Akademik Ziraat Dergisi 13(2): 362-368 (2024)
ISSN: 2147-6403 e-ISSN: 2618-5881 DOI: http://dx.doi.org/10.29278/azd.1589670

Araştırma
(Research)

Effects of Foliar and Soil Applied of Zinc on Yield and Its Components in Soybean (*Glycine max.* L. Merr.)*

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*This study; It was produced from the master's thesis of the second author, which was accepted as a oral presentation to the III. International Field Crops Congress (19-21 September 2024, Tokat) and published as a summary in the Proceedings book of the IFCC 2024.

Alınış tarihi: 22 Kasım 2024, Kabul tarihi: 10 Aralık 2024
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Abstract

Objective: This study; It is carried out to determine the yield and content of yield elements of soybeans by applying different doses of soil (0, 2, 4, 8 kg Zn/ha) and foliar (% 0, 4, 8 kg Zn/ha).

Materials and Methods: Arısoy variety was used as material in the research. Programmed field trials, which were examined with different doses of foliar and soil applications, were carried out with 3 replications according to the randomized block factorial trial design. In zinc fertilization, four doses (0, 2, 4 and 8 kg Zn/ha) were produced from the soil and three doses (0, 4 and 8% $ZnSO_4.7H_2O$) were produced from the leaves. Zinc-sulfate fertilizer ($ZnSO_4.7H_2O$; 21%Zn) was used as the fertilizer formula. Protein and crude oil ratio analyzes were determined on the "Near Infrared Reflection" (NIRS) device with the IC-0923FE soybean calibration set. The data obtained in the study were analyzed with the JMP statistical program and the differences between the averages found to be significant were evaluated by applying the LSD multiple comparison test.

Results: As a result of the research; plant height 95.01-108.33 cm, first pod height 12.98-15.95 cm, number of branches per plant 4.67-6.73, number of pods per plant 62.03-118.40, number of grains per plant 149.73-254.36, number of grains per pod 1.99-2.54, weight of 100 seeds varied between 16.06-18.31 g, seed yield 3443.2-5897.1 kg/ha, grain protein rate 42.62-44.18%, crude oil rate 19.84-20.29%, crude oil yield 692.9-1193.5 kg/ha. While the effects of zinc application doses from the soil on the number of branches in the plant, the number of pods in the plant, 100 seed weight and seed yield were found to be statistically significant, the effect of the application of foliar and soil together on the number of grains in the plant and crude oil yield was significant, while its effect on other characteristics was found to be significant. was found to be insignificant.

Conclusion: As a result of the study; In soybeans, the highest seed yield per unit area (5193.8 kg/ha) and crude oil yield (1041.0 kg/ha) were obtained by applying 4 kg Zn fertilizer per hectare to the soil.

Keywords: Zinc fertilization, crude oil yield, protein ratio

Yapraktan ve Topraktan Uygulanan Çinkonun Soya Fasulyesinin (*Glycine max*. L. Merr.) Verim ve Verim Öğeleri Üzerine Etkileri

Öz

Amaç: Bu çalışma; farklı dozlarda topraktan (0, 2, 4, 8 kg Zn/ha) ve yapraktan (% 0, 4, 8 kg Zn/ha) çinko uygulamalarının soya fasulyesinin verim ve verim unsurları üzerine etkilerini belirlemek amacıyla yürütülmüştür.

Materyal ve Yöntem: Araştırmada materyal olarak Arısoy çeşidi kullanılmıştır. Yapraktan ve topraktan farklı dozlarda çinko uygulamalarının incelendiği araştırmanın tarla denemeleri tesadüf blokları faktöriyel deneme desenine göre 3 tekerrürlü olarak yürütülmüştür. Çinko gübrelemesinde topraktan dört doz (0, 2, 4 ve 8 kg Zn/ha) ve yapraktan üç doz (% 0, 4 ve 8 $ZnSO_4.7H_2O$) uygulanmıştır. Gübre formu olarak çinko-sülfat ($ZnSO_4.7H_2O$; 21%Zn) gübresi kullanılmıştır. Protein ve ham yağ oranı analizleri "Yakın Kızılötesi Yansıma" (NIRS) cihazında IC-0923FE soya kalibrasyon seti kullanılarak belirlenmiştir. Araştırmada elde edilen veriler, JMP istatistik programında analiz edilmiş ve önemli bulunan ortalamalar arasındaki farklılıklar LSD çoklu karşılaştırma testi uygulanarak değerlendirilmiştir.

