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THE EFFECT of DIFFERENT PHOSPHORUS and NITROGEN DOSES on BEAN's (*Phaseolus vulgaris* L.) GRAIN QUALITY

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Abstract: Leguminous plants fix nitrogen in the air by forming nodules. Phosphorus fertilizer, on the other hand, contributes to plant growth and grain yield together with nitrogen. For this purpose, four phosphorus (0, 3, 6, 9 kg da^{-1}) and four nitrogen (0, 4, 8, 12 kg da^{-1}) doses were applied to the Göksun bean variety, and the most appropriate dose for plant growth and grain yield was tried to be determined. In the study, the oil rate (%), ash rate (%), moisture rate (%), fiber rate (%), protein rate (%), starch rate (%) and thousand grain weight (g) values of Göksun bean cultivar were investigated. The study found that nitrogen fertilization significantly affected starch content and thousand-seed weight, two of the most important grain quality criteria for beans. The highest thousand-grain weight was obtained with the 12 kg da^{-1} nitrogen dose and the combination of 12 kg da^{-1} nitrogen and 6 kg da^{-1} phosphorus doses.
Keywords: *Phaseolus vulgaris* l., phosphorus doses, nitrogen doses, grain quality criteria

Fasulyenin (*Phaseolus Vulgaris* L.) Tane Kalitesine Farklı Fosfor ve Azot Dozlarının Etkisi

Öz: Baklagil bitkileri nodül oluşturarak havanın azotunu fikse etmektedir. Fosfor gübresi ise azot ile birlikte bitki gelişimi ve tane verimine katkı sağlamaktadır. Bu nedenle Kahramanmaraş koşullarında Göksun fasulye çeşidine dört fosfor (0, 3, 6, 9 kg da^{-1}) ve dört azot (0, 4, 8, 12 kg da^{-1}) dozu uygulanarak, bitkinin gelişim gösterdiği en uygun dozun belirlenmesi amaçlanmıştır. Araştırmada Göksun fasulye çeşidinin yağ oranı (%), kül oranı (%), nem oranı (%), lif oranı (%), protein oranı (%), nişasta oranı (%) ve bin tane ağırlığı (g) değerleri incelenmiştir. Yapılan araştırma sonucunda; azotlu gübrelemenin, fasulyenin en önemli tane kalite kriterleri olan nişasta oranı ve bin tane ağırlığı özelliklerinde istatistiksel olarak önemli bir farklılığa neden olduğu tespit edilmiştir. En yüksek bin tane ağırlığı değeri 12 kg da $^{-1}$ azot dozundan elde edilmiş olup, bulguları azot x fosfor dozu interaksiyonu olarak ele aldığımızda ise en yüksek bin tane ağırlığı değerinin 6 kg da^{-1} P x 12 kg da $^{-1}$ N dozu kombinasyonu ile elde edildiği belirlenmiştir.
Anahtar Kelimeler: Fasulye, fosfor dozu, azot dozu, tane kalite kriterleri.

Introduction

Inadequate and unbalanced nutrition are among the most significant health problems in many countries and in Türkiye. The most important problem here is that most foods taken in the daily diet are carbohydrates. Beans are a basic food with high nutritional value. They are rich in protein and a quality source of protein (rich in leucine, phenylalanine, and lysine), which helps people develop their body and intelligence (Alfaro-Diaz et al., 2023). However, a protein deficit may arise due to the cost and sometimes limited availability of animal-based protein sources due to health concerns. In such cases, legumes are the most important plant-based source of protein. Legumes are an extremely healthy food group and are close to animal proteins in terms of protein quality (Njintang et al., 2001). On the other hand, their fat content is also extremely low. At the same time, they are a good energy source due to their carbohydrate content of around 60 % (Shimelis et al., 2006).

In addition to human nutrition, the grains and stems of edible leguminous plants are also used in animal nutrition. On the other hand, legumes not only provide nitrogen fixation in the soil but also accelerate the micro-organism work in the channels rich in organic matter, which they open, and increase the soil vitality in the root zone. At the same time, it prevents soil compaction by opening deep root channels (Uysal, 2002).

