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The Effect of Microbial Fertilizers on Technological Characteristics of Some Cowpea (*Vigna unguiculuta* L. *Walp.*) Cultivars

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ABSTRACT

Cowpea (*Vigna unguiculata* L. Walp.) is an annual herbaceous plant in the *Fabaceae* family. It is an important legume plant with 20-25% protein, 1.3-1.5% fat and 5.1-5.8% fiber, and has an important place in human and animal nutrition. In recent years, the rapid increase in the world population, the zoning of agricultural areas and the excessive use of chemical fertilizers in order to obtain higher yields from the unit area cause deterioration of the soil structure. Different methods have started to be applied to improve soil structure. One of these methods is the use of microbial fertilizers. Microbial fertilizers are an innovative and sustainable approach that improves chemical, physical and microbiological properties of soil and facilitates the uptake of plant nutrients. In this study, it was aimed to determine the effect of different microbial fertilizer applications on the technological characteristics of Akkız 86 and Karagöz 86 cowpea varieties by multivariate analysis methods. The minimum and maximum values obtained in the study are as follows: dry weight 17.98 - 19.29 g, dry volume 18.16 - 20.66 ml, fresh weight 42.15 - 46.53 g, fresh volume 44.16 - 47.83 ml, water absorption capacity 0.24 - 0.27 g/piece, water absorption index 1.33 - 1.66%, hydration coefficient 132.80 - 142. 55%, swelling capacity 0.256 - 0.296 ml/grain, swelling index 2.25 - 2.63%, unit volume weight 0.93 - 0.99 g/ml, cooking time 18.16 - 20.16 min and number of grains dispersed after cooking 0.33 - 2.66. In this study, İmed microbial fertilizer applied to cowpea plant had positive effects on cooking time, water absorption index, swelling index and swelling capacity parameters.

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Introduction

Cowpea (*Vigna unguiculata* L. *Walp.*), an annual herbaceous plant, is distributed in the tropical regions of Africa, South Asia and Latin America and is included in the *Fabaceae* family (Baukar et al., 2018). The Fabacea family, known as the largest group of flowering plants, consists of approximately 700 genera and 18,000 species, and the genus *Vigna* includes 80 species (Ovalıoğlu, 2023). In the cowpea plant, which has a taproot system, the main root is more developed than the side roots, and the cowpea, whose stem resembles the bean plant, has different growth forms such as erect, semi- prostrate, creeping and clumbing. The flowers of the self-fertilized cowpea plant have white and blue colors, depending on the variety. The fruits of cowpea plant vary in flat, cylindrical and decurved. In addition, the number of pods in the plant varies between 7-23 depending on the variety and environmental conditions (Çiftçi and Adak, 2011).

Carbohydrates, fats and proteins are among the basic nutrients required for people to sustain their lives in a healthy way. In the world and in Turkey, edible grain legumes constitute the basis of plant-based proteins and meat 22% of the vegetable proteins used in human nutrition and 38% of the proteins used in animal nutrition (Tosun, 2024; Şahin, 2016). The dry grains of cowpea have high nutritional content in terms of human nutrition, and the protein, fat and fiber ratio varies according to the variety and growing region conditions. The protein content between 20% and 25%, fat was between 1.3% and 1.5% and fiber rate between 5.1-5.8% (Tshovhote et al., 2003). Cowpea is consumed as dry grain and vegetable and used as a feed source in animal nutrition. İt contributes the nitrogen that is free in the atmosphere and the nitrogen fixation that cannot be used directly by the plant in the soil

to the soil by forming nodules through nitrogen-fixing bacteria. In addition, cowpea is considered as a cover crop for soil erosion protection and weed control since it has a morphologically spreading form (Wortman and Dawson, 2015).

The use of biological fertilizers is becoming increasingly important for sustainable agriculture. Biological fertilizers has accelerated the uptake of plant nutrients by improving soil structure and increasing symbiotic life activities (Wei et al., 2024). Microbial fertilizers are among the biological methods using beneficial bacteria, fungi and other organisms. In studies, microbial fertilizer applications provide 15-30% yield increase in legumes (Stamenković et al., 2018). Microorganisms, which are naturally found in the rhizosphere, positively affect the cultivated plants, increase productivity and increase the resistance of plants against pathogens and promote plant growth, are found in nutrient-rich soil regions (Avan and Kotan, 2021).

