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Evaluation of Some Agro-morphological Characteristics of Dwarf Snap Bean Genotypes Collected from Erzurum Province

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ABSTRACT

The study was conducted in the trial area of the Department of Horticulture at Atatürk University during the 2022 cropping season to evaluate some agro-morphological characteristics of the dwarf-type snap bean genotypes collected from Erzurum along with the commercial cultivars SARIKIZ and GINA have been widely cultivated there. The genotypes tested in the study showed statistically significant variations in terms of all parameters examined. Genotypes ERZ PA 28 and ERZ UZ 36 reached the earliest fresh maturity time by 58 days. The genotype with the longest pod was ERZ NR 104 (17.35 cm); the genotypes with the widest pod were ERZ UZ 36 (15.29 mm) and ERZ TO 49 (15.43 mm); and the genotype with the thickest pod was ERZ İS13 (8.75 mm). The ERZ TO 49 genotype had the most pods per plant (32.41), the highest yield per plant (217.73 g), and the highest yield per square meter (1360.79 g/m^2), while the ERZ UZ 35 genotype produced the heaviest average pod weight (8.63 g). Additionally, in terms of the number of pods per plant, yield per plant, and yield per square meter, ERZ PA 28 has been determined to produce the results that are closest to ERZ TO 49. According to the study's findings, ERZ IS 13, ERZ PA 28, ERZ UZ 32, ERZ UZ 35, ERZ UZ 36, ERZ TO 48, ERZ TO 49, ERZ NR 104, ERZ PS 111, ERZ PS 115, and ERZ PS 116 genotypes yields per square meter was founded that higher than commercial cultivars and other genotypes, can offer the producer a sufficient level of yield.

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Introduction

Although the common bean originated in America, it spread throughout the world following the continent's discovery. The common bean (*Phaseolus vulgaris* L.; 2n = 2x = 22) is a species belonging to the Fabaceae family, the Phaseoleae tribe, and the Papilionoideae subfamily (Gepts, 1998). All commercially cultivated beans in Turkey belong to the *P. vulgaris* species (Balkaya and Yanmaz, 2003). This species known as baked, cannellini, common, dwarf, flageolet, frijoles, French, kidney, navy, pinto, snap, string, wax, haricot, or Nunas bean, is one the most commonly produced Fabaceae species (Broughton et al., 2003; Koutsika-Sotiriou and Traka-Mavrona, 2008). The cultivars in this group can be grown with high yields over a wide range due to their remarkable adaptability. This has made them globally recognized and a popular food worldwide for its edible unripe fruits and dried seeds (Chaurasia, 2020). Dry beans and green beans (snap beans) the two major commercial classes of *P. vulgaris* (Singh, 1999; Broughton et al., 2003). Snap beans, green beans, or string beans-whichever term you like, are all the same and are eaten as fragile, immature pods (Chaurasia, 2020). The snap bean, which is a popular food all around the world, is the oldest cultivated vegetable. Only a small portion of the 40,000 bean varieties stored in the world's gene banks are mass cultivated for human consumption (McGinnis and Suszkiw, 2006).

Snap beans are a group of common beans selected for their succulent pods and low fiber content (< 20 %) (Vaz et al., 2017). Vitamins A, C, and K, folate, thiamine, minerals, antioxidants, and a variety of bioactive substances including carotenoids, phenols, and flavonoids are all abundant in snap beans (Sgarbieri and Whitaker, 1982). Snap beans are nutrient-dense vegetables with great flavor and health benefits. They include a lot of fiber, vitamins, minerals, and protein. In addition to being devoid of cholesterol, they have a remarkable amount of sodium and fat (Broughton et al., 2003; Chaurasia, 2020). In daily nutrition programs based on the good eating habits that are supported by governments all over the world, beans are a highly essential resource with great health advantages (Asciogul et al., 2020). Turkey has witnessed an increase in snap bean consumption in recent years. The increased use of snap beans in the canned and frozen food sectors are two factors contributing to this, along with changes in society's eating habits. Production of snap beans worldwide is 23,411,172 tons. Turkey, on the other hand, stands fourth with 510,366 tons of snap bean production, after China (18,090,542 tons), Indonesia (904,043 tons), and India (661,923 tons) (FAOSTAT, 2021). Snap bean production is widely carried out in the microclimate areas of Erzurum, which are located in the Northeast Anatolian agricultural region. According to the latest statistical data, the Northeast Anatolia region produced 8,900 tons of snap beans in 2017, 3617 tons of which were produced in Erzurum (TUIK, 2021).

Common beans have developed a significant degree of variation as a result of selection for specific agro-ecological conditions and applications, such as local agronomic practices and food culture (Miles, 2002). Snap bean varieties differ significantly phenotypically as a result of strong selection pressure on snap bean pod traits (Vaz et al., 2017). Snap bean varieties have been classified into two groups based on their growth habits: (i) pole type varieties, which have tall plants with longer internodes and require support, and (ii) bush (dwarf) type varieties, which have dwarf plants with short internodes and do not require support. Pole cultivars are frequently preferred for cultivation in areas with plentiful rainfall (Rana and Kamboj, 2017). Pole snap beans prevail in tropical regions while determinate erect dwarf beans are more common in temperate regions (Blair et al., 2010). However, cultivars with determined or dwarf growth not only eliminate support, but also grow early, allowing for a concentrated harvest in a short amount of time. Breeding programs must be efficient in order to increase the availability and release of new dwarf snap bean cultivars that meet grower and consumer demands. This includes the introduction and evaluation of new germplasms, crosses among the best available parents, accurate selection of plants and progenies, and, finally, the release of superior lines as cultivars (Krause et al., 2009). The first step in a snap bean breeding program is correctly characterizing present genotypes. Additionally, snap bean is primarily farmed by small farmers that rely on family labor, and contribute to increased income, diversification, and the maintenance of their rural lifestyle (Gül and Parlak, 2017). Traditional crop varieties often referred to as farmers' varieties or landraces are an important component of agrobiodiversity (Villa et al., 2005). Farmers' varieties have generally a lower yield than breeding varieties, but as they are required for the production of cultural foods and are more credible under a wider range of conditions, their local demand is generally high (Abera et al., 2020). Farmers' varieties, despite their various advantages, are in danger of going extinct owing to extensive changes in agricultural systems. Snap bean breeding has not received enough attention in Turkey as the producers there usually use their seeds or the seeds of their neighbors, in cultivating this species. Therefore, Turkish farmers who operate on a local scale still consider snap bean landraces to be valuable genetic resources (Balkaya and Ergün, 2008).

