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AGRONOMIC AND QUALITY PROPERTIES AND MINERAL CONTENTS OF MUNG BEAN [*VIGNA RADIATA* (L.) WILCZEK] GENOTYPES GROWN AT DIFFERENT ALTITUDES

RUZIYE KARAMAN AND CENGIZ TURKAY

Department of Field Crops, Faculty of Agriculture, Isparta University of Applied Sciences, Isparta, Turkey
**Corresponding author's email: ruziyekaraman@isparta.edu.tr*

Abstract

Vigna radiate L. (Mung bean) is an edible leguminous plant that has adapted to different environmental conditions and possesses many varieties and local formas. Agronomic traits and nutrient compositions change depending on genotype and environmental conditions. In the present study, changes in agronomic properties, qualitative properties, and nutrient composition of 7 mung bean genotypes grown at different altitudes (L1: 1050 m, L2: 314 m) in two different locations [Isparta (L1) and Mersin (L2)] were investigated. It was found that there were significant differences between genotypes in both locations in terms of all characteristics examined in the study. In the study, it was found that the L2 location was superior in terms of agronomic characteristics. Water absorption capacity and swelling index were higher in the L2 location, while fat content, protein ratio, ash content, and carbohydrate content were higher in the L1 location. In terms of mineral element content, phosphorus, magnesium, and iron were higher in the L1 location, whereas calcium, copper, and zinc were higher in the L2 location, and potassium and manganese were not affected by locations. Examining both locations, the G2 genotype was superior in terms of agronomic characteristics, the G6 genotype was superior in terms of quality characteristics, and the G5 genotype was superior in terms of mineral content characteristics compared to other genotypes. Also, it was found that growing mung beans at low altitudes was more advantageous in terms of yield and yield components. However, it was found that the quality and nutrient composition of mung beans grown at higher altitudes were higher.

Key words: Mungbean, Location, Agronomic properties, Quality properties, Nutrient composition.

Introduction

Mung bean (*Vigna radiata* L.) is one of the critical warm-season legumes cultivated in the world. The homeland of mung beans has been reported to be India (Zaid *et al*., 2012). The seeds (fresh or dry) can be used as whole or processed to make bread, noodles, porridge, soup, snacks, and even ice cream (Mogotsi, 2006). The nutritional value of mung beans is associated with their high and easily digestible protein content (Baraki *et al*., 2020). It also contains approximately 61% carbohydrates, 23.8% protein, 1.2% fat, 3.5% ash, and 4.5% fiber on a dry weight basis (Dahiya *et al*., 2015). Mung bean stands out in terms of lysine and threonine, amino acids, and is complementary to cereal grains (Asaduzzaman *et al*., 2008). Also, mung beans are rich in Ca, Mg, Fe, P, and K (Nagrale *et al*., 2018). Due to the symbiotic relationship of mung bean with *Bradyrhizobium japonicum* bacteria, it can fix nitrogen in the soil at levels varying between 58-109 kg ha^{-1} (Singh & Singh, 2011). On the other hand, the feed remaining from the mung bean after the pods are collected and blended is also vital and can be preferred for animal feed (Baraki *et al*., 2020; Karaman *et al*., 2020; Karaman *et al*., 2022).

Mung beans can adapt well to medium-textured soils due to their short vegetation period and drought tolerance (Shil & Bandopadhyay, 2007). Also, mung bean height varies in the range of 25-116 cm tall (Waniale *et al*., 2014) and is an annual, upright, or wrapping plant that can yield up to 2457 kg ha^{-1} (Gebremariam & Baraki, 2018). There is a production of 5.3 million tons of mung beans in an area of approximately 7.3 million hectares worldwide. India and Myanmar account for 30% of this production (Nair & Schreinemachers, 2020). In Turkey, mung bean production uses local varieties for family needs or local markets. Also, it is cultivated locally in the Mediterranean and Southeastern regions of Turkey (Karaman, 2019). The present study was aimed to evaluate the mung bean genotypes cultivated in Turkey and obtained from abroad in terms of agronomic, quality, and mineral content by growing in different locations at different altitudes.