Cowpea is recognized as a source of high quality vegetable protein in many countries around the world. It is known as a plant food with high nutritional value and low energy density (Ton and Anlarsal, 2018). On a dry weight basis, cowpea grain contains an average of 50-60% carbohydrate (Jayathilake et al., 2018). Although cowpea is a low-cost source of energy and protein, its nutritional value is limited due to the presence of anti-nutritional compounds that can have a negative impact on human and animal nutrition (Ton, 2023). These anti-nutritional compounds may include trypsin inhibitors, tannins, phytic acids, lectins, protease inhibitors and flatus-producing oligosaccharides. If it is consumed regularly, these anti-nutritional compounds can lead to toxin accumulation and have harmful health effects. These compounds can disrupt the functioning of metabolism in the human body and make nutrients difficult to digest (Abebe and Alemayehu, 2022). The effects of these anti-nutritional compounds can be easily and cheaply removed by methods such as germination, soaking or cooking. Heat treatments such as cooking are an effective method to eliminate the effects of trypsin inhibitors (Ibrahim et al., 2002). Legumes such as cowpea are usually ready for consumption after cooking. Cooking both increases digestibility by reducing the effect of anti-nutritional compounds and improves flavor. A short cooking time is a desirable feature for consumers and those who produce processed products such as canned products, as a long cooking time will cause more energy consumption. Cooking time in legumes is thought to be a hereditary trait, but growing conditions, environment and storage conditions are other factors affecting cooking time (Wood, 2017). For this reason, it is important for legume producers to develop new varieties to shorten the cooking time in legumes or to determine agricultural practices that shorten the cooking time in order to use energy efficiently and to provide products that can be cooked in a short time in accordance with the demands of the market.

In this study conducted in Kayseri ecological conditions, different microbial fertilizer varieties were applied to cowpea plant and it was aimed to examine their effects on the technological characteristics of the seeds.

Material and Method

The cowpea grains obtained from the research conducted in the experimental plots of Erciyes University Agricultural Research and Application Center in 2022 according to the split plots experimental design in randomized blocks were used. Experiments were set on 27th of May 2022, with a hand marker and sowing was performed as to have 0.45 m row spacing and 0.10 m on-row plant spacing. In the study, Akkız 86 and Karagöz 86 cowpea varieties were used as plant material, while commercial fertilizers named Omed, İmed, Omed+4 and Çim+14-3, which have nitrogen-fixing and phosphorus solubilizing effects, were used as microbial fertilizers. While İmed is a liquid microbial fertilizer containing *Bacillus nitratireducens* strains isolated from our country's soil, Omed is a liquid microbial fertilizer containing *Bacillus thuringiensis, Bacillus simplex, Bacillus amyloliquefaciens* strains isolated from our country's soil. Dry weight, fresh weight, water absorption capacity, water absorption index, dry volume, fresh volume, swelling capacity, swelling index, hydration coefficient, cooking time and number of grains dispersed after cooking were examined according to (Özaktan 2021). The data were subjected to analysis of variance with the "JMP 17.0 Pro" statistical package program. The mean values of the treatments were compared with the Tukey multiple comparison test (Özaktan and Doymaz, 2022).

Results and Discussion

The results of the analysis of variance for dry weight, dry volume, fresh weight, fresh volume, cooking time and number of grains dispersed after cooking among the technological characteristics of the seeds obtained from different microbial fertilizers applied on two different cowpea varieties are given in Table 1.; The analysis of variance for water absorption capacity, swelling index, hydration coefficient, swelling capacity, water absorption index and unit volume weight values are given in Table 2.

Among the sources of variation, the effect of bacteria treatment and cultivar*bacteria interaction on dry weight was found significant at 1% level. The highest value (19.29 g) was obtained from Omed microbial fertilizer and it was in the same statistical group with Omed+4 (18.85 g) and Çim+14-3 (18.77 g) microbial fertilizers. When the cultivar*bacteria interaction was examined, the highest value with 19.65 g was obtained from Omed+4 application in Karagöz 86 cultivar, while the values obtained as a result of Omed application in Akkız 86 (19.64 g) and Karagöz 86 (18.94 g) cultivars were statistically in the same group.

Among the sources of variation, the effect of bacteria and cultivar*bacteria interaction on the dry volume parameter was statistically significant at 1% level, while the effect of cultivar was significant at 5% level. According to the general averages of the varieties were examined, Karagöz 86 variety was recorded as 19.47 ml and Akkız 86 variety as 18.87 ml. According to the general averages of bacteria were examined, the highest value was recorded in Omed microbial fertilizer application with 20.67 ml, followed by Omed+4 microbial fertilizer application with 19.50 ml.

Table 1. Averages and Tukey groups of Dry weight, Dry volume, Fresh weight, Fresh volume, Cooking time, Number of grains dispersed after cooking in some cowpea varieties of different microbial fertilizer sources

