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Effects of adding different levels of Sulfur on the number of Thiobacillus thioparus and soil pH on the growth of the Canola crop (Brassica napus L.)

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Abstract

The experiment was applied during the winter season 2021/2022 in Al-Shahimiya city, Wasit governorate, Iraq. The aim of study was to add different levels of sulfur and the bacteria Thiobacillus thioparus on the degree of soil interaction and their influence on the growth of Brassica napus L. The experiment has been used randomized completed block design (RCBD) in the field experiment. The experiments included two factors, the first factor was added four concentrations of sulfur (0% - 12% - 24% - 36%), and the second factor was to add two levels of T. thioparus. It was adding 5 and 10 ml of bacteria) with three replications for all treatments. They were randomly distributed to the treatments. The total number of units was 36 experimental units.

*The results showed that adding 36% sulfur and T. thioparus 10 ml/ hole have been recorded the highest number of bacteria colonies in the field experiment that after 30 days of germination, which is the best time for bacteria growth. It has been reached 1866.66 * 104 cells/ g of soil, while it reached 1066.66 * 104 cells/ g in the control treatment. The results showed that adding 36% sulfur concentration and T. thioparus 10 ml / hole at the time of harvest has been indicate the highest rate of decrease in the degree of soil interaction. The pH recorded 6.89 compared control treatment, which reached 7.8. Also, the treatment of adding 36% sulfur and 10 ml / hole of T. thioparus recorded the highest rate of ready sulfur in the soil at the time of harvest. It has been reached 42 mg/ kg soil in the compared the control treatment, which record 20.44 mg/ kg soil. In addition, the treatment of adding 36% sulfur and 10 ml / hole of T. thioparus recorded the highest concentration of nitrogen, phosphorous and potassium in B. napus. The concentrations of NPK were 3.81, 0.85 and 2.66%, respectively, while the NPK rates in the control treatments were 1.13, 0.51 and 1.20%, respectively.*

Key words: Sulfur, Thiobacillus thioparus, soil pH, Brassica napus

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Introduction

Sulfur is one of the major and important elements for plants. The sulfur is found in both organic and inorganic forms. In most soils, organic sulfur is the main source of sulfur. The soil with a high content of decomposing plant, the percentage of organic sulfur is 100% of the total sulfur. It is divided into two parts; sulfur consisting of phenolic sulphates (choline sulfur) and sulfur belonging to amino acids and fats.

The inorganic sulfur consists of sulfate 2-SO4. Sulfur is present in the atmosphere, which is record 0.1% of the earth's crust. It is found in different forms in the soil, either combined with the basic elements such as Mg, Ca, K, Na in the dry and semi-arid areas. The *confiscation* of the mineral pyrite contains mining sulfur and volcanic sources. As well as what is extracted from gas and oil. In Iraq, mining sulfur is freely formed in the eastern regions of Iraq (Ansari et al., 2017; Chahal et al., 2020). Sulfur purification residues such as pure sulfur 100% S, foamed sulfur 75% S and agricultural sulfur 90% S is a by-product of sulfur manufacture to increase the availability of phosphorous, sulfur and other nutrients from soil sediments by lowering the soil pH with the formation of sulfuric acid H2So4 when oxidized or its biochemical oxidation residues. The oxidation is carried out by aerobic organisms of the *Thiobacillus* Spp (Sadegh Masoodi & Leila Hakimi, 2017).

To reduce the chemical fertilizers uses and to compensate for the deficiency in nutrients and sulfur, it is necessary to increase the production of crops and their resistance to fungal diseases and to increase the efficiency of nitrogen representation in plants and to build amino acids such as cysteine and cysteine (Jadhav et al., 2022; O'Brien et al., 2018). Bio-fertilizer is a group of microorganisms that play a role to provide the necessary nutrients for the plant growth. It works to convert the nutrients from their uneasy form to their easy and absorbable form by the plant, especially the important nutrients for the plant such as phosphorous, nitrogen, potassium and sulfur. Bio-fertilizers are becoming environmentally friendly fertilizers that used in most countries around the world. They work to supply the soil with plant nutrients. Bacteria and blue-green algae are the most important bio-fertilizers that used in plant service by increasing the availability of nutrients and plant resistance to the inappropriate environmental conditions such as environmental soil stress and climatic changes (S Masoodi & Leila Hakimi, 2017; Pareniuk et al., 2015).

