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Impact of Agricultural Sulfur and Ground Yellow Corn Cob Amendments on Soil Nutrient Availability and Safflower (*Carthamus Tinctorius* L.) Growth**Ismail Razak Al-Shahbani**

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ABSTRACT: The field experiment was conducted in one of the private farms in the city of Musayyib, during the winter season of 2023-2024, on the 11th day of 15th month in the Islamic lunar calendar on 11/15/2024 at an altitude of 32 meters above sea level at the latitude of 32° 40' 23" North and longitude of 44° 9' 41" East. The local variety of safflower (*Carthamus tinctorius* L.) was cultivated to study the effect of adding agricultural sulfur and crushed yellow corn cobs on the availability of some nutrients and safflower growth indicators. This experiment was conducted with completely randomized block design (CRBD) with three replications and the results were analyzed using least significant difference (LSD) test at 5% probability. The study variables represented four levels of agricultural sulfur (0, 500, 1000, and 1500 kg ha⁻¹) and four levels of crushed yellow corn cobs (0, 20, 40, and 60 ton ha⁻¹), which were added to the soil before planting and during land preparation. The results were as follows: The treatment with agricultural sulfur at the (1500 kg ha⁻¹) level was significantly superior, giving the highest average values for available nitrogen, available phosphorus, available potassium, organic matter percentage, and safflower growth indicators was plant height, number of leaves, chlorophyll content, and weight. Dry matter content for the vegetative parts was 39.78 mg kg⁻¹ soil, 14.45 mg kg⁻¹ soil, 149.03 mg kg⁻¹ soil, 8.85 g kg⁻¹, 120.35 cm, 106.98 leaf plant⁻¹, 44.28 spad, and 51.28 g, respectively. The treatment with added crushed yellow corn kernels (40 ton ha⁻¹) significantly increased the average values of the above parameters, and gave the highest averages of 35.70 mg kg⁻¹ soil, 13.18 mg kg⁻¹ soil, 146.08 mg kg⁻¹ soil, 9.45 g kg⁻¹, 115.00 cm, 102.70 leaf plant⁻¹, 41.40 spad, and 44.95 g. In other hand there was no difference between this treatment and the treatment (60 tons ha⁻¹) any significant differences for all studied parameters.

KEYWORDS: Safflower, Sulfur, Maize, Nutrients, Soil.**INTRODUCTION**

Sulfur is among the macronutrients required for plant nutrition. Sulfur deficiencies are indicated when the level of S in the plant is below 0.1%. Plants have a range of 0.1-1% sulfur. A slow moving component of the plant. Plants absorb sulfur from the soil in the form of sulfate ions (SO₄). Atmospheric sulfur (H₂S) and SO₂ can be absorbed by the plant through the stomata and the cuticle layer. Subsequently, sulfur can be reduced and metabolized in the plant as amino acids, such as cysteine (2.7% S), which are involved in protein synthesis, and methionine (21% S), which contains sulfur. It is also observed that sulfur is also participating in the biosynthesis of B vitamins like biotin and thiamine and the glutathione involved in oxidation-reduction processes and protoplasmic regeneration in the plant cells. It is also important in the reduction of nitrate in plants (Masudur et al., 2018). In the case of application of sulfur before planting and at soil preparation, the timing factor in this application plays an important role in the oxidation process (Al-Khafaji, 2023). This could also be explained due to the addition rate that the higher rate of sulfur addition, the more it will oxidize the sulfur in the soil and thus reduce the soil reaction, causing an increase in the availability of nutrients in the soil and therefore increasing the release of nitrogen which will lead to a higher availability in the soil (Jasim, 2015). Moreover, the introduction of S and its effect on reducing pH may also be responsible for dissolving some of the precipitated phosphorus compounds and bringing the phosphorus into the soil solution which increases its availability (AL-Hasson, 2010; Al-Zubaidi, 2015). Some materials in the soil can also be dissolved by adding different levels of agricultural sulfur - which increases the availability of macronutrients such as potassium. In addition, it accelerates the activity of the hydrogen ions generated during oxidation, which compete with the potassium ions that are in the soil solution and are adsorbed on the surface of soil exchange complexes and release potassium into the soil solution. Agricultural sulfur also makes a contribution to the capacity of microorganisms to increase the availability of K by secreting enzymes and organic acids (citric and oxalic) that help weather K-bearing minerals and avoid the fixation of K (Shanware et al., 2014). It may also be explained because of the possible improvement of the growing environment due to different levels of agricultural sulfur. Root excretions raises the nutrient availability in soil (Ali et al., 2022).