Material and Methods

Plant material and field experiments: In the study, 7 exotic mung bean genotypes [Pavdora (G1), Celera (G2), Partow (G3), Niab-M51 (G4), Vidiyala (G5), 27 S 08 (G6, pure line) and Jade (G7)] were used. Mung bean genotypes were grown in two locations (Isparta and Mersin). The study was conducted in Isparta (L1) at Isparta University of Applied Sciences Faculty of Agriculture trial fields and in Mersin (L2) on a farmer's land in the growing season of 2020. L1 (37^o 83 58 87, 30^o 53 85 14) is located at the intersection point of Central Anatolia, Aegean, and Mediterranean Regions, which is called the Lakes Region. L2 (36^o 70 12 73, 33^o 42 42 16) is located in the Central Mediterranean region. The altitude of L1 is 1050 m, and the altitude of L2 is 314 m. The soil texture of L1 was clay loamy, while the soil texture of L2 was loamy. L2 location (1.87%) had higher organic material (1.54%) than L1. Regarding pH values, it was determined that L1 was more neutral than L2, and the L2 location was alkaline. Considering the electrical conductivity (322-357 µS cm^{-1}), it was determined that there was no salinity problem in the soils in both locations. L1 location was richer in terms of P, K, Mg, Mn, and Ca elements, whereas the L2 location was richer in Fe and Cu elements (Table 1). In the months of the study (May-September), the total precipitation of the L1 location (except September) was higher than that of the L2 location. The average temperature was found to be higher in the L2 location, especially in June, and the temperature difference between the two locations was very high (Fig. 1).

Table 1. Soil characteristics of Isparta (L1) and Mersin (L2) locations.

Soil properties	Isparta (L1)	Mersin (L2)	Soil Properties	Isparta (L1)	Mersin (L2)
Soil texture	Clay loam	Loam	Ca (mg/kg)	8229.8	3500
Organic matter (%)	1.54	1.87	Mg (mg/kg)	169.5	270
pH	7.66	8.01	Fe (ppm)	6.21	8.0
EC (µS/cm)	322	357	Cu (ppm)	2.99	16.0
K (mg/kg)	772.2	250	Mn (ppm)	16.2	7.2
P (mg/kg)	23.5	12.0	Zn (ppm)	7.33	3.4

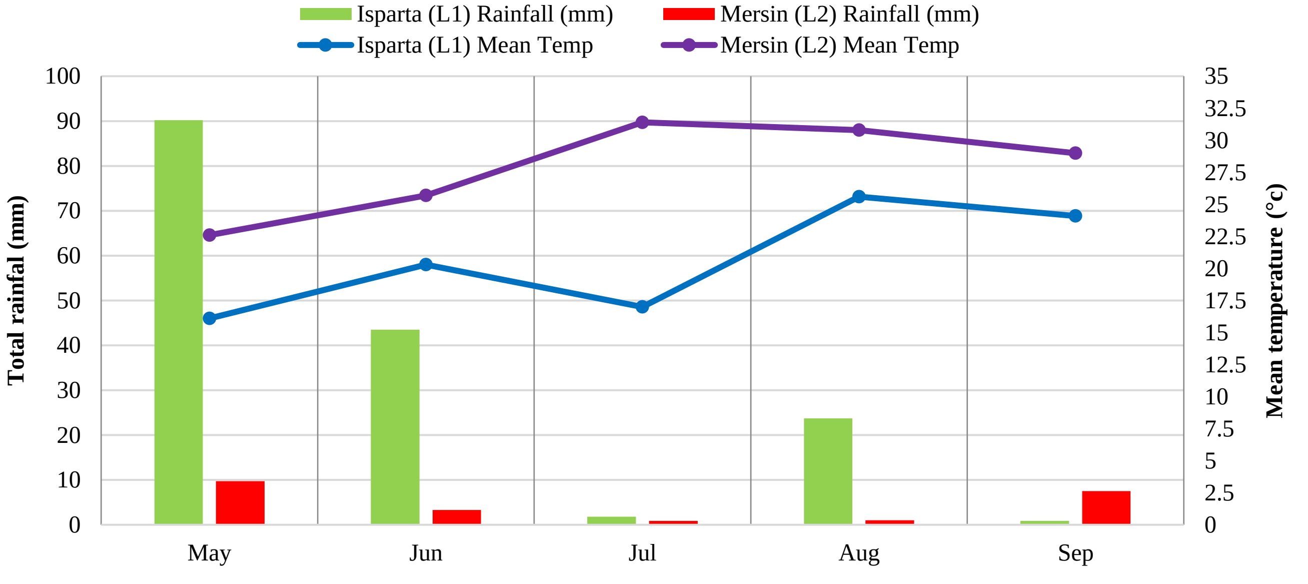

Fig. 1. Climatic data of Isparta (L1) and Mersin (L2) locations.

The research was carried out in randomized complete blocks experimental design with three replications. The sowing process was carried out on 18 May 2020 at the L1 location and 20 May 2020 at the L2 location. Each plot consisted of six rows of 4 m in length. Sowing was carried out manually with 30x10 cm intra-row spacings or above. During the sowing process, fertilization was carried out at 6 kg da^{-1} N and 6 kg da^{-1} P_2O_5. In both locations, the plants' water needs were met with drip irrigation, taking the humidity of the soil and the climatic conditions into consideration. Weed control was mechanically controlled throughout the entire vegetation period. Harvest processes were completed in the last week of September in the L1 location and in the first week of September in the L2 location based on the ripening of the pods.