The *Thiobacillus* spp is one of the most important biological factors that found in the roots of plants. It has many mechanisms that make it capable of oxidizing mineral sulfur to SO4-2 sulfate absorbable by the plant(Kumar et al., 2018; Thom, 1975). It has been worked to reduce the degree of soil interaction and increase the availability of nutrients in the rhizosphere area (Khan et al., 2012).

The *B. napus* crop is considered one of the necessary oil crops in many countries around the world. It is planted in millions of hectares of agricultural land. It is grown primarily in Canada, China, Algeria and India (Bagheri and Somarin, 2011). Also, it is grown in the United States of America and Germany (Brian, 2006). The extract oils are suitable for human consumption. According to the Food and Agriculture Organization (FAO, 2014), production of the cultivar has been reached 39.8 million tons out of 70 million tons of total global oilseeds in 2020, while the total estimated production of oilseeds in 2020 was 68.9 million tons, canola seeds contributed 71.8 million tons. The oil is used for cooking purpose, and in other edible products. The seeds contain 0.5-1% erucic acid, which is less than the 2% specified by the US Department of Agriculture. The rest of the plant parts are used as sources of animal feed. Japan has also expanded its cultivation to achieve self-sufficiency in bio-fuel (Biodeasel) extracted from seed oil (Brian, 2006).

In this study, this crop has been chosen because there are a few studies have been done in Iraq. Also, to encourage the farmers to planting it because of its important economic. The rapeseed crop is considered one of the important strategic crops for many economic reasons. The cultivation in winter does not require much irrigation water compared to summer crops. Thus, studies need to be carried out and expanding its cultivation because of the solutions it provides in the production of oils and the production of high-protein fodder (Eskandari and Kazemi, 2012;(Maloney, 2012). The study aims were to study the effect of different levels of sulfur on the degree of soil interaction, growth and yield of rapeseed plants. As well as, to study the effect of the interaction of sulfur and Thiobacillus bacteria on the growth and yield of rapeseed plant.

Materials and Methods

The experiment was applied in Al-Suwaira city, Wasit governorate, which is located at latitude (32.5-32.7) north and longitude (45.5-45.2) east (19) meters. The soil was Silty loam, the *B. napus* was planted on 10-2021 for the autumn season. The cultivar was (Bactol) which was obtained from the local market at a rate of 8 kg / ha in the form of lines and the distance between one line and another was 50 cm. It was planted in the form of holes, and the distance between one hole and another was 20 cm. The experimental unit consisted of three lines, and each line consisted of eight holes, and each hole consisted of only one plant. The fertilizer was added before planting at a rate of 50 kg. The rate of adding fertilizer to one experimental unit was 45 g. The *Thiobacillus* spp that prepared in the laboratory was injected into the soil with 5 ml/ hole and 10 ml/ hole five days before planting and the soil was wet to ensure the spread of bacteria in the soil.

The seeds were planted and the crop continued to be irrigated when 50% of the ready water was depleted. The weeding operations were carried out for the crop at the beginning of growth to get rid of the bush attached to the crop. The practical experiment used the randomized completed block design (RCBD). The experiment included two factors, the first factor was four concentrations of sulfur (0%-12%-24%-36%), and the second factor was adding two levels of *Thiobacillus* spp. It has added 5 ml and 10 ml of bacteria/ hole respectively. Three replications have been applied for all treatments, which were distributed randomly. Soil samples were taken before planting from the field, dried, crushed and sifted with a sieve with a diameter of 2 mm. The physical and chemical analyzes were calculated for them. Samples were taken at each growth stage at the beginning of growth, before flowering, before the decade and at the harvest stage. The necessary analyzes were carried out for them using the methods as mentioned by page et al., (1982).