Araştırma Bulguları: Araştırma sonucunda; bitki boyu 95.01- 108.33 cm, ilk bakla yüksekliği 12.98-15.95 cm, bitkide dal sayısı 4.67-6.73, bitkide bakla sayısı 62.03-118.40, bitkide tane sayısı 149.73-254.36, baklada tane sayısı 1.99-2.54 adet, 100 tane ağırlığı 16.06-18.31 g, tane verimi 3443.2- 5897.1 kg/ha, tanede protein oranı %42.62-44.18, ham yağ oranı %19.84-20.29, ham yağ verimi 692.9-1193.5 kg/ha arasında değişim göstermiştir. Çinkonun topraktan uygulama dozlarının bitkide dal sayısı, bitkide bakla sayısı, 100 tane ağırlığı ve tohum verimi üzerine olan etkileri istatistiksel olarak önemli bulunurken, yapraktan ve topraktan birlikte uygulanmasının ise bitkide tane sayısı ve ham yağ verimi üzerine olan etkisi önemli, diğer özellikler üzerine olan etkisi ise önemsiz bulunmuştur.

Sonuç: Çalışma sonucunda; soya fasulyesinde birim alanden en yüksek tohum verimi (5193.8 kg/ha) ve ham yağ verimi (1041.0 kg/ha) dekara 4 kg Zn gübresinin toprağa uygulanmasından elde edilmiştir.

Anahtar kelimeler: Çinko gübrelemesi, ham yağ verimi, protein oranı

Introduction

Soybean, which is in the legume family, is a cultivated plant with the largest planting area in the world among oil crops. Soybean is a plant with a high protein content (35-45%) as well as an oil content (18-24%). It is an important source of nutrition for humans and animals because it contains high protein, carbohydrates, fat and vitamins (Kaya and Erdönmez, 2020). It is also a very important crop rotation plant because it binds the free nitrogen of the air to the soil thanks to the Rhizobium bacteria that they live in common with in their roots and leaves a nitrogen-rich soil for the plants that come after them.

According to 2022 data, soybeans have a global cultivation area of 133.8 million hectares, a production of 348.9 million tons, and a yield of 2607.5 kg/ha; in the same year, 155 thousand tons of production was obtained in our country from an area of 38 thousand hectares, yielding 4078 kg/ha. When evaluated in terms of vegetable oil production, soybean oil ranks second after palm oil (FAO, 2024).

In Turkey, soybean products (soybean oil, soybean meal, soybean lecithin etc.) are used in large quantities. At the same time, the wide range of industrial usage opportunities (medicine, paint, paper, rubber food etc.) necessitates the increase in soybean production (Güneş, 2006). There are two ways to increase production in any plant product. One of these is to expand the planting areas, and the second is to increase the yield obtained from the unit area. One of the basic principles of increasing the yield and quality obtained from the unit area is to apply the nutrients that the plants need at the appropriate time and in the appropriate amount. Fertilization is one of the main ways to increase yield and quality in plants and in recent years, interest in microelements has increased. Zinc has an important place among these microelements for increasing plant productivity.

Zinc (Zn) deficiency is a common micronutrient problem in the world and in Turkey. It has been determined that the amount of zinc available to plants is low in approximately 50% of the agricultural lands in Turkey (Çakmak et al., 1996). Zinc, the essential component of many enzymes, is taken up by plants from the soil solution as the Zn^{2+} ion and plays many vital roles in protein production and the metabolism of plant hormones (Korkmaz et al., 2018; Korkmaz et al., 2024). Zinc availability in soils and its absorption in plants is affected by physicochemical properties of soils such as high pH, low level of organic matter, high contents of calcite and bicarbonate ions and high levels of available phosphorus (Korkmaz et al., 2021). Therefore, the method of fertilizer application needs to be considered in zinc applications. Moreover, the appropriate fertilizer application method can be an important approach for better uptake and utilization of Zn. Field crops only uptake a small fraction (0.3-3.5%) of the applied Zn, while a considerable amount of Zn fertilizer remains in the soil (Lu et al., 2012). The positive effect of applied Zn on succeeding rotation crops can last for variable periods of time, depending on the sources of Zn and the concentration of plant-beneficial Zn in the soil (Zhao et al., 2020). However, there is not enough research in the literature on the effects of foliar and soil Zn applications on forage soybean growth. Therefore, the present experiment aimed to investigate the effects of foliar and soil applied of zinc on yield and its components in soybean.