One way to increase soil nutrients is through the use of organic fertilizers such as plant or animal residues, or inorganic fertilizers (Dauda et al., 2005). Organic matter is an important source for increasing nutrient availability in the soil and is a source of many nutrients, especially nitrogen. Its use as a fertilizer in soils poor in organic matter is particularly important for plant nutrition. It also improves soil structure and aeration, as well as increasing the soil's ability to retain water and nutrients. The value of organic fertilizers is not only measured by their nutrient content but

also by their ability to increase nutrient availability in the soil through their high organic acid content, which reduces soil acidity and dissolves some insoluble compounds (Al-Balkhi, 2006). Ajayi et al. (2009) also indicated that adding poultry manure or plant residues improved soil productivity by increasing its organic carbon and microbial content, as well as improving soil structure and nutrient availability. Nitrogen (N) is a major component of poultry manure.

Safflower (*Carthamus tinctorius* L.) is an important oilseed crop belonging to the Asteraceae family. It is cultivated for its seed oil, which constitutes approximately 30-40% (Camas et al., 2007). It is an economically and medicinally valuable crop. Furthermore, its colorful flowers are used in various industries, such as soap making, ink production, and dyeing for clothing and food. The oilseed meal remaining after extraction is rich in protein (approximately 14-40%) and carbohydrates (19.8%), making it suitable for animal feed (Gupta, 2011).

This study aims to determine the effect of adding agricultural sulfur and crushed yellow corn husks as organic waste on the availability of some nutrients and the growth of safflower plants.

MATERIALS AND METHODS

The field experiment was conducted during the winter season of 2023-2024, on November 15, 2024, at a private farm in the city of Musayyib, within the coordinates of latitude 32° 40' 23" North and longitude 44° 9' 41" East, at an altitude of 32 m above sea level. Safflower (*Carthamus tinctorius* L.) local variety was planted. The field soil was prepared by cleaning it of the remains of the previous crop and weeds, then harrowing it with a hoe to obtain completely clean soil. It was then plowed with a moldboard plow in a perpendicular direction to obtain well loose soil and harrowed with disc harrows. After that, it was leveled and the experimental land was divided into experimental units. Each experimental unit included three rows (replications) with dimensions of 4 * 3 m, with a distance of 75 cm between rows and 20 cm between plants. Soil samples were collected from different areas of the field at random and to a depth of (0-30 cm), were air-dried, ground and crushed well using a hammer, and passed through a sieve with openings of 2 mm. Then the samples were mixed well to homogenize them, and one composite sample was taken. Some chemical and physical properties were estimated before planting, as shown in table (1).

Table 1. properties of soil experiment

Character	Unit	Value
Depth	Cm	0 – 30
Ece	dS m ⁻¹	2.78
pH	---	7.8
Organic matter	g kg ⁻¹ soil	5.1
CaCO ₃		218
CaSO ₄ .2H ₂ O		5.7
Sand		170
Silt		535
Clay		295
Texture		Silty Clay Loam
Bulk density	g cm ⁻³	1.32
Available N	mg kg ⁻¹	28.2
Available P		9.1
Available K		136.1