Evaluation of Traits: In the study, plant height (cm), the number of pods per plant, the number of seeds per plant, and seed yield (g) per plant were determined in 10 randomly selected plants from each plot, and the average values per plant were calculated by calculating their mean values. At the beginning and end of the rows, 50 cm margins were left from each plot, and the seed yield (kg ha^{-1}) was determined by harvesting the remainder. The 100-seed-weight values were calculated by taking 100 seeds four times from the harvested seeds of all plants, weighed, and calculated the mean values (Karaman, 2019).

For determining the water absorption capacity, the hard-coated seeds without received water seeds were separated from the samples whose 100-seed weight was determined, the water absorption capacity of the weighed seeds was determined according to the formula below (Equation 1). The seeds that did not absorb any water and did not change in weight at the end of the 16-hour soaking period were accepted as hard-coated seeds (Karaman, 2019).

Water absorption capacity (g seed^{-1}) = (Y-(X-(X/100) x N2))/(N1 – N2) (Eq. 1)

In the above equation, Y = Wet weight (g) after the non-swelling seeds is separated, X = Dry 100 seed weight (g), N1= the Initial number of seed, N2= Number of unswelled hard-shelled seeds If there is no swelling seed, it is determined according to equation 2.

Water absorption capacity (g seed^{-1}) = (Wet weight-Dry weight)/100 (Eq. 2)

The swelling index was determined according to the formula below (Equation 3; Karaman, 2019).

Swelling index (%) = (Wet volume-100)/(Dry volume-50) (Eq. 3)

To determine the cooking time, 100 soaked mung bean seeds were kept into boiling water, then checked after every three minutes, and the cooking time was recorded with the disappearance of white spot and the seed coat was peeled and split into two (Karayel, 2012; Karaman, 2019). Before determining the protein ratio, the nitrogen content of the seeds was determined by the Kjeldahl method (Kacar & Inal, 2010). The nitrogen content was multiplied by the coefficient of 6.25, and the crude protein ratio of the seeds was calculated as % (Bremner, 1965). The fat content was determined as % in the Nuclear Magnetic Resonance (NMR) device. The seeds were kept in an oven set at 70°C for 48 hours for the fat content, and the moisture was evaporated. Two dehumidified seeds were weighed, 5 readings were taken for each sample in the NMR device, and the averages were taken (Erbas, 2012). To determine the ash content, the seeds were first ground and then kept in an oven at 65 °C until the weight became constant (48 hours) to remove their moisture. For each sample, the value obtained by processing 3 g of sample in an ashing furnace at 550°C for 4 hours was calculated by multiplying by 100 (Yılmaz, 2005). The carbohydrate content of the sample was determined by using the following formula (Equation 4; James, 1995).

Carbohydrate connect (%) = [100 – (Moisture – Ash – Fat – Protein)] (Eq.4)

The plant nutrients Fe, Mg, Ca, Cu, Mn and Zn were determined by Atomic Absorption Spectrophotometer and K-Fleymphotometric method, and P was determined according to the molybdovanado-phosphoric acid method (Kacar & Inal, 2010).

Statistical analysis

The data obtained from the analyses were subjected to variance analysis by using the TOTEMSTAT package program in accordance with the randomized complete blocks experimental design over locations. The differences between the mean values were determined according to the Duncan test (0.05).

Results and Discussion

Agronomic properties: It was determined that the interaction of genotype, location, and genotype x location on agronomic characteristics was significant ($p \leq 0.01$) (Table 2). The plant heights of the genotypes varied between 46.0 and 91.5 cm. In both locations, the highest plant height was found in the G2 genotype (84.4 cm in L1 and 98.6 cm in L2), whereas the lowest was observed in the G6 genotype (45.3 cm in L1 and 46.7 cm in L2). Plant height has a medium to high heritability (67.32% – 83.40%) (Kumar *et al*., 2010; Sneha *et al*., 2019). Therefore, plant height is also affected by environmental conditions, as reported by many researchers (Degefa *et al*., 2014; Sabatina *et al*., 2021). The temperature in the L2 location during the vegetation period was higher than the L1 location, and it seemed that the differences in plant height were caused by the temperature differences in these locations.

The number of pods per plant in the L2 location (18.9) was higher than in the L1 location (13.5). The number of pods per plant varied between 21.1 and 12.3 depending on the genotypes. In both locations, the highest number of pods per plant was found in the G5 genotype (19.9 in L1 and 22.1 in L2), whereas the lowest was in the G7 genotype (9.3 in L1 and 15.3 in L2). Although the number of pods per plant in mung bean is a character that can change according to the environmental and growing conditions, it is one of the selection criteria that directly affect seed yield in early generations in a breeding program (Hakim, 2008). It has been reported that there is a high heritability for the number of pods per plant in mung bean, and the possible variations are associated with environmental factors (Kumar *et al*., 2010; Degefa *et al*., 2014). The variation in the number of pods per plant was within the values specified in the literature (Karaman, 2019; Sineka *et al*., 2021).