		DW	DW	FW	FW	CT	NGD
Akkız 86	Omed	19.64 a	22.00 a	47.48 a	48.27 ab	17.67 d	3.33
	İmed	18.25 bc	17.67 cd	42.57 cd	46.00 abc	18.67 bcd	0.00
	Omed+4	18.05 bc	18.67 bcd	42.32 cd	47.00 ab	20.00 ab	0.00
	Çim+14-3	18.96 ab	18.67 bcd	46.38 ab	48.67 ab	18.33 cd	0.67
	Control	17.62 c	17.33d	42.37 cd	44.00 bc	18.67 bcd	0.67
Karagöz 86	Omed	18.94 ab	19.33 bc	45.58 ab	44.67 abc	19.33 abc	2
	İmed	17.78 c	18.67 bcd	44.78 bc	49.67 a	17.67 d	2.00
	Omed+4	19.65 a	20.33 ab	45.39 ab	46.33 abc	20.33 a	0.67
	Çim+14-3	18.58 bc	19.33 bc	44.10 bcd	41.67 c	19.00 a-d	1.33
	Control	18.34 bc	19.67 b	41.94 d	44.33 bc	19.67 abc	1.33
General Average							
Bacteria	Omed	19.29 A	20.67 A	46.53 A	46.47 AB	18.50 BC	2.67
	İmed	18.02 B	18.17 C	43.67 BC	47.83 A	18.17 C	1.00
	Omed+4	18.85 A	19.50 B	43.86 B	46.67 AB	20.17 A	0.33
	Çim+14-3	18.77 A	19.00 BC	45.24 AB	45.17 AB	18.67 BC	1.00
	Control	17.98 B	18.50 BC	42.16 C	44.17 B	19.17 B	1.00
Cultivar	Akkız 86	18.50	18.87 *B*	44.22	46.79	18.67	0.93
	Karagöz 86	18.66	19.47 *A*	44.36	45.33	19.20	1.47
Sum of Squares							
Sources of Variation	Block	0.53331	3.26667	0.88071	1.256	1.26667	10.4
	Cultivar (A)	0.17941	2.7*	0.13669	15.8413	2.13333	2.13333
	Error1	0.02899	0.2	1.27589	3.12267	0.46667	13.0667
	Bacteria (B)	7.71432**	23**	66.3094**	48.3653*	14.5333**	18.1333
	AxB	5.75792**	22.4667**	34.8995*	98.0987*	5.86667*	8.53333
	Error2	1.77704	6.533333	12.91755	47.248	3.6	40.533333
	General	15.99099	58.16667	116.4197	213.932	27.866667	92.8

*,** It is statistically significant at the 0.05 and 0.01 probability levels, respectively; DW: Dry Weight (g); DW: Dry Volume (ml); FW: Fresh Weight (g); FW: Fresh Volume (ml); CT: Cooking Time (min.); NGD: Number of Grains Dispersed After Cooking (pcs.)

Table 2. Averages and Tukey groups of Water absorption capacity, Swelling index, Hydration coefficient, Swelling capacity, Water absorption index, Unit volume weight values of some cowpea varieties of different microbial fertilizer sources

		WAC	SI	HC	SC	WAI	UVW
Akkız 86	Omed	0.278 a	2.201 cd	141.78 abc	0.263 abc	1.337 bc	0.894 b
	İmed	0.243 de	2.606 ab	133.22 cde	0.283 ab	1.552 ab	1.034 a
	Omed+4	0.243 de	2.519 abc	134.61 b-e	0.283 ab	1.572 ab	0.968 ab
	Çim+14-3	0.274 ab	2.607 ab	144.62 ab	0.300 ab	1.582 ab	1.016 a
	Control	0.248 cde	2.539 abc	140.50 bcd	0.267 abc	1.514 ab	1.017 a
Karagöz 86	Omed	0.266 abc	2.317 a-d	140.79 bcd	0.253 bc	1.337 bc	0.982 ab
	İmed	0.270 ab	2.665 a	151.89 a	0.310 a	1.744 a	0.953 ab
	Omed+4	0.257 bcd	2.281 bcd	130.99 de	0.260 abc	1.323 bc	0.967 ab
	Çim+14-3	0.255 b-e	2.154 d	137.34 b-e	0.223 c	1.202 c	0.961 ab
	Control	0.236 e	2.255 cd	128.65 e	0.247 bc	1.345 bc	0.933 ab
General Average							
Bacteria	Omed	0.272 A	2.259 B	141.29 A	0.258 B	1.337 B	0.938
	İmed	0.257 BC	2.635 A	142.55 A	0.297 A	1.648 A	0.993
	Omed+4	0.250 CD	2.399 B	132.80 B	0.272 AB	1.447 B	0.967
	Çim+14-3	0.265 AB	2.381 B	140.98 A	0.262 B	1.392 B	0.989
	Control	0.242 D	2.397 B	134.57 B	0.257 B	1.429 B	0.975
Cultivar	Akkız 86	0.257	2.494 A	138.94	0.279	1.511	0.986 A
	Karagöz 86	0.257	2.334 B	137.93	0.259	1.390	0.959 B
Sum of Squares							
Sources of Variation	Block	0.00023	0.06532	179.169	0.00072	0.03684	0.00547*
	Cultivar (A)	0.00	0.19218*	7.65206	0.00316	0.10958	0.00527*
	Error1	0.00012	0.01607	33.4349	0.00039	0.01282	0.00014
	Bacteria (B)	0.00347**	0.44765*	469.256*	0.0066*	0.33536*	0.01156
	AxB	0.00236**	0.34689*	826.586**	0.00827*	0.29796*	0.03121*
	Error2	0.00080026	0.2197277	202.0318	0.00561013	0.13555244	0.02312068
	General	0.00698858	1.2878371	1718.1304	0.02474987	0.9281147	0.07676692

*,** It is statistically significant at the 0.05 and 0.01 probability levels, respectively; WAC: Water Absorption Capacity (g/grain); SI: Swelling Index (%); HC: Hydration Coefficient (%); SC: Swelling Capacity (ml/grain); WAI: Water Absorption Index (%); UVW: Unit Volume Weight (g/ml)

When the mean values obtained from the cultivar×bacteria interaction were examined, the highest and lowest values were obtained from Omed (22.00 ml) and control (17.33 ml) treatments for Akkız 86 cultivar, respectively.