Materials and Methods

This research was carried out in Ordu University, Faculty of Agriculture, Field Crops experimental area in 2016. In the experimental year, the total rainfall, average temperature and average relative humidity during the growing period (May-October) were 624 mm, 22.1 °C and 68.3%, respectively; and in the long-term average, they were 474.7 mm, 19.7 °C and 74.3%, respectively (Anonymous, 2019). Soil samples taken from 0-30 cm depth from the experimental area were analyzed physically and chemically. According to the analysis results, it was determined that the experimental area soil was clayey-loamy, neutral (pH = 7.1), had very low organic matter content, was lime-free and salt-free, insufficient in terms of available P and sufficient in terms of K, and had low Zinc and Manganese content.

The Arısoy variety was used as the material in the research. The field experiments of the research, in which different doses of zinc applications were examined from leaves and soil, were carried out according to the randomized block factorial trial design with 3 replications. Sowing was performed on 14 May 2016. In the experiment, 60 cm between rows and 5 cm between rows were applied (Yaramancı, 2009) and planting was done in 5 rows of 3 m length in each plot. Before planting in the seed, inoculation was made with Rhizobium japonicum type bacterial culture with the calculation of 1 kg bacteria per 100 kg of seed (Arıoğlu, 2007). In the basic fertilization, considering the nutrient deficiencies, equal amounts of 30 kg/ha N and 60 kg/ha P_2O_5 were applied to the whole experimental area before planting. In the research, four doses (0, 2, 4 and 8 kg Zn/ha) of Zn were applied from the soil and three doses (0, 4 and 8% $ZnSO_4.7H_2O$ foliar application) of Zn from the leaves were applied in zinc fertilization. Zinc-sulphate ($ZnSO_4.7H_2O$; 21%Zn) fertilizer was used as fertilizer form. Zinc applications from soil were made after germination in the plots in order not to cause possible negativities or differences on germination, while foliar zinc applications were applied by spraying the leaves during the first flowering period. During the vegetation period, considering the signs of drought, 3 times of sprinkler irrigation and 2 times of hoeing were done before planting, when the plants reached 10-15 cm height and during flowering. Harvesting was done manually in the first half of October and necessary measurements and observations were taken. The seeds obtained from each plot were dried separately in the greenhouse. In the research; plant height, first pod height, number of branches per plant, number of pods per plant, number of seeds per pod, number of seeds per plant, weight of 100 seeds, seed yield, protein ratio, crude oil ratio and crude oil yield were examined. Protein and crude fat ratio analyzes are performed on the "Near Infrared Reflectance" (NIRS) device, Using the IC-0923FE soybean calibration set was determined (Uzun, 2010). The data obtained in the experiment were analyzed using the JMP statistical program to calculate variance. Differences between the averages that were analyzed and found to be significant were evaluated using LSD multiple comparison test was applied.

Results and Discussion

The mean values and variance analysis results of the data obtained from this study, which investigated the effects of different doses of foliar and soil applied zinc on the yield and yield components of soybean, are given in Table 1 and Table 2.

While no effect of different doses of zinc applied from foliar and soil on plant height, first pod height, number of grains per pod, protein content in grain and oil content could be determined, it was determined that the effect of zinc doses applied from soil on the number of branches per plant, number of pods per plant, 100 grain weight and seed yield was significant. Among the examined traits, it was determined that the interaction effect of zinc applied from foliar and soil was significant on the number of seeds per plant and crude oil yield. In a similar study, the effect of 6 kg/ha zinc application on plant height in 3 different soybean varieties was statistically insignificant in the first year and significant in the second year; It was determined that seed yield, number of pods, number of seeds per pod and hundred grain weight were significantly affected by zinc application (Sümer, 2022).