Pod and yield features have a significant role in snap bean farming, and there may be significant variances across genotypes (Balkaya and Odabas, 2002). Yield is a complicated quantitative feature that is influenced by a number of yield-related factors (Alemu et al 2017). The most characterized snap bean yield-related variables are pod yield per plant, pod number per plant, pod weight, pod length, and pod diameter (Stoilova et al., 2005; Luitel et al., 2021).

One of the most essential tasks in fulfilling the increasing demand of stakeholders is the introduction of better snap bean varieties (Luitel et al., 2021). Genotype is the most significant constituent in any crop production program and the basis on which all other technologies for plants are used (Goutam et al., 2001). Genotypes also fluctuate substantially in their performance under various agro-climatic conditions (Luitel et al., 2021).

The purpose of this study was to evaluate the performance of dwarf snap bean genotypes collected from farmers in Erzurum province, as well as two dwarf snap bean cultivars that have recently grown in popularity, under Erzurum conditions in regards to some agro-morphological characteristics. Defining the differences in genotypes taking place in the present study is believed that this will allow materials to be obtained for use in genotype selection for future breeding research as well as genotype conservation.

Material and Method

Plant materials

The dwarf snap bean genotypes used in the study were collected from Erzurum, a province in northeastern Turkey, where traditional agriculture is still commonly practiced. The genetic material includes local snap bean genotypes known to have dwarf growth habits, as well as commercial dwarf snap bean varieties (SARIKIZ and GINA), widely cultivated in Erzurum. In Table 1, local dwarf bean genotypes' accession number, collection location, and GPS information were presented.

Research Area

The research area was located at 41° 16' east longitude and 39° 55' north latitude in the Erzurum. Erzurum is a province in the Northern Eastern Anatolia Region of Turkey. The province is situated at an elevation of 1850 to 1950 meters above sea level and has a temperate climate.

The research was carried out between June and September 2022 at Atatürk University, in the trial area of the Horticulture Department. Several physical and chemical properties of the soil before the experiment were given in Table 2.

Figure 1 represents the climate data during the months the study was conducted. The highest maximum temperature recorded throughout the research period was 34.3°C and 34.4°C in July and August respectively, whilst the highest average temperature was 23.1°C in August. In September, the temperature dropped to 1.2°C. The total rainfall in the region was highest (i.e., 59.5 mm) in June, while it was lowest (i.e., 3.1 mm) in July. The relative humidity to the mean ranged from 37.4% (August) to 60.6% (June).

Table 1. Local dwarf bean genotypes' accession number, collection location and GPS data.

Accession no.	County	Village	Altitude	Coordinates	
				North	East
ERZ İS 13	İspir	Yedigözeler	1164	40º 32’.87”	41º 2’.758”
ERZ İS 15	İspir	Numanpaşa	1689	40º 33’.57”	41º 8’.671”
ERZ PA 28	Pazaryolu	Merkez	1475	40º 25’.057”	40º 46’.294”
ERZ UZ 32	Uzundere	Kirazlı	1246	40º 39’.813”	41º 36’.825”
ERZ UZ 35	Uzundere	Gölbaşı	1153	40º 36’.370”	41º 33’.488”
ERZ UZ 36	Uzundere	Gölbaşı	1153	40º 36’.370”	41º 33’.488”
ERZ TO 48	Tortum	Konak	1524	40º 19’.114”	41º 30’.235”
ERZ TO 49	Tortum	Konak	1524	40º 19’.114”	41º 30’.235”
ERZ NR 104	Narman	Şehitler	1977	40º 19’.473”	41º 44’.288”
ERZ PS 111	Pasinler	Ardıçlı	1718	40º 1’.136”	41º 45’.511”
ERZ PS 112	Pasinler	Ardıçlı	1718	40º 1’.136”	41º 45’.511”
ERZ PS 114	Pasinler	Ardıçlı	1718	40º 1’.136”	41º 45’.511”
ERZ PS 115	Pasinler	Ardıçlı	1718	40º 1’.136”	41º 45’.511”
ERZ PS 116	Pasinler	Ardıçlı	1718	40º 1’.136”	41º 45’.511”

Table 2. Several physical and chemical characteristics of the soil before the experiment (mean ± standard deviation, n = 10)

Soil Properties	Units	Means
Sand	%	64.69±3.75
Silt	%	22.38±2.04
Clay	%	12.93±1.19
Organic matter	%	1.54±0.11
Lime	%	3.47±0.37
pH	1:2.5 (soil/water)	6.9±0.50
EC	mS cm^{-1}	0.58±0.01
CEC	meq 100 g^{-1}	19.82±2.21
Total N	mg kg^{-1}	9.35±0,71
P	mg kg^{-1}	5.71±0.15
K	meq 100 g^{-1}	2.04±0.12