The number of seeds per plant in both locations varied significantly ($p \leq 0.01$) depending on the location and genotype. The number of seeds per plant in the L2 location (175.7) was higher than in the L1 location (131.7). The maximum number of seeds per plant was noted in the G5 genotype in the L1 location, whereas in the G5, G2, and G4 genotypes in the L2 location. The lowest number of pods in both locations was found in the G7 genotype. Since the average temperature in the L2 location during the vegetation period was optimum for mung beans, it was thought the number of seeds per plant will be high. In mung beans, the number of seeds per plant can vary between 30.1 and 162.3 (Dulgerbaki, 2011; Gul *et al*., 2019), and it has been reported that the number of seeds per plant varies depending on the location, genotype, and climate (Thangavel *et al*., 2011).

In the present study, seed yield per plant in the L2 location (10.8 g) was higher than in the L1 location (6.83 g). Seed yield per plant of genotypes varied between 5.3 g and 11.1 g. The highest seed yield per plant was determined in G2 and G3 genotypes in the L1 location and in G2 genotype in the L2 location. The lowest seed yield per plant was recorded in the G7 genotype in both locations. In the present study, it was thought that the differences between plant seed yields, locations, and genotypes were caused by environmental conditions (climate and soil factors) and genetic structure. Although the heritability of plant seed yield in mung beans is low, it has been reported in many studies that environmental conditions have an effect on plant seed yield (Bilgili *et al*., 2010; Ahmad *et al*., 2014). The plant seed yield of mung bean could vary between 8.4 g and 45.4 g, (Begum *et al*., 2013; Mehandi *et al*., 2013) and the results obtained from the present study were similar to previous reports.

Another critical selection criterion determining the seed yield in mung beans is the hundred seed weight. The hundred seed weights of the genotypes varied between 4.09 and 6.57 g. The L2 location (6.15 g) had a higher hundred seed weight than the L1 location (5.27 g). The highest hundred seed weight was found in the G2 and G3 genotypes in the L1 location and in G2 genotype in the L2 location (Table 2). The lowest hundred seed weight was recorded in the G5 genotype in both locations. It has been reported that the 100 seed weight of mung beans, essential for marketing, varies between 3.41 and 7.03 g (Hakim, 2008). Dahiya *et al*. (2015) reported that small-seeded (low hundred-seed weight) and low-yielding varieties had higher protein content in mung beans. The fact that the hundred seed weight was lower at the L1 location can be associated with the low yield and high protein content obtained at this location. The findings of the present study were in line with the earlier reports (Khan *et al*., 2017; Sineka *et al*., 2021).

Table 2. Values of the agronomic characteristics of mung bean genotypes in different locations.

Treatments	Plant height (cm)	Number of pods per plant	Number of seeds per plant	Seed yield (g) per plant	Hundred seed weight (g)	Seed yield (kg ha^{-1})
Locations						
L1	68.2 b	13.5 b	131.7 b	6.8 b	5.27 b	2276.7 b
L2	77.3 a	18.9 a	175.7 a	10.8 a	6.15 a	3592.7 a
F-value	264.7**	329.9**	181.8**	600.8**	356.36**	600.4**
Genotypes						
G1	79.7 b	14.6 c	141.90 c	8.8 c	6.04 b	2915.6 c
G2	91.5 a	15.3 c	166.52 b	11.1 a	6.57 a	3712.6 a
G3	78.4 b	17.3 b	166.13 b	10.5 ab	6.29 b	3502.1ab
G4	72.3 c	16.0 bc	169.15 b	9.9 b	5.77 c	3283.9 b
G5	78.5 b	21.1 a	198.04 a	8.1 c	4.09 d	2699.6 c
G6	46.0 e	17.1 b	140.18 c	8.0 c	5.61 c	2656.2 c
G7	62.7 d	12.3 d	93.99 d	5.3 d	5.58 c	1773.0 d
F-value	389.3**	47.6**	57.26**	83.6**	167.03**	83.6**
Interaction						
L1 x G1	74.1 b	11.7 c	115.27 c	6.2 c	5.39 b	2071.0 c
L1 x G2	84.4 a	12.2 c	135.41 b	8.0 ab	5.93 a	2675.6 ab
L1 x G3	72.8 b	15.3 b	148.3 b	8.8 a	5.93 a	2930.2 a
L1 x G4	69.7 c	13.3 c	145.39 b	7.7 b	5.30 b	2560.3 b
L1 x G5	69.3 c	19.9 a	193.69 a	7.5 b	3.88 c	2505.4 b
L1 x G6	45.3 e	13.0 c	111.12 c	5.8 c	5.23 b	1935.7 c
L1 x G7	61.7 d	9.3 d	72.60 d	3.8 d	5.20 b	1259.1 d
L2 x G1	85.2 bc	17.5 c	168.52 b	11.3 c	6.69 b	3760.2 c
L2 x G2	98.6 a	18.3 bc	197.63 a	14.3 a	7.22 a	4749.6 a
L2 x G3	84.0 c	19.4 b	183.93 ab	12.2 b	6.64 b	4074.1 b
L2 x G4	75.0 d	18.7 bc	192.91 a	12.0 bc	6.23 c	4007.6 bc
L2 x G5	87.7 b	22.1 a	202.38 a	8.7 e	4.31 e	2893.8 e
L2 x G6	46.7 f	21.2 a	169.24 b	10.1 d	5.99 cd	3376.6 d
L2 x G7	63.8 e	15.3 d	115.38 c	6.9 f	5.95 d	2286.8 f
F-value	18.6**	5.7**	4.35**	14.1**	6.69**	14.2**

