Agriculture College – Wasit University

Dijlah Journal of Agricultural Sciences

ISSN 2790 – 5985
eISSN 2790 – 5993

Dijlah J. Agric. Sci.، 5(1):102-111, 2026

The effect of adding sulfur at different levels in the growth of Zea mays in Al-Qadisiyah Province

Wurood Jasim Mohammed

Department of Biology, College of Science, Al-Qadisiyah University, Iraq

Corresponding author: sci.bio.mas.22.13@qu.edu.iq

Abstract:

Zea mays is ranked second in the world after wheat in terms of cultivated area, which may reach about 166 million hectares, while it is ranked first in terms of production from the total global grain production. The aim of study was the effect of four different levels of sulfur at different application times on the growth and yield of plants. The results showed that increasing the levels of sulfur fertilizer in the soil led to an increase in some growth and yield characteristics, and that the highest average leaf area in was achieved in the treatment of adding sulfur at the level of 1500 kg ha-1 in the experiment,. The same treatment also achieved the highest average plant height, which compared to the control level. The treatment of adding sulfur at the level of 1500 kg ha-1 achieved the highest average number of grains per ear, compared to the control. The same treatment achieved the highest average weight of 500 grains. The highest average leaf chlorophyll content, compared to the control treatment. The same treatment achieved the highest average stem diameter, compared to the control treatment.

Keywords: *sulfur, Zea mays, growth and yield, grains.*

Received:22/11/2025 **Accepted:21/12/2025** **Published:11/1/2026**

تأثير إضافة الكبريت بمستويات مختلفة على نمو الذرة الصفراء في محافظة القادسية

ورود جاسم محمد

قسم علوم الحياة، كلية العلوم، جامعة القادسية، العراق

الخلاصة

يحتل الذرة الصفراء (Zea mays) المرتبة الثانية عالميًا بعد القمح من حيث المساحة المزروعة، والتي قد تصل إلى حوالي 166 مليون هكتار، بينما يحتل المرتبة الأولى من حيث الإنتاج من إجمالي إنتاج الحبوب العالمي. هدفت هذه الدراسة إلى بحث تأثير أربعة مستويات مختلفة من الكبريت، مع أوقات تطبيق مختلفة، على نمو وإنتاجية النباتات. أظهرت النتائج أن زيادة مستويات سماد الكبريت في التربة أدت إلى تحسين بعض خصائص النمو والإنتاجية، وأن أعلى متوسط لمساحة الأوراق تحقق عند إضافة 1500 كجم/هكتار من الكبريت في التجربة. كما حققت هذه المعاملة أعلى متوسط لارتفاع النبات، مقارنةً بالمعاملة الضابطة. وحققت أيضًا أعلى متوسط لعدد الحبوب في السنبلة، مقارنةً بالمعاملة الضابطة، وأعلى متوسط

لوزن 500 حبة، وأعلى متوسط لمحتوى الكلوروفيل في الأوراق، مقارنةً بالمعاملة الضابطة. وقد حقق العلاج نفسه أعلى متوسط لقطر الساق، مقارنة بالعلاج الضابط.

الكلمات المفتاحية: *الكبريت، الذرة الصفراء، الحاصل، الحبوب.*

1. Introduction

Zea mays is ranked second in the world after wheat in terms of cultivated area, which may reach about 166 million hectares, while it is ranked first in terms of production from the total global grain production, which amounted to 963 million tons. The cultivation of this plant is still low in Iraq, where the average production of yellow corn reached about 340 thousand tons, and the area used for agriculture is 130 thousand hectares (Rasheed et al., 2004). Sulfur constitutes 0.1% of the earth's crust, and in the soil it is found in many forms, including free forms or combined with basic elements Ca, Mg, Na, and K in the soils of arid and semi-arid regions. The sources of sulfur in the soil are mineral sulfur, which includes pyrite and volcanic sources (Li et al., 2019).