The most produced legume plant in the world is the bean. Chickpeas, peas, black-eyed peas, and lentils follow beans. South America and Central America are the centers of origin for beans. (Kwak and Gepts, 2009). Bean production is carried out in five different regions around the world, namely North, Central, and South America South and East Africa, West Europe, and East Asia (Demircan, 2018). According to the Food and Agriculture Organization of the United Nations in 2020, approximately 34.80 million hectares of land were

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used to grow dry beans worldwide, resulting in a production of 27.55 million tons of dry beans, with an average yield of 790 kilograms per hectare (FAO, 2022). In 2022, Turkey cultivated 99.5 thousand hectares of beans, producing 270 thousand tons of dry beans. The grain yield per hectare was 278 kilograms in Turkey in 2022 (TÜİK, 2022). Beans, which are eaten both fresh and dried, are more nutritious than other similar foods because they are high in protein, have a similar amino acid profile to meat protein, and are rich in iron, phosphorus, carbohydrates, and calcium (Broughton et al., 2003). Dry beans, which are frequently consumed in our country, are an important source of plant protein and have an important place in human nutrition with the increasing population.

Beans are the most ecologically demanding legume species. Many factors affect the bean cultivation in a region. The yield and quality of beans are affected by physical factors (day length, temperature, topography, soil type, precipitation, etc.), biological factors (diseases and pests), and socio-economic factors (Pekşen, 2005). The main goal of research on cultivation techniques for edible legume plants is to grow quality and yield per unit area. Phosphorus and nitrogen are the two most important aliments for crop growth, and their deficiency in the soil can lead to a significant loss of productivity (Acar, 2019). Nitrogen is a component of proteins and is also essential for the structure of chlorophyll, vitamins, and enzymes. Phosphorus is essential for increasing seed quality and yield. Additionally, phosphorus fertilizers can increase nitrogen availability in the soil by stimulating the formation of nodules on legume roots and the activity of nitrogenase enzymes (Arıoğlu, 1994). The study investigated the effects of different phosphorus and nitrogen doses on the quality of common beans.

Material and Method

The Göksun bean variety was used as the experimental material. The application factors were four doses of phosphorus (0, 3, 6, 9 kg da^{-1}) and four doses of nitrogen (0, 4, 8, 12 kg da^{-1}).

The experiment was conducted between March and June 2020 at the Field Crops Research Area of KSÜ, Faculty of Agriculture. The experiment was set up with three replications using a split plots trial design. Plants were cultivated by hand. The trial is 5 m long, the distance between rows is 50 cm, and the distance above rows is 10 cm. The main plots received phosphorus treatment, whereas the subplots received nitrogen treatment. We applied the nitrogen dose using a fertilizer containing 46% urea and the phosphorus dose using a fertilizer containing triple superphosphate. The nitrogen fertilizer was applied in two doses: half during planting and the other half between the rows in the last week of April when the plants were 10-15 cm tall. All phosphorus fertilizer was applied at the time of planting. Depending on the situation of the plants and the soil, the method of drip irrigation was employed to provide the plants with the water they needed. The harvest was completed by hand.

Climate data for the months of March to July in Kahramanmaraş province, where the research was carried out, monthly total precipitation; 173.4 mm, 61.8 mm, 18.5 mm, 0.3 mm, average monthly temperature; 12.5 ^{0}C, 15.9 ^{0}C, 15.9 ^{0}C, 25.4 ^{0}C, monthly average relative humidity was recorded as 67.3 %, 58.2 %, 47.2 % and 46.9 % relatively. The soil of the experimental area is clay loam (69.96%), moderately calcareous (6.09%), with potassium content higher than the recommended level (55.51 kg da^{-1}), non-saline (0.05), poor in organic matter content (1.58%), and phosphorus is found at a very low level in the soil (2.84 kg da^{-1}). This study investigated the oil content, ash content, fiber content, moisture content, protein content, starch ratio, and thousand kernel weight properties of the Göksun bean variety. The JMP software was used to examine the data from the observations, and the Duncan multiple comparison test was used to compare the means of the observations.

