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Phosphorus Solubility from Rock Phosphate Mixed Compost with Sulphur Application and Its Effect on Yield and Phosphorus Uptake of Wheat Crop

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Abstract

A field experiment was conducted to determine the effect of sulphur application with Rock phosphate mixed compost on phosphorus (P) solubility and its effect on yield and P uptake of wheat crop. The experiment was laid out in randomized complete block design (RCBD) with three replications at the research farm of The University of Agriculture Peshawar. The experiment was conducted during rabi 2015-16 with plot size of 3 m × 5 m. Nitrogen, phosphorus and potassium were applied at the rate of 120, 90 and 60 kg·ha^{-1} in the form of urea, compost, or single super phosphate and potassium sulphate, respectively. Elemental sulphur was applied at the rate of 10, 20 and 30 kg·ha^{-1} at the time of sowing. Results showed that sulphur applied with compost significantly improved wheat yield and yield components, soil organic matter, soil total N and AB-DTPA extractable P contents, plant N and P concentrations and their uptake, plant micronutrients concentration and their uptakes. No significant changes were noted in soil pH, ECe and lime contents. Maximum grain yield of 4076 kg·ha^{-1}, total dry matter yield 9721 kg·ha^{-1}, straw yield 5644 kg·ha^{-1}, plant height 98.3 cm, spike length 11.2 cm, grain per spike 61.0, thousand grain weight 50.2 g were recorded on the application of S at the rate 20 kg·ha^{-1} with compost. The highest soil organic matter content of 1.41% was found for the application of S at the rate of 10 kg·ha^{-1} with compost. Maximum soil total N content of 1756 mg·kg^{-1} and P 5.7 mg·kg^{-1} were observed by the application of double recommended S with compost. Plant N uptakes of 125.7 kg·ha^{-1}, and P uptake of 17.5 kg·ha^{-1}, were maximum with application of compost and S @ 20 kg·ha^{-1}. Highest plant uptake of Fe 0.56

kg·ha^{-1}, Zn 0.41 kg·ha^{-1}, Cu 0.16 kg·ha^{-1} and Mn 0.93 kg·ha^{-1} were found by the application of full recommended S with compost. Results suggested that S at the rate of 20 kg·ha^{-1} application with compost prepared from farm yard manure and rock phosphate proved better combination to enhance wheat yield, yield components and nutrients uptakes of wheat crop.

Keywords

Phosphorus Solubility, Rock Phosphate, Compost, Sulphur, Wheat Crop

1. Introduction

Phosphorous (P) is the succeeding important macronutrients following nitrogen (N) indispensable for plant growth [1] and has key function in numerous metabolic processes of plant and animals life. It has functions in metabolic pathways of biosynthesis and degradation and structural nature in macromolecules [2]. It also plays a very important role in several physiological processes such as energy storage, respiration, photosynthesis, and cell enlargement/division. It is an essential structural constituent of various bio chemicals such as nucleic acid (DNA and RNA enzymes and coenzymes). Phosphorus is linked with early maturity of crops and helps in the stimulation of root growth. It also helps to prevent the plants from different diseases. It strengthens the straw by preventing them from lodging [3].

Among different factors accountable for low yield, fertilizer management may be of much importance [4]. It has also been shown in various findings that nearly 90% of Pakistan soils are scarce in phosphorous content [5]. Due to high cost of phosphate fertilizers, substituted sources are needed. For this purpose rock phosphate (RP) can be used practically which has been known as an important substitute source for P fertilizers has received important consideration in recent years. Rock phosphate contains naturally of the group containing apatite having high amount of phosphate minerals. It mostly produces phosphatic fertilizers used for agricultural purposes. Compost manure and RP are the chief and locally available sources of phosphorus [6]. The solubility of RP is still narrow while on the other hand the concentration of P is very low in compost manure [7] [8] [9]. Conversely, by enhancing solubilization of rock phosphate and P concentration in compost manure can handle the concentration of soil P. Availability of phosphorus can be increased when RP are applied with organic manure because it enhances rock phosphate dissolution in the soil. During the process of composting, organic acids are formed which create favorable environment for solubilization of P thus reducing the pH values and improving other properties. RP can be used as a P source in many crops in relationship with organic manure and phosphate solubilizing microorganism [10]. During the decomposition of organic materials, the organic acids produced provide protons for RP dissolution