Sulfur is found freely in Iraq (Al-Azami, 1990 and Al-Tamimi, 2003). Pure sulfur (S) 100% can also be used, as well as sulfur refining waste such as pure sulfur, agricultural sulfur 90%, and foamed sulfur 75% S, which is a by-product of sulfur manufacturing, to increase the availability of sulfur, phosphorus, and other nutrients from their compounds deposited in the soil. This is done by reducing the degree of soil reaction through the formation of sulfuric acid H2SO4, when sulfur or its waste is oxidized by biochemical oxidation (Li et al., 2019). This biological oxidation is carried out by reviving the aerobic soil of the genus Thiobacillus, including the type *Thiobacillus thiooxidance,* to compensate for the sulfur deficiency in plants and soil by reducing the use of phosphorus fertilizers (Riffat et al., 2020). Therefore, it is considered necessary to increase crop productivity and also the resistance of plants to fungal diseases, by increasing the efficiency of nitrogen metabolism in plants and building amino acids such as Cystiene, Cysteine, and Mithionine (Khan et al., 2006).

Adding sulfur as an acidifier reduces the problems of calcareous soils and, as a result, increases the soil's ability to supply the necessary nutrients and their absorption by plants (Ahmad et al., 2016). This will be reflected in the agricultural yield and its components. Its importance lies in the oxidation of sulfur in the soil, which leads to the formation of sulfuric acid. This process is carried out by Thiobacillus bacteria, which are responsible for sulfur oxidation (Rendig et al., 1999). The large quantities of sulfur produced in Iraq, which may reach more than one million tons annually, adding it to calcareous soils will increase the availability of nutrients in the soil, which will lead to increased growth and production of agricultural crops, including maize (El-Fahdawi et al., 2020; Sarheed et al., 2020). Therefore, the aim of study was the effect of four different levels of sulfur at different application times on the growth and yield of plants.

2. Materials and Methods

A field experiment was conducted to grow (*Zea mays* L.) in the fields of the College of Agriculture, University of Al-Qadisiyah. The first factor included three levels of agricultural sulfur: 0, 300, 1500 kg/ha^{-1}.

Preparing the Experimental

The field area was determined with dimensions of 20 x 12 m^2. The experimental land was plowed with a rotary plow, then leveled. The necessary leveling operations were then carried out. The field was divided into three sectors, followed by plowing, leveling, and re-adjusting the land to eliminate weeds. Three main irrigation ditches were opened along the field, along with sub-divisions for each plot. Each divided into experimental units measuring 3 x 3 m^2 and with a total area of 9 m^2. A distance was left between treatments within the sector or replicate as a precautionary measure to prevent water movement from one treatment to another.

1 - Pre-planting samples were taken from most of the experimental units after dividing the field to be representative of the entire field. They were used to assess some soil characteristics.

2. Samples were taken during the germination stage on September 4, 2022, and the flowering stage on February 12, 2024. Soil and plant samples were collected from each experimental unit during the germination and flowering stages to estimate Fe, Mn, Cu, and Zn. The soil reaction rate and electrical conductivity were also measured for these stages.

3. Samples were taken after the harvest stage. Plant and soil samples were collected from each experimental unit at the end of the season to estimate Fe, Mn, Cu, and Zn in the plant after planting.

The studied growth traits include:

Plant Height (cm)

Plant height was measured for five randomly selected plants per experimental unit. A graduated ruler was used to measure the height from the soil surface to the end of the leaves. The average plant height was then calculated.

Stem Diameter (cm^2)

Stem diameter was measured using a Vernier meter up to 1 mm from the second node on the stem, taking into account the removal of the leaf sheath. The average was then calculated from the same plants used to measure plant height.

Leaf Area (cm2/$plant^{-1}$)

Leaf area was calculated from the same plants used to measure plant height. The average was then calculated according to the following equation:

$$\text{Leaf Area} = \text{Square of the leaf length below the main ear} \times 0.75$$

Relative Chlorophyll Content In leaves (SPAD)

Chlorophyll content was estimated using a SPAD chlorophyll meter. Readings were taken from four leaves per plant and averaged for five plants.

Number of grains per ear (grain per ear $^{-1}$)

Five ears were taken for each experimental unit, then separated and graded according to the grains. The average was calculated using the equation:

Number of grains per ear = Number of rows per ear × Number of grains per row

Weight of 500 grains (g)

Five hundred grains were randomly counted from each treatment and weighed using a sensitive electronic balance.