Results and Discussion

This study examined the interactions between both the phosphorus and nitrogen dosages used to the Göksun beans cultivar as well as the impact of each dose separately on the characteristics under investigation. The data underwent statistical analysis, and the average values are presented in Table 1. The oil ratio, ash ratio, fiber ratio, moisture ratio, and protein ratio values of the investigated properties were shown to be insignificant statistically with regard to the phosphorus x nitrogen dosage interaction, but the nitrogen dose alone was determined to be significant for both the starch ratio and the weight of a thousand grains values.

Oil Ratio (%)

Table 1 gives the average oil ratios (%) of the Göksun bean variety grown under Kahramanmaraş conditions with multiple nitrogen and phosphorus dosages. The interaction between nitrogen and phosphorus doses applied in various doses didn't change the grain oil ratio in a way that was statistically significant. While the oil ratio values in the grain were between 2.60-3.06 %, the highest oil ratio value was found at the P_3 x N_8 dose, and the lowest oil percentage value was found at the P_0 x N_0 dose. According to investigations carried out in the past, it's known that the rate of crude oil varies between 0.80-2.40 % in many studies conducted in different ecological conditions and with different varieties (Akçin, 1975; Steel et al., 1995; Akçin, 1988; Perez et al., 1997; Dzudie & Hardy, 1999; Wiryaman, 1997; and Bednar et al. 2001). In this study, in which we applied different doses of phosphorus and nitrogen, it was determined that the oil of the grain was higher than previous literature studies.

Table 1. Averages of phosphorus by nitrogen dose interactions for the investigated properties

P x N	Oil Ratio (%)	Ash Ratio (%)	Fiber Ratio (%)	Moisture Ratio (%)	Protein Ratio (%)	Starch Ratio (%)	Thousand Grain Weight Ratio (%)
P_0 X N_0	2.60	3.75	6.91	10.85	21.01	45.63	260.00
P_3 X N_0	2.92	3.77	6.88	10.83	22.02	45.73	236.66
P_6 X N_0	3.00	3.77	6.94	10.86	20.97	45.80	263.33
P_9 X N_0	2.91	3.75	6.79	11.01	21.78	45.87	230.00
P_0 X N_4	2.65	3.86	7.43	11.11	21.54	44.66	203.33
P_3 X N_4	3.22	3.72	6.84	10.61	20.93	46.23	230.00
P_6 X N_4	2.93	3.80	6.67	10.92	21.57	45.59	260.00
P_9 X N_4	2.85	3.88	7.48	10.81	21.50	44.76	203.33
P_0 X N_8	2.82	3.84	7.37	10.96	21.24	44.97	190.00
P_3 X N_8	3.06	3.80	7.11	10.81	22.31	44.40	240.00
P_6 X N_8	2.80	3.85	7.61	11.31	20.69	44.73	213.33
P_9 X N_8	2.97	3.78	6.97	11.06	20.74	46.66	240.00
P_0 X N_{12}	2.83	3.81	7.25	11.04	21.29	45.01	240.00
P_3 X N_{12}	2.94	3.80	7.39	10.76	22.07	43.57	253.33
P_6 X N_{12}	2.75	3.84	7.32	10.87	21.58	44.14	300.00
P_9 X N_{12}	2.98	3.79	7.16	10.76	21.83	44.33	253.33

Ash Ratio (%)

The ash content in the grain of the Göksun bean variety was not statistically significantly affected by the different phosphorus and nitrogen doses applied. The ash ratio values in the grain were between 3.72-3.88 % (Table 1). The biggest ash ratio was discovered at P_9 x N_4 doses with a value of 3.88 %, while the lowest ash ratio was obtained from P_3 x N_4 doses with a value of 3.72 %. It has been shown in investigations done in past years that the ash content values vary between 1.56 and 5.07% in many studies conducted in different ecological conditions and with different varieties. (Dzudie and Hardy, 1999; Akçin, 1975; Karasu, 1988; Barampama and Simard, 1994; Perez et al. 1997; Akçin, 1988; Wiryaman, 1997; Gökçınar, 2000; Shimelis and Rakshit, 2005). The values obtained in this study are between 3.72-3.88 % and are in agreement with the literature.

