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# Assessment of Mineral Contents and Technological Properties of Dry Bean Genotypes Grown Under Organic Farming Conditions with Multivariate Analysis

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ABSTRACT

Beans are an important source of essential minerals such as iron, zinc, calcium, and magnesium, which are crucial in various physiological functions. The mineral contents of beans are vital in ensuring a balanced and healthy diet, as these minerals are involved in bone health and, immune system function. Additionally, the technological properties of beans, including cooking time, water absorption capacity, and swelling capacity, are important in determining their culinary applications and consumer acceptance. The cooking quality and number of seeds destructed after cooking of beans significantly influence their palatability and overall consumer satisfaction. Assessing the technological properties of different bean genotypes grown under organic farming conditions allows researchers to identify genotypes with desirable cooking characteristics and texture, leading to improved consumer acceptance and culinary applications. Organic farming practices aim to produce food without synthetic chemicals, promoting environmental sustainability and ensuring the production of high-quality and nutritious crops. In this research, 20 bean genotypes were grown under organic conditions for two years. To analyze the complex data obtained from the assessment of mineral contents and technological properties of beans, multivariate analysis techniques (correlation, cluster, scatter plot, biplots etc.) are employed. There was a positive relationship between cooking time and Ca mineral. There was a negative relationship between the coefficient of hydration and water absorption capacity and Zn mineral. Positive correlation between Fe, Mn, Cu, Mg, K, P and S elements was observed. Likewise, examining one of the dry weight, dry volume, wet weight, wet volume, water absorption capacity and swelling index values, which are clustered in the same region and have approximately the same axis length, can save time and be consumable. The zinc, sodium, iron, and copper contents in the beans grown under organic conditions were found to be higher than the data reported in the literature.

Keywords: Cooking time, Dry bean, Macro-micro element, Multivariate analysis, Nutrition, Organic farming

## 1. Introduction

Legumes are an excellent protein source while rich in carbohydrates, resistant starch fiber, potassium, copper, phosphorus, manganese, iron, magnesium and B vitamins (Mullins & Arjmandi 2021). The consumption of legumes such as dry beans and peas increases the intake of dietary fiber, protein, folate, zinc, iron, and magnesium in human nutrition, while reducing saturated fat and total fat intake (Mitchell et al. 2009). Dry beans, due to their high fiber and resistant starch content, elicit a lower glycemic response compared to other high-carbohydrate foods; this may be a factor in the prevention or treatment of diabetes (Ludwig 2002) and colon cancer (Mathers 2002). Additionally, the protein, fiber, and folate in dry beans have been shown to play potential roles in preventing heart disease (Cobiac et al. 1990) and possibly certain types of cancer (Michels et al. 2006). Arunasalam et al. (2004) have also reported that non-nutritive phytochemicals such as saponins, oligosaccharides, and phytate derivatives in dry beans may have a role in cancer prevention. Legumes are an inexpensive and long-term source of protein, micronutrients, essential phytochemicals and complex carbohydrates for a healthier lifestyle. Their composition is suitable for people with diabetes and celiac disease, as well as for consumers concerned about satiety (Singh et al. 2022).

Since deficiencies of potassium (K), phosphorus (P), magnesium (Mg), iron (Fe), zinc (Zn), or copper (Cu) in the human body contribute to the development of various diseases, mineral deficiency is a public health problem affecting thousands of people worldwide (Riberio et al. 2022). Magnesium is an important biological element found in bound form in cells and has many important functions in regulating cellular functions (Jahnen-Dechent & Ketteler 2012). While zinc is crucial for many physiological processes in humans, it also plays essential roles as a regulator or coenzyme of more than 300 enzymes (Schubert et al. 2015). The amount of copper in the body is so perfectly balanced that while a small amount is necessary for many physiological activities, too much can be life-threatening. As a cofactor, for example, it is important to transfer of electrons to oxygen in the respiratory chain (Husain & Mahmood 2019). Iron is an important nutritional mineral for erythropoiesis, cellular energy metabolism, and immune system development and function. Iron-deficiency anemia is the world's most common nutritional disorder (McLean et al. 2009). In light of this information, according to the World Health Organization (WHO) records, 60% of an individual's daily protein intake should be from plant-based proteins and 40% from animal-based proteins for a quality and balanced diet (Ozaktan et al. 2023b).

Organic farming is often practiced to eliminate the dangers of intensive use of chemical fertilizers and offers satisfactory solutions to such problems (Ozaktan & Doymaz 2022). On the other hand, consumers perceive organic foods as healthier and safer than non-organic ones, which is reflected in the increasing number of organic producers worldwide (Barreto et al. 2021). According to Willer et al. (2024) World Organic Agriculture Statistics and Trends report, 72.3 million hectares of land worldwide are managed organically. The organic food market was estimated at 106.4 billion Euros in 2019, while the European market covers 39% of the global market (Malissiova et al. 2022). While P, S, V, Mn, Co, Ni, As, B, K (2% more), Ca (83% more), Fe and, Zn minerals were higher in dry beans grown under organic farming conditions, Mg (8% more) and Cu (16% more) were determined at higher levels in crops grown under conventional conditions (Rodríguez Madrera et al. 2024). Similarly, Akbaba et al. (2012) reported that Ca, Fe, Mn, P, Zn, K, Mg levels in dry bean grains grown under organic conditions were higher than those grown under conventional conditions, while no difference was detected for Cu and S elements. While significant differences in K, Cu, Mn, Ca, Na and Zn levels were determined between organic and non-organic crops, variations in some elements occur depending on the growing region (Barreto et al. 2021).

Determining the technological properties of beans is extremely important. Especially, cooking times for beans are very important for consumers due to two main reasons, the adequacy of time and the scarcity of cooking fuel (Cichy et al. 2019). The age of the seed, environmental conditions during production, cooking method, and genetics are factors that affect the cooking time of kidney beans (Stanley 1992). Therefore, dry beans, known as the meat of the poor, one of the most widely grown edible legumes worldwide, are not only a food source used in the diets of more than 300 million people, but also a good source of protein, vitamins and mineral (Ozaktan et al. 2023a). The mineral profile of beans can vary significantly among genotypes (Pinheiro et al. 2010). The aim of this study was to determine the mineral contents and technological characteristics of bean genotypes grown under organic conditions and to interpret them by multivariate statistical analysis methods.

## 2. Material and Methods

*2.1 Material*

In the experiment, local genotypes named Çomaklı, Gömeç, Kızık and Güzelöz which were intensively grown and consumed in Kayseri province between 1990-2017, together with certified varieties that Akman 98, Adabeyazı, Alberto, Altın, Aras 98, Arslan, Batallı, Berrak, Cihan, Dermason, Göynük 98, Noyanbey 98, Önceler 98, Özdemir, Özmen & Şahin 90 were used. And the term genotype was used for completeness of meaning in the article.

*2.2 Methods*

The experiment was conducted at Erciyes University research field in Kayseri province, located at an altitude of 1094 m above sea level, between the east longitudes of 34° 56'–36° 59' and north latitudes of 37° 45'–38° 18', without the use of any chemical inputs under organic conditions in 2018 and 2019, following a randomized complete block desing with three replications. The trial consisted of plots with a length of 3 m, row spacing of 45 cm, within-row spacing of 10 cm, and 6 rows. A 1 m gap between blocks and a 0.5 m gap between plots were maintained. After hand sowing, the water requirement of the plants was met through sprinkler irrigation until emergence and the first weed control. Subsequently, a drip irrigation system was installed, with one drip line per row.