Grain yield (ton ha $^{-1}$)

This was calculated by multiplying the average grain yield per plant (g/plant $^{-1}$) × plant density. The weight was adjusted for moisture and converted to tons. ha^{-1}.

Statistical Analysis

It was statistically analyzed using an electronic computer and the SPSS program, according to the method used in the analysis of variance mentioned in (Al-Rawi and Khalaf Allah, 1980). The modified Least Significant Difference (LSD) test was used to compare the coefficients at a significance level of 0.05.

3. Results and Discussion

Chlorophyll Content (SPAD)

The results showed that the addition of sulfur led to a significant increase in the leaf chlorophyll content. The treatment (1500 kg S ha^{-1}) for the first date significantly outperformed and yielded the highest average for these traits, reaching 38.9 SPAD, compared to the control treatment, which reached 28.47 SPAD. It did not differ significantly from the treatment T1S3, which reached 35.53 SPAD. It showed a significant superiority over the remaining treatments and dates This is due to the fact that the addition of agricultural sulfur to the soil led to a decrease in the reaction rate. Soil sulfur increases the availability of iron, copper, and manganese, increasing their content in the plant. Sulfur also plays a role in converting dissolved nitrogen in the leaves into protein and protecting chlorophyll from sunlight (Figure 1).

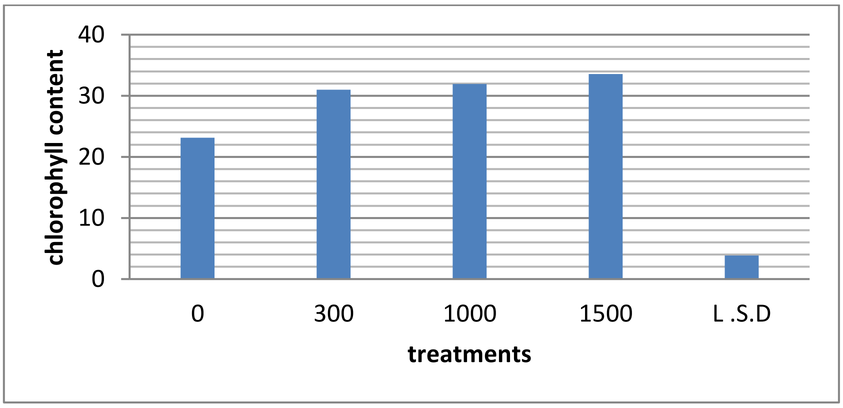

Figure (1) effect the sulfur on the chlorophyll Content (SPAD) of *Zea mays*

The results in showed a significant effect of the dates of agricultural sulfur application on increasing leaf chlorophyll content. The first application date outperformed the second application date, which yielded the lowest rate for this trait. This is because the first application date yielded the highest availability of sulfur, iron, manganese, and copper, thus increasing their content in the plant and, consequently, increasing their chlorophyll content. This is consistent with what was found by Jarallah and Abbas (2019).

Plant height

The results showed a significant effect of the levels of agricultural sulfur addition and the dates of addition on plant height. It shows that increasing the levels of sulfur added to the soil resulted in a significant increase in plant height. The treatment (1500 kg S ha^{-1}) was significantly superior and gave the highest average plant height, reaching 200.17 cm compared to the control treatment. This is due to the importance of sulfur and its role in reducing the degree of soil reaction and thus increasing its readiness. Phosphorus and the production of a good root system for the plant, and increased nitrogen absorption, which led to increased vegetative growth. Also, sulfur caused an increase in zinc and iron, which is one of the essential components of the plant compound tryptophane, which consists of auxin, which is considered primarily responsible for plant height through its role in cell elongation and division. Iron also played a role in increasing chlorophyll in the plant, which is considered essential in the process of photosynthesis. This is consistent with what was found by Maruf and Mam (2019), which indicated that increasing the levels of added agricultural sulfur had a significant effect on plant height. The results showed that the dates of adding agricultural sulfur had a significant effect on plant height, as the first addition date outperformed all levels and gave the highest rate for this trait compared to the second addition date, which gave the lowest rate for this trait.

