Effect of Sulfur-Oxidizing Bacteria Thiobacillus Thioparus and Different Levels of Agricultural Sulfur on Wheat Yield (Triticum Aestivum L.)

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Abstract

A field experiment was carried out in the agricultural season 2020-2021 in an agricultural field located in the Al-Jarboua area (Al Hafez) in Al-Muthanna Governorate to study the effect of inoculation with sulfur-oxidizing bacteria and agricultural sulfur levels and their interactions on the yield of wheat plant Triticum Aestivum L. Ibaa cultivar 99. The study was carried out in two stages, the first is isolation Sulfur oxidizing bacteria and the second used as an inoculant in the agricultural experiment to study its effect on soil characteristics and its content of nutrients NPK and S. At two levels T0 without adding the bacterial inoculum and T1 adding the first isolate of bacteria The second factor included the addition of agricultural sulfur with four levels of sulfur (S0 were taken without addition, S1 added 750 kg ha−1, S2 added 1500 kg ha−1 and S3 added 2250 kg ha−1) In three replications, the number of experimental units reached 36 experimental units. The results of the study also showed that inoculation with bacterial isolates led to a significant increase in the readiness of nutrients N, P, K and S, and the highest rate of sulfur was (1895) mg. The pollination also led to a significant increase in the growth characteristics of the plant (plant height, number of spikes and grain yield), as it recorded (101.25 cm, 393.22 spike m−1 and 6.73 mcg/ha−1), respectively. The addition of agricultural sulfur at different levels affected a significant increase in the availability of nutrients N, P, K and S, and the highest rate of sulfur at the level of S3 was (1817) mg. Also, the bilateral interaction between inoculation with bacterial isolates and agricultural sulfur led to a significant increase in the availability of nutrients N, P, K and S. kg−1 soil.

Keywords: Sulfur, Bacteria, Agricultural, Triticum Aestivum.

1.Introduction

Bio-fertilizers are eco-friendly fertilizers, as well as renewing the fertility of the soil and providing protection for plants against pathogens and drought [1]. Bio-fertilization is also one of the modern methods that aim to reduce the excessive use of chemical fertilizers and reduce the sources of Environmental pollution and reducing the price of chemical fertilizers [2], [3], explained that microorganisms can, under appropriate conditions, play an important role in the oxidation of sulfur biologically in the soil. Soil and increase the availability of nutrients, which in this case works as a reformer of the basic and calcareous properties of the soil. The Iraqi soils have a high content of calcium carbonate, which ranges in most regions of Iraq between 10-45%, and the values of the degree of soil interaction tend to alkaline, which negatively affects the availability of nutrients in the soil necessary for plant growth [4]. Therefore, recent research has directed To add improvers to acid-acting soils such as agricultural sulfur in order to reduce the problems of limestone soils and increase the ability of the soil to prepare the necessary nutrients and absorb them by the plant, and this reflects on increasing the yield of the plant and its components for different agricultural crops. The wheat crop. Triticum Aestivum L, which belongs to the grassy family, is one of the most important food crops and ranks first among cereal crops in Iraq and the world in terms of importance, production and cultivated area. The production of wheat globally reached 761.6 million tons for the year 2019 [5] and in Iraq It reached 4343 thousand tons for an area of 6331 thousand acres [6]. The decrease in productivity per unit area is one of the main problems facing increasing production of wheat and achieving self-sufficiency in this crop. Therefore, it is necessary to work to raise its production efficiency by providing The nutrients necessary for the plant by using bio-fertilizers to increase production, so this study aimed to:

- Studying the effect of adding Thiobacillus bacteria on the availability of sulfur and major elements NP K.
- Studying the effect of bacteria on some growth characteristics and grain yield.
- Studying the effect of sulfur on the availability of elements and some growth indicators.
2. Materials and Methods

A field experiment was carried out in an agricultural field for one of the farmers in the Al-Jarbouia area (Al-Hafiz) in Al-Muthanna Governorate during the agricultural season 2020-2021 in soil whose chemical and physical properties are shown in Table (1) according to the design of the randomized complete sectors in order to study the effect of inoculation with sulfur-oxidizing bacteria and sulfur levels on Agricultural crops and their interactions with the yield and growth of wheat plant L. (Triticum aestivum) class Iba 99.