*2.3 Climate of the study area*

Throughout the trial vegetation period (May-September), the average temperature values recorded during the first year were higher than the long-term average, while the monthly average relative humidity values were partially lower than the long-term average. Upon examining the data for the second year, monthly average temperature values were recorded as 17.4-22.3 °C, and monthly average relative humidity values were recorded as 49.1-55.8%. The total precipitation during the vegetation period was 134.2 mm in the first year, 137.5 mm in the second year, with a long-term average of 125.5 mm. In the second year, particularly the rainfall events in June, July, and August extended the vegetation period for beans.

**Table 1- The monthly temperature (°C), relative humidity (%), and precipitation (mm) values for the vegetation period in the years 2018, 2019, and 1931-2019***

| | *Monthly average temperature (°C)* | | | *Monthly average relative humidity (%)* | | | *Monthly total precipitation (mm)* | | |
|---|---|---|---|---|---|---|---|---|---|
| *Months* | *2018* | *2019* | *1931-2019* | *2018* | *2019* | *1931-2019* | *2018* | *2019* | *1931-2019* |
| *May* | *16.7* | 17.4 | *15.0* | *61.2* | 50.2 | *61.0* | *51.9* | *23.7* | *51.5* |
| *June* | *20.4* | 21.3 | *19.0* | *56.7* | 55.8 | *55.8* | *78.8* | *55.2* | *40.2* |
| *July* | *24.1* | 21.6 | *22.2* | *45* | 49.1 | *49.3* | *0.6* | *35.9* | *10.6* |
| *August* | *22.9* | 22.3 | *22.0* | *42.3* | 50.3 | *49.1* | *-* | *12.1* | *8.7* |
| *September* | *19.2* | 17.4 | *17.4* | *45.5* | 51.2 | *53.7* | *2.9* | *10.6* | *14.5* |

*: Kayseri Meteorology Provincial Directorate data

*2.4 Soil characteristics of the study area*

The experiment was carried out in the area where soil preparation was made after soil cultivation and stone collection in the area where agricultural activities had been carried out for many years (approximately 6-8 years). To determine the initial condition before establishing the trial to represent the trial area, soil samples were collected from different points, representing the trial area, at depths of 0-30 cm. Upon examining the results of the soil analysis for the trial area, it was determined that the trial area soils belong to the sandy loam soil class. The trial was conducted in the same area and with the same trial design in both years. The average values for the soil parameters were determined as follows: available phosphorus 6.785-7.80 kg/ha, pH 7.91-8.0, organic matter 0.30-0.67%, lime content 1.59-2.38%, and electrical conductivity (EC) 0.109-0.117 mmhos/cm.

*2.5 Parameters examined and analyzes*

**Technological traits:** Fresh weight, dry weight, water absorption capacity, water absorption index, fresh volume, dry volume, swelling capacity, swelling index and cooking time were determined in accordance with the methods specified in Gulumser et al. (2008); Ozaktan & Doymaz (2022); hydration coefficient was determined in accordance with the method specified in Savage et al. (2001); Ozaktan & Doymaz (2022); bulk density was determined in accordance with the method specified in Singh et al. (2010); Ozaktan & Doymaz (2022).

**Mineral contents:** Macro (Ca, K, Mg, Na, P, S) and micro element (Cu, Zn, Mn, Fe) contents were determined with the use of Agilent 5800 VDV model ICP-OES device. About 0.5 g ground sample was supplemented with 10 mL Nitric (Merck)+ Perchloric acid (Merck) mixture. Samples were subjected to acid-digestion and mineral composition readings were performed in an ICP-OES spectrometer (Mertens 2005); Ozaktan & Doymaz (2022).

*2.6 Statistical analysis*

The statistics of the data obtained from the examined parameters were separately conducted for each year. To determine the relationships among the examined characteristics, multivariate analysis methods such as correlation, principal component analysis (PCA) - biplot, and cluster analysis were applied to the average values of the examined parameters over the two years. The specified statistical analyses were performed using the JMP Pro 17 software package.

## 3. Results and Discussion

The results of the variance analysis for the first year, second year, and combined years of the examined features are presented in Figure 1. The obtained average values and Tukey groups are provided in Figures 2 and 3. The values derived from the averages of the years were evaluated in a biplot. The impact of the examined technological features and mineral content on bean genotypes was found to be statistically significant in both years (Figure 1). However, when the combined years were examined, only the effects of Cu and Zn contents on genotypes were found to be statistically insignificant (Figure 1).

**Figure 1- Variance analysis data for mineral content and technological traits**

| | | ***Technological traits*** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Years*** | ***Source of variation*** | ***Dry weight (g)*** | ***Dry volume (ml)*** | ***Fresh weight (g)*** | ***Fresh volume (ml)*** | ***Water absorption capacity (g/seed)*** | ***Hydration coefficient (%)*** | ***Swelling capacity (ml/seed)*** | ***Swelling index (%)*** | ***Bulk density (g/ml)*** | ***Cooking time (min.)*** | ***Number of seeds destructed after cooking*** |
| ***2019*** | ***Block*** | 2.223 | 4.789* | 1.832 | 0.211 | 2.166 | 0.119 | 0.6145 | 4.846* | 6.463* | 15.655** | 0.935 |
| | ***Genotypes*** | 45.515** | 52.596** | 32.205** | 19.797** | 34.343** | 3.403* | 7.3177** | 3.232* | 6.113** | 29.035** | 13.171** |
| ***2020*** | ***Block*** | 0.626 | 0.993 | 0.861 | 2.774* | 0.645 | 1.156 | 3.4796* | 3.873* | 1.0975 | 3.376* | 5.636* |
| | ***Genotypes*** | 23.058** | 46.680** | 23.703** | 12.196** | 38.130** | 5.386** | 2.6030* | 7.611** | 9.7264** | 9.113** | 3.9185* |
| ***Average of years*** | ***Year (Y)*** | 10.311* | 23.453* | 3.783* | 3.293* | 0.542 | 7.411 | 2.981* | 5.827** | 10.772* | 0.163 | 11.422* |
| | ***Genotypes (G)*** | 63.545** | 95.547** | 53.982** | 30.230** | 67.778** | 6.290** | 7.325** | 8.093** | 13.992** | 18.178** | 6.010** |
| | ***Y x G*** | 2.804* | 2.412* | 2.958* | 1.739* | 3.554** | 1.732* | 3.060* | 2.064* | 2.164* | 12.595** | 2.452* |
| | | ***Mineral contents*** | | | | | | | | | | |
| | | ***Ca*** | ***Cu*** | ***Fe*** | ***K*** | ***Mg*** | ***Mn*** | ***Na*** | ***P*** | ***S*** | ***Zn*** | |
| ***2019*** | ***Block*** | | | | | | | | | | | |
| | ***Genotypes*** | 0.058 | 0.128 | 1.001 | 0.214 | 0.158 | 0.428 | 0.740 | 0.210 | 0.329 | 0.613 | |
| ***2020*** | ***Block*** | 16.257** | 7.095** | 7.051** | 178.145** | 12.379** | 6.245** | 14.533** | 125.410** | 84.080** | 23.328** | |
| | ***Genotypes*** | 2.576 | 0.022 | 2.914 | 0.626 | 1.013 | 2.054 | 1.250 | 0.879 | 0.872 | 3.235 | |
| ***Average of years*** | ***Year (Y)*** | 202.23** | 95397.260** | 0.072 | 1751.301** | 553.702** | 211.666** | 21.564* | 2546.175 | 1813.345** | 12.146* | |
| | ***Genotypes (G)*** | 18.97** | 3.923** | 5.210** | 110.275** | 9.646** | 9.148** | 10.891** | 71.768 | 42.687** | 17.967** | |
| | ***Y x G*** | 13.28** | 2.386* | 6.632** | 94.979** | 10.335** | 4.152** | 12.956** | 71.180 | 41.074** | 17.967** | |

