Black Sea Journal of Agriculture
doi: 10.47115/bsagriculture.1091565

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 5 - Issue 3: 255-259 / July 2022

# THE EFFECT OF ELEMENTAL SULFUR FERTILIZATION ON GREEN BEANS (*Phaseolus Vulgaris* L.) GROWN IN CALCAREOUS SOIL

**Ayşen AKAY[1]***

[1]*Selcuk University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, 42130, Konya, Türkiye*

**Abstract:** In our country, most of the bean cultivation areas, are in the Central Anatolia Region. This study was carried out to determine the sulphureous fertilizer demand of beans grown in the calcareous soils of the region under field conditions in Konya. Early "seat bean" variety was used as a plant material. In the experiment, elemental - sulphur (S) was applied to the parcels at the doses of "0-20-40-80 kg S/da. At the end of the experiment, leaf chlorophyll SPAD values showed a significant increase in the plots where the highest sulfur dose was applied. Parcel yield and leaf surface area increased significantly with increasing sulfur doses ($P<0.05$), and the highest data were obtained from 80 kg S/da application. With sulfur application, the nitrogen content of bean leaves and fruit was partially decreased compared to the control ($P<0.05$). Some element content of the bean product was found as follows, respectively: 1.87-2.38% nitrogen (N), 0.43-0.72% phosphorus (P) and 0.39-0.44% S. Also, some element content of leaf was as follows: 1.97-2.37% N, 0.46-0.51% P and 0.50-0.59% S. The N/S ratios in the plant varied between 3.44-4.93 for the leaf and 4.79-5.60 for the bean. Considering the results obtained, 80 kg/da elemental sulfur application can be recommended to meet the sulfur fertilizer requirement for green beans grown in calcareous soil.

**Keywords:** Elemental - Sulfur, Beans, Calcareous soil, Yield

***Corresponding author:** Selcuk University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, 42130, Konya, Türkiye
**E mail:** aakay@selcuk.edu.tr (A. AKAY)
Ayşen AKAY https://orcid.org/0000-0002-2541-0167

**Received:** March 22, 2022
**Accepted:** May 12, 2022
**Published:** July 01, 2022

**Cite as:** Akay A. 2022. The effect of elemental sulfur fertilization on green beans (*Phaseolus vulgaris* L.) grown in calcareous soil. BSJ Agri, 5(3): 255-259.

## 1. Introduction

Bean (*Phaseolus vulgaris* L.), which is grown intensively in Türkiye and in the world, is an important member of legumes and is consumed in fresh and dry forms. Fresh and dry bean cultivation areas are 142.218 ha in the 2020 production period in Türkiye, and green beans have been produced in approximately 1/4 of this area. When the yield situation is examined, it has been increased since 1990 until now. According to the data of 2020, while the green bean yield was 139.434 hg/ha, the dry bean yield was 27.147 hg/ha (FAO, 2022). According to 2019 data, most of the cultivation areas in Türkiye are located in the Central Anatolia Region (49%). This is followed by the Eastern Anatolia Region with 14.6%. The province of Konya, where the study was conducted, meets 22.1% of Türkiye's dry bean production alone (Anonymous, 2022a).

Application of elemental sulfur increases the solubility of phosphorus and micronutrient elements in calcareous and alkaline soils (Gupta and Mehla, 1980; Abd-Elfattah and Hilal, 1985; Neilsen et al., 1993). This situation is due to the oxidation of S to $SO_4$ form, it occurs by decreasing pH and also increasing nutrient availability (Burns, 1967). As a result of the applications of sulfur alone and in combination with nitrogen, the soil pH has decreased significantly, the availability of micronutrients and plant dry matter yield increased (Soliman et al., 1992). The dry matter yield and phosphorus (P) uptake increased as a result of a 0.11-0.37 unit decrease in soil pH value with sulfur application (Erdal et al., 2000). It has been reported by various researchers that the applications of waste material containing elemental S and S provide a decrease in soil pH and an increase in usable nutrients in the trial soils (Kaya et al., 2009). In studies on elemental sulfur carried out in different countries (Hussain et al., 2011; Ganie et al., 2014; Teame et al., 2020), it was stated that positive results were obtained regarding the effect of sulfur together with other nutrients in bean yield and elemental content. Sulfur has many functions in plants and is a part of proteins and plays an important role in the synthesis of vitamins and chlorophyll in the cell (Marschner, 1995). In sulfur deficiency, growth retardation and reduction are observed in plants (Kacar and Katkat, 2021). Sulfur is a limiting factor in reducing crop yields in many parts of the world (Mascagni et al., 2008).