The study factors represented 4 levels of agricultural sulfur (0, 500, 1000, 1500 kg ha⁻¹) and 4 levels of crushed yellow corn cobs (0, 20, 40, 60 ton ha⁻¹), which were added to the soil before planting and when preparing the land for planting. The seeds were planted in the experimental unit at a distance of 20 cm between plants, alternating on both sides of the raised bed. 2-3 seeds were planted in each hole, thinned to one plant after 3 weeks of planting. The experimental units were separated from each other by a distance of 1.5 m to allow for free movement and to prevent the transfer of levels of factors with each other. Service operations continued, including irrigation, weeding, and disease control, as needed. A factorial experiment was designed according to a randomized complete block design (RCBD) with two factors and three replicates. Each replicate contained 16 randomly distributed treatments, and the total number of experimental units was 48. The results were statistically analyzed according to the methods described in Al-Rawi and Khalaf Allah (2000). Mineral fertilization was carried out at 50% of the recommended fertilizer application rate. Phosphate fertilizer, specifically triple superphosphate (P48%), was added at a rate of 100 kg ha⁻¹ in a single application at planting time. Nitrogen fertilizer (N) was added at a rate of 120 kg ha⁻¹ in the form of urea (46% N) in two applications: the first one week after planting and the second at the flowering stage. Potassium fertilizer (K) was added at a rate of 120 kg ha⁻¹ in the form of potassium sulfate (K 42%) in two applications as well (Ali, 2012). The following characteristics were studied: estimation of available nitrogen, phosphorus, and potassium in the soil, the percentage of organic matter in soil at the end of the experiment, and some growth characteristics of safflower plants: plant height, number of leaves, chlorophyll content of the leaves, and the dry weight of the vegetative mass of the plants.

RESULT AND DISCUSSION

1-Avialable Nitrogen mg kg⁻¹ soil

Table 2 indicates that there were significant differences between the available soil N of agricultural sulfur and crushed yellow corn cobs. The treatment with agricultural sulfur in the amount of 1500 kg ha⁻¹ was significantly superior, giving an average value of 39.78 mg kg ha⁻¹ soil; whereas the control treatment (no agricultural sulfur added) recorded an average value of 29.63 mg kg ha⁻¹ soil. The results for adding yellow

corn cobs were significantly higher, with an average of 35.70 mg kg ha⁻¹ soil for 40 ton ha⁻¹ treatment compared to 31.55 mg kg ha⁻¹ soil from the no cob treatment. There were no significant differences between this treatment and the 60 ton ha⁻¹ treatment. The interaction treatment of both factors (1500 kg ha⁻¹ agricultural sulfur + 40 ton ha⁻¹ corn cobs) was the most effective. significantly and gave the highest average of 42.5 mg kg-1 soil compared to the treatment without adding the two workers, which gave the lowest average of 28.4 mg kg-1 soil.

Table 2. Effect of agriculture sulfur and corn cob on nitrogen availability

Agriculture Sulfur	Crushed corn cob ton ha ⁻¹				Average
	0	20	40	60	
0	28.4	29.2	30.6	30.3	29.63
500	29.7	30.8	32.4	32.1	31.25
1000	32.5	34.3	37.3	37.1	35.30
1500	35.6	38.8	42.5	42.2	39.78
Average	31.55	33.28	35.70	35.43	
LSD0.05		Ag. Sulfur	Corn cob	interaction	
		2.13	2.13	4.26	

2-Available Phosphorus mg kg⁻¹ soil

The total phosphorus available for use by plants differs significantly among the agricultural sulfur and crushed yellow corn cobs (Table 3). The treatment of adding agricultural sulfur in level 1500 kg ha⁻¹ significantly improved with the highest average of 14.45 mg kg ha⁻¹ soil compared to the treatment of no agricultural sulfur addition which had the lowest average of 10.13 mg kg ha⁻¹ soil. Regarding the treatments of adding yellow corn cobs, the cobs treatment at 40 ton ha⁻¹ had a significantly better average of 13.18 mg kg ha⁻¹ soil than the treatment without cobs which had the lowest average of 11.20 mg kg ha⁻¹ soil. This treatment was no different than the 60 ton ha⁻¹ treatment. The interaction treatment (1500 kg ha⁻¹ agricultural sulfur + 40 ton ha⁻¹ corn cobs) was the most effective. significantly and gave the highest average of 15.3 mg kg-1 soil compared to the treatment without adding the two workers, which gave the lowest average of 9.4 mg kg-1 soil.