**$P \leq 0.05$, ***$P \leq 0.01$*

When Figure 2 is examined for technological features, the Güzelöz genotype has the lowest values for the swelling index and unit volume weight parameters, while it has the highest values for parameters such as dry weight, dry volume, fresh weight, fresh volume, water absorption capacity, hydration capacity, and post-cooking disintegrated grain count.

Upon analyzing the average data for the first and second years, the following observations were made: the highest average dry weight of 68.61 g was obtained from the Güzelöz genotype, while the lowest value of 24.40 g was observed in the Alberto genotype; the highest average dry volume of 77.33 mL was obtained from the Güzelöz genotype, and the lowest dry volume of 19.67 mL was observed in the Berrak genotype; the highest average fresh weight of 151.96 g was observed in the Güzelöz genotype, and the lowest value of 52.33 g was found in the Alberto genotype; the highest average fresh volume of 137.33 mL was obtained from the Güzelöz genotype, while the lowest value of 46.67 mL was observed in the Alberto genotype; the highest average water absorption capacity of 0.904 g/grain was found in the Güzelöz genotype, and the lowest value of 0.229 g/grain was observed in the Alberto genotype; the highest average hydration index of 1.318% was observed in the Güzelöz genotype, and the lowest value of 0.951% was found in the Özdemir genotype; the highest average hydration coefficient of 121.2% was obtained from the Güzelöz genotype, while the lowest value of 84.4% was observed in the Özdemir genotype; the highest average swelling capacity of 0.792 mL/grain was observed in the Güzelöz genotype, and the lowest value of 0.345 mL/grain was found in the Özmen genotype; the highest average swelling index of 3.11% was observed in the Noyanbey 98 genotype, while the lowest value of 1.60% was found in the Güzelöz genotype; the highest average unit volume weight of 1.566 g/mL was observed in the Berrak genotype, and the lowest value of 0.817 g/mL was found in the Güzelöz genotype; the highest average cooking time of 47.33 minutes was observed in the Alberto genotype, while the lowest value of 27.33 minutes was found in the Aras 98 genotype; the highest average post-cooking disintegrated grain count of 26.667 was observed in the Noyanbey genotype, while the Önceler 98 variety showed no disintegration in both years.

In bean research, dry volume values have been reported by Yeken et al. (2019) as 60-100 mL, Çalışkan et al. (2018) as 43.8-56 mL, Ercan et al. (1994) as 13.0-36.0 mL, and Elkoca & Çınar (2015) as 101.3-17.3 mL. Çalışkan et al. (2018) reported water absorption capacity in beans as 0.51-0.25 g/grain. The values reported by Yalçın et al. (2018) and Kaya et al. (2016) are consistent with the results of this study. Swelling capacity in beans has been reported by Wani et al. (2017) as 0.09-0.28 mL/seed, Yeken et al. (2019) as 0.204-0.850 mL/grain, Çalışkan et al. (2018) as 0.87-0.45 mL/grain, Ercan et al. (1994) as 0.165-0.478 mL/grain, and Nadeem et al. (2020) as 0.10-1.445 mL/grain. Swelling index values in beans, as stated by Yeken et al. (2019), ranging from %1.692-9.00, show similarity. The values obtained in this research are higher than early stduies reported by Nadeem et al. (2020), Wani et al. (2017), and Çalışkan et al. (2018). The differences in technological traits could be attributed to using of different materials and climatic conditions of experimental area. Cooking times in beans have been reported by Wani et al. (2017) as 38.67-86.67 minutes, Yeken et al. (2019) as 26-100 minutes, Çalışkan et al. (2018) as 44-67.5 minutes, Ercan et al. (1994) as 22-36 minutes, and Nadeem et al. (2020) as 46.469-218.222 minutes. Özpekmez (2015) reported post-cooking disintegration degrees in beans as %0.33–12.00. Furthermore, the results obtained from the examined parameters align with the findings of many researchers (Yeken et al. (2019), Çalışkan et al. (2018), Biçer et al. (2017), Kaya et al. (2016), Ceyhan (2010), Öztaş et al. (2007), Ercan et al. (1994).

When examining the average data for the mineral content of bean genotypes grown under organic conditions for the first and second years (Figure 3), the calcium content reaches its highest value in the first year at 1914.48 ppm, obtained from the Noyanbey 98 variety. Following closely in the same statistical group are the Berrak with 1833.6 ppm, Dermason with 1809.6 ppm, Çomaklı with 1782.3 ppm, Batallı with 1613.0 ppm, and Aras 98 with 1592.0 ppm. The lowest value is observed in the second year at 811.9 ppm, obtained from the Özdemir variety. Studies on calcium values in beans by various researchers report values such as 3210-3771 ppm (Al-Numair et al. 2009), 970-1600 ppm (Pedrosa et al. 2015), 3800-9100 ppm (Kajiwara et al. 2021), 610-960 ppm (de Oliveira et al. 2018), 881-1162 ppm (Ramírez-Ojeda et al. 2018), 1320-1870 ppm (Ribeiro & Kläsener 2020), 826-1650 ppm (Wang et al. 2010), and 610-960 ppm (Ferreira et al. 2014). The results obtained in this study show similarity with the literature.

The highest copper content, at 22.74 ppm, is obtained from the Arslan variety in the second year, while the lowest value, at 3.74 ppm, is obtained from the Şahin 90 variety in the first year. The Noyanbey 98 variety with 3.92 ppm, Göynük 98 with 4.08 ppm, and Çomaklı with 4.41 ppm follow closely and are statistically in the same group. Studies on copper values in beans by various researchers report values such as 7.24 ppm (Akinyele & Shokunbi 2015), 6.8-5.2 ppm (Al-Numair et al. 2009), 3.1-14 ppm (de Oliveira et al. 2018), 5.5-9.9 ppm (Ramírez-Ojeda et al. 2018), 6.35-8.87 ppm (Ribeiro & Kläsener 2020), 2.9-9.9 ppm (Wang et al. 2010), and 3.1-14 ppm (Ferreira et al. 2014). While the first-year results from the experiment are in line with the literature, some second-year averages appear slightly higher compared to the mentioned sources.