[11]. To increase the productivity of crops fertilizers are very important especially in wheat crop. For good quality and better yield of crops, micronutrients apart from (N, P, K) play a major role in balanced managements of nutrients. Fertilizers responses to crops may differ greatly due to soil and climatic conditions. Generally, Pakistani soils are high in pH, light to medium in texture and calcareous in nature.

Sulfur is one of the imperative nutrients for plant growth and plant tissue containing 0.2% to 0.5% on dry matter basis. [12] showed that requirements of sulphur is quite similar that of phosphorus. It is a building block of protein help in the formation of chlorophyll [13]. The problems of calcareous soils can be resolve with the application of different sulphur fertilizers. Hence, the importance has amplified in by means of elemental S to develop the solubility of plant nutrients especially P. The elemental sulphur applied to soil is oxidized in to H_2SO_4 $\left(2S+3O_2+2H_2O\rightarrow 2H_2SO_4\right)$. This H_2SO_4 so produced is beneficial to make phosphorus and micronutrients more available to plants, supplying of SO_4 to plants and decreasing the pH of the soil. [14] found that by S application dry weight of plant, phosphorus concentration and nutrients uptake were increased and soil pH was reduced 0.11 - 0.37 unit. In Pakistan, sulphur is not measured, in fertilizers as plant nutrients and in the country; information about sulphur condition in soil is quite low. In period of fast growth during early spring, high amount of sulphur is required for wheat plant due to slow release of sulphur from soil organic matter [15]. Sulphur fertilizers application considerably increased wheat yield [16] [17] [18] and rapeseed [19]. [20] showed that grain yield and grain per spike of barley significantly increased by foliar sulphur application. Sulphur is important for many physiological process in plant such as, synthesis of certain vitamins (Biotin and Thiomine), synthesis of co-enzyme A synthesis of S containing amino acids (Cysteine, Cystine and Methionine), and in the metabolism of, fats, carbohydrates and protein. [21] showed that deficiency of sulphur change composition of grain by falling grain sulphur and restricting the structure of proteins enriched with sulphur. Due to poor S flour status, the dough extensibility and baking quality can be restricted [22].

Compost contains lot of nutrients having high content of organic matter. By using compost, the properties of soil such as chemical and physical can be enhanced, which may increase crop yield ultimately. [23] showed that physical properties like porosity, water permeability, hydraulic conductivity, void ratio and bulk density were extensively improved with compost of farmyard manure in combination with different fertilizers. These properties of soil can also be improved by the application of chopped salt grass, rice straw and wheat straw. The paddy yield, biomass, plant height and tillering, were drastically improved [24]. [25] also proved that dissimilar types of compost like water hyacinth, dry leaves, mixed weeds, and barseem increased yields of wheat, and rice, gram and green beans. By the application of urban compost or FYM or green manure @ 12.5 $kg \cdot ha^{-1}$ straw and grain yields of rice were amplified in addition through NPK. Generally, manure fertilizers such as urban compost, green manure and FYM, at the @ 12.5 t·ha^{-1} beside with different inorganic sources could make best use of the rice yield and uptake of nutrients compared to suggested levels of fertilizers exclusive of any manure [26].