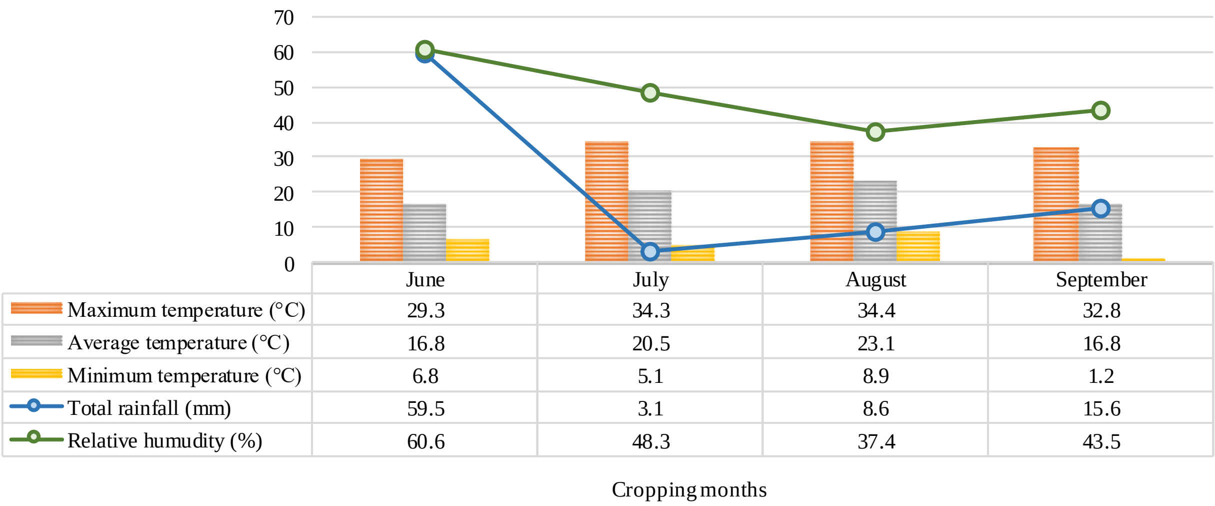

Figure 1. Climatic data of Erzurum province in 2022

The experiment's setup and conduct

On June 2, 2022, seeds were sown at intervals of 20 x 80 cm, in two rows of 6 meters for each genotype (with 30 plants in each row). The experiment was conducted in a randomized complete block design (RCBD) as three replications. The first row was used to measure pod and yield parameters, while the second row was used to measure seed parameters. The drip irrigation system was used to irrigate the plants, and weed control was carried out in keeping with cultural practices.

In the study, the agronomic performance of the dwarf snap bean genotypes was evaluated using 17 agro-morphological parameters regarding yield variables, pod morphology and quality, and seed characteristics. Harvesting of pods was done at the proper edible maturity stage and do not allow the pods to over-mature which lower quality of snap beans. Pod length, pod width, average pod weight and thickness, and pod color (L*, a*, and b*) for all genotypes were measured in green pods that had attained eating maturity in the middle of the harvest season. During the harvest season, green pods attained eating maturity from each genotype were picked, weighed and the following yield components (the number of pods per plant, yield per plant, yield) were estimated. Plants left for seed were harvested when the pods began to dry for each genotype, and the seed measurements (Seed length, width, thickness and weight of 100 seeds) were performed by extracting seeds from the pods.

Agro-morphological characters

First flowering time (day), day from sowing seeds to the formation of the first flower (Ulukapı and Onus, 2014; Madakbaş and Ergin, 201); fresh maturity time (day), day from the sowing seeds until the fruit reaches 2/3 of its typical size (Balkaya, 1999; Kar et al., 2005); pod length (cm), width (mm) and thickness (mm), average length of 10 pods, using a graduated ruler, average width and thickness of 10 pods, using a digital caliper (Kar et al., 2005; Madakbaş and Ergin, 2011); pod weight (g), average weight of 10 randomly selected pods, using a digital scale (Luitel et al., 2021); number of pods per plant (g), average number of all pods per plant (Vaz et al., 2017); yield per plant (g), average weight of all pods per plant (Vaz et al., 2017); yield (g/m^2), ratio between the average weight of all pods and the plot area (Vaz et al., 2017); pod color (L*, a*, and b*), average of taken measurements using a Minolta CR-200 (MINOLTA Camera Co, LTD Ramsey, NJ) chromometer from the pod's surface (Asciogul, 2016); number of seeds per pod, average number of seeds formed in 10 pods (Vaz et al., 2017); seed length, width, and thickness (mm), average length, width, and thickness of 20 randomly selected mature seeds, using a digital caliper (Balkaya and Odabas, 2002); 100 seed weight (g), average weight of 100 seeds harvested mature (Balkaya and Odabas, 2002; Vaz et al., 2017).

Statistical Analysis

Data preparation was done with Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). The presented results are the mean values ± standard errors of three replicates. Multiple comparisons of means were performed using ANOVA (SPSS Inc. v. 25), and means were separated using Tukey's multiple range test, with significant differences defined as $P<0.05$.