Among the sources of variation on fresh weight parameter, bacteria application was found to be significant at 1% level and cultivar*bacteria interaction at 5% level. When the general averages of bacteria were analyzed, the highest value was obtained from Omed treatments while the lowest value was obtained from the control group. When the mean values of variety-bacteria interaction were analyzed, the highest value (47.48-45.58 g) was obtained from Omed treatments in both varieties.

When the fresh volume parameter was analyzed, bacteria and cultivar*bacteria interactions were found to be significant at 5% level. When the general mean values of the bacteria treatments were examined, the highest fresh volume value (47.8 ml) was obtained in the case where İmed microbial fertilizer was applied, while the cases where Omed, Omed+4 and Çim+14-3 microbial fertilizers were applied were in the same statistical group. When the cultivar*bacteria interaction was examined, the highest value (49.67) was obtained when Imed microbial fertilizer was applied to Karagöz 86 cultivar. The closest value to this value (48.67) was obtained when Çim+14-3 microbial fertilizer was applied to Akkız 86 variety. Among the sources of variation on cooking time parameter, bacteria application was found to be significant at 1% level and cultivar×bacteria interaction at 5% level.

When the general averages of the bacteria were considered, the grains obtained from Omed+4 microbial fertilizer application were cooked in the latest time with 20.17 minutes, while İmed applications decreased the cooking time and contributed to the earliest cooking time with 18.17 minutes.

When the mean values of variety×bacteria interaction were analyzed, the earliest cooking time with 17.67 minutes was obtained from Omed and Imed treatments in Akkız 86 and Karagöz 86 varieties, respectively, while the latest cooking time with 20.33 minutes was obtained from Omed+4 treatment in Karagöz 86 variety.

The effect of variation sources on the number of scattered grains after cooking was found to be insignificant. The number of scattered grains after cooking varied between 0.0-3.33 pieces.

Among the sources of variation on water absorption capacity parameter, both bacteria treatment and variety*bacteria interaction were found significant at 1% level. When the general averages of bacterial treatment were analyzed, the highest value was obtained from Omed treatment with 0.272 g/grain. When the interaction mean values were examined, Omed microbial fertilizer applications caused Akkız 86 variety (0.278 g/grain) to have the highest value, while it was in the same statistical group with Karagöz 86 variety with 0.266 g/grain value.

Variety, bacteria and variety*bacteria interactions were found to be statistically significant on swelling index parameter at 5% level. When the general averages of the varieties were analyzed, the swelling index values of Akkız 86 and Karagöz 86 were 2.494% and 2.334%, respectively. When the general averages of bacterial treatments were examined, the highest value with 2.635% was obtained from İmed application and the lowest value with 2.259% was obtained from Omed application, while Omed+4 and Çim+14-3 applications were in the same statistical group. When the cultivar×bacteria interaction was analyzed, the swelling index values varied between 2.665%-2.154%.

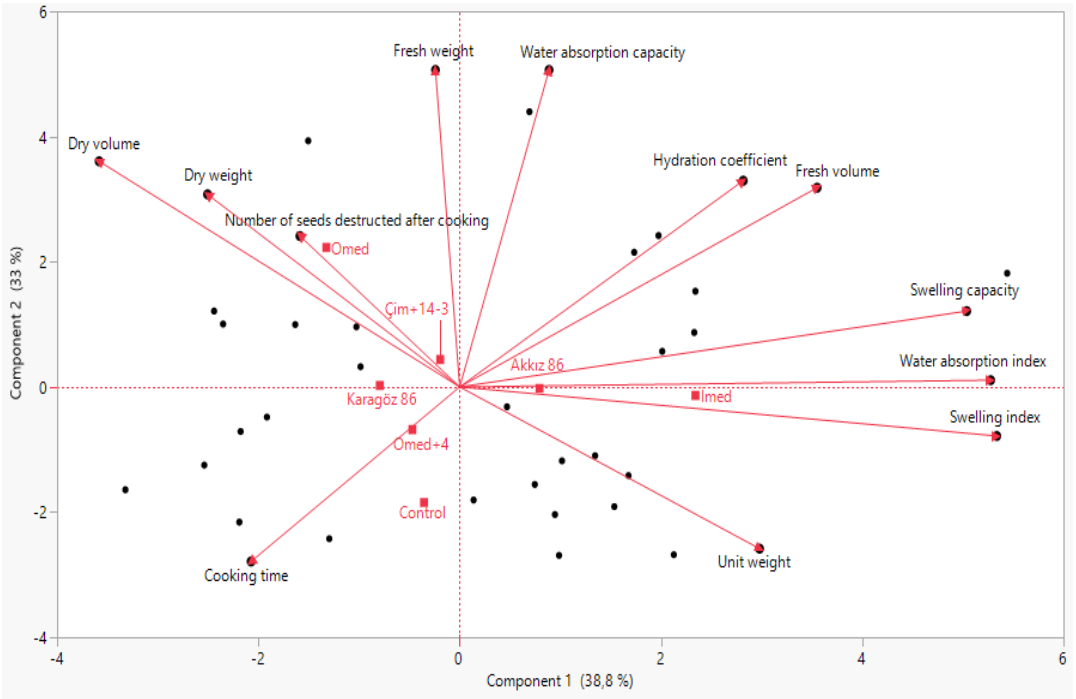
While the effect of bacteria application on the hydration coefficient parameter was found significant at 5% level, variety*bacteria interaction was found significant at 1% level. When the general mean values of bacteria application were considered, the highest values were obtained from İmed, Omed and Çim+14-3 treatments with 142.55, 141.29 and 140.98%, respectively, and they were in the same statistical group. When the cultivar*bacteria interactions were analyzed, the highest value with 151.89% was obtained from İmed application to Karagöz 86 cultivar.