Wheat *(Triticum aestivum* L.*)* is a winter self-pollinated crop, belongs to family *Poacceae* tribe Hordeae is the world's leading cereal crop both in area and production and feeding about one third of the whole world population. Pakistan is the 8th largest wheat producing country of the world. It is a vital staple food inside the country. Wheat is one of the mainly plentiful sources of protein and energy for the world population. It is a most important component in many foods such as breakfast cereals, cakes, doughnuts and roll, pies, pastries, bread, pancakes and other alcoholic beverages. It has been reported that 100 g of spring wheat contains about 12.2 g of fiber, 71 g of carbohydrates, 1.54 g of fats, 12.6 g of protein, vitamins in trace amount and a massive quantity of nutrients [27]. In 2015-2016, wheat was cultivated on 9.25 m ha in Pakistan with a production of 25.45 m tons, while in Khyber Pakhtunkhwa wheat was cultivated on 0.78 m ha with a production of 1.35 m tons [28]. Keeping in observation the significance of sulphur and compost, this experiment was designed to investigate the effect of S applied with compost prepared with RP on yield and uptake of P by wheat crop.

2. Materials and Methods

A field experiment was conducted at research farm of The University of Agriculture, Peshawar during Rabi season 2015-2016 to study the effect of phosphorous solubility from compost prepared with FYM and RP as influenced with sulphur and its effect on yield and P uptake of wheat crop. The experiment was laid out in randomized completely block design (RCBD) with three replications. Wheat variety (Atta Habib) was sown with seed rate of 100 kg·ha^{-1}. There were 8 treatments in the experiment and the plot size was kept 5 m long and 3 m wide containing ten rows of plants. The row to row distance of wheat plants was kept 30 cm apart. Sulphur and compost prepared from rock phosphate (RP) and farm yard manure (FYM) were applied at the time of sowing. Sulphur was applied at three different levels as 10, 20 and 30 kg·ha^{-1} [23]. Compost was applied on the basis of its P content. The N content of compost was adjusted and the rest was fulfilled from urea. Nitrogen, phosphorus and potassium were applied at the rate of 120, 90 kg·ha^{-1} and 60 kg·ha^{-1} in the form of urea, compost or single super phosphate and potassium sulphate respectively. Nitrogen was applied in three split doses, while all phosphorus and potassium doses were applied at the time of sowing. Data recorded were statistically analyzed using ANOVA technique and means were compared using LSD test at 5% level of probability. Treatments combinations used in the experiment are given as follows;

1) Control (No fertilizers)

2) N and K fertilizers as basal dose applied to all treatments except control.

3) N, P and K at the rate of 120, 90 and 60 kg·ha^{-1}

4) Compost @ recommended level of P
5) N, P and K + Sulphur @ 20 kg·ha^{-1}
6) Compost + S @ 10 kg·ha^{-1}
7) Compost + S @ 20 kg·ha^{-1}
8) Compost + S @ 30 kg·ha^{-1}

2.1. Laboratory Study

2.1.1. Soil pH

Ten g soil sample was taken in a shaking bottle. 50 ml distilled water was added and soil water suspension (1:5) was made. The suspension was then shaked for 30 minutes on horizontal shaker. The suspension was then brought for pH meter. With the help of pH, meter pH of the soil was determined. Before measuring the pH meter was calibrated with standard buffers of 4.0 and 10.0 as method shown by [29].

2.1.2. Soil EC(e)

Electrical conductivity of the soil suspension was determined by adding ten g soil with 50 ml distilled water and soil water suspension (1:5) was made. EC of the suspension was determined by EC meter [30]. Before taking readings of the samples with known concentration of KCL solution the ECe meter was calibrated.

2.1.3. Soil Organic Matter Content

Soil organic method was determined by the method of [7]. In a conical flask, 1 g of soil was taken by adding 10 ml of 1N $K_2Cr_2O_7$ solution and 20 ml of concentrated H_2SO_4. It was then set aside for 30 minutes to complete the reaction. The volume was then reached up to 200 ml by adding distilled water. The suspension was then filtered through what man-42 filter paper, and 2 - 3 drops of ortho-phenophthaline was added and titrated against $Fe_2SO_4 \cdot 7H_2O$ of 0.5N, end was recorded when dark brown color was observed.