Results and Discussion

Although the Erzurum region is suitable for bean cultivation, it also has numerous agricultural concerns. Particularly, the plants with immature seeds freeze due to the early frost date of autumn and the short vegetative period. For this reason, it is very important to prefer snap bean genotypes with earliness characteristics in the region. The first flowering time and fresh maturity time of the dwarf snap bean genotypes in this study showed significant differences (Table 3). The first flowering of dwarf snap beans is defined as "early" if it occurs between 36 and 45 days, "moderate" if it occurs between 46 and 51 days, and "late" if it occurs more than 52 days later (Balkaya and Yanmaz, 2003). According to this classification, all of the genotypes we grew were medium and late. The genotypes with the shortest flowering duration in the research were ERZ PA 28, ERZ UZ 32, ERZ UZ 36, ERZ TO 48, ERZ PS 112, and SARIKIZ, which flowered in 48 days. In a study conducted in Antalya ecological conditions, the flowering period of 36 snap bean genotypes (33 local, 3 commercial varieties) collected from Turkey varied between 35 and 50 days (Ulukapı and Onus, 2014). Dwarf snap beans are further divided into three categories: "early" for fresh maturity time between 40 and 50 days, "medium" for harvest dates between 51 and 70 days, and "late" for harvest dates above 72 days (Balkaya and Yanmaz, 2003). According to this classification, it is seen that all of the existing dwarf snap bean genotypes grown are in the middle and late groups. ERZ PA 28 (58 days) and ERZ UZ 36 (58 days) genotypes reached the fresh maturity time earlier than commercial cultivars (SARIKIZ and GINA). Besides, it was determined that the ERZ UZ 32 and ERZ TO 48 genotypes reached the fresh maturity time at the same time as the SARIKIZ commercial variety. Erdinç et al. (2013) reported the earliest flowering period of different bean genotypes as 42 days, the latest flowering period as 77 days, the first pod harvest time as 68 days, and the latest pod harvest time as 127 days. According to Balkaya (1999), the first harvest date for the snap bean genotypes she looked at ranged between 59-124 days for pole types and 53-63 days for dwarf varieties. In another research utilizing 378 landraces of snap beans, the earliest harvest dates of the genotypes were recorded as 61-83 days for dwarf types and 76-105 days for pole types. Whereas, for the 88 snap bean genotypes chosen for the same study, the first harvest time ranged from 62 to 96 days for pole types and from 62 to 80 days for dwarf types (Çirka and Çiftçi, 2016). Also, Neupane et al. (2008) reported that genotype affects flowering days in beans. According to their findings, flowering time ranged from 40 to 84 days depending on the bean genotype.

Long and wide pods in snap beans are a desirable feature. There is a linear relationship between the long and wide pods and the yield (Bekar et al., 2019). The genotypes' pod lengths ranged from 12.69 cm to 17.35 cm, their pod widths from 8.66 mm to 15.43 mm, and their pod thicknesses from 6.74 mm to 8.75 mm. ERZ NR 104 had the longest pod length (17.35 cm), while ERZ TO 49, ERZ UZ 32, and ERZ UZ 36 had the widest pods (15.43 mm, 15.60 mm, and 15.29 mm, respectively). Additionally, the ERZ S 13 genotype had the thickest pod, measuring 8.75 mm, while the genotypes GINA, ERZ PS 111, and ERZ UZ 35 had the closest pod thicknesses, measuring 8.60 mm, 8.56 mm, and 8.45 mm, respectively (Table 3, Figure 2). Stoilova et al. (2005) found that in a study with 30 bean genotypes, the length of the pod was between 8.90 and 12.90 cm while the width of the pod ranged between 8.70-13.0 mm. Erdinç et al. (2013) reported in their study with 105 bean genotypes that pod lengths varied between 7.58 cm and 21.90 cm, however, 90% of the genotypes had pod lengths less than 16.50 cm. According to the same researchers, the pod widths of the bean genotypes they tested ranged from 7.55 mm to 19.41 mm, although half of the genotypes had a pod width of 10.51-12.99 mm. Ulukap and Onus (2014) showed that the pod length, breadth, and thickness of 33 snap bean genotypes ranged from 3 to 20.20 cm, 8.89 to 18.16 mm, and 3.75 to 10.74 mm, respectively. Bekar et al. (2019) determined that the pod thickness of beans varied from 5.57 mm to 11.60 mm. Another researcher reported that the bean meat thickness ranged between 3.78 mm and 9.69 mm, with the genotypes' average bean meat thickness being 6.08 mm (Erdinç 2012). However, according to Galvan et al. (2006), wild bean genotypes' pod thickness varied between 4.10mm to 6.40 mm.

Table 3. Results for first flowering time, fresh maturity time, pod length, width, and thickness for the studied genotypes of dwarf snap beans.