Soil pH is higher than 7.5 in 63% of agricultural lands in Türkiye, and approximately 59% of them contain more than 5% $CaCO_3$ (Eyüboğlu, 1999). Considering that the soils are calcareous and for the stated reasons, sulfur fertilizer applications have increased in our country and in the world in recent years. It is estimated that the global sulfur fertilizers market size will grow by 3.57% in 2026 (Anonymous, 2022b; Anonymous, 2022c).

In the working soil where this field trial was carried out, in the previous 10-week incubation experiments it was indicated that the pH value of the soil decreased partially as the incubation time of elemental sulfur with the soil increased (Akay et al., 2019).

In this study, the effects of elemental sulfur added in different proportions on the development, chemical content and sulfur uptake of green beans were investigated in the calcareous and high pH soil covering large areas in Konya. In the study, it was also aimed to determine the appropriate sulfur fertilizer dose for beans.

## 2. Material and Methods

### 2.1. Experiment Materials

The research was carried out in Konya- Selcuk University Faculty of Agriculture Sarıcalar farm under field conditions. Bean, whose trade name is "seat bean" (Romano 26), was used as a plant material. The characteristics of this bean variety can be listed as follows: The color of the seeds obtained from the plant is white. The length of the pod is 14-15 cm. It is an awnless and early variety (45-50 days). Its flower color is white, and it is a suitable variety for both fresh consumption and canning (Anonymous, 2021).

### 2.2. Establishment of the Experiment and the Actions Taken During the Experiment

The experiment was set up in the field in randomized block factorial design with three replications. The parcels were prepared to be 12 $m^2$ (3mx4m) each. Elemental powdered sulfur (100% S) was applied in different doses (S0-S1-S2-S3) (0-20-40-80 kg/da) to the parcels that were pre-prepared before the experiment was established and mixed with the soil homogeneously.

The experiment, which was established as three replications, was carried out in a total of 12 plots. Taking into account the soil analysis results, phosphorus and nitrogen fertilizers were also applied to all plots (15 kg/da DAP). After these procedures, plant seeds were planted in the plots (in May 2019) and irrigated. After emergence, the plants were regularly irrigated twice a week, considering the field capacity of the soil. In addition, the soil was hoed three times according to the weed situation.

During the flowering period, nitrogen fertilizer (8 kg/da ammonium sulfate) was applied to all parcels from above. At the beginning of flowering, the chlorophyll SPAD value (with Minolta-502 SPAD meter) was determined in mature leaves from each parcel and the surface area was measured with a planimeter by taking leaf samples. During the vegetation period, the beans ripening in each parcel were collected weekly, and their weights were determined on precision scales. Fruit length and width values of bean were measured with a digital caliper.

After the bean development was completed, the plants were harvested. The bean samples harvested, and the leaf samples taken during the flowering period were subjected to wet burning using $H_2SO_4$-$H_2O_2$ as digestion reagents (Bayraklı, 1987). In the solutions obtained as a result of wet burning, N analysis was determined by the Kjeldahl method (Bremler, 1965). Phosphorus was determined according to the vanadomolybdophosphoric acid method (Barton, 1948) in the spectrophotometer (UV-VIS). Sulfur concentrations in the solution obtained after combustion, it determined by using spectrophotometer in the mixture obtained by adding ammonium acetate, barium chloride and resin (Fox et al., 1964).

### 2.3. Soil Analyzes

Before the experiment, soil samples were taken from 0-30 cm from the field and some physical and chemical properties were determined (Table 1). According to the results, soil has clay loam texture, slightly alkaline pH. It is salt free and calcareous. The soil contains moderate organic matter. Phosphorus and potassium content of the soil is sufficient, calcium and magnesium content are high. Fe, Zn, Cu, Mn contents of the soil are high and sulfur content is low.