When examining the averages for iron content, the highest value, at 111.99 ppm, is obtained from the Akman 98 variety in the first year, while the lowest value, at 24.55 ppm, is obtained from the Şahin 90 variety in the first year. Studies on iron values in beans by various researchers report values such as 48.75 ppm (Akinyele & Shokunbi 2015), 106.7-86.0 ppm (Al-Numair et al. 2009), 60.32-60.25 ppm (Pedrosa et al. 2015), 56-101 ppm (de Oliveira et al. 2018), 42-48 ppm (Ramírez-Ojeda et al. 2018), 53.52-65.80 ppm (Ribeiro & Kläsener 2020), 54.1-67.3 ppm (Wang et al. 2010), and 56-94 ppm (Ferreira et al. 2014). The results obtained are consistent with the literature.

The highest potassium content, at 13258 ppm, is obtained from the Akman 98 variety in the first year, followed closely by the Gömeç variety with 13137 ppm, and statistically, they are in the same group. The lowest value, at 7206 ppm, is obtained from the Adabeyazı variety in the second year. Studies on potassium values in beans by various researchers report values such as 13190-11510 ppm (Al-Numair et al. 2009), 13500-16750 ppm (Kajiwara et al. 2021), 10030-11340 ppm (Ribeiro & Kläsener 2020), 15050-12250 ppm (Wang et al. 2010), and 7400-9700 ppm (Ferreira et al. 2014). Our results are consistent with these studies.

The highest magnesium content, at 1700.8 ppm, is obtained from the Gömeç variety in the first year, followed by the Akman 98 variety with 1665.9 ppm. The lowest value, at 748.7 ppm, is obtained from the Aras 98 variety in the second year. Studies on magnesium values in beans by various researchers report values such as 3110-2890 ppm (Al-Numair et al. 2009), 1460-1040 ppm (Pedrosa et al. 2015), 1190-1770 ppm (Kajiwara et al. 2021), 1092-1289 ppm (Ramírez-Ojeda et al. 2018), 2200-2420 ppm (Ribeiro & Kläsener 2020), 1430-1995 ppm (Wang et al. 2010), and 530-700 ppm (Ferreira et al. 2014). The findings are in line with the literature.

The highest manganese content, at 17.71 ppm, is obtained from the Akman 98 variety in the first year, while the Dermason & Gömeç varieties have statistically higher average manganese content. The lowest value, at 5.80 ppm, is obtained from the Cihan variety in the second year. Studies on manganese values in beans by various researchers report values such as 13.58 ppm (Akinyele & Shokunbi 2015), 22.2-28.8 ppm (Al-Numair et al. 2009), 11-15 ppm (Ramírez-Ojeda et al. 2018), and 13.6-19.2 ppm (Wang et al. 2010). Our findings are in line with the literature.

When looking at the sodium content, the highest value, at 686.4 ppm, is observed in the Kızık variety in the second year, while the lowest value, at 189.8 ppm, is found in the Gömeç variety in the first year. Studies on sodium values in beans by various researchers report values such as 230-240 ppm (Al-Numair et al. 2009) and 200 ppm (Pedrosa et al. 2015).

The highest phosphorus content, at 4833 ppm, is obtained from the Gömeç variety in the first year, while the lowest value, at 1978 ppm, is obtained from the Aras 98 variety in the second year. Studies on phosphorus values in beans by various researchers report values such as 1850-2100 ppm (Al-Numair et al. 2009), 1320-1870 ppm (Ribeiro & Kläsener 2020), 3623-5020 ppm (Wang et al. 2010), and 3100-3700 ppm (Ferreira et al. 2014). Our results are consistent with the literature.

When examining the average values for sulfur content, the highest value, at 2673.7 ppm, is obtained from the Akman 98 variety in the first year, while the lowest value, at 993.8 ppm, is obtained from the Aras 98 variety in the second year. Studies on sulfur values in beans by de Oliveira et al. (2018) report values ranging from 1000 to 2300 ppm, and Ferreira et al. (2014) report values ranging from 1700 to 2000 ppm. Our results show similarity with these findings.

When examining the average values for zinc content in bean varieties, the highest value, at 60.63 ppm, is obtained from the Özdemir variety in the first year, while the lowest value, at 20.74 ppm, is obtained from the Aras 98 variety in the second year. Studies on zinc values in beans by Akinyele and Shokunbi (2015) report a value of 36.14 ppm, Al-Numair et al. (2009) report a range of 24.6-27.5 ppm, Pedrosa et al. (2015) report a range of 21.24-21.60 ppm, de Oliveira et al. (2018) report a range of 33-58 ppm, Ramírez-Ojeda et al. (2018) report a range of 21-37 ppm, Wang et al. (2010) report a range of 25.3-30.4 ppm, and Ferreira et al. (2014) report a range of 33-58 ppm. Our obtained results show similarity with the literature.