**: p≤0.01ns, *: p≤0.05, ns: Non-significant

Seed yields of the genotypes varied between 1773.0 and 3712.6 kg ha^{-1}. The L2 location had a higher seed yield compared to the L1 location. While the highest seed yield was determined in the G2 genotypes in both locations, the lowest seed yield was determined in the G7 genotype (Table 2). The seed yield of a genotype in a year may vary depending on the light, water, precipitation, temperature, humidity, and nutrient competition (Koutroubas *et al*., 2004). Mung bean has a low heritability because many genes with additive effects effectively inherit the seed yield per unit area (Ahmad *et al*., 2014; Azam *et al*., 2018). The seed yield of mung bean has been reported by Cancı & Toker (2014) as 33.3-3916.6 kg ha^{-1}, by Ullah *et al*. (2012) as 2108.6-3204.7 kg ha^{-1}, by Raturi *et al*. (2015) as 4631.5 kg ha^{-1}, by Khan *et al*. (2017) as 3401.8 kg ha^{-1} and by Ton (2021) as 2737 kg ha^{-1}.

Quality properties: The water absorption capacity of the genotypes varied between 0.059 g seed^{-1} and 0.090 g seed^{-1}. In both locations, the highest water absorption capacity was noted in the G1 genotype, whereas the lowest was in the G5 genotype (Table 3). Water absorption capacity and the swelling index had the highest values at the L2 location. Depending on the genotypes, the swelling index varied between 2.01% and 2.40%. The highest was detected in the G2 genotype, whereas the lowest was in the G3 and G6 genotypes. Swelling capacities of G2, G1, G4, G5, and G7 genotypes were in the same statistical group. Properties such as water absorption capacity and index, swelling capacity and index, seed size, and volume are essential selection criteria in the cultivation stage that affect the cooking properties (Karaman, 2019). Water absorption capacity and swelling index have a positive and significant relationship with seed weight (Kaur & Sing, 2006). While the water absorption capacity of the varieties with a high hundred seed weight is higher, the water absorption capacity decreases as the weight decreases (Karasu, 2003). Similar results were also obtained in the present study.

The cooking times of the genotypes varied between 10.5 and 17.7 minutes. The shortest cooking time was determined in the G6 genotype in both locations. The longest cooking time was determined in the G2 genotype in the L1 location and the G3 genotype in the L2 location. Cooking time is an important parameter used to evaluate the cooking quality of legumes. Also, cooking time is crucial for energy requirements in developing countries (Nadeem *et al*., 2020; Ozaktan 2021). The cooking time of mung bean has been reported by Dahiya *et al*., (2015) as 14-60 minutes and by Khattak and Bibi (2007) as 14.0-26.5 minutes. The difference between the findings in the study and the literature was associated with the genetic structure of the genotypes used or the climate and soil characteristics of the region.

Table 3. Values of quality traits of mung bean genotypes in different locations.