### 2.4. Statistical Analyzes

All measurements were performed at three times and the results expressed as mean ± standard deviation (SD). Statistical analyses for all data were performed using Minitab 18 package program. Data were analyzed by General linear model to evaluate significant differences between mean at 95% level of confidence. Significant differences were determined by Tukey's Pairwise Comparison test (Düzgüneş, 1963; Yurtsever, 1984).

## 3. Results and Discussion

According to the variance analysis results of the data obtained at the end of the experiment, parcel yield increased significantly with increasing S doses compared to the control ($P<0.05$) (Table 2). The highest average parcel yield is 80 kg S/da (1959 g/parcel). In the study in which the effect of sulfur application with bacterial inoculation in soybean was determined, it was found that the application of 30 kg S $ha^{-1}$ provided a significant increase in yield compared to the control. It was also stated that plant height, number of pods per plant, straw yield, seed yield and dry matter yield increased by 14%, 56%, 25%, 20% and 26% compared to the control, respectively (Hussain et al., 2011). Togay et al. (2008) stated that, the combined application of P and S increases the yield in beans, and also the best results were obtained with 80 kg P /ha and 120kg S /ha application.

In the random sampling of the products taken in the experiment, the width and height measurements of the bean fruit were made. According to the results obtained, it was seen that the effect of S application on fruit width and length was not statistically significant (Table 2). Low and high rates of S application to beans do not affect yield, seed number and weight values, as agronomic parameters (Pandurangan and Marsolais, 2015).

**Table 1.** Physical and chemical properties of experimental soil

| Properties | Values | Analysis Methods |
|---|---|---|
| Physical properties | | |
| Texture class | Clay loam | (Bouyoucos, 1951) |
| Field capacity | 25 | (Cassel and Nielsen, 1986) |
| Fading point | 15 | (Cassel and Nielsen, 1986) |
| Chemical properties | | |
| pH (1:2.5 soil:pure water) | 8.19 | (Jackson, 1969) |
| EC(μS/cm) (1:5 soil:pure water) | 388.7 | (Staff US Salinity Lab, 1954) |
| Organic matter (%) | 3.00 | Walkley and Black's modified method (Jackson, 1969) |
| $CaCO_3$(%) | 12.1 | (Nelson, 1996) |
| Available P(mg/kg) | 37.8 | (Olsen and Sommers, 1982) |
| Extractable K (mg $kg^{-1}$) | 867 | Extraction method with 1 N neutral ammonium acetate |
| Extractable Ca(mg $kg^{-1}$) | 8.378 | |
| Extractable Mg(mg $kg^{-1}$) | 703 | |
| Extractable Na(mg $kg^{-1}$) | 213 | |
| Available Zn(mg $kg^{-1}$) | 1.66 | DTPA (Diethylene triamine penta acetic acid) ekstraction method (Lindsay and Norvell,1978) |
| Available Fe (mg $kg^{-1}$) | 4.45 | |
| Available Cu (mg $kg^{-1}$) | 2.48 | |
| Available Mn (mg $kg^{-1}$) | 47.8 | |

**Table 2.** Effect of sulfur fertilizer applications on yield, fruit width and height, chlorophyll Spad value and leaf surface area of bean plant

| S doses (kg/da) | Yield (gr/parcel) | Bean width(mm) | Bean height(mm) | Chlorophyll Spad value | Leaf surface area ($mm^2$) |
|---|---|---|---|---|---|
| 0 | 1548 ± 56 $^{b}$ | 13.27 ± 0.51 | 110.34 ± 0.77 | 43.61 ± 2.11 $^{b}$ | 55.53 ± 12.90 $^{b}$ |
| 20 | 1663 ± 180 $^{ab}$ | 13.16 ± 0.30 | 109.78 ± 7.13 | 40.79 ± 2.91 $^{b}$ | 58.23 ± 3.77 $^{b}$ |
| 40 | 1804 ± 160 $^{ab}$ | 12.48 ± 0.31 | 107.89 ± 3.36 | 41.39 ± 0.16 $^{b}$ | 73.03 ± 3.18 $^{ab}$ |
| 80 | 1959 ± 56 $^{a}$ | 12.69 ± 0.20 | 109.34 ± 3.17 | 52.32 ± 2.04 $^{a}$ | 81.63 ± 3.82 $^{a}$ |

$^{a,b}$Mean values with different superscripts in the same column indicate a significant difference (P<0.05).