Leaves area

The results showed a significant effect of the added sulfur levels and the time of its addition on leaf area. The results of Figure (8) show that increasing the levels of sulfur added to the soil led to a significant increase in leaf area, as the treatment (1500 kg S ha-1) was significantly superior and gave the highest average for these traits, reaching 5272.01 cm2 compared to the treatment without adding 4513.80 cm2. It did not differ significantly from the treatment, in which the leaf area reached 5122.40 cm2. It also showed a significant superiority over the other levels and for both dates. This is due to the direct role of sulfur in increasing leaf area through its participation in the process of cell division and elongation. It also plays a role in the formation of chlorophyll (Figure 3).

The level (1500 kg S ha^{-1}) for the first date was the best in increasing leaf readiness. Iron in the soil, thus increasing its content in the plant, played an important role in the formation of chlorophyll in the plant. This is consistent with what was found by Ullah (2023) and Sun et al., (2020). The results showed that the dates of adding agricultural sulfur significantly affected the leaf area of the plant. The first addition date outperformed all levels and gave the highest rate for this trait, compared to the second addition date, which gave the lowest rate for this trait.

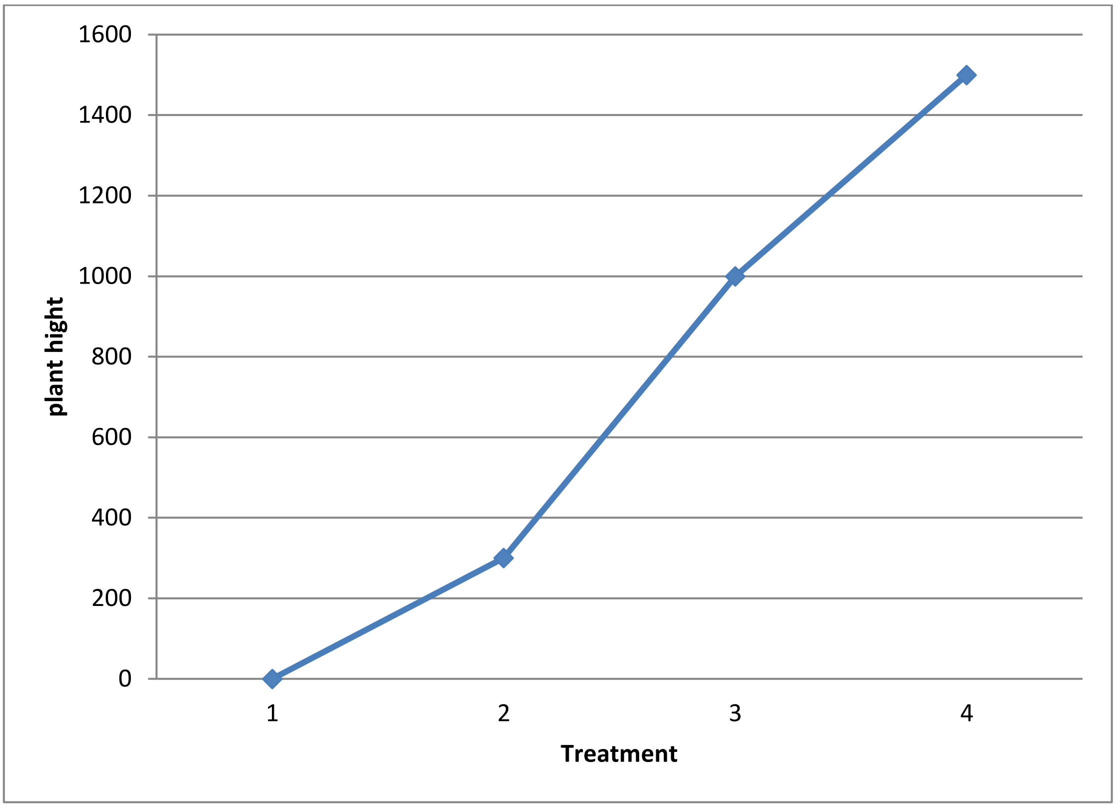