**Figure 2- Average data and Tukey groups for the technological traits of dry bean genotypes**

| Traits | Years | Genotypes | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Adabeyazı | Akman 98 | Alberto | Altın | Aras 98 | Arslan | Batallı | Berrak | Cihan | Çomaklı | Dermason | Gömeç | Göynük 98 | Güzelöz | Kızık | Noyanbey 98 | Önceler 98 | Özdemir | Özmen | Şahin |
| Dry weight (g) | 2019 | 33.03 e-h | 35.12 efg | 24.40 ı | 35.81 d-g | 36.77 def | 35.29 efg | 32.87 e-h | 26.96 hı | 43.39 cd | 28.40 ghı | 45.01 bc | 30.91 f-ı | 36.79 def | 68.61 a | 30.89 f-ı | 40.01 cde | 33.68 e-h | 52.43 b | 28.77 ghı | 32.49 e-h |
| | 2020 | 39.33 c-h | 36.39 c-ı | 34.83 d-ı | 36.35 c-ı | 38.05 c-h | 35.55 c-ı | 34.17 e-ı | 31.40 ghı | 41.53 b-e | 30.72 hı | 43.56 bcd | 32.08 ghı | 43.93 bc | 63.25 a | 32.73 f-ı | 41.20 c-f | 34.72 e-ı | 50.29 b | 28.68 ı | 39.61 c-g |
| Dry volume (ml) | 2019 | 24.0 efg | 24.0 efg | 16.0 h | 26.0 def | 25.3 ef | 24.7 efg | 24.0 efg | 17.3 gh | 33.3 cd | 18.7 fgh | 36.0 bc | 20.7 e-h | 25.3 ef | 64.0 a | 22.0 e-h | 27.3 de | 26.0 def | 41.3 b | 20.0 e-h | 23.3 e-h |
| | 2020 | 28.67 c-f | 27.33 def | 26.67 def | 33.33 cd | 28.00 c-f | 27.33 def | 22.67 ef | 22.00 ef | 33.33 cd | 22.67 ef | 37.33 bc | 21.33 f | 32.67 cd | 77.33 a | 24.00 def | 31.33 cde | 26.67 def | 46.67 b | 20.67 f | 29.33 c-f |
| Fresh weight (g) | 2019 | 66.60 e-ı | 72.29 d-ı | 52.33 ı | 73.91 c-h | 77.04 b-g | 69.97 e-ı | 67.08 e-ı | 56.33 ghı | 93.97 bc | 56.12 ghı | 92.63 bcd | 59.57 f-ı | 77.51 b-f | 151.96 a | 60.69 f-ı | 87.16 b-e | 69.67 e-ı | 96.85 b | 55.56 hı | 69.68 e-ı |
| | 2020 | 79.85 b-f | 72.73 c-h | 74.83 c-h | 76.63 c-g | 79.81 b-f | 68.93 d-h | 68.51 d-h | 58.53 gh | 85.72 bcd | 61.95 fgh | 82.99 b-e | 63.65 fgh | 90.84 bc | 132.83 a | 64.91 e-h | 86.04 bcd | 73.81 c-h | 98.17 b | 56.53 h | 83.91 bcd |
| Fresh volume (ml) | 2019 | 57.33 ef | 66.67b-f | 46.67 f | 73.33 b-e | 70.67 b-f | 68.00 b-f | 64.00 c-f | 50.67 ef | 85.33 bcd | 51.33 ef | 88.00 bc | 57.33 ef | 72.67 b-e | 137.33 a | 62.67 def | 84.67 bcd | 68.00 b-f | 89.33 b | 54.67 ef | 66.67 b-f |
| | 2020 | 76.00 b-f | 68.00 b-f | 70.00 b-f | 73.33 b-f | 76.67 b-e | 68.00 b-f | 64.67 c-f | 52.67 ef | 85.33 bc | 60.67 def | 78.67 bcd | 65.33 c-f | 85.33 bc | 124.00 a | 62.67 c-f | 83.33 bcd | 69.33 b-f | 92.00 b | 52.00 f | 70.67 b-f |
| Water absorption capacity (g/seed) | 2019 | 0.417 c-h | 0.399 e-h | 0.299 h | 0.426 c-g | 0.438 c-f | 0.413 d-h | 0.382 e-h | 0.306 gh | 0.536 bc | 0.335 fgh | 0.526 bcd | 0.346 fgh | 0.418 c-h | 0.904 a | 0.380 e-h | 0.478 b-e | 0.422 c-g | 0.584 b | 0.329 fgh | 0.393 e-h |
| | 2020 | 0.445 b-f | 0.389 d-h | 0.410 c-g | 0.414 c-g | 0.447 b-f | 0.379 e-h | 0.384 d-h | 0.351 gh | 0.442 b-f | 0.361 fgh | 0.527 b | 0.344 gh | 0.469 bcd | 0.804 a | 0.367 fgh | 0.462 b-e | 0.391 c-h | 0.479 bc | 0.307 h | 0.443 b-f |
| Hydration coefficient (%) | 2019 | 101.3 abc | 106.2 abc | 114.4 ab | 106.2 abc | 109.5 abc | 98.3 abc | 103.9 abc | 108.8 abc | 117.1 ab | 97.5 abc | 106.1 abc | 92.7 bc | 110.6 abc | 121.2 a | 96.4 abc | 117.9 ab | 106.9 abc | 84.4 c | 93.1 bc | 114.5 ab |
| | 2020 | 102.7 a-e | 99.9 a-e | 114.7 a | 110.8 abc | 109.5 abc | 93.7 cde | 100.2 a-e | 86.3 e | 106.6 a-d | 101.6 a-e | 90.3 de | 98.4 a-e | 106.8 a-d | 110.2 abc | 98.8 a-e | 109.3 abc | 112.6 ab | 95.1 b-d | 97.1 a-e | 112.2 abc |
| Swelling capacity (ml/seed) | 2019 | 0.416 cde | 0.457 b-e | 0.328 e | 0.531 b-e | 0.493 b-e | 0.517 b-e | 0.447 b-e | 0.347 de | 0.548 bcd | 0.397 cde | 0.576 bc | 0.443 b-e | 0.486 b-e | 0.792 a | 0.521 b-e | 0.582 bc | 0.492 b-e | 0.631 ab | 0.427 b-e | 0.458 b-e |
| | 2020 | 0.521 ab | 0.435 ab | 0.445 ab | 0.411 ab | 0.521 ab | 0.464 ab | 0.469 ab | 0.397 ab | 0.520 ab | 0.439 ab | 0.551 a | 0.485 ab | 0.527 ab | 0.538 a | 0.441 ab | 0.535 a | 0.427 ab | 0.453 ab | 0.345 b | 0.413 ab |
| Swelling index (%) | 2019 | 2.41 ab | 2.83 ab | 2.92 a | 2.84 ab | 2.79 ab | 2.76 ab | 2.67 ab | 2.93 a | 2.57 ab | 2.77 ab | 2.44 ab | 2.78 ab | 2.88 ab | 2.15 b | 2.85 ab | 3.11 a | 2.62 ab | 2.16 b | 2.74 ab | 2.86 ab |
| | 2020 | 2.65 a-d | 2.49 a-e | 2.65 a-d | 2.20 c-f | 2.75 abc | 2.50 a-e | 2.86 ab | 2.40 b-e | 2.56 a-e | 2.69 a-d | 2.10 def | 3.06 a | 2.61 a-d | 1.60 f | 2.65 a-d | 2.68 a-d | 2.61 a-e | 1.97 ef | 2.55 a-e | 2.36 b-e |
| Bulk density (g/ml) | 2019 | 1.377 abc | 1.483 abc | 1.525 ab | 1.389 abc | 1.457 abc | 1.431 abc | 1.369 abc | 1.566 a | 1.302 bcd | 1.533 ab | 1.250 cd | 1.497 abc | 1.457 abc | 1.072 d | 1.410 abc | 1.469 abc | 1.297 bcd | 1.269cd | 1.446 abc | 1.394 abc |
| | 2020 | 1.373 ab | 1.333 a-d | 1.320 a-d | 1.093 cde | 1.370 abc | 1.307 a-d | 1.513 a | 1.437 ab | 1.247 a-d | 1.367 abc | 1.167 bcd | 1.510 a | 1.343 a-d | 0.817 e | 1.380 ab | 1.320 a-d | 1.307 a-d | 1.080 de | 1.407 ab | 1.367 abc |
| Cooking time (min.) | 2019 | 33.00 abc | 42.67 g-j | 47.33 j | 35.33 b-ı | 34.67 b-ı | 34.33 b-ı | 45.67 ıj | 43.67 hıj | 38.33 d-g | 43.67 hıj | 42.00 f-ı | 33.67 bcd | 39.00 e-h | 36.67 cde | 38.33 d-g | 39.00 e-h | 28.00 a | 37.00 c-f | 33.00 abc | 30.33 ab |
| | 2020 | 44.00 e | 39.67 bcd | 36.33 bcd | 40.33 de | 27.33 a | 39.00 de | 42.33 de | 40.00 de | 30.67 abc | 39.00 de | 42.00 de | 35.67 bcd | 29.00 ab | 38.67 de | 40.00 de | 36.67 cde | 36.00 bcd | 36.00 bcd | 37.00 cde | 37.67 cde |
| Number of seeds destructed after cooking | 2019 | 6.333 de | 2.333 abc | 0.000 a | 4.333 bcd | 0.000 a | 4.667 cde | 1.000 ab | 0.333 a | 4.667 cde | 0.000 a | 0.000 a | 1.333 abc | 0.333 a | 1.667 abc | 0.667 a | 4.667 cde | 0.000 a | 0.333 a | 2.000 abc | 8.000 e |
| | 2020 | 12.000 abc | 2.667 ab | 2.667 ab | 9.333 abc | 16.000 abc | 14.667 abc | 6.667 ab | 1.333 a | 12.000 abc | 6.667 ab | 4.000 ab | 12.000 abc | 4.000 ab | 4.000 ab | 9.333 abc | 26.667 c | 0.000 a | 0.000 a | 6.667 ab | 21.333 bc |