Table (1): shows some physical and chemical characterization before planting

characterize	Measurement units	Values
Ph		7.86
EC_e	Desi Siemens m^{-1}	3.8
Organic element	g/kg^{-1}	1.3

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Ca^{+2}		28
Mg^{+2}		5.36
Cl^{-1}		78
$SO_4^{=}$	Centimol liter^{-1}	1.1
$CO_3^{=}$		Nil
HCO_3^{-}		4.53
nitrogen		27.51
phosphorous	mg/kg^{-1}	13.5
potassium		161.8

soil texture	sand	silt	clay	Silty Loam
	g/kg^{-1}	g/kg^{-1}	g/kg^{-1}	
	180	700	120	
total bacteria	CFu g^{-1} soil dry			2.1*10^7
Spp *Thiobacillus*	CFu g^{-1} soil dry			3.5*10^3

The isolation, purification and counting of bacteria numbers were measured in the Microbiology Laboratory of Field Crops Department, College of Agriculture, Wasit University, Iraq. The bacteria were isolated using the 9K selective culture medium, which consisted of the following materials at 2.0 pH:

Items	Value
Ammonium sulphate	0.400 g
Monopotassium phosphate	4.000 g
Ferrous sulphate	0.010 g
Calcium chloride	0.250 g
Magnesium sulphate	0.500 g
Sodium thiosulphate	5.000 g
Agar	12.500 g
distilled water	1000 mL

The dilution technique has been used in the experiment. Soil samples were taken and 1g was taken from it and placed in 9 ml of sterile distilled water, then dilution was carried out to 4-10, and the last dilution was poured into Petri dishes containing the sterilized medium with oxidizer at a temperature of 121 ml and a pressure of 15 inches^2.

The dishes were incubated in the electric incubator at a temperature of 30 °C for a period 2 days. The number of bacterial colonies growing in the dishes was calculated and according to the growth obtained at the highest dilution using an equation that includes multiplying the number of developing colonies by the reciprocal of the dilution.

Number of bacteria = number of colonies × reciprocal of dilution

Results and Discussion

The study of soil characterization

Number of *Thioacillus thioparus* in soil

The results of showed that after 30 days of germination of rapeseed recorded the highest rate of colonies of *T. thioparus* was when adding *T. thioparus* at a rate of 10 ml/ hole and sulfur concentration 36% to T2S4 treatment, which is amounted to 1866.66 cells/ ml. It did not differ significantly from the treatments T2S3, T2S2, T1S4, T1S3, T2, S4, S3 and S2. They were recorded 1566.66, 1333.33, 1766.66, 1433.33, 1600, 1866.66, 1700 and 1566.66 cells/ml, respectively (Table 2). The T2S4 treatment did not show a significant difference with T1 and T1S2 treatments, which ranged 1166.66 and 1100 cells/ml respectively. The results of the field experiment showed that there is a relationship between the rate of sulfur addition and the number of bacteria in the soil.

The results of measure the number of colonies of *T. thioparus* before flowering after 75 days of showed that the highest rate was 1800 cells/ml for T2S4 treatment, where it significantly differences with the control treatment, which was amounted 1066.66 cells/ml. It also did not significantly different from the treatments T2S3, T2S2, T1S4, T1S3, T1S2, T2, S4 and S3. The numbers of bacteria colonies were recorded 1566.66, 1433.33, 1633.33, 1466.66, 1433.33, 1233.33, 1433.33 and 1333.33, cells/ml, respectively. There was no significant difference between the treatments T1, S2 and the control treatment, which have been recorded 1173.33 and 1133.33 cells/ml, respectively (Table 2). It appeared that the higher the rate of sulfur added and *T. thioparus* bacteria, the activity rate and density of the perennial bacteria were increased (Emky et al., 2010; Veith et al., 2012; Vikromvarasiri et al., 2014; Vikromvarasiri et al., 2015).

Table (2) shows that the number of *T. thioparus* bacteria after planting 120 days before flowering. There were significant differences between the treatments and the control treatment, as the treatment of *T. thioparus* adding at a rate of 10 ml/ hole was the best treatment in the number of bacteria that record 1353.33 cells/ ml. This is because increasing the rate of addition of sulfur concentration cause the higher activity and density of sulfur-oxidizing bacteria *T. thioparus*. There were significant differences in the treatments T2S3, T2S2, T1S4, T1S3, T1S2, T2, T1, S4, S3 and S2. The results were 1100, 920, 1300, 1066.66, 840, 1206.66, 833.33, 1100, 1000 and 700 cells/ml, respectively, where it appeared that the higher rate of addition of sulfur and *T. thioparus* causes increased on activity rate and density of bacteria (Westrich and Berner, 1988; Kely et al., 2000; Ito et al., 2005; Maamiri, 2007; Yang et al., 2009; Emky et al., 2010).