Fiber Ratio (%)

The mean fiber ratios (%) achieved from various nitrogen and phosphorus applications to the Göksun variety are shown in Table 1. The interaction between phosphorus and nitrogen doses did not significantly affect the grain fiber ratio. The fiber content of the beans ranged from 6.67% to 7.43%, with the P_0 x N_4 treatment producing the highest fiber content, whereas the P6 x N4 treatment produced the lowest fiber content. Legumes contain a large amount of dietary fiber. This rate is 18 % for peas, lentils, and chickpeas and 28 % for beans. The seed coat contains an enormous amount of fibers. Therefore, peeling the bark reduces the amount of fiber. A great source of soluble dietary fiber is legumes. They contain approximately 3-7 % soluble fiber (Pekşen & Artık, 2004). The findings obtained from the experiment are compatible with the literature reviews.

Moisture Ratio (%)

The moisture content in the grain of the Göksun bean variety was not statistically significantly affected by the different phosphorus and nitrogen doses applied. Moisture ratio values in the grain took values between 10.61-11.31 %. The P_6 x N_8 doses had the highest humidity value, which was 11.31%, while the P_3 x N_4 doses had the lowest humidity value, which was 10.61%. In previous studies, Güvenç and Güngör (1996) found moisture content between 7.89-10.64 % in their study on different bean varieties, Peirce (1987) found 11%, Cemeroğlu and Acar (1986) found 11.2-12%, and Shellie-Dessert et al., (1991) and Gunay (1992) reported it as 12 % moisture ratio. Trial findings are in agreement with literature values.

Protein Ratio (%)

The mean protein content (%) values of the Göksun bean variety grown using various phosphorus and nitrogen doses under Kahramanmaraş conditions are shown in Table 1. No statistically significant effect of the applications on grain protein ratio was observed in plants grown by applying various phosphorus and nitrogen doses. While the protein ratio values in the grain were between 20.69-22.31%, the highest protein ratio value was obtained from the P_3 x N_8 dose, and the lowest protein ratio value was obtained from the P_6 x N_8 dose. In the literature review of previous years, Altunkaynak and Ceyhan (2018) found that the highest protein ratio was obtained in the control treatment when different nitrogen fertilization rates were applied to the bean of Alberto. The increase in the protein ratio did not go hand in hand with the increase in the nitrogen rate. Öztürk (2019) conducted a study in which nitrogen fertilizer was divided into the bean plant, and the irrigation situation was taken into account. Splitting the application of nitrogen fertilizer (1.5 kg da^{-1} at sowing and 1.5 kg da^{-1} in three separate irrigations) resulted in the highest protein ratio in beans. İdikut and Karabacak (2020) found that the protein ratio of eleven bean varieties grown in Elazığ conditions ranged from 24.65 to 28.24%. Aydogan et al. (2020) found that the protein ratio of twelve bean genotypes grown in Konya conditions ranged from 19.99 to 22.50%. According to Mtua (2015), the protein ratio of the Göynük 98 bean variety was not significantly affected by different phosphorus doses and TKİ-Humas applications. The protein ratio ranged from 23 to 24.5%. According to Ülker and Ceyhan (2008), the protein ratio of seventeen bean genotypes grown in the Çumra and Sarayönü districts of Anatolia varies depending on environmental conditions. It has been determined that the crude protein ratios obtained from many studies conducted in different ecological conditions and with different varieties vary between 17.31-36 % (Barampama & Simard, 1993; Lantz et al., 1958; Rutger, 1968; Akçin, 1975; Eser, 1981; Perez et al., 1997; Karasu, 1988; Dzudie & Hardy, 1999; Bednar et al., 2001; Shimelis et al., 2006). The values obtained in this study are between 20.69-22.31 % and are in harmony with the above literature. In the study, the protein ratio increased with the increase of the nitrogen dose, but no statistically significant difference was obtained. It was thought that the experiment was carried out under field conditions.