Among the sources of variation on the swelling capacity parameter, bacteria and cultivar*bacteria interactions were found significant at 5% level. When the general averages of bacterial treatments were examined, the highest value was obtained from İmed microbial fertilizer application with 0.297 ml/grain, while Omed+4 application with 0.272 ml/grain was in the same group statistically. The values obtained from the external control group, Omed and Çim+14-3 microbial fertilizer applications were in the statistical group with the lowest value. When the interaction averages were examined, the highest value was obtained from Imed microbial fertilizer application in Karagöz 86 variety with 0.310 ml/grain, while the values obtained from all applications in Akkız 86 variety were statistically in the highest group.

When the effect of variation sources on water uptake index parameter was analyzed, bacteria and cultivar*bacteria interaction were found to be statistically significant at 5% level. When the general mean values of bacteria treatments were analyzed, the highest value was obtained from İmed treatment with 1.648%, while the data obtained from other bacteria treatments were in the lowest statistical group. When the interaction means were examined, the highest value was obtained from İmed application to Karagöz 86 variety with 1.744%, while the other microbial fertilizer applications except for Omed application in Akkız 86 variety were in the highest statistical group.

Among the sources of variation, the effect of cultivar and cultivar*bacteria interaction on unit volume weight was found statistically significant at 5% level. When the general average values of the varieties were examined, the unit volume weight values of Akkız 86 and Karagöz 86 varieties were recorded as 0.986 g/ml and 0.959 g/ml, respectively. When the interaction averages were examined, the lowest value was obtained from Omed microbial fertilizer application to Akkız 86 variety with 0.894 g/ml, while the results obtained from the other treatments were in the highest statistical group.

When the technological studies on cowpea plant are examined, Karaman and Türkay (2021) with dry weight, fresh weight, dry volume and fresh volume parameters and Özkorkmaz and Yılmaz (2022) with cooking time, water absorption capacity and swelling capacity parameters are in parallel with our findings. All the technological results obtained are also supported by some researchers (Gull et al. 2012 and Doğan et al. 2011).



Number	Eigenvalue	Percent	Cum Percent
1	4,659204	38,827	38,827
2	3,956846	32,974	71,800
3	1,347246	11,227	83,027
4	0,905929	7,549	90,577
5	0,622042	5,184	95,761
6	0,503186	4,193	99,954
7	0,004416	0,037	99,991
8	0,000884	0,007	99,998
9	0,000184	0,002	99,999
10	0,000063	0,001	100,000

Figure 1. Biplot analysis and values on cultivars, microbial fertilizers and parameters studied