Genotype	First flowering time (day)	Fresh maturity time (day)	Pod length (cm)	Pod width (mm)	Pod thickness (mm)
ERZ İS 13	50 ± 0.00 cd***	65 ± 0.00 c***	12.83 ± 0.31 c***	14.76 ± 0.60 a-c***	8.75 ± 0.73 a***
ERZ İS 15	56 ± 0.00 b	75 ± 0.00 b	15.17 ± 0.5 b	14.06 ± 0.69 a-c	6.74 ± 0.22 e
ERZ PA 28	48 ± 0.00 d	58 ± 0.00 e	13.65 ± 0.52 c	15.13 ± 0.17 ab	7.05 ± 0.24 c-e
ERZ UZ 32	48 ± 0.00 d	61 ± 0.00 de	13.77 ± 0.25 c	15.60 ± 0.63 a	7.42 ± 0.09 c-e
ERZ UZ 35	50 ± 0.00 cd	65 ± 0.00 c	13.34 ± 0.17 c	14.84 ± 0.25 ab	8.45 ± 0.00 ab
ERZ UZ 36	48 ± 0.00 d	58 ± 0.00 e	12.88 ± 0.05 c	15.29 ± 0.26 a	7.96 ± 0.59 a-c
ERZ TO 48	48 ± 0.00 d	61 ± 0.00 de	12.69 ± 0.16 c	15.05 ± 0.44 ab	7.95 ± 0.04 a-c
ERZ TO 49	50 ± 0.00 cd	65 ± 0.00 c	13.44 ± 0.49 c	15.43 ± 0.07 a	6.91 ± 0.02 de
ERZ NR 104	50 ± 0.00 cd	67 ± 0.00 c	17.35 ± 0.01 a	10.71 ± 0.08 e	7.43 ± 0.09 c-e
ERZ PS 111	60 ± 0.00 a	80 ± 0.00 a	13.47 ± 0.85 c	8.66 ± 0.31 f	8.56 ± 0.28 ab
ERZ PS 112	48 ± 0.00 d	64 ± 0.00 cd	13.79 ± 0.56 c	14.77 ± 0.05 a-c	6.82 ± 0.20 e
ERZ PS 114	52 ± 0.00 c	66 ± 0.00 c	13.44 ± 0.29 c	13.46 ± 0.78 bc	7.68 ± 0.20 b-e
ERZ PS 115	58 ± 0.00 ab	74 ± 0.00 b	13.97 ± 0.52 bc	13.01 ± 1.77 cd	7.87 ± 0.69 a-d
ERZ PS 116	56 ± 0.00 b	66 ± 0.00 c	14.02 ± 0.3 bc	11.42 ± 0.58 de	7.65 ± 0.02 b-e
SARIKIZ	48 ± 0.00 d	61 ± 0.00 de	13.31 ± 0.41 c	14.42 ± 0.04 a-c	7.33 ± 0.28 c-e
GİNA	50 ± 0.00 cd	65 ± 0.00 c	13.25 ± 0.72 c	15.17 ± 0.08 ab	8.60 ± 0.25 ab
Mean	51.25	65.69	13.77	13.86	7.70

The means in a column with the same letters are not statistically ($P<0.05$) different from one another. ***: Analysis of variance significant at $P<0.001$.

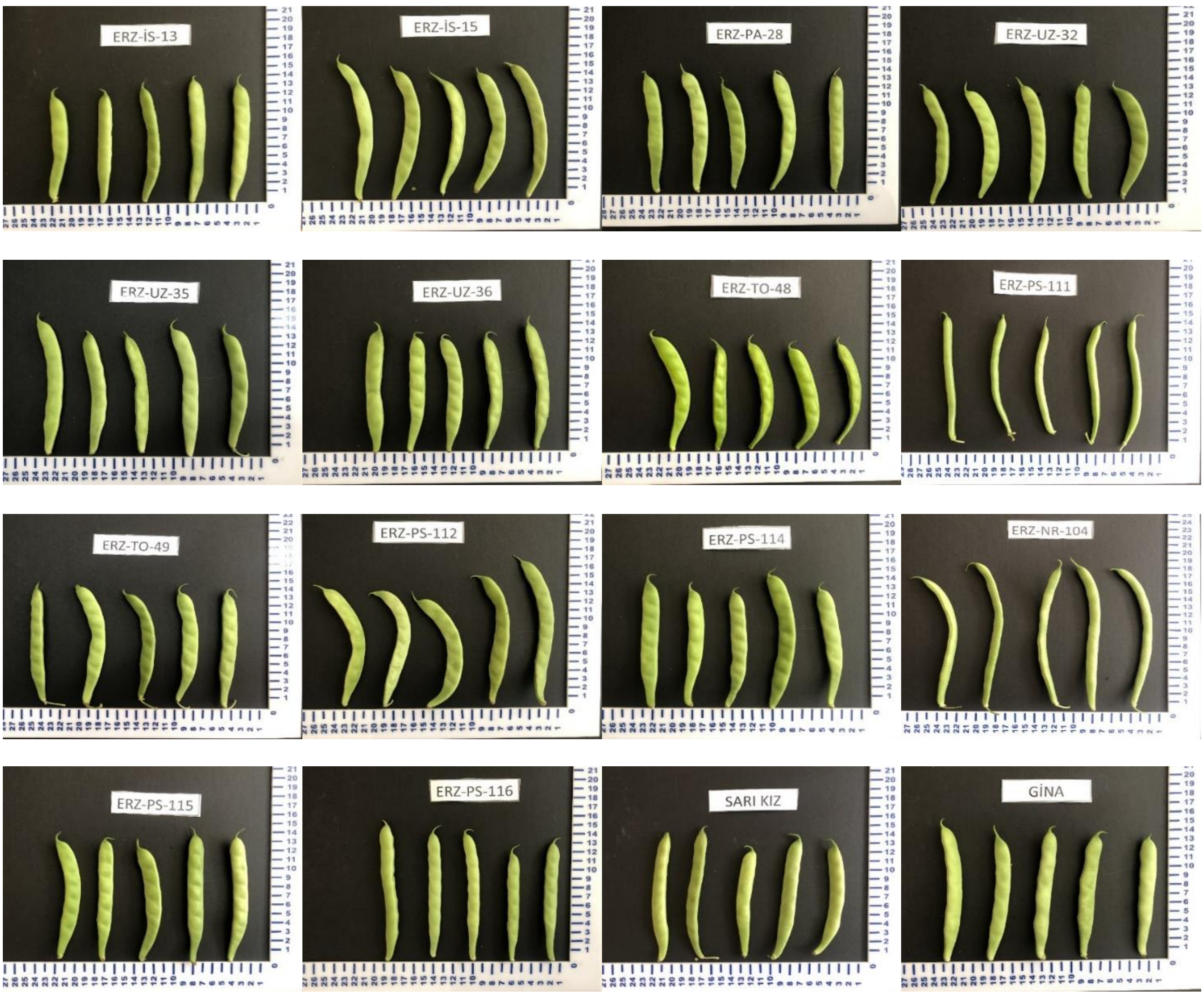

Figure 2. Pod pictures of tested genotypes.