Table 1. Some physical and chemical properties of the study soil.

| Adjective                                | Value     |
|------------------------------------------|-----------|
| pH Reaction                              | 7.1       |
| dsm-1 ECe Electrical Conductivity ppm Ca+2| 4.5       |
| ppm Ca+2                                 | 320.64    |
| Ready N mg kg⁻¹                         | 13.3      |
| Ready-made P mg kg⁻¹                    | 20.1      |
| Ready K mg kg⁻¹                         | 270       |
| SO4²⁻ mg kg⁻¹                           | 20.5      |
| Organic matter (gm.kg⁻¹) O.M            | 1.10      |
| CO⁻²                                    | Nil       |
| HCO⁻³                                   | 427       |
| Sand g⁻¹ kg soil                        | 235.2     |
| Silt gram kg⁻¹ soil                     | 624.5     |
| Clay g kg⁻¹ soil                        | 140.3     |
| Silty loam                               | Silty loam|

The experiment included two factors, the first is the addition of the biological inoculant at two levels (without addition, and the addition of isolation) and its symbol is T₀ and T₁, what is the second factor is the addition of agricultural sulfur at four levels (0, 750, 1500 and 2250) kg S ha⁻¹ at once and a month before planting and its symbol is 0, S₁, S₂, and S₃, I plowed the soil of the field with two perpendicular plows, and the soil was smoothed and the land was leveled and divided into boards. The planting took place on 11/28/2020 and harvested on 4/14/2021 and 15/4/2021, and the total number of experimental units was 36 units and the area of the experimental unit was 4 m² (m² x m) it included 8 lines with a length of 1 m, the distance between one line and another was 15 cm. M Determine an area 50 cm length x 60 cm width in the stage of 100% flowering and at full maturity and after the plants of the area mentioned in the stage of 100% flowering and after cutting the roots and drying them in an electric oven I grinded their leaves and took a sample of them to estimate the elements N, P and K, and the plant samples were digested by the wet method Using sulfuric and perchloric acid and a saucepan:

- Nitrogen according to the Micro Keldahl method and as mentioned in [7].
- Phosphorous according to the method of ammonium molybdate and ascorbic acid for color development and measurement by a spectrophotometer at a wavelength of 882 nm according to the method mentioned in [8]
- Potassium was measured by the flame-photometer apparatus as mentioned in [9].

The growth characteristics of the plant were measured:

- Plant height (cm): It was estimated at flowering from the base of the plant touching the soil surface to the top of the main spike of six plants [10].
- The number of branches (spike.m-2): When the plants were fully mature, three middle lines were harvested with an area (0.45 x 1 = 0.45 m2). The number of branches was calculated from them and then converted on a square meter basis, and ten spikes were randomly selected from each unit. Experimental, including averages.
- Grain yield megagram/ha⁻¹

The data were statistically analyzed using the computer within the program Genstat-Version12 and the results were compared using the least significant difference L.S.D under the probability level of 0.05.
3. Results and Discussion

3.1 The percentage of nitrogen in the plant

The results of the analysis of variance in Table (2) showed that there were significant differences when adding the bio-inoculant and the levels of agricultural sulfur in the plant’s nitrogen content. The T₁ bio-inoculant treatment was skipped, where the highest average was (1.28)%, with an increase of 116.9% compared to the treatment without addition, which The lowest average was recorded at (0.59)%. The reason for this is due to the biological oxidation of non-oxidizing sulfur compounds by the action of sulfur-oxidizing bacteria and the formation of sulfuric acid, which affects the solubility of the elements’ compounds and thus increases the availability of phosphorus and sulfurs and increases their absorption, which is accompanied by increased nitrogen absorption [11].

The results also showed that there were significant differences when adding agricultural sulfur levels. The level of addition of S₃ surpassed it, as it recorded the highest average of (1.213)% and an increase of (77.85)% compared to the treatment without addition, which recorded the lowest average of (0.682)%. The reason may be attributed to the fact that the addition of sulfur may have caused a decrease in the degree of soil reaction through its oxidation and transformation into sulfuric acid, and then increasing the availability of nutrients in the soil as well as the added elements at this level better than the rest of the levels and thus increasing the absorption of nitrogen by the roots, which led To increase its concentration in the plant [12].