2.1.4. Soil Lime Content

By acid neutralization method lime content of soil was determined [31]. In this method, soil of 5 g was taken in conical flask, and then 50 ml of HCl of 0.25N was added to it. For 5 minutes, flask was put on hot plate and was allowed to cool for some time. Then 2 - 3 drops of phenolphthalein indicator was supplemented to the flask and titrate against 0.25N NaOH. The titration was completed when pink color appeared.

2.1.5. Soil Total Nitrogen Content

Total nitrogen of the soil was determined by the Kjeldhal method of [32]. Soil sample of 0.2 g and 1.1 g digestion mixture was taken in a digestion tube. Then concentrated sulphuric acid of 3 ml was added. After that 2 - 3 ml distilled water was added. At 350˚C digestion tube was kept in a digestion block for 3 - 4 hours. The digestion method was continued till greenish color appeared. When greenish color appeared the tubes was removed from digestion block and for some time the solution was allowed to cool. Then with distilled water the solution was diluted to 100 ml. In a distillation flask, 20 ml sample was taken along with 4 ml of 40% NaOH for distillation process. For collecting evaporated extract, boric acid of 5 ml mixed indicator was taken in 100 ml conical flask until the volume reached up to 65 ml. The distillate of 65 ml was then analyzed for total nitrogen by titrate it against 0.005N HCl until pink color appeared and then reading was noted. Blank sample was also run which contain 20 ml distilled water as a substitute of soil sample.

2.1.6. Soil AB-DTPA Extractable P

Phosphorus content of soil was determined by extracting it with AB-DTPA extracting solution as described by [33]. In a flask soil of 15 g was taken and solution of 30 ml AB-DTPA extracting was added to it. The sample was then kept on a horizontal shaker and shaked the samples for 15 minutes. With the help of watt man-42 filter paper suspension was filtrated in to small bottles. Then 1 ml extract was taken from filtrate and transferred it into 25 ml volumetric flask. Ascorbic mix reagent of 5 ml along with distilled water of 4 ml of distilled water and adjusted the volume up to 25 ml by adding distilled water. The flask was then kept in dark for about 15 minutes in order to developed blue color. For calibration of spectrophotometer, then absorption curve was developed on spectrophotometer for 0, 2, 4, 6, 8 and 10 ppm standard solution. With the help of spectrophotometer, the samples were analyzed. Fe, Zn, Mn, and Cu, concentration were determined through atomic absorption spectrophotometer.

2.1.7. Plant Nitrogen Concentration

Plant nitrogen concentration was determined by the Kjeldhal method of [32]. Plant sample of 0.2 g along with digestion mixture of 1.1 g was taken in a digestion tube. Concentrated sulphuric acid of 3 ml and distilled water 2 - 3 ml was added. At 350˚C digestion tube was kept for 3 - 4 hours in a digestion block. The process of digestion was continued until greenish color appeared. When greenish color appeared the tubes was detached from digestion block and was allowable to cool for some time. In 100 ml distilled water the solution was diluted. In a digestion flask sample of 10 ml was taken beside with 4 ml of 40% NaOH for distillation process. Mixed indicator boric acid of 5 ml was taken in conical flask of 100 ml for collecting evaporated extract the volume reached up to 100 ml. then for determination of nitrogen concentration the 65 ml distillate was titrate against 0.005N HCl until pink color appeared and then reading was noted. Blank sample was also run which contain only 20 ml distilled water.