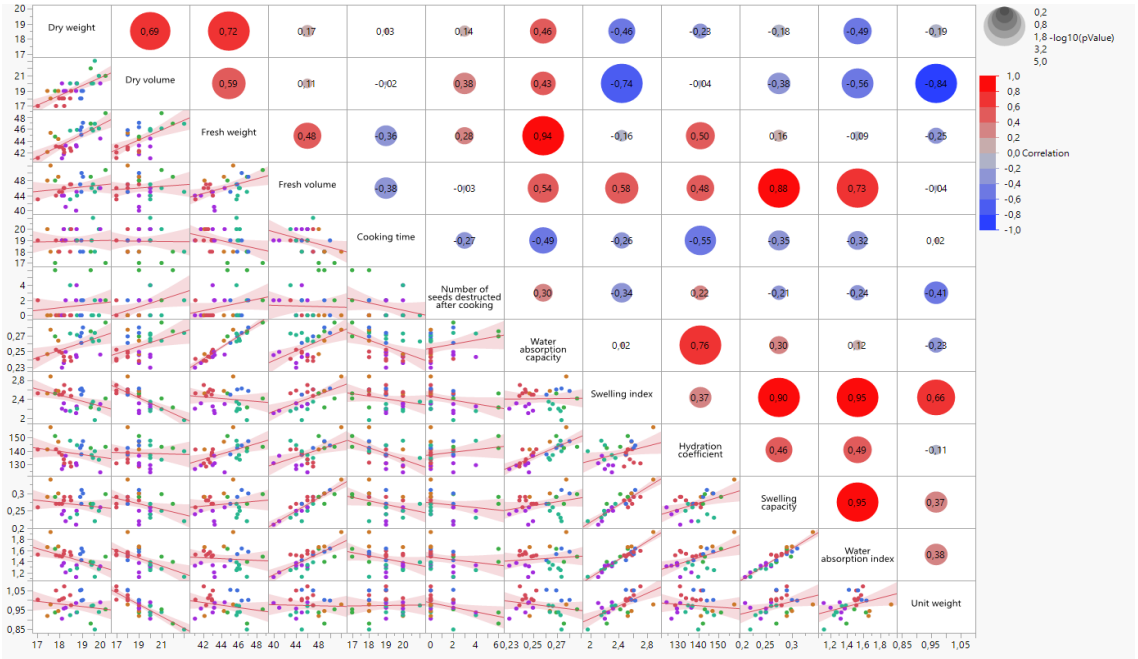


Figure 2. Scatterplot matrix for overview of correlations and fit lines.

In addition, the technological data obtained by Hamid et al. (2016), Addo et al. (2016) (except swelling capacity), Aydın et al. (2008), Kabas et al. (2007), Nielsen et al. (1993) and Demooy and Demooy (1990) on cowpea plants differ with the technological data obtained from the studies on cowpea plants. The differences in some parameters in the literature may be due to the differences in the genotypes used as well as the climate and growing conditions of the cultivar used.

The result of biplot analysis of different microbial fertilizer applications on the technological characteristics of cowpea plant is given in Figure 3. Three principal components with eigenvalues higher than 1 and 10 independent principal component axes were obtained. The eigenvalues of the first 3 principal component axes, which account for 83.027% of the total variation, vary between 1.347-4.659. As a result of these values obtained, principal component analysis can be interpreted successfully (Erol et al. 2023).

The length of the independent axes formed by the examined parameters, the angle between each other and the region where they are located reveal the negative or positive relationship between these parameters (Özaktan et al. 2023). When Figure 3 is examined, it is seen that the water uptake index, swelling capacity, fresh volume, hydration coefficient and water uptake capacity axes are positively correlated with each other, while the water uptake index and swelling capacity axes; hydration coefficient and fresh volume axes have a higher positive relationship with each other. Dry volume, dry weight, dry weight, grain dispersed after cooking and fresh weight axes were positively correlated with each other since they were located in the same region, while a positive correlation was also observed between unit volume weight and swelling index. When the scatter of microbial fertilizer sources and cowpea varieties in the biplot output plane were examined, Imed microbial fertilizer source increased the water uptake index and swelling capacity values. The effect of Omed microbial fertilizer on the number of grains dispersed after cooking and Omed+4 microbial fertilizer application on cooking time was high. While Akkız 86 variety was the leader in terms of swelling index, water uptake index, swelling capacity, fresh volume, hydration coefficient and water uptake capacity parameters; Karagöz 86 variety was the leader in terms of dry volume, dry weight, number of grains dispersed after cooking and fresh weight parameters.

The results and values of scatterplot, fit line and correlation analysis on the parameters examined in cowpea grains are given in Figure 2. Red circles define positive correlation, while blue circles define negative correlation.

When the values in Figure 2 are analyzed, it is found that there is a positive relationship between the dry weight parameter and the fresh weight (r=0.72) and dry volume (r=0.69) parameters. While there is a positive relationship between dry volume and fresh weight (r=0.59), there is a negative relationship between unit volume weight (r=-0.84), swelling index (r=-0.74) and water uptake index (r=-0.56). There is a positive correlation between fresh weight parameter, water absorption capacity (r=0.94) and hydration coefficient (r=0.50). There is a positive relationship between the fresh volume parameter, swelling capacity (r=0.88) and water absorption index (r=0.73). The cooking time parameter showed a negative relationship with all parameters except for the unit volume weight parameter, while the highest negative relationship was recorded as the hydration coefficient (r=-0.55). There is a positive relationship between the water absorption capacity parameter and the hydration coefficient (r=0.76). There is a positive relationship between the swelling index parameter and water uptake index (r=0.95), swelling capacity (r=0.90) and unit volume weight (r=0.66). There was also a positive relationship between swelling capacity and water absorption index (r=0.95). As a result of the literature evaluation, Oral et al. (2022) reported that there were significant positive correlations between dry weight values and fresh weight, fresh volume, dry volume and swelling capacity, and significant and positive correlations between fresh weight values and fresh volume, dry volume and swelling capacity in bean plants. Erol et al. (2023) reported that there were significant positive correlations between dry weight and dry volume, fresh weight, fresh volume, water absorption capacity and number of grains dispersed after cooking and significant negative correlations with swelling index in chickpea plants. Özaktan (2021) reported that significant positive correlations were determined between dry weight values and fresh weight, freshvolume and water absorption capacity in chickpea plants and significant negative correlations were determined between fresh volume and swelling index and unit volume weight. Tripathi et al. (2012) reported that there were positive correlations between swelling capacity and swelling index in chickpea plants and that the correlations with cooking time were negative and insignificant.