The results also showed the average number of *T. thioparus* bacteria in the harvest period after 180 days has been showed that there was a significant difference in the T2S4 treatment, which amounted to 1546.66 cells/ml compared to the control treatment, which was amounted 433.33 cells/ml. It showed a significant difference between the treatments T2S3, T2S2, T1S4, T1S3, T1S2, T2, T1, S4, S3 and S2. They have been reached 1166.66, 1100, 1233.33, 933.33, 873.33, 1133.33, 1033.33, 1400, 1333.33 and 1300 cells/ml, respectively (Table 2). The higher the rate of adding sulfur, the higher the growth rate of the *T. thioparus* in the soil. It appeared that the higher the rate of addition of sulfur and *T. thioparus*, the higher the activity and density of bacteria (Vikromvarasiri et al., 2015).

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Table (2) the numbers of *T. thioparus* bacteria during the growth stages plants

Treatment	Treatment/means	Number of *T. thioparus* bacteria cell/ml			
		After germination	Before flowering	before bearing	After harvest
S1	0 Sulfur	1066.66	1066.66	566.66	*433.33
S2	12% sulfur	1566.66	1133.33	700	1300.00
S3	24% sulfur	1700.00	1333.33	1000	1333.33
S4	36% sulfur	1866.66	1433.33	1100	1400.00
T1	5ml of bacteria	1166.66	1173.33	833.33	1033.33
T2	10ml of bacteria	1600.00	1233.33	1206.66	1133.33
T1S2	12% sulfur+5ml bacteria	1100.00	1433.33	840	873.33
T1S3	24% sulfur+5ml bacteria	1433.33	1466.66	1066.66	933.33
T1S4	36% sulfur+5ml bacteria	1766.66	1633.33	1300	1233.33
T2S2	12% sulfur+10ml bacteria	1333.33	1433.33	920	1100,00
T2S3	24% sulfur+10ml bacteria	1566.66	1566.66	1100	1166.66
T2S4	36% sulfur+10ml bacteria	1866.66	1800.00	1353.33	1546.66
LSD		194.5	140	116.2	85.37

*Each number indicates three replicates

Soil pH measurement

The results found that the effect of different levels of sulfur and the addition of different levels of *T. thioparus* bacteria after planting showed that there were significant differences between the studied treatments compared to the control. The lowest level of pH was 7.78 in the treated soils by adding *T. thioparus* bacteria at a rate of 10 ml/ hole and at a sulfur concentration level of 36%. It did not significantly different from all other treatments T2S3, T2S2, T1S4, T1S3, T1S2, T2, T1, S4, S3 and S2. They reached 7.79, 7.80, 7.81, 7.83, 7.84, 7.85, 7.86, 7.85, 7.85 and 7.8, respectively. All the treatments were significantly different with the control treatment, which amounted 7.89 (Table 3). The of sulfur and bacteria added to the soil led to a high population density of bacteria in the soil, which in turn affected the availability of sulfur, and led to a decrease in the degree of soil pH (Brown & Morra, 2009; Chahal et al., 2020). The rate of decrease in soil reaction degrees after 75 days of planting the results showed that the best rate was found in the T2S4 treatment, which amounted 7.40 compared to the control treatment, which recorded 7.78 (Table 3).

The results also indicate that there were no significant differences from the rest of the treatments T2S3, T2S2, T1S4, T1S3, T1S2, T2, T1, S4, S3 and S2. The rates of decreasing soil interaction degrees have been reached 7.42, 7.45, 7.46, 7.51, 7.54, 7.55, 7.65, 7.64, 7.75 and 7.76, respectively. Also, the rates of decrease in the degree of soil reaction after 120 days of planting before the bearing recorded significant differences between the treatments. The T2S4 treatment achieved the highest decrease in pH soil 7.27 compared to the control treatment, which was 7.55. There are significant differences found between the T2S3 treatment and T2S2, T1S4, T1S3, T1S2, T2, T1, S4-S3 and S2, as they recorded 7.34, 7.38, 7.40, 7.42, 7.43, 7.45, 7.48, 7.48, 7.51 and 7.52, respectively. Through the experiments, the results detect that whenever the concentration of sulfur added to the soil increases, it reduces the degree of soil interaction. The reason is due to the role of sulfur-oxidizing bacteria, which play a role to convert sulfur into sulfuric acid. It works to reduce the degree of soil interaction. (McCauley et al., 2009; Spiers, 1984).