**Figure 3- Average data and Tukey groups for the mineral contents of dry bean genotypes**

| Element | Years | Genotypes | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Adabeyazı | Akman 98 | Alberto | Altın | Aras 98 | Arslan | Batallı | Berrak | Cihan | Çomaklı | Dermason | Gömeç | Göynük 98 | Güzelöz | Kızık | Noyanbey 98 | Önceler 98 | Özdemir | Özmen | Şahin |
| Ca (ppm) | 2019 | 1413.8 cde | 1474.9 b-e | 1505.6 b-e | 1328.6 de | 1592.0 a-e | 1290.1 de | 1613.0 a-d | 1833.6 ab | 1392.3 de | 1782.3 abc | 1809.6 ab | 1312.2 de | 1358.3 de | 1276.5 de | 1242.3 de | 1914.5 a | 847.1 fg | 811.9 g | 1505.6 b-e | 1215.0 ef |
| | 2020 | 1157.9 d-h | 1247.4 b-f | 1161.8 d-h | 1299.6 a-e | 1002.8 ghı | 1509.8 a | 1227.6 c-g | 1193.3 c-g | 1003.3 ghı | 1048.5 f-ı | 1158.1 d-h | 1240.1 b-g | 952.4 hı | 1416.2 abc | 1136.3 e-h | 1384.4 a-d | 840.8 ı | 1114.2 e-h | 1470.6 ab | 1313.2 a-e |
| Cu (ppm) | 2019 | 5.63 bc | 8.59 a | 5.76 bc | 5.43 bc | 4.60 bc | 5.32 bc | 6.79 ab | 4.85 bc | 5.00 bc | 4.41 c | 5.35 bc | 6.75 ab | 4.08 c | 5.27 bc | 5.26 bc | 3.92 c | 5.17 bc | 5.06 bc | 4.64 bc | 3.74 c |
| | 2020 | 18.00 ab | 21.30 ab | 19.41 ab | 19.58 ab | 17.14 b | 22.74 a | 19.61 ab | 22.11 ab | 19.87 ab | 19.59 ab | 17.93 ab | 19.52 ab | 17.79 ab | 21.77 ab | 21.69 ab | 19.04 ab | 20.99 ab | 21.23 ab | 18.50 ab | 19.49 ab |
| Fe (ppm) | 2019 | 27.38 cd | 111.9 a | 42.97 bcd | 30.91 cd | 85.48 ab | 30.50 cd | 61.36 bcd | 58.62 bcd | 46.95 bcd | 43.32 bcd | 38.56 cd | 67.30 bc | 34.19 cd | 44.71 bcd | 39.53 cd | 39.05 cd | 40.07 cd | 37.98 cd | 45.99 bcd | 24.55 d |
| | 2020 | 34.41 b | 45.52 b | 47.42 b | 38.52 b | 38.97 b | 83.34 a | 45.61 b | 50.37 b | 36.25 b | 40.02 b | 41.04 b | 43.49 b | 39.22 b | 54.79 ab | 48.03 b | 64.59 ab | 48.52 b | 37.08 b | 49.30 b | 49.73 b |
| K (ppm) | 2019 | 8912 fgh | 13258 a | 8745 ghı | 8772 ghı | 9036 efg | 8350 hıj | 8941 fg | 9027 efg | 9571 cde | 9409 def | 11494 b | 13137 a | 8327 hıj | 9785 cd | 9683 cd | 9282 d-g | 10063 c | 8038 j | 9665 cd | 8365 ıj |
| | 2020 | 7206 g | 8488 b-e | 8603 bcd | 8533 b-e | 7439 fg | 9074 b | 8795 bcd | 8287 de | 8275 de | 8389 cde | 8827 bcd | 8369 cde | 8538 b-e | 10285 a | 8694 bcd | 8700 bcd | 9929 a | 8852 bcd | 8930 bc | 7964 ef |
| Mg (ppm) | 2019 | 1094.8 bc | 1665.9 a | 1143.3 bc | 1031.7 bc | 1061.1 bc | 1010.9 bc | 1191.2 bc | 1029.0 bc | 1007.8 bc | 974.2 bc | 1302.0 b | 1700.8 a | 936.6 c | 1140.9 bc | 1107.5 bc | 1022.5 bc | 1169.9 bc | 896.9 c | 1018.8 bc | 869.9 c |
| | 2020 | 797.7 bc | 836.2 abc | 899.3 abc | 959.6 ab | 748.7 c | 1030.1 a | 933.5 abc | 787.7 bc | 821.1 bc | 861.7 abc | 866.4 abc | 846.0 abc | 786.0 bc | 926.1 abc | 836.3 abc | 866.6 abc | 1035.5 a | 915.7 abc | 890.2 abc | 874.0 abc |
| Mn (ppm) | 2019 | 9.21 bcd | 17.71 a | 11.32 bcd | 9.27 bcd | 9.55 bcd | 9.00 cd | 11.69 bcd | 11.80 bcd | 9.89 bcd | 10.72 bcd | 12.91 abc | 14.21 ab | 8.74 cd | 11.44 bcd | 11.82 bcd | 11.25 bcd | 9.14 bcd | 6.93 d | 11.81 bcd | 8.43 cd |
| | 2020 | 7.55 c-g | 8.64 a-e | 8.73 a-e | 7.63 b-g | 6.21 fg | 9.88 a | 8.90 a-e | 9.33 abc | 5.80 g | 9.11 a-d | 8.27 a-e | 9.10 a-d | 6.90 efg | 9.23 abc | 8.65 a-e | 7.86 a-f | 7.08 d-g | 6.96 efg | 9.61 ab | 7.67 b-g |
| Na (ppm) | 2019 | 308.0 bc | 555.1 a | 350.9 bc | 193.1 c | 303.3 bc | 313.3 bc | 320.2 bc | 228.9 c | 266.2 c | 234.7 c | 229.5 c | 189.8 c | 262.0 c | 196.9 c | 227.6 c | 203.8 c | 495.0 ab | 588.3 a | 574.6 a | 584.4 a |
| | 2020 | 364.5 bc | 453.9 bc | 369.2 bc | 302.8 c | 348.6 bc | 388.2 bc | 314.8 bc | 362.1 bc | 403.5 bc | 310.5 bc | 408.1 bc | 325.1 bc | 317.6 bc | 466.9 bc | 686.4 a | 354.0 bc | 479.0 b | 314.8 bc | 329.8 bc | 317.9 bc |
| P (ppm) | 2019 | 3146 c-f | 4447 b | 2756 g-j | 3147 c-f | 2966 efg | 3057 def | 2737 g-j | 2898 f-ı | 3127 c-f | 2930 e-h | 3349 c | 4833 a | 2313 k | 3317 cd | 2970 efg | 2516 jk | 3118 c-f | 2617 ıj | 3187 cde | 2661 hıj |
| | 2020 | 2211 ef | 2179 ef | 2548 bcd | 2687 abc | 1978 f | 2844 a | 2433 cde | 2507 bcd | 2275 de | 2358 de | 2365 de | 2464 cde | 2322 de | 2981 a | 2338 de | 2259 def | 2785 ab | 2543 bcd | 2796 ab | 2384 de |
| S (ppm) | 2019 | 1416.9 h-k | 2673.7 a | 1388.3 h-k | 1634.7 fgh | 1622.4 fgh | 1364.7 ıjk | 2354.9 b | 2239.6 bc | 1964.5 de | 1018.6 l | 2030.2 cd | 2289.1 bc | 1186.4 kl | 1734.6 ef | 1451.0 g-j | 1447.4 g-k | 1239.6 jkl | 1460.1 g-j | 1680.1 fg | 1229.5 jkl |
| | 2020 | 1026.9 bc | 1162.7 abc | 1161.2 abc | 1149.6 abc | 993.8 c | 1248.4 abc | 1159.6 abc | 1182.2 abc | 1051.0 abc | 1147.9 abc | 1174.3 abc | 1134.3 abc | 1069.4 abc | 1236.5 abc | 1059.5 abc | 1206.8 abc | 1272.4 ab | 1033.4 | 1300.5 a | 1153.1 abc |
| Zn (ppm) | 2019 | 27.12 efg | 40.98 bcd | 26.08 efg | 24.88 efg | 27.51 ef | 24.05 efg | 42.48 bc | 26.34 efg | 31.64 cde | 16.02 g | 30.43 def | 46.79 b | 19.05 fg | 25.61 efg | 28.37 ef | 23.10 efg | 26.08 efg | 60.63 a | 27.37 efg | 28.44 ef |
| | 2020 | 23.84 bc | 26.76 abc | 27.47 abc | 26.37 abc | 20.74 c | 31.71 ab | 27.98 abc | 30.25 ab | 25.48 bc | 23.70 bc | 29.64 ab | 23.83 bc | 23.29 bc | 34.45 a | 29.80 ab | 26.71 abc | 34.23 a | 26.53 abc | 30.75 ab | 28.30 abc |