Conclusion

As a result, the highest values in dry weight, dry volume, fresh weight and water uptake capacity parameters were recorded from Omed bacteria treatment; the highest values in fresh volume, swelling index, hydration coefficient, swelling capacity, water uptake index and unit volume weight parameters were recorded from Imed bacteria treatment. It is seen that the microbial fertilizers used had positive effects on the technological characteristics of cowpea plant. There was a highly significant positive correlation between swelling index parameter and swelling capacity, water absorption index and unit volume weight parameters. A highly significant negative correlation was recorded between the dry volume parameter and the swelling index and unit volume weight parameters. In order to ensure the sustainability of natural resources in agriculture, the use of microbial fertilizers should be increased, especially in natural, ecological and organic farming systems, in addition to conventional agriculture.

Declarations

Ethics Committee Approval

There is no need for an ethics committee decision for this study.

Author Contributions

The authors contributed equally to the development and writing of the manuscript.

Declarations of Interests

The authors have no conflict of interest to declare.

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References

Abebe, B. K., & Alemayehu, M. T. (2022). A review of the nutritional use of cowpea (Vigna unguiculata L. Walp) for human and animal diets. *Journal of Agriculture and Food Research*, *10*, 100383. https://doi.org/10.1016/j.jafr.2022.100383

Addo, J. K., Amoah, S., Boateng, A. M., Okyere, H., Adu-Dapaah, H., & Amoa-Owusu, A. (2016). Physical, functional and cooking characteristics of six newly released cowpea (Vigna unguiculata [L] Walp) varieties in Ghana. Agricultural and Food Science Journal of Ghana, 9: 742-753.

Avan M, Kotan R. 2021. Fungusların mikrobiyal gübre veya biyopestisit olarak tarımda kullanılması. Uluslararası Doğu Anadolu Fen Mühendislik ve Tasarım Dergisi, 3(1): 167-191.

Aydın, C., Paksoy, M., Özer, A., & Şen, Ö. (2008). Some physical properties and nutritional compositions of cowpea (Vigna sinensis L.) seeds. Selcuk Journal of Agriculture and Food Sciences, 22(44): 71-77.

Baukar, O., Belko, N., Chamarthi, S., Togola, A., Batieno, J., Owusu, E., Haruna, M., Diallo, S., Lawan, U.M., Olufajo, O., & Fatokun, C. (2018). Cowpea (*Vigna unguiculata*): Genetics, genomics and breeding. Plant Breeding, 138(4):379-499.

Demooy, B. E., Demooy, C. J. (1990). Evaluation of cooking time and quality of seven diverse cowpea (Vigna unguiculata (L.) Walp.) varieties. International Journal of Food Science & Technology, 25(2), 209–212. https://doi.org/10.1111/j.1365-2621.1990.tb01076.x

Doğan, Y., Toğay, N., &Toğay, Y. (2011). Türkiye'de Yetiştirilen Börülce (Vigna Unguilata L. WALP) Çeşit ve Genotiplerin Hidratasyon Kapasiteleri, Hidratasyon İndeksleri ve Sert Tohum Kabuğu Oranlarının Belirlenmesi Üzerine Bir Araştırma. Yüzüncü Yıl Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 16(1), 1-4.

Erol, O., Özaktan, H., & Tosun, Z., (2023). Kayseri Ekolojik Koşullarında Yetiştirilen Bazı Tescilli Nohut (Cicer arietinum L.) Çeşitlerinin Teknolojik Özelliklerinin Çok Değişkenli İstatistiksel Analizlerle Belirlenmesi. Çukurova Tarım ve Gıda bilimleri dergisi (Online) , vol.38, no.1, 66-75.

Gull, M., Sofi, P. A., Mir, R. R., Ara, A., Rashid, M., Tahir, M., ... & Rather, I. A. (2017). Natural variation for seed physical and hydration parameters in cowpea (Vigna unguiculata L.) in relation to hard to cook trait. *International Journal of Pure & Applied Bioscience*, *5*, 321-330.

Hamid, S., Muzaffar, S., Wani, I. A., Masoodi, F. A., & Bhat, M. M. 2016. Physical and cooking characteristics of two cowpea cultivars grown in temperate Indian climate. Journal of the Saudi Society of Agricultural Sciences, 15(2): 127-134. https://doi.org/10.1016/j.jssas.2014.08.002

Ibrahim, S. S., Habiba, R. A., Shatta, A., & Embaby, H. E. (2002). Effect of soaking, germination, cooking and fermentation on antinutritional factors in cowpeas. *Nahrung - Food*, *46*(2), 92–95. https://doi.org/10.1002/1521-3803(20020301)46:2<92::AID-FOOD92>3.0.CO;2-P

Jayathilake, C., Visvanathan, R., Deen, A., Bangamuwage, R., Jayawardana, B. C., Nammi, S., & Liyanage, R. (2018). Cowpea: an overview on its nutritional facts and health benefits. *Journal of the Science of Food and Agriculture*, *98*(13), 4793–4806. https://doi.org/10.1002/jsfa.9074

Kabas, O., Yilmaz, E., Ozmerzi, A., & Akinci, İ. (2007). Some physical and nutritional properties of cowpea seed (Vigna sinensis L.). Journal of Food Engineering, 79(4), 1405–1409. https://doi.org/10.1016/j.jfoodeng.2006.04.022