2.1.8. Plant Phosphorus Concentration

In a conical flask plant sample of 0.5 g and 10 ml of nitric acid was taken in conical flask to determine concentration of P in plants [30]. The flask was then kept for the night to complete the reaction. Then 4 ml perchloric acid was added to it. The flask was then kept on a hot plate for digestion until the color changes and white fumes were appeared. The sample was then allowed to cool for some time. The sample was then diluted into 100 ml volumetric flask and the volume was adjusted up to 100 ml by adding distilled water. Then 0.5 ml extract was taken from the solution and transferred it into volumetric flask of 25 ml. Ascorbic mix reagent of 5 ml along distilled water of 4 ml was added and up to 25 ml the volume was adjusted by adding distilled water. The flask was then kept in dark for about 15 minutes in order to developed blue color. On spectrophotometer absorption curve was developed for 0, 2, 4, 6, 8, and 10 ppm standard solution for calibration of spectrophotometer. Then extractable phosphorus was determined with the help of spectrophotometer.

2.1.9. Plant Fe, Zn, Cu and Mn Concentrations

Plant sample of 0.5 g plant sample with 10 ml of nitric acid in a conical flask was taken for determination of micronutrients. The flask was kept for the night to complete the reaction. Then 4 ml perchloric acid was added to it. The flask was then kept on a hot plate for digestion until the color changes and white fumes were appeared. The sample was then allowed to cool for some time. The sample was then diluted into 100 ml volumetric flask and the volume was adjusted up to 100 ml by adding distilled water. The samples were analyzed by the help of atomic absorption spectrophotometer for the determination of Fe, Zn, Cu and Mn.

2.1.10. Plant Nutrients Uptake

Nutrients uptake by wheat crop were determined by using the formula.

Plant nutrient concentration × total dry matter yield.

3. Results and Discussion

A field experiment was conducted at the research farm of the University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan to determine the influence of sulphur applied with compost on yield and nutrients uptake of wheat crop.

Physical and chemical properties of soil under investigation are presented in **Table 1**.

Data in **Table 1** showed that soil under study was calcareous in nature, alkaline in reaction. Silt loam in texture, low in OM content, poor in available phosphorus and total nitrogen contents.

3.1. Compost Analysis

Concentration of N and P in compost under use contains 1.189% N and 0.547% P_2O_5.

3.1.1. Yield and Yield Components of Wheat

Yield and yield components of wheat are significantly affected by sulphur applied with compost prepared with FYM and RP is presented in **Table 2**.

Table 1. Physico-chemical properties of soil under investigations.

Property	Units	Concentration
Silt	%	64.5
Sand	%	29.6
Clay	%	5.4
Textural Class	-	Silt loam
EC(e)	$dS \cdot m^{-1}$	0.25
pH	-	7.81
Organic matter content	%	0.76
Lime	%	14.7
Soil total N content	%	0.12
AB-DTPA extractable P	$mg \cdot kg^{-1}$	3.26

Table 2. Grain yield, biological yield and Straw yield of wheat as affected by sulphur applied with compost.

Treatments	Grain	Total dry matter	Straw
	yield ($kg \cdot ha^{-1}$)		
Control (No fertilizers)	2463e*	6705f*	4242c*
N and K fertilizers	2769d	7706e	4937b
N, P & K fertilizers	3670b	9085b	5415ab
Compost	3198c	8323d	5125ab
N, P & K + S @ 20 $kg \cdot ha^{-1}$	3688b	9303b	5615a
Compost + S @ 10 $kg \cdot ha^{-1}$	3396bc	8710c	5313ab
Compost + S @ 20 $kg \cdot ha^{-1}$	4076a	9721a	5644a
Compost + S @ 30 $kg \cdot ha^{-1}$	4037a	9645a	5638a
LSD $P \leq 0.05$	299.2	341.7	531

*Means with different letter (S) in columns are significantly different at $P \leq 0.05$.