The scatterplot and correlation analysis outputs for the examined parameters are presented in Figure 4. Red circles indicate a positive relationship between parameters, while blue circles represent a negative relationship. The size of the circle reflects the strength of the relationship. Additionally, the scatterplot analysis output shows five different-colored scatterings, representing five different groups obtained from cluster analysis. The fitted line in the analysis also illustrates the relationship between two parameters. Among the technological parameters, both positive and negative high-level relationships were observed. Similar relationships were also observed among mineral content parameters. When examining the relationships between technological and mineral content parameters, especially for the cooking time, positive correlations were found with Ca content (r= 0.538), positive relationships with Cu, Fe, Mn, and S elements, and a negative relationship with Na element. Negative relationships were observed between the hydration coefficient (r= -0.352) and water absorption index (r= -0.310) with Zn content. Positive relationships were observed between bulk density and Ca, Fe, and Mn contents. Swelling index showed positive relationships with Ca and Mn contents, and a negative relationship with Zn. Negative relationships were also observed between dry weight and dry volume with Ca content. The findings obtained are consistent with the results found by many researchers (Rodríguez Madrera et al. 2024; Ozaktan 2021; Ozaktan & Doymaz 2022).

Principal component analysis (PCA) is a versatile statistical method used to reduce the state-by-variables data table to its basic characteristics called principal components, which are several linear combinations of the original variables that maximally explain the variance of all variables (Greenacre et al. 2022). The biplot analysis output for the technological characteristics and mineral content of 20 different bean genotypes is presented in Figure 5. The colored circles in Figure 5 represent the positions of genotypes on the biplot resulting from the cluster analysis of the examined parameters. In PCA analysis, the lengths of the axes, their positions, and the angles with other axes express relationships. In the biplot analysis obtained from the two-year averages, 22 independent principal components were identified, with PC1 and PC2 values being 32.1% and 24.5%, respectively. In PC1, descriptors with high impact values were dry weight, dry volume, fresh weight, fresh volume, water absorption capacity, and swelling capacity; in PC2, Mg, K, S, P, Cu, Mn, and Fe were the descriptors with the highest impact values (Table 2). The axes of fresh weight, fresh volume, dry weight, dry volume, water absorption capacity, and swelling capacity were positioned in the same region, forming low-degree angles among them, and the sufficiently long axes indicated a high positive relationship between these parameters. Findings obtained by is compatible with the literature (Ozaktan 2021; Ozaktan & Doymaz 2022). Kibar (2019) reported that the first two PCs explained 58.45% of the total variance in principal component analysis for biochemical properties (mineral, ash, protein, pH) of wheat. He reported that the first principal component (PC1), accounted for 35.72% of the variance and was associated with K, P, Ca, Mn, Co, As, Pb, Ni, Cr, protein and pH contents and the second principal component (PC2) accounted for 22.73% of the mineral composition consisting of Na, Fe, Sn and Cd contents. Additionally, the genotype Güzelöz, located within the pink-lined circle, had the highest values for these parameters, followed by the Özdemir genotype. When examining the position, length, and angles between the axes formed by Mg, K, S, P, Cu, Mn, and Fe parameters, a high positive relationship between them was observed. Furthermore, the genotypes Gömeç and Akman were identified as leading genotypes with the highest values for these mineral contents. Positive relationships were observed between the Ca mineral and cooking time, with the Batallı genotype having the longest cooking time among the genotypes located in the same region and approximately the same axis length. Analyzing the biplot output of the cluster analysis on the examined parameters to determine the relationship between genotypes, it is observed that Güzelöz, Akman 98, and Gömeç varieties are distinct from the other varieties.

**Table 2- Eigen values, percent and cum percent, for investigated characteristics**

| ***Number*** | ***Eigenvalue*** | ***Percent*** | ***Cum Percent*** |
|---|---|---|---|
| **1** | 7.058311 | 32.083 | 32.083 |
| **2** | 5.394635 | 24.521 | 56.604 |
| **3** | 2.535145 | 11.523 | 68.128 |
| **4** | 1.668333 | 7.583 | 75.711 |
| **5** | 1.056192 | 4.801 | 80.512 |
| **6** | 0.931535 | 4.234 | 84.746 |
| **7** | 0.841928 | 3.827 | 88.573 |
| **8** | 0.641969 | 2.918 | 91.491 |
| **9** | 0.423336 | 1.924 | 93.415 |
| **10** | 0.364414 | 1.656 | 95.072 |
| **11** | 0.287439 | 1.307 | 96.378 |
| **12** | 0.239557 | 1.089 | 97.467 |
| **13** | 0.211780 | 0.963 | 98.430 |
| **14** | 0.165151 | 0.751 | 99.181 |
| **15** | 0.079363 | 0.361 | 99.541 |
| **16** | 0.052090 | 0.237 | 99.778 |
| **17** | 0.034666 | 0.158 | 99.936 |
| **18** | 0.009674 | 0.044 | 99.980 |
| **19** | 0.002581 | 0.012 | 99.991 |
| **20** | 0.001115 | 0.005 | 99.996 |
| **21** | 0.000724 | 0.003 | 100.000 |
| **22** | 0.000062 | 0.000 | 100.000 |