The most important point that draws attention in this study is that the effect of foliar zinc application alone on all the traits examined is insignificant, while the zinc doses applied from the soil have significant effects on many traits. According to the results of this research; the effect of zinc doses applied in different ways and doses on plant height and first pod height was found to be insignificant. In many studies on the subject, it has been determined that zinc application increases plant height (Öztürk, 2009; Öktem et al., 2016; Singh et al., 2017), the effect of zinc on first pod height was insignificant in mungbean (Dülgerbaki, 2010) and increasing zinc doses increased first pod height in lentil plants (Togay et al., 2001).

Table 1. Average values and variance analysis obtained from different doses of zinc application to foliar and soil

Soil App. (kg Zn/ha)	Foliar App. (%)	Plant height (cm)	First pod height (cm)	Number of branches per plant	Number of pods per plant	Number of seeds per pod	Number of seeds per plant
0	0	95.01	14.24	4.67	62.03	2.41	149.73 d
	4	101.22	16.51	5.03	76.73	2.45	187.03 cd
	8	98.41	13.96	5.10	80.63	2.34	188.36 cd
Means Soil Application		98.21	14.90	4.93 C	73.13 B	2.40	175.04 B
2	0	102.09	14.22	5.87	118.40	1.99	208.43 bc
	4	100.79	14.73	5.73	88.10	2.44	214.73.abc
	8	102.14	15.38	6.30	98.00	2.40	232.70 ab
Means Soil Application		101.60	14.78	5.97 A	101.50 A	2.27	218.62 A
4	0	108.33	15.32	6.73	100.20	2.54	254.36 a
	4	103.29	15.22	5.67	89.40	2.39	213.63 abc
	8	98.74	12.98	5.43	81.13	2.37	193.36 bc
Means Soil Application		103.45	14.51	5.94 B	90.24 AB	2.43	220.45 A
8	0	97.28	14.37	5.30	77.86	2.41	188.03 cd
	4	95.76	13.58	5.53	92.60	2.41	225.40 abc
	8	101.27	15.95	5.13	81.16	2.40	194.53 bc
Means Soil Application		98.10	14.63	5.32 BC	83.87 B	2.40	202.65 A
Means Foliar App.	0	100.68	15.54	5.64	89.62	2.34	200.14
	4	100.27	15.01	5.49	86.70	2.42	210.20
	8	100.14	14.57	5.49	85.23	2.37	202.24
Means		100.36	14.71	5.54	87.18	2.38	
Significance level				$LSD_{TÇU}$ (0.01): 0.63	$LSD_{TÇU}$ (0.05): 17.53		$LSD_{TÇU}$(0.05): 24.89 $LSD_{TÇU\,xYÇU}$(0.01): 43.09

Table 2. Average values and variance analysis obtained from different doses of zinc application to foliar and soil

Soil App. (kg Zn/ha)	Foliar App. (%)	100 Seeds weight (g)	Seed Yield (kg/ha)	Protein Ratio (%)	Crude fat ratio (%)	Crude oil yield (kg/ha)
0	0	17.25	3443.2	44.11	20.15	692.9 e
	4	16.06	3978.2	43.83	20.12	800.6 de
	8	17.50	4384.2	43.54	20.14	881.9 b-e
Means Soil App.		16.93 AB	3935.2 B	43.83	20.14	791.8 C
2	0	18.31	5081.7	44.09	20.04	1018.4 abc
	4	17.77	5071.5	43.90	20.16	1022.7 abc
	8	17.28	5363.4	42.62	20.08	1075.8 ab
Means Soil App.		17.78 A	5172.2 A	43.54	20.09	1039.0 A
4	0	17.38	5897.1	43.37	20.27	1193.5 a
	4	18.17	5167.9	44.18	19.84	1024.2 abc
	8	17.69	4516.4	43.63	20.07	905.4 bcd
Means Soil App.		17.75 A	5193.8 A	43.73	20.06	1041.0 A
8	0	16.81	4253.7	43.62	20.29	862.1 cde
	4	16.27	4861.3	43.26	20.28	986.6 bcd
	8	17.23	4442.6	43.64	20.17	896.1 bcd
Means Soil App.		16.77 B	4519.2 B	43.50	20.24	914.8 B
Means Foliar App.	0	17.43	4668.9	43.80	20.18	941.7
	4	17.07	4769.7	43.79	20.10	958.5
	8	17.42	4676.7	43.36	20.12	939.8
Means		17.31	4705.1	43.65	20.13	946.7
Significance level		$LSD_{TÇU}$ (0.05):0.85	$LSD_{TÇU}$ (0.01): 604.4			**$LSD_{TÇU}$(0.01):** 111.9 **$LSD_{TÇU\,x\,YÇU}$ (0.05): 193.9**