Table 3. Effect of agriculture sulfur and corn cob on phosphorus availability

Agriculture Sulfur	Crushed corn cob ton ha ⁻¹				Average
	0	20	40	60	
0	9.4	9.8	10.7	10.6	10.13
500	10.2	11.3	12.6	12.2	11.58
1000	11.7	12.9	14.1	14.1	13.20
1500	13.5	13.9	15.3	15.1	14.45
Average	11.20	11.98	13.18	13.00	
LSD0.05		Ag. Sulfur	Corn cob	interaction	
		0.38	0.38	0.76	

3-Available Potassium mg kg⁻¹ soil

The agricultural sulfur treatment and corn grits treatment differ significantly in potassium availability of the soil (Table 4). The 1500 kg ha⁻¹ agricultural sulfur treatment gave the highest average of 149.03 mg kg ha⁻¹ soil potassium compared to the control treatment (no agricultural sulfur added), which gave the lowest average of 138.80 mg kg ha⁻¹ soil potassium. The highest K levels in the soil were obtained in 40 t ha⁻¹ corn grits treatment with K average of 146.08 mg kg ha⁻¹, which was significantly higher than the lowest K average of 141.20 mg kg ha⁻¹ of soil in the control treatment (no corn grits added). No significant differences were found between the 40 ton ha⁻¹ and control treatments. The combined treatment (1500 kg ha⁻¹ agricultural sulfur + 40 ton ha⁻¹ corn grits) was the most effective. significantly and gave the highest average of 152.2 mg kg⁻¹ soil compared to the treatment without adding the two workers, which gave the lowest average of 136.8 mg kg⁻¹ soil.

Table 4. Effect of agriculture sulfur and corn cob on potassium availability

Agriculture Sulfur	Crushed corn cob ton ha ⁻¹				Average
	0	20	40	60	
0	136.8	138.4	140.2	139.8	138.80
500	139.7	141.5	143.8	143.5	142.13
1000	142.6	144.7	148.1	148	145.85
1500	145.7	148.4	152.2	149.8	149.03
Average	141.20	143.25	146.08	145.28	
LSD0.05		Ag. Sulfur	Corn cob	interaction	
		3.36	3.36	6.72	

4-Organic Matter g kg⁻¹

Table 5 indicates that there were significant differences in the effect of the agricultural sulfur and crushed yellow cornbob treatments on soil organic matter. Agricultural sulfur treatment significantly outperformed the others, with the best average of 8.85 g kg⁻¹ and the worst average of

6.85 g kg⁻¹ for the control treatment (no agricultural sulfur added). The treatments of adding yellow corn cobs, the 40-ton ha⁻¹ treatment was significantly superior with an average of 9.45 g kg⁻¹ while the treatment without cobs had the lowest average of 5.80 g kg⁻¹. No significant difference between this treatment and that of 60 ton ha⁻¹ treatment. The interaction treatment of both factors (1500 kg ha⁻¹ agricultural sulfur + 40 ton ha⁻¹ corn cobs) was significantly superior, yielding the highest average. 10.6 g kg⁻¹ compared to the treatment without adding the two workers, which gave the lowest average of 5.2 g kg⁻¹.

Table 5. Effect of agriculture sulfur and corn cob on organic matter

Agriculture Sulfur	Crushed corn cob ton ha ⁻¹				Average
	0	20	40	60	
0	5.2	5.9	8.4	7.9	6.85
500	5.7	6.7	8.9	8.6	7.48
1000	6.1	8.4	9.9	9.8	8.55
1500	6.2	8.2	10.6	10.4	8.85
Average	5.80	7.30	9.45	9.18	
LSD0.05		Ag. Sulfur	Corn cob	interaction	
		0.28	0.28	0.56	

5-Height of plant cm

Table 6 shows significant differences between the treatments of agricultural sulfur and crushed yellow corn cobs in plant height. The treatment with 1500 kg ha⁻¹ of agricultural sulfur was significantly superior, yielding the highest average height of 120.35 cm compared to the control treatment (no agricultural sulfur added), which yielded the lowest average height of 101.00 cm. For the treatment with 40 tons ha⁻¹ of yellow corn cobs, the highest average height was significantly superior, reaching 115.00 cm compared to the treatment without cobs, which yielded the lowest average height of 104.23 cm. No significant differences were found between this treatment and the treatment with 60 tons ha⁻¹. The combined treatment (1500 kg ha⁻¹ of agricultural sulfur + 40 tons ha⁻¹ of cobs) was significantly superior, yielding the highest average height of 125.3 cm compared to the treatment without either treatment. Which gave the lowest average of 95.5 cm.