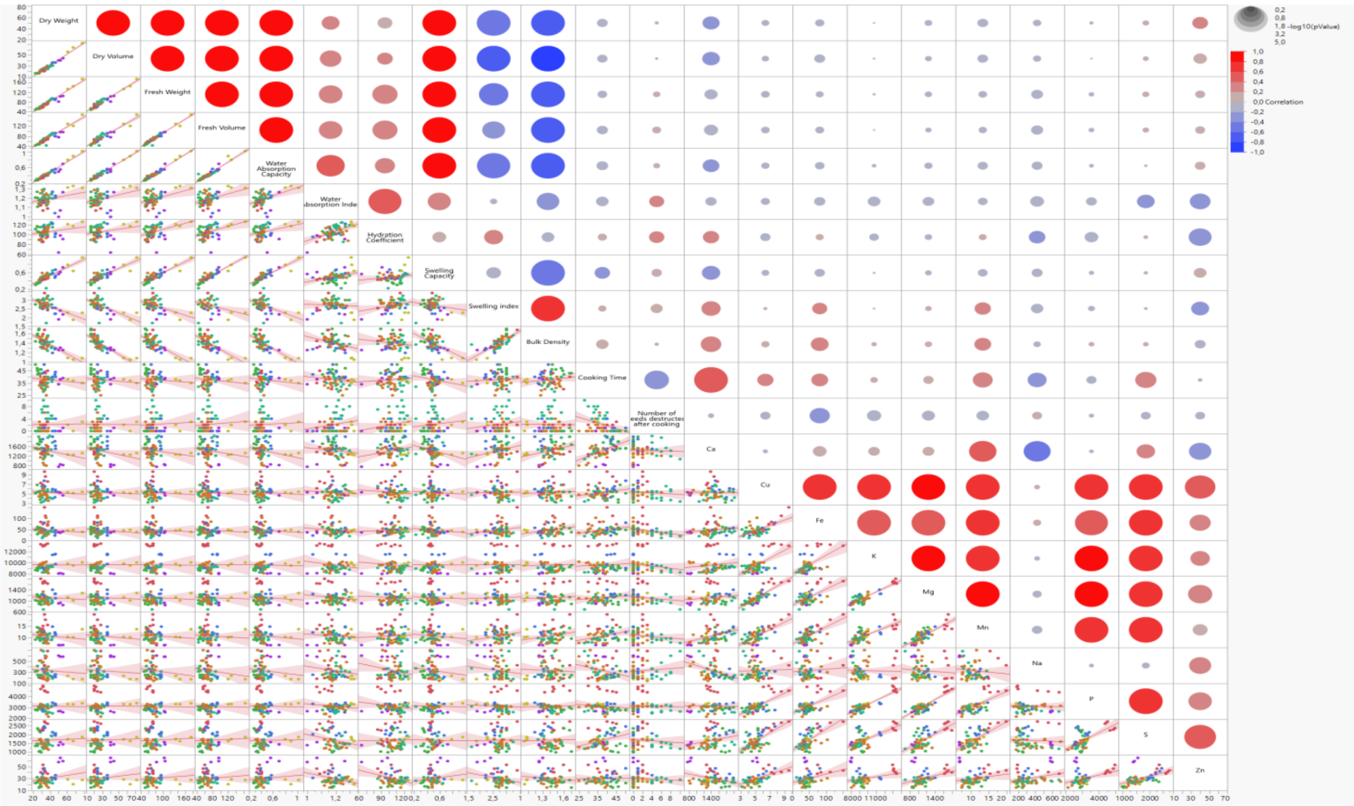

**Figure 4- Scatterplot matrix for overview of correlations and fit lines**

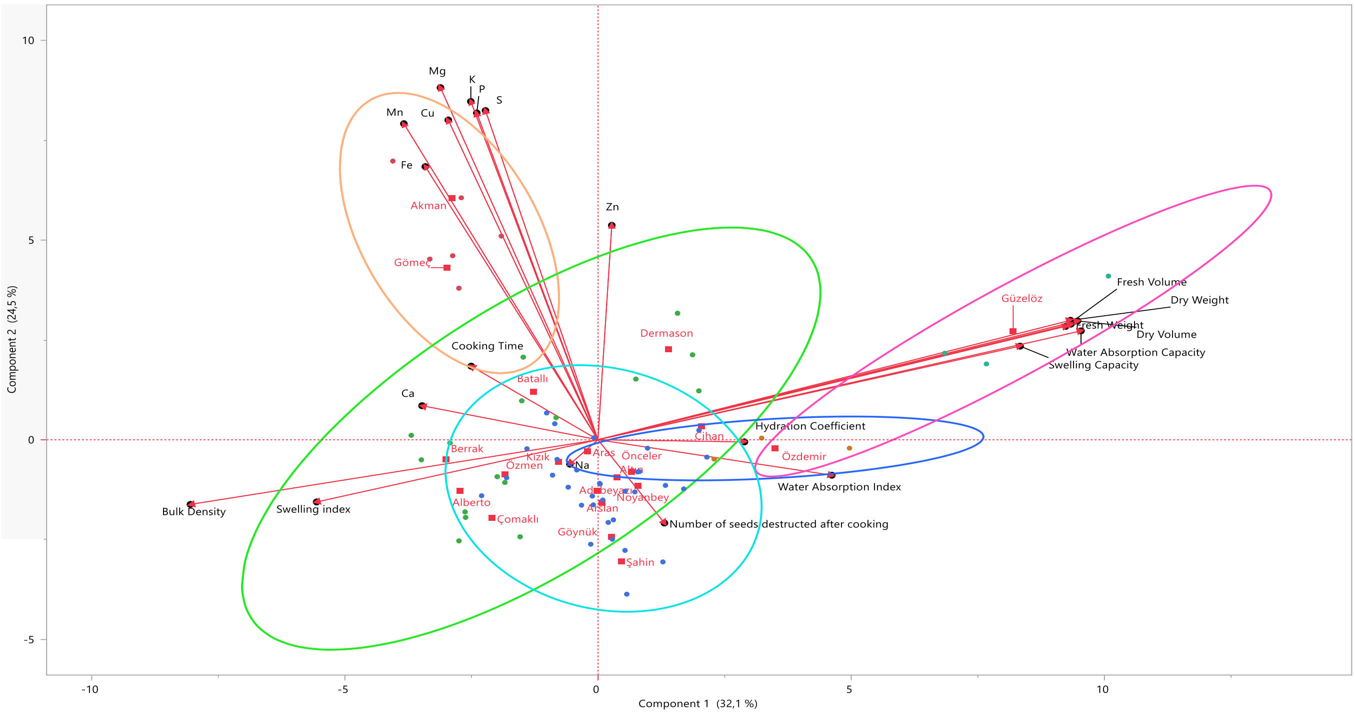


**Figure 5- The groups formed by biplot analysis on dry bean genotypes and the examined parameters**

## 4. Conclusions

In this study, which evaluated the mineral composition and technological characteristics of 20 bean genotypes grown under organic conditions, genotypes were clustered into 5 different groups. Among the genotypes, Güzelöz differed from the other genotypes in terms of the analyzed characteristics. There was a positive relationship between cooking time and Ca mineral. There was a negative relationship between the coefficient of hydration and water absorption capacity and Zn mineral. A positive correlation was found between each of the elements Fe, Mn, Cu, Mg, K, P and S with all other elements. Especially when examining mineral matter in beans, reading one of the elements K, P and S can give us information about the other two elements. Likewise, examining one of the dry weight, dry volume, wet weight, wet volume, water absorption capacity and swelling index values, which are clustered in the same region and have approximately the same axis length, can save time and consumable. The zinc, sodium, iron, and copper contents in the beans grown under organic conditions were found to be higher than the data reported in the literature.

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**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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