It was stated that the bean responded to S fertilization at a low rate (under 10%) in field conditions (Malavolta et al., 1987).

Leaf chlorophyll SPAD values measured at the beginning of flowering did not increase with increasing S doses compared to the control. However, a statistically significant increase was observed in the parcels where the highest S dose was applied, compared to both the control and other S doses (P<0.05). In field trials conducted in Ethiopia in dry beans, it was found that the combination of 20 kg $ha^{-1}$ P and 30 kg $ha^{-1}$ S was the optimum ratio and maximum vegetative growth was achieved. It has been stated that it can be used to provide earliness and high grain yield for Melka Awash-98 variety (Teame et al., 2020).

In the study, it is noteworthy that there was a partial decrease in the N concentration of the leaf and bean with S application compared to the control, and that the S application had a negative effect (Table 3). The N concentration values of the leaf vary between 1.97-2.37% and these values are within the adequacy limit given for the upper leaf at the beginning of flowering for beans (2.00% sufficient and 1% insufficient) (Jones 2001). N concentrations in both leaves and fruit are highest in control treatments. Sulfur applications negatively affected the N concentration in the plant. On the other hand, considering the amount of N removed from the soil by bean fruit, the highest N uptake was observed in 80 kg S/da application compared to control and other S application doses (P<0.05). Although the N concentration in the bean fruit decreased a little compared to the control, the amount of N taken by the plant from the soil increased (Table 4). Teame et al. (2020) stated that the protein content with the effect of P - S fertilization in different bean varieties varied between 22.5-27.1%.

With increasing doses of elemental S, the P concentration in bean leaves and fruit decreased significantly compared to the control (P<0.05), and S adversely affected the P concentration in the plant (Table 3). The P concentration values in the leaf varied between 0.46-0.51%, and these values are above the proficiency limit (0.2%-0.4% sufficient) (Yıldız, 2008). While the P content in the bean fruit were 0.72% in the control application, they decreased to 0.43% in the 80 kg S/da application. Similar to N concentrations, P concentrations in leaves and bean fruits are highest in control treatments. The amount of P removed from the soil by bean fruit also decreased significantly with increasing sulfur doses compared to the control ($P<0.05$). This value was an average of 3.73 kg/da in the control application, and it's decreased gradually with the sulfur application and decreased to 2.79 kg/da in 80 kg S/da application. Sulfur adversely affected phosphorus uptake by the plant (Table 4).

Considering the effect of S application on the S concentration in leaves and bean fruits, there was no statistically significant difference between these values compared to the control. The S concentration of the leaf is between 0.50 - 0.59%, and this value is between sufficient and high in the limit values given for sulfur (Yıldız 2008). In the bean fruit, the S concentration varied between 0.39 and 0.44%. The amount of S removed from the soil by the bean fruit increased with increasing S doses, but there was no statistical difference between these values (Table 4). With the bean fruit, an average of 2.16-2.85 kg/da of S was taken from the soil.

When the N/S ratios in the plant were examined at the end of the experiment, it changed between 3.44-4.93 for the leaf and 4.79-5.60 for the bean fruit. The total N/S ratio for protein synthesis in legume plants is 17 (Kacar and Katkat, 2021). Sulfur deficiency will limit protein formation if the total N/S ratio is above 16. If this ratio is above 20, it is stated that there is a serious sulfur deficiency in plants (Stewart and Porter, 1969). Orman and Kaplan (2017) stated that sulfur and manure applications alone in beans significantly affected the total N/S ratio in shoots, reported that the rate changed as 23.76 and 18.72. The fact that the total N/S ratio in the study is lower than the value stated for legumes is thought to be related to the limit value of N concentration in both leaves and fruits of the plant. Mn, Ni and Mo in plant leaves increased when insufficient S was applied to bush beans (*Phaseolus vulgaris* L. var. Tendergreen) to completely neutralize $CaCO_3$ in calcareous soil. It has been observed that $CaSO_4$, which is used as a sulfur source, does not have the same effect as elemental S (Procopiou et al., 1976).

