the NGP. During the vegetation period when the study was carried out, the monthly average temperatures in June were high (Table 2), and it is thought that the NGP was less in June sowing times especially in June 21 (Table 4). Similar results were reported as 5.2 pcs by Cakir (2019) (as mean 5.2 pcs); Aydogan (2017) (3.27-6.13 pcs) and Peksen (2005) (3.24-6.06 pcs).

100-Grain Weight (HGW)

Sowing time (p<0.05) and sowing norm (p<0.01) showed statistically significant differences for HGW (Table 3). According to the mean of the sowing densities, the highest HGW was obtained from the 6 June sowing time with 43.11 g. For mean of sowing times, the highest HGW (42.83 g) was from the 45×10 cm and 45×15 cm sowing densities; the lowest was observed in the 30×10 cm (41.94 g) sowing norm (Table 4). Masa et al. (2017) stated the HGW as 44.07 g in their study, which is similar to our study. Among the other studies on this trait, wider distributions were observed like the findings of Cengiz (2007) as 17.45-46.37 g and Aydogan (2017) as 42.2-60.3 g. These broad variations may be due to the different ecologies and agricultural conditions.

Grain Yield (GY)

All variation sources showed statistically significant differences ($p<0.01$) for GY (Table 3). So, mean GY of Gümüşhane Sugar Bean was found as higher in 22 May sowing time (7.43 t ha^{-1}) compared to 6 June sowing time (6.20 t ha^{-1}) and 21 June sowing time (5.75 t ha^{-1}) (Table 4). GY ranged between 5.18 t ha^{-1} (45×5 cm) and 7.76 t ha^{-1} (30×10 cm) depending on sowing densities (Table 4). Moreover, when the interaction of sowing time × sowing density was evaluated, GY was ranged between 4.61 t ha^{-1} and 8.96 t ha^{-1} and this significant interaction (Table 3; Table 4) is due to the change in GY according to the different sowing densities at different sowing times. The other studies presented lower GY values such as Taskesen (2019) with 2.39-3.81 t ha^{-1}; Serengul (2019) with 1.84-3.26 t ha^{-1} and Karabacak (2018) with 1.41-3.33 t ha^{-1}. It is thought that the high values in our study are due to different ecology, good care conditions and high sowing density. Even more, bean is a crop that prefers the water and responds well to the water; so, in this trial, plants were not limited in terms of water.

Technological Traits

Water Absorption Capacity (WAC)

No statistically significant differences were found for all variation sources (sowing time, sowing density and sowing time × sowing density interaction) for WAC (Table 3). Even so, overall mean of the trial for this trait was found as 0.42 g grain^{-1}; it was ranged between 0.39-0.45 g grain^{-1} according to the sowing time and sowing density (Table 5). Aydogan et al. (2020) reported the WAC as 0.36-0.59 g grain^{-1}, depending on the bean genotype and years. Kaur et al. (2006) stated different WAC values depending on the chemical content of the seeds and cell wall properties. There is an important relationship between the weight of the seed and its WAC. Karasu (1993) reported that genotypes with high WAC generally have high 100-grain weight, while genotypes with low WAC have low 100-grain weight.

Water Uptake Index (WUI)

No statistically significant differences were found for all variation sources (sowing time, sowing density and sowing time × sowing density interaction) for WUI (Table 3). Although the mean values of the WUI were not significant, the WUP was observed at 1.02 on 6 June sowing time and 1.13 on 21 June sowing time, according to the mean of the sowing densities (Table 5). According to mean of sowing times, the WUI varied between 1.06 and 1.09. Cengiz (2007) found the WUI between 0.963-1.157 in his study, which is similar to our study. Sehirali et al. (1993) determined the values of the water uptake index to be between 0.257-1.278 with different bean genotypes under different ecological conditions.

Swelling Capacity (SC)

While there were significant differences at $p<0.01$ for sowing time; there were no statistically significant differences for sowing density and sowing time × sowing density interaction for SC (Table 3). SC values changed between 0.45 mL grain^{-1} (22 May and 6 June) and 0.47 mL grain^{-1} (21 June) depending on the sowing time. SC were found as the same value (0.46 mL grain^{-1}) except for 30×5 cm sowing density (0.45 mL grain^{-1}) (Table 5). Sozen et al. (2020) stated the SC as 0.297-0.420 mL grain^{-1}. Atli et al. (1994) reported that an increase was observed in WAC and SC values. Our study was conducted with one genotype and also understood from the statistical analysis that evaluated cultural techniques like sowing density did not affect the technological traits related to water uptake. Morover, it should be emphasized once again that water uptake in legumes begins in the parts called hilum and microphyll and that this varies according to the genotypes. In fact, this view was expressed many years ago by Korban et al. (1981). They reported that water uptake in dry beans was affected by hilum/raphe areas in 'Pinto JI111 *cv*', while in 'Great Northern *cv*' microphylls were prominent.

Swelling Index (SI)

While the swelling index was statistically significantly affected by the sowing time ($p<0.05$); other variation sources were not found statistically effective on SI (Table 3). While the highest SI (22.33%) was obtained from 21 June sowing time (Table 5).

Protein Ratio (PR)

Only the sowing density showed statistically significant differences ($p<0.01$) for PR while other variation sources were not so (Table 3). The mean of PR in general of trial was 21.38%; the highest PR was obtained from 30×15 cm (21.71%) and 45×5 cm (21.68%) sowing densities while the lowest PR was from 30×5 cm (21.03%) and 30×10 cm (21.19%) sowing densities (Table 5). Aydogan (2017) stated that the PR values among the cultivars were ranged between 20.48%-25.05%. Kahraman (2008) conducted with 41 different bean genotypes under Konya ecological conditions and found the PR between 20.11%-28.59%.