3.1.2. Wheat Grain Yield

Wheat grain yield as affected by sulphur applied with compost is presented in Table 2. Data revealed that grain yield was significantly affected by treatments combination of sulphur applied with compost. Maximum grain yield of 4076 $kg \cdot ha^{-1}$ was found with application of compost with S @ 20 $kg \cdot ha^{-1}$ with 65% increase over control (Figure 1). This data were statistically similar with 4037 $kg \cdot ha^{-1}$ compost and sulphur at the rate of 30 $kg \cdot ha^{-1}$ followed by N, P and K with S, and N, P and K fertilizers. Lowest yield of grains 2463 $kg \cdot ha^{-1}$ was recorded in control treatment. [34] investigated that application of sulphur drastically improved wheat yield and yield components. This improvement probably due to creating favorable and healthy environment for plant growth by compost

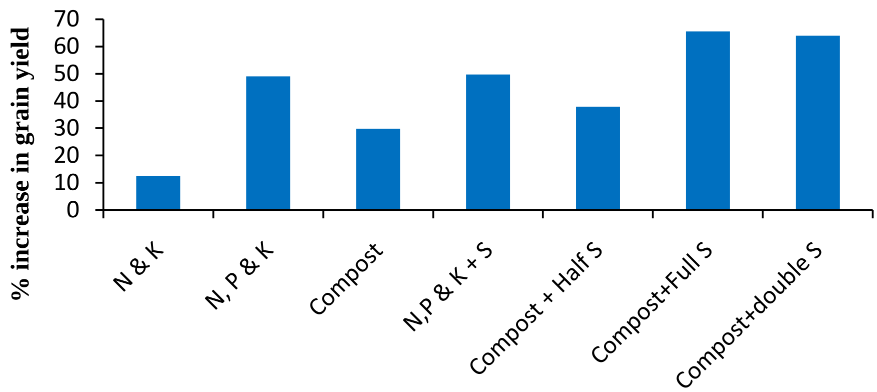

Figure 1. % increase in grain yield over control as affected by S applied with compost.

applied with [35] [36] and [16] reported similar results. Our results are also similar with [16] and [18] who reported that sulfur use increased wheat grain yield and other cereals. Our results are also similar with [37] and [38] who reported that wheat grain yield considerably increased when RP is mixed with different organic materials. [39] found that maize gain yield was significantly increased by applying RP and organic residues.

3.1.3. Total Dry Matter Yield

Data regarding total dry matter yield of wheat as affected by sulphur practical by means of compost prepared with RP are presented in **Table 2**. Highest dry matter yield of 9721 kg·ha^{-1} was observed in the plot treated with compost and S @ 20 kg·ha^{-1} which was 44.9% increase over control (**Figure 2**) Which was statistically comparable to 4037 kg·ha^{-1} produced by compost and S @ 30 kg·ha^{-1} followed, by N, P and K with S @ 20 kg·ha^{-1} and N, P and K fertilizers. The lowest dry matter yield of 6705 kg·ha^{-1} was recorded in the control treatment. These results are in an agreement with of [16] and [18] who noticed that use of sulfur raise biological yield. Our results show similarity with the findings of [40] who concluded that total dry matter yield increases with soil and foliar application of [41] found that RP when applied with organic materials enhanced biological yield of wheat. [42] reported that biological yield improved when RP are applied with different organic materials.

3.1.4. Wheat Straw Yield

Table 2 showed mean data of wheat dry straw yield as affected by sulphur applied with compost. Treatment combinations significantly affected straw yield. Highest straw yield of 5644 kg·ha^{-1} was produced with compost and S at the rate of 20 kg·ha^{-1} which was 31% increase over control (**Figure 3**), and was statistically comparable to 5638 and 5615 kg·ha^{-1} compost with S @ 30 kg·ha^{-1} and N, P, K and S at the rate of 20 kg·ha^{-1}. The lower straw yield of 4242 kg·ha^{-1} was noticed in the control treatment. This result is resembled by the outcome of [34] who reported that application of sulphur considerably enhanced yield of wheat and yield components. The same results have also been shown by [43] recorded