The bean's low production can be attributed to a variety of biotic and abiotic factors (Nkhata et al., 2020). In light of this, it is important to include genotypes that are well adapted to the area in which they will be grown into the production system. In the current study, a genotype's average pod weight, number of pods per plant, yield per plant, and yield all showed substantial variations. Average pod weights for the genotypes were observed to range from 5.51 g (ERZ PS 111) to 8.63 g (ERZ UZ 35). SARIKIZ commercial cultivar had a lower average pod weight than the genotype average (7.02 g), whereas GINA, ERZ S 13, ERZ S 15, ERZ UZ 35, ERZ TO 49, and ERZ NR 104 genotypes had higher (Table 4). The average pod weights in another research using 121 common bean collections from Spain and Portugal were reported to range from 3.72 to 13.34 g (De Ron et al., 2004).

The number of pods per plant in the tested genotypes varied from 9.15 (ERZ PS 116) to 32.41 (ERZ TO 49). The genotypes ERZ TO 49 and ERZ PA 28 had the most pods per plant, while ERZ UZ 32, ERZ UZ 36, ERZ PS 111, and ERZ PS 115 had pod counts that were greater than the average (21.17) of all genotypes. However, it was found that commercial cultivars (SARIKIZ and GINA) produce fewer pods per plant than the average number of pods per plant. Many researchers have found significant variations between genotypes in terms of the number of green pods per plant (Seymen et al., 2010; Sharma et al., 2013; Muthuramu et al., 2015; Yohannes et al., 2020). The number of green pods per plant may differ according on the dropping tendency of flowers, inflorescences, and the number of pods per raceme of the genotypes (Khan, 2003).

The yield per plant and yield per square meter calculations of the genotypes varied between 49.99 g (ERZ PS 116) - 217.73 g (ERZ TO 49) and 312.48 g/m^2 (ERZ PS 116) - 1360.79 g/m^2 (ERZ TO 49) respectively. The genotypes' mean yield per plant and yield per square meter was calculated to be 142.73 g and 892.07 g/m^2, respectively. It was also revealed that ERZ PA 28, ERZ UZ 32, ERZ UZ 35, ERZ UZ 36, ERZ TO 49, and ERZ PS 115 genotypes were more productive in terms of yield per plant and yield per square meter than SARIKIZ and GINA commercial genotypes. In a study conducted in Konya (Turkey), the yield per decare of 8 dwarf snap bean varieties varied between 605.9 and 1551.2 kg/da, and the yield per plant varied between 121.2 and 310.2 g/plant (Seymen et al., 2010). Madakbaş et al. (2004) reported yields ranging from 1112 to 2278 kg/da from dwarf snap bean varieties cultivated on the Çarşamba plain (in Turkey). In another study, 7 local (Samsun province, Turkey) genotypes of Aysekadin type dwarf snap beans, and 4 commercial control cultivars, yield characteristics were investigated. Local genotypes generally yielded larger yields than commercial cultivars in this study, with genotype yields ranging from 544.3 to 1856.2 kg/da (Madakbaş et al., 2010). Kar et al. (2005) reported a maximum of 2104 kg/da yield from dwarf snap bean cultivars cultivated in the early season in Samsun (in Turkey). In the fall and spring seasons, Çelikel and Tunar (1996) obteined yields ranging from 812 to 2279 kg/da in dwarf snap bean varieties. It is thought that the low of yield per plant and yield per square meter obtained in our study is due to the ecological conditions of the region.

Among the snap bean genotypes studied, significant differences were observed for the L*, a*, and b* characteristics of the pod (Table 5). According to the CIE scale: "L" parameter represents brightness ranging from 0 (black) to 100 (white), a* denotes red for positive values, green for negative values, b* means yellow for positive values, blue for negative values (García-Fernández et al., 2021). The one of most essential quality indications of snap beans is the color brightness of the pods (Kasim and Kasim, 2015). The L* value of the genotypes in the present study ranged from 52.32 (ERZ PS 111) to 69.19 (ERZ TO 49). Consumers prefer green and dark green color tones more in snap bean pods (Bekar et al., 2019). The negative value of the genotypes, expressed as greenery, ranged from -16.39 to -21.97.

Table 4. Results for the studied genotypes of dwarf snap beans in terms of average pod weight, number of pods per plant, yield per plant, and yield.