**Table 3.** The effect of sulfur fertilizer applications on the N, P and S concentrations in the leaf and grain of the bean plant

| S doses (kg/da) | Leaf N(%) | Bean N(%) | Leaf P(%) | Bean P(%) | Leaf S(%) | Bean S(%) |
|---|---|---|---|---|---|---|
| 0 | 2.31 ± 0.088$^{a}$ | 2.38 ± 0.038$^{a}$ | 0.51 ± 0.009$^{a}$ | 0.72 ± 0.014$^{a}$ | 0.58 ± 0.211 | 0.43 ± 0.045 |
| 20 | 2.37 ± 0.048$^{a}$ | 1.87 ± 0.066$^{c}$ | 0.48 ± 0.012$^{ab}$ | 0.65 ± 0.016$^{b}$ | 0.50 ± 0.122 | 0.39 ± 0.011 |
| 40 | 2.11 ± 0.105$^{ab}$ | 2.12 ± 0.070$^{b}$ | 0.46 ± 0.026$^{b}$ | 0.61 ± 0.016$^{c}$ | 0.58 ± 0.040 | 0.39 ± 0.051 |
| 80 | 1.97 ± 0.148$^{b}$ | 2.22 ± 0.026$^{b}$ | 0.46 ± 0.009$^{b}$ | 0.43 ± 0.002$^{d}$ | 0.59 ± 0.152 | 0.44 ± 0.043 |

$^{a,b}$Mean values with different superscripts in the same column indicate a significant difference ($P<0.05$).

**Table 4.** The effect of sulfur fertilizer applications on the amount of N, P, S removed from the soil by the bean fruit, the N/S ratio in the fruit and the N/S ratio in the leaf

| S doses (kg/da) | Bean removed N (kg/da) | Bean fruit removed P (kg/da) | Bean fruit Removed S (kg/da) | N/S ratio in leaf | N/S ratio in bean |
|---|---|---|---|---|---|
| 0 | 12.25 ± 0.025 $^{b}$ | 3.73 ± 0.200 $^{a}$ | 2.20 ± 0.220 | 4.35 ± 1.380 | 5.60 ± 0.590 |
| 20 | 10.36 ± 0.831 $^{c}$ | 3.59 ± 0.297 $^{a}$ | 2.16 ± 0.183 | 4.93 ± 1.305 | 4.79 ± 0.163 |
| 40 | 12.70 ± 0.865 $^{b}$ | 3.69 ± 0.422 $^{a}$ | 2.35 ± 0.401 | 3.65 ± 0.192 | 5.50 ± 0.866 |
| 80 | 14.52 ± 0.524 $^{a}$ | 2.79 ± 0.297 $^{b}$ | 2.85 ± 0.311 | 3.44 ± 0.608 | 5.13 ± 0.426 |

$^{a,b}$Mean values with different superscripts in the same column indicate a significant difference ($P<0.05$).

## 4. Conclusion

As a result, in this study carried out with green beans grown in calcareous soil, S applications increased bean yield. Although there was no change in bean sizes and chlorophyll content, it was observed that the leaf surface area of the plant was significantly and positively affected by S doses. N, P concentrations in bean leaves and bean fruit decreased partially, but the N removed from the soil by the product increased. Concentration of sulfur in leaves and bean, S removed by fruit, N/S ratios in leaf and bean did not change with sulfur doses. When considering these results, 80 kg/da elemental sulfur can be recommended for sulfur fertilizer for bean growing in calcareous soil.

**Author Contributions**

All task made by A.A. (100%) data acquisition and analysis, writing up, submission and revision. The author reviewed and approved final version of the manuscript.

**Conflict of Interest**

The author declared that there is no conflict of interest.

## References

Abd-Elfattah AA, Hilal MH. 1985. Effect of S application on some properties of Egyptian desert soils. In Proc. Arab Reg. Conf. on Sulphur and Its Usages in the Arab Countries. Riyadh, Saudi Arabia, pp. 2-5.