Table 6. Effect of agriculture sulfur and corn cob on height of plant

Agriculture Sulfur	Crushed corn cob ton ha ⁻¹				Average
	0	20	40	60	
0	95.5	98.6	105.1	104.8	101.00
500	99.7	106.2	112.4	112.1	107.60
1000	108.3	111.7	117.2	116.6	113.45
1500	113.4	118.5	125.3	124.2	120.35
Average	104.23	108.75	115.00	114.43	
LSD0.05		Ag. Sulfur	Corn cob	interaction	
		2.96	2.96	5.92	

6-No. of leaves per plant

The leaf count following the sulfur and crushed yellow corn cobs treatments are significantly different as indicated in Table 7. The treatment with 1500 kg ha⁻¹ agricultural sulfur significantly outperformed the control treatment, the number of leaves per plant for this treatment being the highest average of 106.98 leaf per plant, while the control treatment (no agricultural sulfur added) was the lowest average of 91.38 leaf per plant. The treatment with 40 tons ha⁻¹ crushed yellow corn cobs significantly outperformed the control treatment with the highest average of 102.70 leaves per plant while the control treatment (no corn cobs added) had the lowest average of 94.25 leaves per plant. No significant differences were found between the control treatment and the treatment with 60 tons ha⁻¹. The interaction treatment (1500 kg ha⁻¹ of agricultural sulfur + 40 tons ha⁻¹ of crushed corn cobs) significantly outperformed the control treatment, yielding the highest average. 110.4 leaf per plant compared to the treatment without adding the two workers, which gave the lowest average of 86.7 leaf per plant.

Table 7. Effect of agriculture sulfur and corn cob on plant leaf No.

Agriculture Sulfur	Crushed corn cob ton ha ⁻¹				Average
	0	20	40	60	
0	86.7	88.6	95.4	94.8	91.38
500	90.2	96.5	100.7	100.1	96.88
1000	97.8	100.5	104.3	103.7	101.58
1500	102.3	105.6	110.4	109.6	106.98
Average	94.25	97.80	102.70	102.05	
LSD0.05		Ag. Sulfur	Corn cob	interaction	
		3.26	3.26	6.52	

7-Chlorophyll leaves spad

Table 8 shows significant differences between the agricultural sulfur and maize cob treatments in leaf chlorophyll content. The treatment with 1500 kg ha⁻¹ of agricultural sulfur significantly outperformed the control (no sulfur added), yielding the highest mean chlorophyll content of 44.28 spad, compared to the control (no sulfur added), which yielded the lowest mean 34.38 spad. The treatment with maize cob added significantly outperformed the control (40 tons ha⁻¹), yielding the highest mean 41.40 spad, compared to the control (no cob added), which yielded the lowest mean 36.58 spad. No significant differences were found between the control and the treatment with 60 tons ha⁻¹. The interaction treatment (1500 kg ha⁻¹ of agricultural sulfur + 40 tons ha⁻¹ of maize cob) significantly outperformed the control (no cob added), yielding the highest mean 46.5 spad. The treatment of not adding employees gave the lowest average of 32.8 spad.

Table 8. Effect of agriculture sulfur and corn cob on leaves chlorophyll

Agriculture Sulfur	Crushed corn cob ton ha ⁻¹				Average
	0	20	40	60	
0	32.8	33.7	35.8	35.2	34.38
500	34.5	37.2	40.1	39.7	37.88
1000	37.8	40.9	43.2	43.0	41.23
1500	41.2	43.3	46.5	46.1	44.28
Average	36.58	38.78	41.40	41.00	
LSD0.05	Ag. Sulfur		Corn cob	interaction	
	2.08		2.08	4.16	