When the number of branches per plant and the number of pods per plant were examined, it was determined that the effect of zinc doses applied from the soil was statistically significant and the highest values in both characteristics were obtained from 2 kg Zn/ha zinc application, while the effect of increasing zinc doses was in a decreasing direction. Similarly, in studies (El-Haggan, 2014; Sing et al., 2017; Çomaklı and Pejuhan, 2018), it was determined that zinc application increased the number of branches and pods per plant in soybean and therefore the number of seeds per plant.

In this study, the highest number of seeds per plant (254.36 pieces) was obtained from 4 kg Zn/ha, while the lowest number of seeds (149.73 pieces) was obtained from the control plot.

The effect of soil zinc application on seed weight was increasing at 2-4 kg Zn/ha and decreasing at 8 kg Zn/ha dose. While some studies conducted with soybean showed that increasing zinc doses increased seed weight (El-Haggan, 2014; Sing et al., 2017), it was determined that seed weight decreased in mungbean due to increasing Zn doses (Dülgerbaki, 2010). The effect of 2-4 kg Zn/ha applied from soil on the number of branches, number of pods and number of seeds per plant was also observed in seed yield, and the highest seed yield was obtained with 5172.2 and 5193.8 kg/ha Zn doses respectively at 2 and 4 kg Zn/ha (Table 2). The 8 kg Zn/ha applied after this dose caused a decrease in yield. In similar studies conducted under different ecological conditions (Hossain et al., 2008; Kobraee et al., 2011; El-Haggan, 2014; Seyed Sharifi, 2016; Singh et al., 2017), it was determined that zinc application had a positive effect on yield and increased total yield. Similarly, foliar application of Fe, Zn and Mn in corn plants provided the highest dry matter yield (Khalili and Rushdi, 2009).

In this study, the effects of both foliar and soil applied zinc doses on protein and oil content in the seed were found to be statistically insignificant. Although the effect of zinc doses on protein and oil content of the seed was found to be insignificant in this study, it is stated in different studies that zinc application has an effect on increasing the protein content in soybean (Kobraee et al., 2011; Choudhary et al., 2014; El-Haggan, 2014; Singh et al., 2017; Şahin and İşler, 2022).

Soybean is an oil plant and its main purpose of cultivation is to obtain vegetable oil. When the crude oil yield values obtained in this study are examined (Table 2), it is seen that the interaction effect of zinc doses applied from leaves and soil is found to be statistically significant and the highest crude oil yield of 1193.5 kg/ha was obtained from only 4 kg Zn/ha from soil. The effect on crude oil yield and grain number characteristics in the plant is parallel and the highest values in both characteristics were obtained from 4 kg Zn/ha.

Shahsavari et al. (2014) reported that zinc treatment resulted in improved metabolism of fatty acids, especially saturated palmitic, stearic, behenic acids and unsaturated linoleic fatty acids. They reported that the increase in seed oil caused by zinc application was mainly due to the increase in the amount of saturated fatty acids, which may be due to the prevention of oxidation of these oils due to the presence of zinc in the seed. In agreement with the results of this study, Jat et al. (2021) reported that Zn application led to an increase in oil content in soybean. These findings are supported by studies in different crops, such as those conducted by Rad et al. (2019) in rapeseed and Keerio et al. (2020) in sunflower.

Conclusions

In this study, the effects of soil and foliar Zn applications on soybean yield and quality parameters were investigated. According to the results of the study, Zn applications had a positive effect on all parameters examined. According to the results of this study, soil application of 4 kg Zn/ha provided a significant increase in both seed yield per unit area and crude oil yield in soybean compared to foliar applications. However, considering the negative effects of increasing doses of Zn applications, it is necessary to pay attention to Zn doses in soybean.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authorship Contribution Statement

ÖD: Determining the research topic and writing the manuscript.

İA: Conducting field trials, writing the thesis.

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