Akay A, Seker C, Negis H. 2019. Effect of enhanced elemental sulphur doses on pH value of a calcareous soil. Yüzüncü Yıl Üniv Tarım Bil Derg, 29: 34-40.

Anonymous. 2021. URL: https://pratiktarim.com/taze-fasulye-cesitleri/ (access date: March 11, 2022).

Anonymous. 2022a. Tarimsal Ekonomi ve Politika Geliştirme Enstitüsü (TEPGE) Enstitümüz tarım, gıda, çevre ve kırsal kalkınma konularında ekonomik araştırma. Kuru Fasulye - Tarım ve Orman Bakanlığı. URL: https://arastirma.tarimorman.gov.tr (access date: March 11, 2022).

Anonymous. 2022b. URL: https://www.statista.com/statistics/439012/potential-supply-of-sulfur-fertilizer-worldwide/ (access date: March 11, 2022).

Anonymous. 2022c. URL: https://www.globenewswire.com/en/newsrelease/2021/11/05/2328565/28124/en/Global-Sulfur-Fertilizers-Market-Research-Report-2021-to-2026-by-Type-Formulation-Crop-Type-Application-and Region.html/ (access date: March 11, 2022).

Barton CJ. 1948. Photometric analysis of phosphate rock. Anal Chem, 20(11): 1068-1073.

Bayraklı F. 1987. Toprak ve bitki analizleri (Çeviri ve Derleme) OMÜ, Zir Fak, Yay No: 17, Samsun, Türkiye, pp. 194.

Bremler JM. 1965. Methods of soil analysis. American Society of Agronomy Inc.: Madison, WI, US.

Bouyoucos GJ. 1951. A Recalibration of the hydrometer method for making mechanical analysis of soils 1. Agronomy J, 43(9): 434-438.

Burns GR. 1967. Oxidation of sulfur in soils. Technical Bul Number 13. The Sulphur Institute, Washington, DC, US.

Cassel DK, Nielsen DR. 1986. Field capacity and available water capacity. In: Klute, A., Ed., Methods of Soil Analysis. Part I. Physical and Mineralogical Methods, Agronomy Monograph No. 9, Soil Science Society of America, Madison, US, pp. 901-926.

Düzgüneş O. 1963. İstatistik - prensip ve metotlari. Ege Üniversitesi Matbaası, İzmir, Türkiye, pp. 375.

Erdal İ, Gülser F, Tüfenkçi Ş, Sağlam M, Karaca S. 2002. Kükürtlü gübrelemenin kireçli bir toprakta mısır bitkisi (Zea mays L.) gelişimi ve bitki fosfor alımına etkisi. Yüzüncü Yıl Üniv Fen Bil Enst Derg, 7(1): 37-42.

Eyuboglu F. 1999. Fertility of Turkish Soils. Soil and Fertilizer Research Institute Publications.

Fageria NK, Santos AB. 2008. Yield physiology of dry bean. J Plant Nutr, 31: 983-1004.

Fox RL, Olson RA, Rhoades HF. 1964. Evaluating the Sulfur Status of Soils by Plant and Soil Tests. DOI: 10.2136/sssaj1964.03615995002800020034xCitations: 133.

Ganie MA, Akhter F, Bhat MA, Najar GR. 2014. Growth yield and quality of French bean (Phaseolus vulgaris L.) as influenced by sulphur and boron application on inceptisols of Kashmir. The Bioscan, 9(2): 513-518.

Gupta VK, Mehla DS. 1980. Influence of sulphur on the yield and concentration of copper, manganese, iron and molybdenum in berseem (Trifolium alexandrinum) grown on two different soils. Plant and Soil, 56(2): 229-234.

Hussain K, Islam M, Siddique MT, Hayat R, Mohsan S. 2011. Soybean growth and nitrogen fixation as affected by sulfur fertilization and inoculation under rainfed conditions in Pakistan. Int J Agri Biol, 13(6): 951-955.

Jackson ML. 1969. Soil chemical analysis-advanced course. Soil Chemical Analysis-Advanced Course. Edition 2, US, pp. 1790.