The results also showed significant differences for the interaction between the biological inoculant treatments and agricultural sulfur levels, where the interaction treatment T₁S₃ recorded the highest average of (1.56)% compared to the treatment without addition, which recorded the lowest average of (0.35)%

Table 2. Effect of Thiobacillus thioparus bio-inoculant and agricultural sulfur levels on plant nitrogen content (%) .

| S | T | S₀ | S₁ | S₂ | S₃ | Average |
|---|---|----|----|----|----|---------|
| T₀ | 0.350 | 0.490 | 0.676 | 0.863 | 0.595 |
| T₁ | 1.015 | 1.190 | 1.377 | 1.564 | 1.286 |
| Average | 0.682 | 0.84 | 1.026 | 1.213 |
| l.s.d. | T | S | S | T |
| | 0.029 | 0.033 | 0.058 |

3.2 The percentage of phosphorous in the plant

The results of the analysis of variance in Table (3) showed that there were significant differences when adding the bio-inoculant and the levels of agricultural sulfur in the plant’s phosphorous content. The T₁ bio-inoculant treatment was skipped, as it recorded the highest average of (0.50)% and an increase of 11.11% compared to the treatment without addition, which The lowest average was recorded at (0.45)%. The reason for this is due to the high percentage of phosphorus in the soil as a result of the activity of bacteria, which increased the amount absorbed from it[13]. The solubility and release of basic nutrients in the rhizosphere and increasing their absorption, including phosphorous.

The results also showed significant differences when adding agricultural sulfur levels. The level of addition of S₃ surpassed it, as it recorded the highest average of (0.49)% and an increase of (6.52)% compared to the treatment without addition, which recorded the lowest average of (0.46)%. And these results are consistent with the findings of [5]that adding sulfur to the soil leads to a significant increase in the ready-made phosphorous and consequently an increase in its absorption. It contains phosphorous in the soil, such as mono-, di-, triple- and octa-calcium phosphate (Ocp, Tcp, Dcp, Mcp), which are the predominant compounds in the soil, as well as the role of liberated hydrogen ions in reducing the degree of interaction of the soil solution, which increases the readiness of most nutrients, including phosphorous, and thus increases the absorption of phosphorous from Before the plant [14].

The results also showed that there were significant differences for the interaction between biological inoculant treatments and agricultural sulfur levels, where the interaction treatment T₁S₃ recorded the highest average of (0.51)% and an increase of (18.60)% compared to the treatment without addition, which recorded the lowest average of (0.43)%.
Table 3. Shows the effect of the bio-inoculant of Thiobacillus thioparus and the levels of agricultural sulfur on the plant's phosphorous content (%)

| S  | T  | S0  | S1  | S2  | S3  | Average |
|----|----|-----|-----|-----|-----|---------|
| T0 |    | 0.439 | 0.451 | 0.470 | 0.477 | 0.459 |
| T1 |    | 0.488 | 0.495 | 0.508 | 0.515 | 0.501 |
|    | Average | 0.463 | 0.473 | 0.489 | 0.496 |

| l.s.d | T   | S   | S   | T   |
|-------|-----|-----|-----|-----|
|       | 0.0017 | 0.0029 | 0.0034 |

3.3 The percentage of potassium in the plant

The results of the analysis of variance in Table (4) showed that there were significant differences when adding the bio-inoculant and the levels of agricultural sulfur in the potassium content of the plant. The T1 bio-inoculant treatment was skipped, where the highest average was (2.58)%, with an increase of 63.29% compared to the treatment without addition, which The lowest average was recorded (1.58)%. The reason for this is due to the low degree of reaction as a result of the biological oxidation of incompletely oxidized sulfur compounds in the soil and thus increasing the solubility of nutrient compounds and increasing their absorption by the plant, including potassium [15].

The results also showed that there were significant differences when adding agricultural sulfur levels. The level of addition of S3 surpassed it, as it recorded the highest average of (2.46%) and an increase of (40.57%) compared to the treatment without addition, which recorded the lowest average of (1.75)%. These results are in agreement with the findings of [16], that adding sulfur to limestone soil leads to an increase in the acidity of the soil, resulting in an increase in the availability of potassium, phosphorous, iron, zinc, manganese and copper and their uptake by the plant.