Figure (2) effect the sulfur on the plant height of *Zea mays*

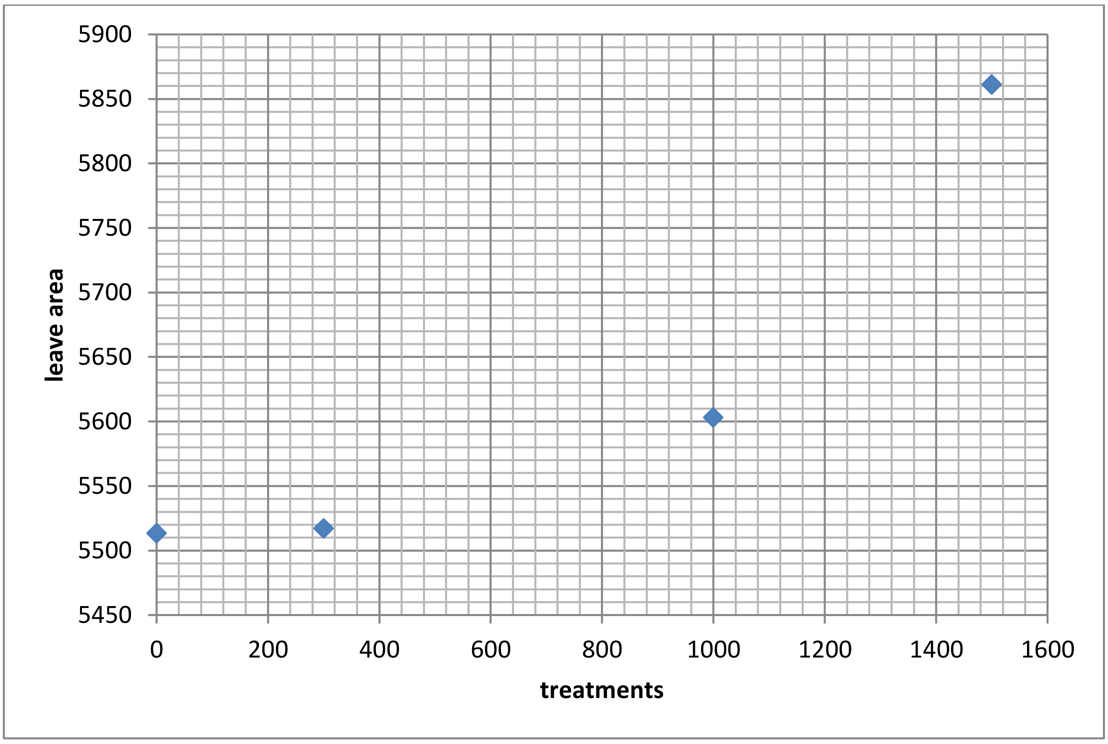

Figure (3) effect the sulfur on the Leaves area of *Zea mays*

Stem diameter

The results of Figure (4) showed that there was a significant effect of the levels of agricultural sulfur and the dates of addition on the stem diameter of the yellow corn plant, as the results showed that the addition level of (1500 kg. ha^{-1}) for the first date achieved the highest rate for this trait, as it reached 1.27 g^{-1}) compared to the control treatment, which reached 1.78 cm, and the addition level of (1500 kg. ha^{-1}).

From the results, it was found that the lower the rate of agricultural sulfur addition, the higher the dry weight rate, as it works to reduce the degree of soil interaction and increase the availability of micronutrients in the soil, which increases their absorption by the plant, and thus is reflected in growth traits, including plant height, number of leaves, and leaf area per plant, which increases the average stem diameter. This is consistent with what was found by Sun et al., (2020). The results in Figure (4) indicated a significant effect of the dates of agricultural sulfur addition on the dry weight of the yellow corn crop, as the first addition date significantly outperformed the second addition date, giving the highest rate for this trait. The second one gave the lowest score for this trait.