The best rate of decrease in the degree of soil reaction after harvest (180 days after planting) was found with T2S4 treatment, which reached 6.89 compared to the control treatment, has been recorded 7.46. There were significant differences in all the experimental treatments T2S3, T2S2, T1S4, T1S3, T1S2, T2, T1, S4, S3 and S2, in which the degree of soil interaction reached 6.99, 7.08, 7.11, 7.12, 7.21, 7.26, 7.30, 7.28, 7.33 and 7.39 respectively. The addition of sulfur and bacteria to the soil led to a high population density of bacteria in the soil, which in turn affected the availability of sulfur. It is led to a decrease in the degree of soil interaction pH(Bolan & Hedley, 2003; Osman & Rady, 2012; Wang et al., 2006).

Table (3) pH measurement rate during the growth stages of *B. napus* in the soil

Treatment	Treatment/means	Average of pH measurement			
		After germination	Before flowering	before bearing	After harvest
S1	0 Sulfur	7.89	7.78	7.55	*7.46
S2	12% sulfur	7.88	7.76	7.52	7.39
S3	24% sulfur	7.85	7.75	7.51	7.33
S4	36% sulfur	7.85	7.64	7.48	7.28

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T1	5ml of bacteria	7.86	7.65	7.48	7.30
T2	10ml of bacteria	7.85	7.55	7.45	7.26
T1S2	12% sulfur+5ml bacteria	7.84	7.54	7.43	7.21
T1S3	24% sulfur+5ml bacteria	7.83	7.51	7.42	7.12
T1S4	36% sulfur+5ml bacteria	7.81	7.46	7.40	7.11
T2S2	12% sulfur+10ml bacteria	7.80	7.45	7.38	7.08
T2S3	24% sulfur+10ml bacteria	7.79	7.42	7.34	6.99
T2S4	36% sulfur+10ml bacteria	7.78	7.40	7.27	6.89
LSD		194.5	0.0093	0.019	0.016

*Each number indicates three replicates

Sulfur concentration in soil (mg/kg soil)

The results showed that the concentration of ready sulfur in the soil after planting reached its highest levels when 36% sulfur was added and *T. thioparus* bacteria at a rate of 10 ml/ hole. It was 39 mg/kg compared to the control treatment that recorded the lowest rate 20.44 mg/kg and did not differ significantly with T1 treatment in which the sulfur concentration was 22.59 mg/kg. There are significant differences appeared between all treatments T2S3, T2S2, T1S4, T1S3, T1S2, T2, S4, S3 and S2 compared to the control. The sulfur levels were 30.67, 24, 36, 31.34, 25.68, 27.25, 34.66, 29.36 and 23.77 mg/kg, respectively (Table 4). This is because the percentage of sulfur added to the soil led to an increase in the activity of the sulfur-oxidizing *T. thioparus*. It was caused by oxidative processes that transformed into sulfuric acid and reduced the soil pH and increased the availability of sulfur and nutrients in it. The presence of sulfur has been significantly affects the increase the readiness of sulfur in the soil (Singh et al., 2014).

Table (4) indicated that the percentage of sulfur in the soil after 75 days of planting. The T2S4 treatment achieved the highest rate of ready sulfur in the soil, which recorded 39.33 mg/ kg compared to the control, which achieved the lowest average percentage of ready sulfur in the soil, as it reached 21 mg/ kg. There were significant differences between the treatments T2S3, T2S2, T1S4, T1S3, T1S2, T2, T1, S4, S3 and S2, which averaged sulfur levels 32, 26.66, 38.33, 32, 27.25, 26.66, 27.66, 35.65, 31.61 and 23.66 mg/kg, respectively, compared to the control treatment. The results found that an increase in the rate of sulfur availability in the soil and an increase in the rate of adding sulfur and *T. thioparus*, which oxidizes sulfur and increases its availability in the soil. The higher of the sulfur addition rate were significant differences appeared in the availability of sulfur and nutrients in the soil (Emky et al., 2010; Singh et al., 2014; Kumar, 2014).