Treatment	Water absorption capacity (g seed⁻¹)	Swelling index (%)	Cooking time (min)	Fat content (%)	Protein content (%)	Ash content (%)	Carbohydrate content (%)
Locations							
L1	0.075 b	2.00 b	14.1	0.43 a	24.73 a	4.7 a	67.9 a
L2	0.079 a	2.30 a	14.4	0.34 b	21.20 b	4.3 b	63.6 b
F-value	48.29**	24.67**	3.9 ns	1586.16**	298.44**	91.3**	272.6**
Genotypes							
G1	0.090 a	2.17 ab	12.2 c	0.46 c	23.01 bc	4.3 b	65.7 bc
G2	0.082 b	2.40 a	17.5 a	0.22 e	24.22 a	4.6 a	64.4 cd
G3	0.075 d	2.01 b	17.7 a	0.45 c	22.51 c	4.6 a	65.7 bc
G4	0.080 bc	2.08 ab	12.7 c	0.23 e	24.02 ab	4.4 ab	64.5 b-d
G5	0.059 e	2.07 ab	13.0 c	0.48 b	24.42 a	4.2 b	64.1 d
G6	0.077 cd	2.01 b	10.5 d	0.49 a	19.94 d	4.6 a	69.7 a
G7	0.076 d	2.31 ab	16.5 b	0.37 d	22.55 c	4.6 a	66.0 b
F-value	181.24**	3.81**	226.4**	1789.75**	32.68**	7.7**	31.3**
Interaction							
L1 x G1	0.088 a	2.00	12.3 e	0.52 b	25.01 a-c	4.6	67.7 b
L1 x G2	0.080 b	2.43	18.7 a	0.23 f	24.77 bc	4.8	65.8 cd
L1 x G3	0.075 c	1.87	16.7 b	0.44 d	24.41 c	4.9	67.8 b
L1 x G4	0.079 b	1.88	13.3 d	0.24 e	26.16 a	4.5	67.2 bc
L1 x G5	0.057 e	1.89	13.0 de	0.49 c	25.54 a-c	4.4	65.2 d
L1x G6	0.075 c	1.81	10.0 f	0.54 a	21.47 d	4.8	71.3 a
L1 x G7	0.071 d	2.12	15.0 c	0.52 b	25.77 ab	4.7	70.0 a
L2 x G1	0.092 a	2.33	12.0 d	0.39 c	21.18 bc	3.9	63.7 b
L2 x G2	0.084 b	2.38	16.3 b	0.21 e	23.68 a	4.4	62.9 b-d
L2 x G3	0.074 d	2.14	18.7 a	0.45 b	20.62 c	4.4	63.5 bc
L2 x G4	0.081 c	2.28	12.0 d	0.22 de	21.87 b	4.3	61.9 d
L2 x G5	0.060 e	2.25	13.0 c	0.47 a	23.30 a	4.0	63.0 b-d
L2 x G6	0.080 c	2.20	11.0 e	0.45 b	18.41 d	4.4	68.1 a
L2 x G7	0.081 bc	2.50	18.0 a	0.23 d	19.32 d	4.4	62.0 cd
F-value	5.43**	0.99 ns	23.6**	359.89**	9.73**	2.3 ns	7.9**

**: $p \leq 0.01$, *: $p \leq 0.05$, ns: Non-significant

The highest fat content was found in the G6 genotype (0.49%), whereas the lowest was recorded in the G2 (0.22%) and G4 (0.23%) genotypes. The highest fat content was found in the G6 genotype (0.54%) in the L1 location and in the G5 genotype (0.47%) in the L2 location. The lowest fat content was determined in the G2 genotype (0.23% and 0.21%) at both locations. The fat content of mung bean genotypes has been reported by Zia-Ul-Haq *et al*. (2014) between 2.1 and 2.7%. Fat contents reported in the study partially aligned with previously reported values. It has been stated that the reason for the change in fat content among countries and genotypes was the environmental and geological conditions (Ibrahim *et al*., 1974). Karaman (2019) showed that the fat contents of mung bean genotypes changed between 0.4 and 1.33% and stated that these values differed depending on the years and genotypes. The study's low-fat content of the genotypes is supported by the view that legumes are generally fat-free products (Mabaleha & Yeboah, 2004).

Mung beans are a good source of protein. In the present study, the protein content of the genotypes varied between 19.94% and 24.42%. The L1 location (24.73%) had higher protein content than the L2 location (21.20%). The highest protein content in the L1 location was in the G1, G4, G5, and G7 genotypes, while in the L2 location, it was detected in the G2 and G5 genotypes. The lowest protein content was in the G6 genotype at the L1 location and the G6 and G7 genotypes at the L2 location. Dahiya *et al*. (2015) stated that the protein content of mung beans was 23.6% (14.6%-32.6%). Karaman (2019) stated that the protein content of mung bean genotypes in Turkey varied between 12.51 and 25.04%. Significant variations in the protein content of mung beans depend on genotypes, analysis methods, and growing conditions (Thakare *et al*., 1988; Dahiya *et al*., 2015). Examining the results of the present study, the results were in line with the previously published studies.