The results also showed that there were significant differences for the interaction between the bio-inoculant treatments and agricultural sulfur levels, where the interaction treatment T1S3 recorded the highest average (3.06)% compared to the treatment without addition, which recorded the lowest average of (1.33)%

Table 4. Shows the effect of the bio-inoculant of Thiobacillus thioparus and the levels of agricultural sulfur on the potassium content of plants (%)

| S  | T  | S0  | S1  | S2  | S3  | Average |
|----|----|-----|-----|-----|-----|---------|
| T0 |    | 1.335 | 1.505 | 1.646 | 1.871 | 1.589 |
| T1 |    | 2.173 | 2.385 | 2.711 | 3.060 | 2.582 |
|    | Average | 1.754 | 1.945 | 2.178 | 2.465 |
| l.s.d | T   | S   | S   | T   |
|       | 0.043 | 0.049 | 0.086 |

3.4 The availability of sulfur in the soil (gm.kg⁻¹ soil)

The results of the analysis of variance in Table (5) showed that there were significant differences when adding the bio-inoculant in the availability of sulfur in the soil (gm.kg⁻¹ soil), so the T1 bio-inoculant treatment was skipped, where the highest average was recorded (1895) gm.kg⁻¹ soil. With an increase rate of 21.16% compared to the treatment without addition, which recorded the lowest average of (1564) g. kg⁻¹ soil. This is due to the fact that inoculation with sulfur-oxidizing bacteria leads to an increase in the availability of sulfur in the soil, as it oxidizes incompletely oxidized sulfur compounds to sulfate [17].

The results also showed that there were significant differences when adding agricultural sulfur levels. The level of the addition of S3 was superior, as it recorded the highest average of (1817) g. kg⁻¹ of soil, with an increase of (13.27)% compared to the treatment without addition, where the lowest average was recorded at (1604) g. kg⁻¹ soil. This is attributed to the increase in the oxidation of sulfur and its incompletely oxidized sulfate compounds due to physical, chemical and biological factors, and these results are consistent with [18].
The results also showed that there were significant differences for the interaction between bio-inoculant treatments and agricultural sulfur levels, where the interaction $T_1S_3$ treatment recorded the highest average of (2037) g kg$^{-1}$ of soil compared to the treatment without addition, which recorded the lowest average of (1493) g kg$^{-1}$ soil.

Table 5. Shows the effect of the bio-inoculant of Thiobacillus thioparus and the levels of agricultural sulfur on the availability of sulfur in soil (gm kg$^{-1}$ soil).

|       | S0  | S1  | S2  | S3  | Average |
|-------|-----|-----|-----|-----|---------|
| T0    | 1493.00 | 1576 | 1591 | 1597 | 1564    |
| T1    | 1715 | 1865 | 1964 | 2037 | 1895    |
| Average | 1604 | 1720.5 | 1777.5 | 1817 |

3.5 Plant Height(cm)

The results of the analysis of variance for Table (6) showed that there were significant differences when adding the bio-inoculant in the plant height characteristic. The $T_1$ bio-inoculant treatment was missed, as it recorded the highest average of (101.25) cm and an increase of 2.6% compared to the treatment without addition, which recorded the lowest average of (98.65) cm. The reason for this is that the process of oxidation of sulfur and a decrease in the value of the soil reaction has led to an increase in the readiness of some nutrients, which increased the growth of the plant, in addition to the importance of the sulfur element, which is included in the formation of protein through the amino acids that enters its composition.

The results also showed significant differences when adding agricultural sulfur levels. The level of addition of $S_3$ surpassed it, as it recorded the highest average of (101.2) cm and an increase of (2.68)% compared to the treatment without addition, where the lowest average was recorded (98.55) cm. This is due to the role of sulfur in reducing the degree of soil interaction and its role in increasing the readiness of nutrients, such as increasing nitrogen absorption, which in turn leads to increased vegetative growth, and an increase in the readiness of phosphorous element and the production of a good root system for plants. [19,20]. indicated that the increase in the amount of agricultural sulfur added to the soil had a significant effect on the increase in plant height.

The results also showed that there were significant differences for the interaction between the bio-inoculant treatments and agricultural sulfur levels, where the interaction treatment $T_1S_3$ recorded the highest average of (102.2) cm and an increase of (5.79)% compared to the treatment without addition, which recorded the lowest average of (96.6) cm.