Karaman, R., Türkay, C., 2021. Börülcede Bazı Fiziksel ve Teknolojik Özelliklerin Belirlenmesi, Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 12(Ek Sayı 1): 477-485

Nielsen, S. S., Brandt, W. E., & Singh, B. B. (1993). Genetic Variability for Nutritional Composition and Cooking Time of Improved Cowpea Lines. Crop Science, 33(3), 469–472. https://doi.org/10.2135/cropsci1993.0011183X003300030010x

Oral, E., Tunçtürk, R., Tunçtürk, M., Altuner, F., & Kulaz, H. (2022). Determination of quality and some technological characteristics of some bean varietes (Phaseolus vulgaris L.). *Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi*, *27*(1), 155–165. https://doi.org/10.37908/mkutbd.1058316

Ovalıoğlu, G. 2023. Börülce (*Vigna unguiculata* L.). ISPEC of Science Institute. *2*(1):28–32. https://doi.org/10.5281/zenodo.10442702Journal.

Özaktan, H. (2021). Technological Characteristics of Chickpea (*Cicer arietinum* L.) Cultivars Grown Under Natural Conditions. Turkish Journal of Field Crops, 26(2), 235–243. https://doi.org/10.17557/tjfc.1018627

Özaktan, H., Doymaz, A. (2022). Mineral composition and technological and morphological performance of beans as influenced by organic seaweed-extracted fertilizers applied in different growth stages. Journal of Food Composition and Analysis, 114:104741.

Özaktan, H., Kıbık, G., & Erol, O. (2022). Yeni Nohut (Cicer arietinum L.) Çeşitlerinin Kayseri Koşullarında Agro-morfolojik Özelliklerinin Belirlenmesi. Erciyes Tarım Ve Hayvan Bilimleri Dergisi, 5(2), 62-70. https://doi.org/10.55257/ethabd.1181270

Özkorkmaz, F., Yılmaz, N. (2022). Farklı dozlarda uygulanan bor ve demir gübrelerinin börülce (Vigna unguiculata L.) bitkisinde tane kalitesi üzerine etkilerinin belirlenmesi. Akademik Ziraat Dergisi, 11(2), 285–294. https://doi.org/10.29278/azd.1088663

Stamenković, S., Beškoski, V., Karabegović, I., Lazić, M., & Nikolić, N. (2018). Microbial fertilizers: A comprehensive review of current findings and future perspectives. Spanish Journal of Agricultural Research, 16(1).

Şahin, G. (2016). 2016 Uluslararası Bakliyat Yılı Hasebiyle Türkiye'de Mercimek (*Lens culinaris* Medik) Yetiştiriciliği/Lentil (Lens culinaris Medik) Cultivation in Turkiye on the Occasion of International Year of Pulse 2016. *Atatürk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *20*(4), 1665-1696.

Ton, A., Anlarsal, A. E. (2018). Effects of Nitrogen Fertilizer Application on Yield and Yield Components of Different Cowpea Genotypes (*Vigna unguiculata* L.). August 2018. Fresenius Environmental Bulletin. 27(8):5605-5609.

Ton A**.** (2023). Response of cowpea (*Vigna unguiculata* L.) to organic and chemical fertilizer applications on grain yield and yield components. 3rd International Conference on Research of Agricultural and Food Technologies, 85, 1-7.

Tosun Z., 2024. **F**arklı gibberellik asit (ga3) dozlarının fasulye (*Phaseolus vulgaris* L.) bitkisinde verim ve verim ögelerine etkisi. Erciyes Üniversitesi Fen Bilimleri Enstitüsü Tarla Bitkileri Anabilim Dalı, Yüksek Lisans Tezi, 57s.

Tripathi, S., Sridhar, V., Jukanti, A. K., Suresh, K., Rao, B. V., Gowda, C. L. L., & Gaur, P. M. (2012). Genetic variability and interrelationships of phenological, physicochemical and cooking quality traits in chickpea. Plant Genetic Resources: Characterisation and Utilisation, 10(3), 194–201. https://doi.org/10.1017/S147926211200 0251

Tshovhote, N.J., Nesamvuni, A.E., Raphulu, T., & Gous, R.M., (2003). The chemical composition, energy and amino acid digestibility of cowpeas used in poultry nutrition. South African Journal of Animal Science, 33(1), 65-69.

Wei, X., Xie, B., Wan, C., Song, R., Zhong, W., Xin, S., & Song, K. (2024). Enhancing Soil Health and Plant Growth through Microbial Fertilizers: Mechanisms, Benefits, and Sustainable Agricultural Practices. *Agronomy*, *14*(3), 609. https://doi.org/10.3390/agronomy14030609

Wood, J. A. (2017). Evaluation of Cooking Time in Pulses: A Review. *Cereal Chemistry*, *94*(1), 32–48. https://doi.org/10.1094/CCHEM-05-16-0127-FI

Wortman, S.E., Dawson, J.O., 2015. Nitrogenase activity and nodule biomass of cowpea (*Vigna unguiculata* L. *Walp*.) decrease in cover crop mixtures. Communications in Soil Science and Plant Analysis, 46(11), 1443-1457.