Cooking Time (CT)

While sowing density and sowing time × sowing density interaction showed statistically significant differences ($p<0.05$) for CT, there were no significant differences for sowing times (Table 3). It was observed that the CT varied between 33 min and 33.89 min depending on the sowing densities. Although the sowing time × sowing density interaction may be due to the fact that 21 June sowing time showed higher CT at 30×15 cm and 45×15 cm sowing densities compared to the other sowing times, this difference is negligible (Table 3 and 5). Cengiz (2007) determined the CT as 31.8-37.8 min, which is similar to our study. Turker (2019) found the CT as 45.00-52.00 min in his study.

Table 5. Mean values of technological traits in Gümüşhane Sugar Bean at different sowing times and sowing densities

Sowing density (SD)	WAC (g grain^{-1})				WUI (unit)				SC (mL grain^{-1})			
	Sowing time (ST)				Sowing time				Sowing time			
	22 May	6 June	21 June	Mean	22 May	6 June	21 June	Mean	22 May	6 June	21 June	Mean
30 × 5 cm	0.41	0.43	0.40	0.41	1.10	1.07	1.10	1.09	0.45	0.45	0.45	0.45
30×10 cm	0.40	0.45	0.40	0.42	1.07	1.07	1.15	1.09	0.44	0.46	0.47	0.46
30×15 cm	0.40	0.44	0.40	0.41	1.03	1.00	1.15	1.06	0.45	0.45	0.47	0.46
45 × 5 cm	0.40	0.44	0.39	0.41	1.07	1.00	1.13	1.07	0.45	0.44	0.47	0.46
45×10 cm	0.40	0.45	0.40	0.42	1.03	1.00	1.13	1.06	0.45	0.45	0.48	0.46
45×15 cm	0.40	0.45	0.40	0.42	1.03	1.00	1.13	1.06	0.45	0.45	0.48	0.46
Mean	0.40	0.44	0.40	0.42	1.06	1.02	1.13	1.07	0.45^{b*}	0.45^{b}	0.47^{a}	0.46
$LSD_{(ST)}$	ns				ns				0.003			
$LSD_{(SD)}$	ns				ns				ns			
$LSD_{(ST×SD)}$	ns				ns				ns			

Sowing density (SD)	SI (%)				PR (%)				CT (min)			
	Sowing time				Sowing time				Sowing time			
	22 May	6 June	21 June	Mean	22 May	6 June	21 June	Mean	22 May	6 June	21 June	Mean
30 × 5 cm	14.33	14.67	14.67	14.56	20.71	21.88	20.50	21.03^{b}	33.67^{bcd}	33.67^{bcd}	34.00^{a-d}	33.78^{a}
30×10 cm	14.17	15.00	24.67	17.94	20.84	21.43	21.29	21.19^{b}	33.00^{d}	33.33^{cd}	33.00^{d}	33.11^{b}
30×15 cm	10.00	10.00	20.00	13.33	21.49	22.20	21.44	21.71^{a}	33.00^{d}	33.00^{d}	34.67^{ab}	33.56^{ab}
45 × 5 cm	10.00	9.87	24.67	14.84	21.11	22.07	21.86	21.68^{a}	35.00^{a}	33.00^{d}	33.67^{bcd}	33.89^{a}
45×10 cm	8.75	10.00	25.00	14.58	21.33	21.40	21.28	21.34^{ab}	33.00^{d}	33.00^{d}	33.00^{d}	33.00^{b}
45×15 cm	8.75	8.75	25.00	14.17	21.13	21.29	21.59	21.34^{ab}	33.00^{d}	33.00^{d}	34.33^{abc}	33.44^{ab}
Mean	11.00^{b*}	11.38^{b}	22.33^{a}	14.90	21.10	21.71	21.33	21.38	33.44	33.17	33.78	33.46
$LSD_{(ST)}$	6.33				ns				ns			
$LSD_{(SD)}$	ns				0.40				0.63			
$LSD_{(ST×SD)}$	ns				ns				1.09			

***** Values within the same letter group are not different at the 0.05 significance level. ns: non-significant, LSD: least significant difference, WAC: water absorption capacity, WUI: water uptake index, SC: swelling capacity, SI: swelling index, PR: protein ratio, CT: cooking time.

CONCLUSION AND SUGGESTIONS

Based on sowing times, the highest values of grain yield is 7.43 t ha^{-1}; number of pods per plant, 9.72; number of grains per pod, 5.67; plant height, 51.39 cm) was obtained from the sowing time of May 22. When evaluated technological traits for sowing time and sowing density; the findings show that technological traits are not significantly affected by these variation sources. This situation is due to the fact that only a single genotype was used in the study; and when we exclude protein, other traits related to cooking are directly dependent on the genotype. Moreover, although protein also varies according to genotype, it was affected by the sowing density in this study; however, this effect is not at a level to recommend any sowing density. Therefore, when all these technological traits are to be ignored for a single cultivar, the issue of which sowing time and which sowing density gives the highest value for grain yield, which is the most important agricultural traits, comes to the fore. Therefore, the most suitable sowing time for Gümüşhane Sugar Bean is recommended as between 22 May and 6 June and the best sowing norm is 30×15 cm.

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