Jones JB. 2001. Laboratory guide for conducting soil tests and plant analysis. CRC press, Wales, UK, pp. 384.

Kacar B, Katkat V. 2021. Bitki besleme. Nobel Akademik Yayıncılık, Türkiye, pp. 678.

Kaya M, Küçükyumuk Z, Erdal I. 2009. Effects of elemental sulfur and sulfur-containing waste on nutrient concentrations and growth of bean and corn plants grown on a calcareous soil. African J Biotechnol, 8(18): 4481-4489.

Lindsay WL, Norvell WA. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper 1. Soil Sci Soc America J, 42(3): 421-428.

Malavolta E, Vitti GC, Rosolem CA, Fageria NK, Guimarães PTG. 1987. Sulfur responses of Brazilian crops. J Plant Nutri, 10: 2153-2158.

Marschner H. 1995. Mineral nutrition of higher plants, 2nd edn. Academic Press, the Netherlands, pp. 889.

Mascagni HJJr, Harrison SA, Padgett GB. 2008. Influence of sulfur fertility on wheat yield performance on alluvial and upland soil. Commun Soil Sci Plant Anal, 39: 2133-2145.

Neilsen D, Hogue EJ, Hoyt PB, Drought BG. 1993. Oxidation of elemental sulfur and acidification of calcareous orchard soils in southern British Columbia. Can J Soil Sci, 73:103-114.

Nelson DW, Sommers LE. 1996. Total carbon, organic carbon, and organic matter. Methods of Soil Anal Cheml Methods, SSSA Book Series, New York, US, pp. 961-1010.

Olsen LE, Sommers SR. 1982. Phosphorus, In: Page, A.L., Ed., Methods of Soil Analysis Part 2 Chemical and Microbiological Properties, American Society of Agronomy, Soil Science Society of America, Madison, US, pp. 403-430.

Orman Ş, Kaplan M. 2017. Agronomic biofortification of green bean (Phaselous vulgaris L.) with elemental sulphur and farmyard manure. App Ecol Environ Res, 15(4): 2061-2069.

Pandurangan S, Marsolais F. 2015. Determining sulfur-limiting conditions for studies of seed composition in common bean (Phaseolus vulgaris). In Molecular Physiology and Ecophysiology of Sulfur. Springer, Cham, US, pp. 207-213.

Procopıou J, Wallace A, Alexander GV. 1976. Microelement composition of plants grown with low to high levels of sulfur applied to calcareous soil in a glasshouse. Plant and Soil, 44: 359-365.

Soliman MF, Kostandi SF, Van Beusichem ML. 1992. Influence of sulfur and nitrogen fertilizer on the uptake of iron, manganese, and zinc by corn plants grown in calcareous soil. Commun Soil Sci Plant Anal, 23(11-12): 1289-1300.

Staff US Salinity Lab. 1954. Diagnosis and improvement of saline and alkali soils. Agri Handbook, 60: 83-100.

Stewart BA, Porter LK. 1969. Nitrogen-sulfur relationships in wheat (Triticum aestivum L.), corn (Zea mays), and beans (Phaseolus vulgaris) 1. Agronomy J, 61(2): 267-271.

Teame G, Mengistu DK, Araya T. 2020. Effects of combined application of phosphorus and sulfur fertilizers on agronomic traits and protein content of supplementary irrigated haricot bean (Phaseolus Vulgarıs) varieties in Raya Valley Northern Ethiopia. Afr J Food Agric Nutr Dev, 20(1): 15383-15401.

Togay Y, Togay N, Erman M, Dogan Y. 2008. Performance of dry bean (Phaseolus vulgaris) as influenced by phosphorus and sulphur fertilization. Indian J Agri Sci, 78(4): 299.

Yıldız N. 2008. Bitki beslemenin esasları ve bitkilerde beslenme bozukluğu belirtileri. Eser Ofset Matbaacılık, İstanbul, Türkiye, pp. 304.

Yurtsever N. 1984. Deneysel İstatistik Metodları. T.C. Tarım Orman ve Köyişleri Bakanlığı, Köy Hizmetleri Genel Müdürlüğü Yayınları, Genel Yayın No:121, Teknik Yayın No:56, Ankara, Tukey.