Starch Ratio (%)

There was no statistically significant interaction between phosphorus and nitrogen doses on the grain starch ratio. Starch ratio values in grain were between 43.57- 46.66 %. The highest level of starch was found that P_9 x N_8 doses, with a value of 46.66 %, while the lowest starch ratio value was obtained from P_3 x N_{12} doses, with a value of 43.57 %. In other words, applying different amounts of nitrogen fertilizer had a significant effect on the percentage of starch in the bean grain, while applying different amounts of phosphorus fertilizer did not have any effect. (Table 2). The starch ratio of the Göksun bean cultivar varied between 45.76 % and 44.26 % at different nitrogen doses applied. The starch ratio in terms of nitrogen dosing was grouped under two groups. We applied different amounts of nitrogen fertilizer to bean crops and measured the starch content of the beans, and we found that the highest starch content was obtained when no nitrogen fertilizer was applied. The next highest starch content was obtained when 4 kg da^{-1} of nitrogen fertilizer was applied. However, the difference in starch content between the 0 kg/da and 4 kg da^{-1} nitrogen treatments was not statistically significant. The lowest starch ratio was obtained from 12 kg da^{-1} nitrogen application. It was noted that the starch ratio was 45.19 % in the other 8 kg da^{-1} nitrogen application and was in the transition group between the two groups. The starch ratio varied between 44.98 % and 45.40 % in different phosphorus dose applications. Different phosphorus doses did not create statistical differences in terms of starch ratio.

Türksoy (2018), it was noted that the lowest starch ratio in whole grain flours of chickpea, pea, bean, and red lentil plants was obtained from bean grain with 39.60 %. İdikut and Karabacak (2020) reported that the

starch ratio in eleven bean varieties grown in Elazığ conditions varied between 40.80-46.31%. The starch ratio decreased with increasing nitrogen dose. It is thought that the nitrogen dose is mostly due to its contribution to the formation of the protein network and that the study was carried out under field conditions.

Table 2. Averages of phosphorus and nitrogen doses of starch ratio alone

	0 kg da^{-1} P	3 kg da^{-1} P	6 kg da^{-1} P	9 kg da^{-1} P	Averages
0 kg da^{-1} N	45.630	45.733	45.806	45.876	45.761 a
4 kg da^{-1} N	44.660	46.233	45.596	44.763	45.313 a
8 kg da^{-1} N	44.973	44.400	44.733	46.663	45.192 ab
12 kg da^{-1} N	45.016	43.573	44.140	44.330	44.265 b
Averages	45.070	44.985	45.069	45.408	

Thousand Grain Weight (g)

Applied different amounts of phosphorus and nitrogen fertilizer to the Göksun bean variety and measured the thousand grain weight bean seeds. However we found that the combination of phosphorus and nitrogen fertilizer did not have a significant effect on the thousand grain weight bean seeds. The weight of the thousand grain ranged from 190.00 to 300.00 grams, regardless of the combination of phosphorus and nitrogen fertilizer that was applied. The application of P_6 x N_{12} doses resulted in the highest thousand grain weight value (300.00 g), while the application of P_0 x N_8 doses resulted in the lowest thousand grain weight value (190.00 g). Nitrogen and phosphorus doses were applied separately and their effects on thousand grain weight were examined. Nitrogen dose application had a statistically significant effect, while phosphorus dose application did not (Table 3). The thousand grain weight of the Göksun bean variety varied between 220.83 -261.67g according to the nitrogen dose application of 0, 4, 8, and 12 kg da^{-1}. Thousand grain weight formed two groups in terms of nitrogen dosing. The highest thousand grain weight was 261.47 g and 12 kg da^{-1} nitrogen application. The lowest value was obtained with 8 kg da^{-1} (220.83 g), followed by 224.17 g with 4 kg da^{-1} in the second place (same group). It was recorded that the thousand grain weight was 247.50g in nitrogen application at 0 kg, and it formed the transition group between the two groups. In different phosphorus (0, 3, 6, 9 kg da^{-1}) dose applications, thousand grain weights varied between 223.33 - 259.17g. Different phosphorus doses did not create statistical differences in terms of thousand grain weight.