Genotype	Pod weight (g)	Number of pods per plant	Yield per plant (g)	Yield (g/m^2)
ERZ İS 13	8.31 ± 1.84 ab***	19 ± 1.39 e-h***	146.80 ± 10.69 de***	917.50 ± 66.81 de***
ERZ İS 15	7.63 ± 1.1 a-c	11.95 ± 0.87 j	84.91 ± 6.19 f	530.71 ± 38.66 f
ERZ PA 28	6.87 ± 0.49 a-c	32.31 ± 2.36 a	206.05 ± 15.01 ab	1287.83 ± 93.78 ab
ERZ UZ 32	6.73 ± 0.72 a-c	27.78 ± 2.02 ab	180.64 ± 13.16 bc	1128.98 ± 82.22 bc
ERZ UZ 35	8.63 ± 0.94 a	19.10 ± 1.39 e-h	158.85 ± 11.57 cd	992.79 ± 72.3 cd
ERZ UZ 36	6.95 ± 0.78 a-c	22.44 ± 1.64 c-e	151.14 ± 11.01 cd	944.63 ± 68.79 cd
ERZ TO 48	6.92 ± 1.11 a-c	21.94 ± 1.6 d-f	142.70 ± 10.39 de	891.90 ± 64.95 de
ERZ TO 49	7.14 ± 0.81 a-c	32.41 ± 2.36 a	217.73 ± 15.85 a	1360.79 ± 99.09 a
ERZ NR 104	8.34 ± 0.67 ab	16.37 ± 1.19 g-i	137.81 ± 10.03 de	861.29 ± 62.71 de
ERZ PS 111	5.51 ± 0.22 c	25.24 ± 1.84 b-d	140.69 ± 10.25 de	879.29 ± 64.03 de
ERZ PS 112	6.77 ± 0.66 a-c	15.05 ± 1.09 ij	100.07 ± 7.29 f	625.46 ± 45.55 f
ERZ PS 114	6.85 ± 0.98 a-c	17.56 ± 1.28 f-h	114.16 ± 8.31 ef	713.48 ± 51.96 ef
ERZ PS 115	6.32 ± 0.74 a-c	26.88 ± 1.96 b	160.52 ± 11.69 cd	1003.27 ± 73.05 cd
ERZ PS 116	5.80 ± 0.54 bc	9.15 ± 0.67 k	49.99 ± 3.64 g	312.48 ± 22.75 g
SARIKIZ	6.30 ± 0.71 a-c	20.56 ± 1.5 d-g	142.09 ± 10.35 de	888.06 ± 64.66 de
GİNA	7.20 ± 0.62 a-c	20.98 ± 1.53 d-g	149.55 ± 10.89 cd	934.67 ± 68.06 cd
Mean	7.02	21.17	142.73	892.07

The means in a column with the same letters are not statistically ($P<0.05$) different from one another. ***: Analysis of variance significant at $P<0.001$.

Table 5. Results for pod L* value, pod a* value, pod b* value, and the number of seeds per pod for the tested dwarf snap bean genotypes.

Genotype	Pod L^* value	Pod a^* value	Pod b^* value	Number of seeds per pod
ERZ İS 13	63.33 ± 1.35 b-e***	-19.82 ± 1.54 a-c***	36.9 ± 0.95 b-d***	4.85 ± 0.16 de***
ERZ İS 15	66.51 ± 0.92 ab	-18.58 ± 0.46 cd	35.57 ± 1.34 de	5.00 ± 0.2 d
ERZ PA 28	59.99 ± 2.55 d-g	-19.2 ± 1.08 a-d	36.82 ± 1.73 b-d	4.87 ± 0.2 de
ERZ UZ 32	64.29 ± 3.13 b-d	-21.97 ± 0.35 a	40.37 ± 1.44 a-c	5.25 ± 0.16 c
ERZ UZ 35	63.70 ± 1.36 b-e	-19.75 ± 0.44 a-c	35.85 ± 1.15 d	5.20 ± 0.16 c
ERZ UZ 36	65.16 ± 1.43 a-c	-21.43 ± 1.15 ab	40.81 ± 0.62 ab	4.81 ± 0.19 de
ERZ TO 48	66.27 ± 0.57 ab	-19.76 ± 0.98 a-c	38.19 ± 0.86 b-d	4.31 ± 0.17 f
ERZ TO 49	69.19 ± 1 a	-19.23 ± 0.33 a-d	35.63 ± 0.63 de	5.20 ± 0.16 c
ERZ NR 104	58.22 ± 1.13 f-h	-19 ± 0.19 b-d	34.26 ± 1.23 d-f	5.75 ± 0.21 b
ERZ PS 111	52.32 ± 1.7 i	-16.39 ± 1.14 d	30.92 ± 1.28 f	4.98 ± 0.2 d
ERZ PS 112	59.08 ± 1.2 e-g	-18.81 ± 0.33 b-d	37.3 ± 1.94 b-d	6.11 ± 0.25 ab
ERZ PS 114	61.20 ± 1.19 c-g	-20 ± 0.51 a-c	35.66 ± 1.37 de	5.66 ± 0.23 bc
ERZ PS 115	56.68 ± 1.13 g-i	-19.59 ± 1.94 a-c	36.06 ± 1.12 d	4.98 ± 0.2 d
ERZ PS 116	53.44 ± 1.83 hi	-17.55 ± 0.75 cd	31.69 ± 0.91 ef	6.33 ± 0.25 a
SARIKIZ	62.68 ± 1.91 b-f	-20.27 ± 1.21 a-c	43.10 ± 2.44 a	5.40 ± 0.19 bc
GİNA	65.25 ± 1.17 a-c	-19.03 ± 0.3 b-d	36.45 ± 1.36 cd	4.85 ± 0.08 de
Mean	61.71	-19.40	36.60	5.21

The means in a column with the same letters are not statistically ($P<0.05$) different from one another. ***: Analysis of variance significant at $P<0.001$.

Table 6. Results for the tested dwarf snap bean genotypesin terms ofseed length, width, thickness, and weight per 100 seeds.