Table 6. Shows the effect of the bio-inoculant of Thiobacillus thioparus and agricultural sulfur levels on plant height (cm).

|       | S0  | S1  | S2  | S3  | Average |
|-------|-----|-----|-----|-----|---------|
| T0    | 96.6 | 98.4 | 99.4 | 100.2 | 98.65   |
| T1    | 100.5 | 100.9 | 101.4 | 102.2 | 101.25  |
| Average | 98.55 | 99.65 | 100.4 | 101.2 |

3.6 Number of branches (branch M$^{-2}$)

The results of the analysis of variance in Table (7) showed that there were significant differences when adding the bio-inoculant and agricultural sulfur levels in the characteristic of the number of branches (M$^{-2}$ spike) The treatment of the $T_1$ bio-inoculant was missed, as it recorded the highest average of (393.22) (Spike M$^{-2}$). With an increase of 25.17% compared to the treatment without addition, which recorded the lowest average of (314.14) m$^{-2}$ branch. This is attributed to the fact that biofertilization caused an increase in the leaf area, which led to an increase in the efficiency of the photosynthesis process and thus an increase in the outcomes of this process. This is reflected in the increase in the number of branches per square meter.
The results also showed that there were significant differences when adding agricultural sulfur levels. The level of the addition of S3 surpassed it, as it recorded the highest average of (385.45) m² spike, with an increase of (17.84)% compared to the treatment without addition, where the lowest average was recorded (327.08) m² spike. The reason for this is that the increased availability of nutrients, including nitrogen, phosphorous, potassium and some micro-nutrients, which have a role in increasing the formation of cytokinin, which is responsible for increasing plant branches.

The results also showed that there were significant differences for the interaction between biological inoculant treatments and agricultural sulfur levels, where the interaction T1S3 treatment recorded the highest average of (415.83) branches m⁻², with an increase rate of (48.73)% compared to the treatment without addition, which recorded the lowest average of (279.58) branches m⁻².

Table 7. Shows the effect of the bio-inoculant of Thiobacillus thioparus and the levels of agricultural sulfur on the number of branches (branches M⁻²).

|       | S³   | S²   | S¹   | S₀   | Average |
|-------|------|------|------|------|---------|
| T₀    | 279.58 | 303.16 | 318.75 | 355.08 | 314.142 |
| T₁    | 374.58 | 387.08 | 395.41 | 415.83 | 393.225 |
| Average | 327.08 | 345.12 | 357.08 | 385.45 |
| l.s.d  | 3.989 | 4.607 | 7.979 |

### 3.7 Grain yield (Mgram/ha⁻¹)

The results of the analysis of variance for Table (8) showed that there were significant differences when adding the bio-inoculant and agricultural sulfur levels in the trait of grain yield, megagrams/ha⁻¹. With an increase of 43.19% compared to the treatment without addition, which recorded the lowest average of (4.70) mcg/ha⁻¹. The results also showed that there were significant differences when adding agricultural sulfur levels. The level of the addition of S₃ outperformed, as it recorded the highest average of (6.212) megagrams / hectares⁻¹, with an increase of (18.60)% compared to the treatment without addition, which recorded the lowest average of (5.16) mica / hectare⁻¹. The reason for the increase in grain yield is due to the addition of sulfur, which reduced the degree of soil reaction and increased its absorption by the plant, which led to an increase in plant growth, which was reflected in an increase in the components of the yield (the number of spikes per square meter, the number of grains per spike, and the weight of 1000 grains, which means increasing the efficiency of the source in processing the represented materials, increasing the ability of the downstream to receive these materials, and increasing the grain yield per tonne hectares. These results are in agreement with the findings of [1,3]. The results also showed that there were significant differences for the interaction between biological inoculant treatments and agricultural sulfur levels, where the interaction treatment T₁S₃ recorded the highest average of (7.37) mcg/ha⁻¹ and an increase of (79.75)% compared to the treatment without addition, which recorded the lowest average of (4.108) mica / ha⁻¹.

Table 8. Shows the effect of the bio-inoculant of Thiobacillus thioparus and agricultural sulfur levels on grain yield (micrograms/ha⁻¹).

|       | S³   | S²   | S¹   | S₀   | Average |
|-------|------|------|------|------|---------|
| T₀    | 4.106 | 4.775 | 4.905 | 5.050 | 4.709   |
| T₁    | 6.233 | 6.512 | 6.800 | 7.375 | 6.730   |
| Average | 5.169 | 5.643 | 5.852 | 6.212 |
| l.s.d  | 0.133 | 0.154 | 0.267 |
References

[1] Abu Dahi, Youssef Muhammad. (1999). Effect of adding foamed sulfur and phosphate fertilizer on the availability of zinc and copper in the soil and their concentration in the dry matter of the upper parts and grain yield and quality of wheat (Triticum aestivum L.). Journal of Agricultural Sciences 30(1): 16-17.