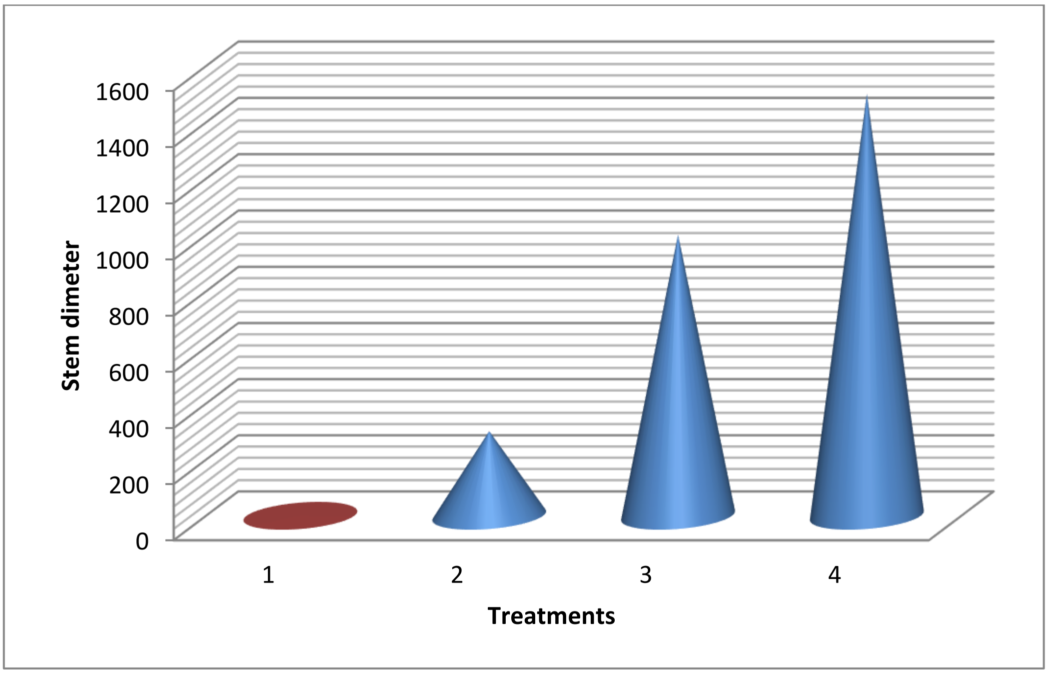

Figure (4) effect the sulfur on the Leaves area of *Zea mays*

Seeds number

The results showed the average number of grains per ear of yellow corn in the experiment, where the highest average number of grains per ear was in treatment for the first date, which had an average weight of 451 grains. Ear^{-1} compared to the control level, which had an average weight of 432 grains. Ear^{-1}. The results showed that the level of 1500 kg S. ha^{-1} was significantly superior and gave the highest rate for this trait compared to the control treatment (without addition). It also outperformed the levels of 1500, 1000, and 300 kg S. ha^{-1}. These treatments also outperformed the control treatment for the first date. The reason for this may be due to the importance of sulfur and its role in increasing the availability of micronutrients, including iron, and increasing their content in the plant. This led to an increase in the fertilization process, thus supplying the grains with nutrients produced by photosynthesis, and subsequently increasing the number of grains in the ear. This is consistent with what was found by Friedrich and Schrader (1978), who found an increase in the number of grains per head of corn with increased sulfur addition.

Table (1) effect the sulfur on the Seeds number of *Zea mays*

Seeds number	Treatment
432	0
456	300
457	1000
451	1500
1.768	LSD

Grain yield

The results showed a significant effect of agricultural sulfur levels and dates of addition on the grain yield of yellow corn plants. The results showed that the addition level of 1500 kg ha^{-1} was significantly superior to the first date, giving the highest rate for these traits, reaching 8.40 tons ha^{-1} compared to the control treatment, which reached 7.34 tons ha^{-1}. The addition level of 1500 kg was also superior. The reason for the increase in grain yield is due to the role of adding agricultural sulfur in reducing the degree of soil reaction and increasing the absorption of nutrients by the plant, which led to an increase in plant growth, which was reflected in the amount of yield (Table 2).

This means an increase in the source's efficiency in preparing the represented materials and thus an increase in grain yield. These results are consistent with Abd and Huwaidi (2023) found when adding sulfur at levels (2000 and 4000 kg. ha^{-1}) caused a significant increase in the amount of yield compared to the control treatment (without addition) and with Sun(2020) showed a significant increase in yield when adding agricultural sulfur.