Genotype	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	100 seed weight (g)
ERZ İS 13	12.94 ± 0.23 g***	6.11 ± 0.11 e-g***	7.82 ± 0.14 g-i***	43.08 ± 0.76 gh***
ERZ İS 15	15.19 ± 0.27 c	6.38 ± 0.11 c-e	9.96 ± 0.28 a	60.18 ± 1.06 a
ERZ PA 28	14.13 ± 0.25 d-f	6.26 ± 0.11 d-f	8.51 ± 0.15 c-e	45.25 ± 0.80 fg
ERZ UZ 32	15.09 ± 0.27 c	6.63 ± 0.12 bc	9.03 ± 0.16 b	56.06 ± 0.99 b
ERZ UZ 35	13.48 ± 0.24 fg	6.55 ± 0.12 b-d	7.63 ± 0.14 hi	47.18 ± 0.84 ef
ERZ UZ 36	15.11 ± 0.27 c	6.88 ± 0.12 ab	8.81 ± 0.16 b-d	49.51 ± 0.88 de
ERZ TO 48	13.75 ± 0.25 ef	6.29 ± 0.11 c-f	8.52 ± 0.15 c-e	52.06 ± 0.92 cd
ERZ TO 49	13.8 ± 0.25 d-f	6.59 ± 0.12 b-d	8.97 ± 0.16 bc	53.26 ± 0.94 c
ERZ NR 104	16.32 ± 0.29 b	5.04 ± 0.09 h	7.97 ± 0.14 f-h	40.84 ± 0.72 h
ERZ PS 111	14.25 ± 0.25 de	5.93 ± 0.11 fg	7.42 ± 0.14 i	34.97 ± 0.62 i
ERZ PS 112	14.55 ± 0.26 cd	6.53 ± 0.12 b-d	9.25 ± 0.16 b	62.56 ± 1.10 a
ERZ PS 114	13.68 ± 0.24 e-g	6.34 ± 0.14 c-e	8.15 ± 0.14 e-g	48.93 ± 0.86 e
ERZ PS 115	17.39 ± 0.31 a	5.75 ± 0.10 g	8.45 ± 0.15 d-f	47.64 ± 0.84 ef
ERZ PS 116	13.4 ± 0.24 fg	5.81 ± 0.11 g	7.85 ± 0.14 g-i	40.75 ± 0.72 h
SARI KIZ	13.93 ± 0.10 d-f	6.31 ± 0.12 c-e	8.38 ± 0.13 d-f	41.26 ± 0.91 h
GİNA	13.41 ± 0.25 fg	7.20 ± 0.09 a	8.39 ± 0.12 d-f	48.85 ± 0.71 e
Mean	14.40	6.29	8.44	48.28

The means in a column with the same letters are not statistically ($P<0.05$) different from one another. ***: Analysis of variance significant at $P<0.001$.

The greenest genotype was ERZ UZ 32 (-21.97) with the highest negative a^* value, while the ERZ UZ 36 (-21.43) genotype gave the closest negative a^* value. On the other hand, the b^* value expressed as chlorosis was found in genotypes in the range of 30.92 to 43.10. The yellowest pod was found in the commercial cultivar SARIKIZ (43.10). Among all genotypes, ERZ PS 111 was less bright, green, and yellow than other genotypes. Martnez et al. (1995) investigated the pod color of round and flat pod bean genotypes and found that flat pod samples were lighter, greener, and yellower than round pod samples. The difference between genotypes in terms of the number of seeds per pod was found to be statistically significant. The number of seeds per pod of the genotypes ranged from 4.31 (ERZ TO 48) to 6.33 (ERZ PS 116). According to Seymen et al. (2010), commercial snap bean cultivars grown in Konya (Turkey) have 6.7-7.5 seeds per pod.

The genotypes investigated in the study showed significant variations in terms of seed length, width, thickness, and weight per 100 seeds (Table 6). Seeds of genotypes ranged from 12.94 mm (ERZ İS 13) to 17.39 mm (ERZ PS 115) in length, from 5.04 mm (ERZ NR 104) to 7.20 mm (GİNA) in width, from 7.42 mm (ERZ PS 111) to 9.96 mm (ERZ İS 15) in thickness, and from 34.97 g (ERZ PS 111) to 60.18 g (ERZ İS 15) in weight. According to Balkaya and Odabas (2002), the seed length of 13 snap bean cultivars grown in Samsun (Turkey) varied between 12.00 and 17.24 mm, the seed width between 7.04 to 9.17 mm, the seed thickness between 4.6 to 7.23 mm, and the weight of 100 seeds varied between 33.69 and 67.21 g. It was notable that the conclusions derived by the researchers and those obtained currently are all in agreement. Nadeem et al. (2020) reported that the seed length of 183 common bean accessions was in the range of 7.41-16.4 mm.

The same researchers reported that the weight of 100 genotypes of seeds ranged from 27.94 g to 73.80 g. Meza et al. (2013), Lázaro et al. (2013), and Gomez et al. (2004) all found that the range of 100 seed weight for beans was between 8.0 and 48.9 g, 22.0 and 78.1 g, and 22.0 and 78.1 g, respectively.

Conclusion

Analysis of variance results showed that there were significant differences among genotypes in terms of the traits examined. The agro-morphological variation identified in the genotypes indicates that there is enough variety for selecting suitable genotypes for diverse production systems. The variability observed in the agro-morphological characters of genotypes could be utilized in a variety of breeding programs. As a result, it was concluded that these genotypes may have the potential to be a direct seed source for snap bean production, given that the genotypes examined in the trial were well adapted to the study region. Future research should concentrate on the agronomic management and assessment of genotypes across a variety of locations in order to find and select location-specific and widely adaptable genotypes.

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