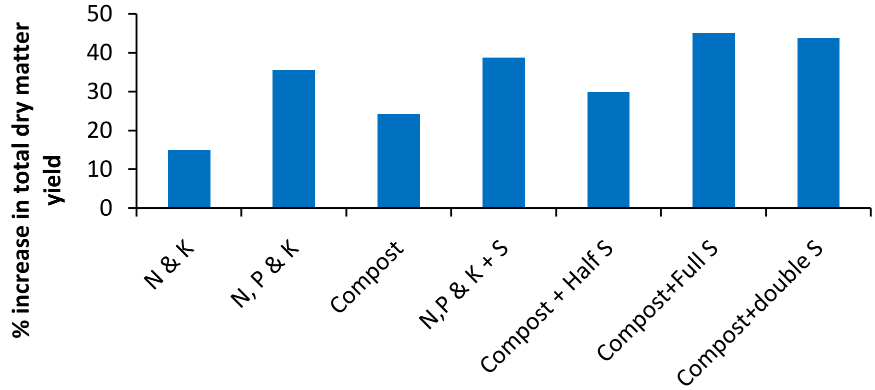

Figure 2. % increase in total dry matter yield over control as affected by S applied with compost.

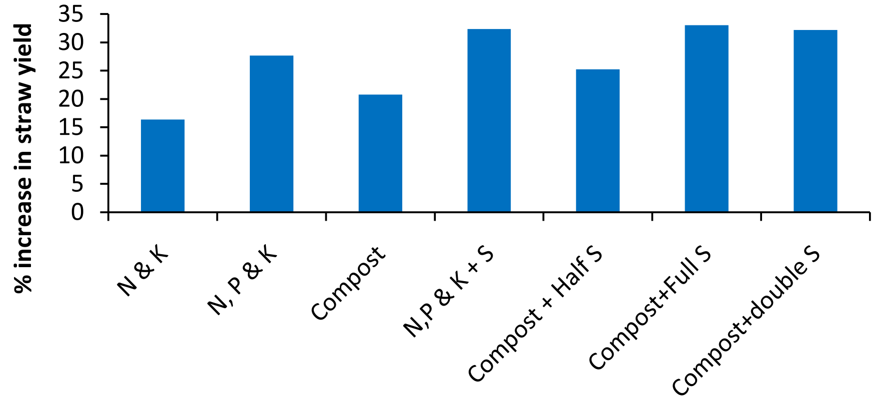

Figure 3. % increase in straw yield over control as affected by S applied with compost.

that straw yield of wheat enhanced with composts submission organized from different organic materials. The results compiled by [44] showed that by the application of organic and inorganic fertilizers total dry matter yield of crop was drastically increased.

3.1.5. Plant Height

Plant height as affected by sulphur applied with compost is shown in **Table 3**. Data indicated that plant height was significantly affected by sulphur applied with compost. Highest plant height of 98.3 cm was recorded with compost and S at the rate of 20 kg·ha^{-1} followed by compost and S @ 30 kg·ha^{-1}. The smallest plant height was recorded in control treatment. These results are also in agreement with [45], in which he noticed that application of S fertilizers drastically affect plant height. [46] supported these results that plant height could be significantly affected with composts enriched with chemical fertilizers.

3.1.6. Spike Length

Spike length as affected by sulphur applied with compost is present in **Table 3**. Data reveled for plant height is significantly affected by sulphur applied with

Table 3. Effect of sulphur applied with compost on plants height, spike length, grain per spike and thousand grain weight.

Treatments	Plant height	Spike length	Grain per spike	Thousand grain weight
	(cm)		No	(g)
Control (No fertilizers)	78.0e*	7.4e*	39.3e*	33.0f*
N & K fertilizers	81.1d	8.4d	43.3de	37.9e
N, P & K fertilizers	95.7ab	10.1b	56.7b	48.3ab
Compost	87.5c	9.0cd	47.4d	40.7d
N, P & K + S @ 20 kg·ha^{-1}	95.8ab	10.3b	56.7b	48.6ab
Compost + S @ 10 kg·ha^{-1}	89.3c	9.2c	52.3c	43.2c
Compost + S @ 20 kg·ha^{-1}	98.3a	11.2a	61.0a	50.2a
Compost + S @ 30 kg·ha^{-1}	93.6b	9.9b	54.7bc	46.8b
LSD $P \leq 0.05$	3.0	0.62	4.108	2.40