Table (1) effect the sulfur on the grain yield of *Zea mays*

grain yield (tons ha^{-1})	Treatment
7.34	0
7.99	300
8.09	1000
8.40	1500
0.143	LSD

4. Conclusions

The study concludes that response of *Zea mays* to sulfur levels, especially at the high level 1500 kg/ha^{-1}, achieved a significant increase in all studied traits, which was reflected in the increase in yield. The use of sulfur at the level of 1500 kg/ha^{-1} 30 days before planting reduces the degree of soil reaction during germination, flowering and harvesting, and thus increases the availability of elements during the flowering and harvesting stages, which is reflected in increasing the plant's content of micronutrients.

References

Abd, A. M., & Huwaidi, M. I. (2023, November). The effect of planting dates and spraying with boron and sulfur on raising the yield efficiency of maize (Zea mays L.). In IOP Conference Series: Earth and Environmental Science (Vol. 1259, No. 1, p. 012098). IOP Publishing.

Friedrich, J. W., & Schrader, L. E. (1978). Sulfur deprivation and nitrogen metabolism in maize seedlings. Plant Physiology, 61(6), 900-903.

Sun, K., Yue, Y., Wen, D., Li, X., Yang, Y., Yang, N., ... & Wang, K. (2020). Effects of exogenous sulfur on maize (Zea mays L.) growth and Cd accumulation in Cd-contaminated plastic shed soil. Environmental Monitoring and Assessment, 192(10), 651.

Ullah, I., Muhammad, D., & Mussarat, M. (2023). Effect of various nitrogen sources at various sulfur levels on maize–wheat yield and N/S uptake under different climatic conditions. Journal of Plant Growth Regulation, 42(3), 2073-2087.

Maruf, M. T., & Mam-Rasul, G. A. (2019). Effect of humic acid and sulfur fertilizer levels on some physiological traits of maize (Zea mays L.) on calcareous soil. Applied Ecology & Environmental Research, 17(6).

Jarallah, R. S., & Abbas, N. A. (2019). The Effect of Sulfur and Phosphate Fertilizers Application on the Dissolved Phosphorus Amount in Rhizosphere of Zea Maize L. Al-Qadisiyah Journal For Agriculture Sciences, 9(2), 233-239.

El-Fahdawi, W. A., Ahmed, F. W., & Cheyed, S. H. (2020). Effect of Agricultural sulfur on Availability of NPK in the soil growth and yield of corn (Zea mays L.). Indian journal of ecology, 47(12), 275-280.

Sarheed, B. R., Rasheed, M. A., Alani, A. R., & Yaquop, M. T. (2020). Influence of agricultural sulphur and organic matter on the growth of corn (Zea mays L.) and leaves content of some nutritious elements. Int. J. Agricult. Stat. Sci, 16(1), 1451-1456.

Khan, M. J., Khan, M. H., Khattak, R. A., & Jan, M. T. (2006). Response of maize to different levels of sulfur. Communications in soil science and plant analysis, 37(1-2), 41-51.

Riffat, A. L. I. A., Sajid, M., & Ahmad, A. (2020). Alleviation of adverse effects of salt stress on growth of maize (Zea mays L.) by sulfur supplementation. Pak. J. Bot, 52(3), 763-773.

Ahmad, R., Dawar, K., Iqbal, J., & Wahab, S. (2016). Effect of sulfur on nitrogen use efficiency and yield of maize crop. Advances in Environmental Biology, 10(11), 85-91.

Rendig, V. V., Oputa, C., & McComb, E. A. (1999). Effects of sulfur deficiency on non-protein nitrogen, soluble sugars, and N/S ratios in young corn (Zea mays L.) plants. Plant and Soil, 44(2), 423-437.

Rasheed, M., Ali, H., & Mahmood, T. (2004). Impact of nitrogen and sulfur application on growth and yield of maize (Zea mays L.) crop. Journal of Research (Science), 15(2), 153-157.

Li, N., Yang, Y., Wang, L., Zhou, C., Jing, J., Sun, X., & Tian, X. (2019). Combined effects of nitrogen and sulfur fertilization on maize growth, physiological traits, N and S uptake, and their diagnosis. Field Crops Research, 242, 107593.