8-Dry matter of vegetative part g

The results for dry weight of shoot as shown in table 9 are significantly different between the treatments of Agri-S and crushed yellow corn cobs. The treatment with addition of agricultural sulfur at level of 1500kg ha⁻¹ was significantly superior with the highest average weight of 51.28g as opposed to the control treatment (no addition of agricultural sulfur) which had the lowest average weight of 34.15g. Regarding treatments with the incorporation of yellow corn cobs, the treatment with 40t ha⁻¹ was significantly better with an average weight of 44.95g against the treatment without any cobs which obtained the lowest average weight of 37.38g. This treatment was not significantly different to the 60 ton ha⁻¹ treatment. The interaction of two factors (1500 kg ha⁻¹ agricultural sulfur + 40 t ha⁻¹ corn cobs) was significantly better than the control treatment with an average weight of 55.6 g. The lowest mean of 31.2 g was obtained in the treatment that did not involve the addition of the workers.

Table 9. Effect of agriculture sulfur and corn cob on plant dry matter

Agriculture Sulfur	Crushed corn cob ton ha ⁻¹				Average
	0	20	40	60	
0	31.2	33.4	36.2	35.8	34.15
500	33.9	37.1	40.5	40.2	37.93
1000	39.8	42.6	47.5	47.2	44.28
1500	44.6	49.7	55.6	55.2	51.28
Average	37.38	40.70	44.95	44.60	
LSD0.05		Ag. Sulfur	Corn cob	interaction	
		2.36	2.36	4.72	

The effect of the two study factors (agricultural sulfur and maize sorghum) on the properties of the studied soils was observed and as shown in the results of the study in Tables (2-5) there was an increase in soil properties. The 1500 kg ha⁻¹ rate was significantly higher and resulted in the maximum average amount of nitrogen, phosphorous and potassium available in the soil, and a significant increase in the percentage of soil organic matter at the end of the crop production process. This is due to the oxidation of the soil sulfur, and the formation of sulfuric acid H₂SO₄ which led to decrease the degree of soil reaction as the availability of nutrients increased (Jasim 2015) and (Al-Zubaidi 2015). In addition, agricultural sulfur can also play an essential role in increasing the availability of K by secreting enzymes and organic acids such as citric and oxalic which can have a role in weathering N, P, and K minerals and maintaining their fixation processes to be released in the soil solution (Shanware et al., 2014). The increased availability of studied nutrients when crushed yellow corn kernels are added is due to the decomposition of organic matter and the formation of humic acids such as humic and fulvic acids. These acids help lower the soil pH, thus increasing nutrient availability. The accumulation of organic matter in the soil also contributes to raising its percentage (Youda, 2018). Furthermore, the decomposition of organic matter increases the number of exchange sites in the soil, thereby increasing cation exchange capacity and contributing to a higher percentage of organic matter in the soil (Al-Janabi, 2012).

The greater availability of these nutrients is due to breakdown of organic matter and creation of cation exchange capacity in the soil. Increases in growth indicators that were studied for safflower plants are clearly demonstrated in the results presented in Tables (6-9) for the application of agricultural sulfur and crushed yellow corn grits. This is due to the synergistic effect of both of these: the nutritional completeness and soil productivity/fertility in terms of nutrient provision, including nitrogen. Moreover, this interaction positively affects the plant growth indicators including plant height, plant leaf number, chlorophyll content and dry matter of the shoot and root system. It also improves metabolic activity by producing substances called organic acids which dissolve materials, freeing elements in their easily absorbed form for the plant. This stimulates

mineralization, enzyme activity and growth stimulators, resulting in more available macronutrients in the soil. The incorporation of organic matter also enhances the properties of soil, which is conducive to plant growth (Sinchi et al., 2011).

CONCLUSION

We conclude from the study that adding agricultural sulfur at a level of 1500 kg ha⁻¹ and crushed yellow corn at a level of 40 tons ha⁻¹ led to a significant increase in the availability of nitrogen, phosphorus, and potassium elements, the percentage of organic matter, and also a significant increase in some indicators of safflower plant growth, such as plant height, number of leaves, leaf chlorophyll content, and dry weight of the dry matter.

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