Table 3. Averages of Phosphorus and Nitrogen doses per thousand grain weight ratio alone.

	0 kg da^{-1} P	3 kg da^{-1} P	6 kg da^{-1} P	9 kg da^{-1} P	Averages
0 kg da^{-1} N	260.000	236.666	263.333	230.000	247.50 ab
4 kg da^{-1} N	203.333	230.000	260.000	203.333	224.17 b
8 kg da^{-1} N	190.000	240.000	213.333	240.000	220.83 b
12 kg da^{-1} N	240.000	253.333	300.000	253.333	261.67 a
Averages	223.33	240.00	259.17	231.67	

Kaçar et al. (2004) found that applying different amounts of nitrogen fertilizer did not have a significant effect on the thousand grain weight bean seeds. The thousand grain weight bean seeds ranged from 439.2 to 453.6 grams, regardless of the amount of nitrogen fertilizer applied. Altınkaynak and Ceyhan (2018) noted that different nitrogen fertilization applied to the Alberto bean variety did not affect the thousand grain weight. Öztürk (2019), who conducted his study by dividing nitrogen fertilizer into the bean plant and taking into account the irrigation situation, found that the highest thousand grain weight was obtained from the application of 6 kg da^{-1} nitrogen by sowing, followed by 1.5 kg da^{-1} nitrogen by sowing and the remaining nitrogen by applying 1.5 kg da-1 nitrogen in three separate irrigations. Mtua (2015) found that applying different amounts of phosphorus fertilizer did not have a significant effect on the thousand grain weight in the Göynük 98 bean variety. The thousand grain weight bean seeds remained the same, regardless of the amount of phosphorus fertilizer applied, even when TKİ-Humas was also applied. Thousand-seed weight ranged from 317 to 359 g. Iyigun (2019) found that thousand-seed weights varied from 230.78 to 370.31 g and that there were significant differences in thousand grain weights between the cultivars. Most of the nitrogen applied to the plant is transported to the vegetative organs and storage organs, and this is reflected in the thousand-grain weight.

Conclusion

In this study, bean grain quality criteria were examined. For this purpose, the effect of grain on quality criteria was examined by using four different phosphorus (0, 3, 6, 9 kg da^{-1}) and four different nitrogen doses

(0, 4, 8, 12 kg da^{-1}). High rates of nitrogen fertilization and topdressing are commonly used in bean cultivation in Kahramanmaraş and its vicinity, but the optimal doses for maximum efficiency are not well-established. This study aimed to determine the optimal nitrogen and phosphorus doses for bean cultivation in Kahramanmaraş. The study found that phosphorus doses alone did not affect yield, but the highest thousand-grain weight was obtained with the 12 kg nitrogen dose. Applied nitrogen doses had a statistically significant effect on starch and thousand-grain weight values, while phosphorus dose applications alone did not. Therefore, this study concluded that the combined application of nitrogen and phosphorus, rather than applying them alone, is very important for improving grain quality criteria. It is recommended that farmers in the Kahramanmaraş region apply nitrogen and phosphorus fertilizer together to obtain high-quality products.

Author Contribution

The authors contributed equally to the preparation of the article.

Conflict of Interest

As the authors, we declare that there is no conflict of interest regarding the planning, execution, and writing of the article.

Note

This article is the revised and developed version of the unpublished conference presentation entitled "The Effect of Different Phosphorus and Nitrogen Doses Applied to Bean (*Phaseolus vulgaris* L.) On Grain Quality Criteria", orally delivered at the 6th International Agriculture Congress (UTAK2023) Symposium.

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