The ash content of the genotypes varied between 4.2 and 4.6%. The highest ash content was recorded in the G3 genotype, whereas the lowest was in the G5 genotype. The L1 location had higher ash content than the L2 location. Raw ash forms the inorganic materials in the seeds. The high ash content and the variations constitute a rich gene source for plant breeding (Karayel, 2012). The ash content of mung bean has been reported by Ahmad *et al*., (2016) as 3.8–4.0, by Oo *et al*., (2017) as 3.2%, and by Das *et al*., (2018) as 4.5-5.5%. These differences in the ash content in the were associated with the climate, soil, and genetic structure of the genotypes of the region where they were grown.

Carbohydrate content at both locations varied significantly ($p \leq 0.01$) depending on the location and genotype. The L1 location had higher carbohydrate content (67.9%) than the L2 location (63.6%). The highest carbohydrate content was determined in the G6 (69.7%) genotype, whereas the lowest was in the G5 (64.1%) genotype. The results obtained in the present study were in line with those reported by El-Adawy *et al*., (2003) and Mubarak (2005). Carbohydrates are the primary energy source for the human body. Dahiya *et al*. (2015) had stated that there was a wide variation in the carbohydrate fractions of mung beans due to genetic structure or seed ripeness (El-Adawy *et al*., 2003; Mubarak, 2005).

Mineral composition: In the present study, significant ($p \leq 0.01$) differences in all properties were observed between the genotypes. On the other hand, the effect of location on all properties except for potassium and manganese and the effect of location x genotype interaction on all properties except for iron and manganese was significant ($p \leq 0.01$). The potassium content of the genotypes varied between 1575.7 and 1230.8 mg 100 g^{-1}. The highest potassium content was determined in the G5 genotype, whereas the lowest was in the G6 and G7 genotypes. The highest phosphorus content was determined in the L1 location (442.7 mg 100 g^{-1}) and the G6 (450.4 mg 100 g^{-1}) genotype. The calcium content was higher at the L2 location (148.2 mg 100 g^{-1}) compared to the L1 location (116.3 mg 100 g^{-1}). In both locations, the calcium content of the mung bean was determined to be the highest in the G2 genotype and the lowest in the G1 genotype. The magnesium contents of mung bean genotypes varied between 67.9 and 81.9 mg 100 g^{-1}, the highest magnesium content was found in the G5 genotype, whereas the lowest was in the G1 genotype. The magnesium content of the L1 location (75.2 mg 100 g^{-1}) was higher than the L2 location (70.1 mg 100 g^{-1}).

The iron contents of mung bean genotypes varied between 2.71-4.61 mg 100 g^{-1}, and the highest iron content was determined in the G5 genotype. The lowest iron content was detected in the G1, G3, G4, and G7 genotypes. The L1 location (3.47 mg 100 g^{-1}) had higher iron content values. Among the genotypes, the G2 genotype (1.02 mg 100 g^{-1}) had the highest copper content, whereas the G7 (0.70 mg 100 g^{-1}) and G3 genotypes (0.68 mg 100 g^{-1}) had the lowest. In terms of copper content, the G2 and G5 genotypes were in the same statistical group. The copper content at the L2 location (0.87 mg 100g^{-1}) was higher than that in the L1 location (0.80 mg 100 g^{-1}). The highest zinc content of the genotypes was determined in the G6 genotype (2.96 mg 100 g^{-1}), and the G6 and G1 genotypes were in the same statistical group. The G4 (2.14 mg 100g^{-1}) genotype detected the lowest copper content. L2 location (2.72 mg 100 g^{-1}) had a higher zinc content than the L1 location (2.41 mg 100 g^{-1}). The manganese content of the genotypes ranged from 0.37-0.66 mg 100g^{-1}. The highest manganese content was determined in the G5 and G1 genotypes, whereas the lowest was in the G4 genotype.

Table 4. Values of mineral content (mg 100 g^{-1}) of mung bean genotypes in different locations.