[2] Al-Bayati, Ali Hussein Ibrahim, Bashir Hamad Abdullah Solagh and Muayyad Hadi Al-Ani. (2009). The Effect of Plant Density and Level of Sulfur Addition to Grassland on Growth and Yield of Sunflower Crop under Dry Conditions in Western Iraq. The Arabian Journal of Dry Environments, 2(3): 27-43.

[3] Taj al-Din, Munther Majid. (1979). The effect of sulfur on the availability of nutrients in some Iraqi soils. Master Thesis. College of Agriculture - University of Baghdad.

[4] Jassem, Adnan Aswad. (2011). The role of sulfur and the quality of irrigation water in some characteristics of calcareous soil and the growth of wheat variety (Mexipac). Diyala Journal of Agricultural Sciences. 3(1): 51-60.

[5] Al-Zahidi, Walid Falih Hassan. (2005). The effect of agricultural sulfur, poultry waste and phosphate rock on the readiness and absorption of phosphorous and some nutrients, growth and yield of wheat (Triticum aestivum L. Master’s thesis - College of Agriculture - University of Baghdad).

[6] Zaboon, Najat Hussain and Intisar Hadi Hamidi Al-Halfi. (2014). Effect of sulfur and nitrogen and potassium fertilizers on the concentration of NPK in wheat leaves and grains. Iraqi Journal of Agricultural Sciences, 45(7) (special issue): 700-707.

[7] Directorate of Agricultural Statistics. (2020). Central Statistical Organization. Iraq.

[8] Besharat, H. A. K. and Hatami, S. (2007). Biosuper asaphosphate fertilizer in a calcareous soil with low available phosphorus. African J. of Biotechnology, 6(11): 1325-1329.

[9] Choudhary, Seema and P.C. Trivedi. (2008). Biostimulator: boon for Agriculture. Biofertilizers pointer publishers india p:1-38.

[10] Choulisans .N. and Tsadila, C.(1996). The influence of acidulation of calcareous soil by elemental sulfur application on soil properties. Georike Ereuna-Neaseira.Cite from CBA Abstracts.

[11] FAO. 2020. Summary of cereal supplies and demand.

[12] Page, A. L.; Miller, R. H. and Keeny, D. R. (1982). Methods of soil analysis part 2 , 2nd (Edn.). Agron. 9, pub. Madison Wisconsin, U. S. A.

[13] Skwierawska,M and Zawartka,L.(2008).The effect of different rates and forms of sulphur applied on changes of soil agrochemical properties. Plant soil environ, 54(4):171-177.

[14] Soaud, A.A.; Al-Darwish, F.; Saleh, M.E.; El-Tarabily, K.A.; Azirun, M.S. and Rahman, M.M. (2011). Effect of element sulfur, phosphorous micronutrient and paracoccus versutus on nutrient availability of calcareous soils Aus.J.Cro.Sci., 5(5): 619-619.

[15] Subba-Rao, N. S.; K. Talik and S. Shende. (1989). Response of Azospirillum brasilense grain yield of pearl. Millet. Cited by Advances in Agricultural Microbiology, sulfur compound from west water sludge. Environ. Eng. Sci. 17(1). sulphur-oxidizing in soil. J. Agron. Soil Sci., 60(3): 367-375.

[16] Valdebenito-Rolack, E. H.; T. C. Aaya; L. E. Abarzua; N. M. Ruiz-Tagle; K. E. Sossa; G. E. Aroca and H. E. Urrutia. 2011. Thioulsphate oxidation by Thiothecillus thioparous and Halothiobacillus neapolitanus strains isolated from the Petrochemical industry. Electro. J. Biotechno., Chile Univ., 14(1): Fulltext-10.

[17] vidyalakshim.r.paranthanam, R.and Bhakyaraj, R.(2009).Sulphur Oxidizing Bacteria and Pulse Nutrition-A Review. World J. of Agr. Sci. 5(3): 270-278.

[18] Janzen, H. H. and J. R. Bettany. 1984. Sulfur nutrition of rap-seed. I-Influence of fertilizer nitrogen and sulfur rates. Soil Sci. Soc. Am. J. 48: 100-107.

[19] Wiersma, D.W.; Oplinger E.S. and Guy, S.O. (1986). Environmental and cultivar effects winter wheat response to ethephon plant growth regulator. Agron. J. 78: 761-764.

[20] Haynes, R.J. (1980). A comparison of two modified kjeldahl digestion techniques for multi – element plant analysis with conventional wet digestion and dry ashing method. Communications in soil & plant analysis.11(5):459-467.