The results also showed that the average sulfur availability in the soil after 120 days of planting. The T2S4 treatment has been recorded the highest sulfur readiness rate of 41.01 mg/kg compared to the control treatment that recorded 22.05 mg/kg. It has been significantly different for treatments T2S3, T2S2, T1S4, T1S3, T1S2, T2, T1, S4, S3 and S2, whose sulfur readiness rates were 37, 28.33, 40.66, 35.86, 29.31, 30.01, 30.33, 39, 33.90 and 27.03 mg/kg, respectively. The rate of adding sulfur and *T. thioparus* increases. The sulfur availability in the soil increases as a result of the increase in the density and activity of sulfur oxidizing of *T. thioparus*, which in turn increases sulfur availability, reduces the degree of soil interaction, and increases the availability of sulfur and nutrients.

Furthermore, the results shows that the rate of ready sulfur concentrations after 180 days of planting at the time of harvest (Table 4). It was found that T2S4 treatment has been reached the highest rate of ready sulfur compared to the control treatment as it reached 42 mg/kg, while the lowest rate of sulfur in the control treatment was 22.66 mg/kg. It also indicated that treatments T2S3, T2S2, T1S4, T1S3, T1S2, T2, S4, S3 and S2 did not show significant differences between them and T2S4 treatment. The rates of ready sulfur in the soil have been reached 34, 26.26, 40, 30.87, 29, 29.62, 36 and 30.33 mg / kg, respectively. There were no significant differences between the treatment of adding *T. thioparus* at a rate of 5 ml/ hole and the control where the rate of sulfur concentration reached 25.66 mg/kg. The results have been indicating that the higher adding sulfur and *T. thioparus* cause the higher of sulfur readiness. The age of 120 days is the peak of sulfur readiness and bacterial activity in the soil, not in the treatment of 36% sulfur addition and *T. thioparus* at a rate 10 ml/hole is the highest rate of sulfur at the time of harvest. This is because the best treatment that achieved a decrease in the degree of soil reaction and achieved the highest rate of sulfur availability in the soil (Veith and et al., 2012; Vikromvarasiri et al., 2014; Vikromvarasiri et al., 2015).

Table (4) concentration of sulfur in the soil during the growth stages of *B. napus* plants

Treatment	Treatment/means	Average of pH measurement			
		After germination	Before flowering	before bearing	After harvest
S1	0 Sulfur	20.44	21.00	22.05	22.66
S2	12% sulfur	23.77	23.66	27.03	26.66
S3	24% sulfur	29.36	31.61	33.90	30.33
S4	36% sulfur	34.66	35.65	39.00	36.00

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T1	5ml of bacteria	22.59	27.66	30.33	25.66
T2	10ml of bacteria	27.25	26.66	30.01	29.62
T1S2	12% sulfur+5ml bacteria	25.68	27.25	29.31	29.00
T1S3	24% sulfur+5ml bacteria	31.34	32.00	35.86	30.87
T1S4	36% sulfur+5ml bacteria	36.00	38.33	40.66	40.00
T2S2	12% sulfur+10ml bacteria	24.00	26.66	28.33	26.66
T2S3	24% sulfur+10ml bacteria	30.67	32.00	37.00	34.00
T2S4	36% sulfur+10ml bacteria	39.00	39.33	41.01	42.00
LSD		194.5	3.19	1.87	2.12

*Each number indicates three replicates

Conclusions

The results showed that adding sulfur to the soil increases number of *T. thioparus* bacteria specialized in oxidizing sulfur, which increases the availability of sulfur in the soil. Also, the sulfur concentration increases to 36% and *T. thioparus* bacteria at a rate of 5 to 10 ml to the root, the readiness of sulfur increases, which works to reduce the degree of soil reaction and which increases the availability of nutrients in it. In addition, increasing the concentration of sulfur and the *T. thioparus* leads to an increase in the percentage of nutrients in the soil and an increase in the percentage of NPK in the plant as well as an increase in the rate of chlorophyll in the rape leaves. The use of sulfur at a concentration of 36% leads to improving the properties of the soil, decreasing the degree of soil interaction and increasing the availability of nutrients. The adding the *T. thioparus* at a rate of 5 or 10 ml to the plant leads to an increase in the availability of sulfur in the soil, which in turn reduces the degree of soil interaction. The crop is one of the crops that are grown in both seasons, and its cultivation in the winter season does not require high amounts of water, and the vegetative sum of it is high and thus the soil does not lose its moisture quickly. From the oil and the rest of the plant parts contain a high percentage of protein, which is used in feeding animals and fish, and it is also an important source for feeding honey bees.

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