Treatments	K	P	Ca	Mg	Fe	Cu	Zn	Mn
Locations								
L1	1378.3	442.7 a	116.3 b	75.2 a	3.47 a	0.80 b	2.41 b	0.52
L2	1372.6	425.2 b	148.2 a	70.1 b	3.30 b	0.87 a	2.72 a	0.50
F-value	1.5ns	3723.7**	1097.8**	117.1**	5.21**	25.31**	88.47**	1.42ns
Genotypes								
G1	1520.2 b	421.9 f	111.8 e	67.9 e	2.71 d	0.76 de	2.83 ab	0.65 a
G2	1280.6 e	418.4 g	154.8 a	69.9 c-e	3.56 c	1.02 a	2.52 c	0.44 bc
G3	1437.8 c	430.9 e	141.1 b	75.5 b	3.10 d	0.68 e	2.46 c	0.42 bc
G4	1333.1 d	437.8 c	121.8 d	72.5 c	2.79 d	0.82 cd	2.14 d	0.37 c
G5	1575.7 a	444.8 b	123.3 d	81.9 a	4.61 a	0.96 ab	2.75 b	0.66 a
G6	1230.8 f	450.4 a	143.9 b	69.3 de	4.06 b	0.90 bc	2.96 a	0.50 b
G7	1249.7 f	433.5 d	129.0 c	71.6 cd	2.89 d	0.70 e	2.31 cd	0.51 b
F-value	510.7**	920.5**	137.4**	57.1**	55.78**	47.69**	44.44**	32.02**
Interaction								
L1 x G1	1529.2 b	431.9 e	96.1 e	69.4 d	2.71	0.77 cd	2.77 ab	0.66
L1 x G2	1280.7 e	425.9 f	141.1 a	73.2 c	3.52	0.92 ab	2.35 c	0.46
L1 x G3	1416.1 c	425.9 f	119.2 c	78.5 c	3.17	0.66 e	2.23 c	0.41
L1x G4	1309.1 d	468.1 b	105.1 d	78.3 b	2.75	0.77 cd	2.01 d	0.36
L1 x G5	1592.9 a	474.1 a	108.2 d	81.1 a	4.92	0.94 a	2.61 b	0.68
L1 x G6	1246.2 f	438.0 c	134.1 b	74.1 c	4.29	0.84 bc	2.88 a	0.53
L1 x G7	1273.7 e	435.0 d	110.2 d	72.1 cd	2.95	0.70 de	2.01 d	0.52
L2 x G1	1511.3 b	411.9 e	127.5 f	66.3 c	2.71	0.75 d	2.90 a	0.63
L2 x G2	1280.6 e	410.8 e	168.6 a	66.6 c	3.6	1.12 a	2.69 bc	0.42
L2 x G3	1459.6 c	436.0 b	163.0 b	72.6 b	3.03	0.71 d	2.68 c	0.44
L2 x G4	1357.1 d	407.4 f	138.5 e	66.6 c	2.82	0.87 c	2.26 d	0.38
L2 x G5	1558.5 a	415.4 d	138.3 e	82.7 a	4.31	0.98 b	2.88 ab	0.65
L2 x G6	1215.5 f	462.7 a	153.7 c	64.6 c	3.84	0.96 b	3.05 a	0.48
L2 x G7	1225.6 f	431.9 c	147.9 d	71.1 b	2.83	0.71 d	2.62 c	0.5
F-value	9.91**	1826.0**	9.0**	13.7**	1.88ns	3.90**	3.54**	0.67ns

**: $p \leq 0.01$ns, *: $p \leq 0.05$, ns: Non-significant

Minerals are essential for human health as they play an important role in metabolism by acting as cofactors of enzymes (Dahiya *et al*., 2015). Potassium plays a vital role in human metabolism. It affects blood pressure and improves heart health (Aslam *et al*., 2005). The present study determined that mung beans were the richest in K>P>Ca elements (Table 4). The potassium (1246 mg 100 g^{-1}) and phosphorus (367 mg 100 g^{-1}) contents were found to be higher than the values reported by the Anon., (2001). Studies show that mung beans contain significant amounts of potassium, calcium, and iron. Also, it has been stated that the amount of calcium in mung beans is four times higher than in cereals (Dahiya *et al*., 2015). Dahiya *et al*. (2015) have reported the calcium content of mung bean as 55-200 mg 100 g^{-1}, copper content as 0.9-1.5 mg 100 g^{-1}, iron content as 4-7.6 mg 100 g^{-1}, potassium content as 326-1246 mg 100 g^{-1}, magnesium content as 50-320 mg 100 g^{-1}, manganese content as 1.0-1.1 mg 100 g^{-1}, phosphorus content as 271-590 mg 100 g^{-1}, and zinc content as 2.4-3 mg 100g^{-1}. Ulker & Ercan (2008) have stated that the differences in the mineral composition of seeds may be caused by genetic structure or environmental conditions (climate and soil).

Conclusions

In the study, mung bean genotypes were grown in two locations with different altitudes, and the agronomic, quality characteristics, and mineral contents of the seeds were determined. It was determined that there were significant differences between the genotypes in both locations regarding all the characteristics examined in the study. According to the results, the G2 genotype had a higher seed yield in both locations than other genotypes. At the L1 location, the G2 and G3 genotype were in the same statistical group. The G6 genotype had higher values in terms of quality characteristics, while the G5 genotype was in terms of mineral content. Whereas the L2 location (altitude 314 m) was superior in seed yield, while the L1 location (altitude 1050 m) was superior in terms of quality characteristics such as protein and fat, and carbohydrates. The G2 genotype can be recommended for both locations regarding yield and quality characteristics.

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