*Means with different letter (S) in columns are significantly different at $P \leq 0.05$.

compost. Maximum spike length of 11.2 cm was recorded in the plot treated with compost with S @ 20 kg·ha^{-1} followed by N, P and K with S at the rate 20 kg·ha^{-1} and compost with S at the rate of 30 kg·ha^{-1} and N, P and K fertilizers with 10.3, 9.9 and 10.1 cm respectively. The smallest plant height of 7.4 cm was recorded in the control treatment. The above values are in lined by means of the outcome of [34] reported that submission of different sullphur fertilizers considerably enhanced yield and yield components of wheat. [35] [36], have also reported comparable results and [16] [47] [48] and [49] that use of organic materials growth of crop may be improved.

3.1.7. Grain per Spike

Sulphur applied with compost significantly influenced grain spike^{-1} as shown in **Table 3**. Maximum grains spike^{-1} 61 was observed in the plot treated with compost and S at the rate of 20 kg·ha^{-1} followed by grain spike^{-1} of 56.7 was found with N, P and K with S at the rate of 20 kg·ha^{-1} and N, P and K fertilizers respectively. Minimum grains spike^{-1} 39.3 were observed at control plot which was statistically similar 43.3 of N and K at recommended level. These results indicated that grain spike^{-1} was increased with the increasing level of sulphur and compost as shown by [50] who reported that sulphur when applied with HA increased grain per spike and thousand grain weight, because it has the capability of decomposing residues and make nitrogen gradually accessible to soil and plant. [20] and [51] reported that S could increase number of grain per spike. These values resemble to the finding of [52] who investigated that at optimum timings of application of sulphur and nitrogen increased number of grain per spike in wheat. This may be owing to that either foliar spray or through soil application of both sulphur and nitrogen at various growth stages create encouraging environment for tillers and proper nourishment for crops. [53] reported the same results.

3.1.8. Thousand Grains Weight

Thousand grains weight of wheat as affected by sulphur applied with compost is presented in **Table 3**. Data regarding mean thousand grains weight was significantly affected by the treatment combinations. Maximum thousand grains weight of 50.2 g was observed with application of compost and S at the rate of 20 kg·ha^{-1} followed by thousand grains weight of 46.8 g was found with compost and S at the rate of 30 kg·ha^{-1}. Minimum thousand grains weight of 33.0 g was recorded in the control treatment. This may be due to that, competent metabolic behavior which improved moisture and gluten contents of grain and thus increased in weight of grain occurred. [54] showed that thousand grain weight increased with nitrogen and sulphur application. The same results were also presented by [55]. Similar results were also reported by [34] that use of sulphur drastically enhanced wheat yield and its components. These results also support the findings of [56] and [57] who reported that all the growth parameters could be enhanced with compost appliance.

3.1.9. Soil pH Values

pH values noted after crop harvest were non considerably exaggerated by the treatment combination of sulphur applied with compost is shown in **Table 4**.

The pH values ranged from 7.75 to 7.46. These results are in contrast with [58] who stated that make use of sulfur has a major effect in falling soil pH. [59] observed that after five years sulphur intake can diminish soil pH. [60] also accomplished considerable optimistic association with soil pH due to oxidation of sulfur [30]. [61] found that 0.07-0.35 units decreased in soil pH was noticed and due to increasing application of sulphur to calcareous soil pH of the soil was decreased up to the 5th week and after that increased was started in soil pH [62].

Table 4. Effect of sulphur applied with compost on post harvest soil pH, ECe and SOM contents.

Treatments	pH (1:5)	EC(e) (dS·m^{-1})	SOM	Lime
			(%)	
Control (No fertilizers)	7.75	0.29	0.50d*	17.61
N & K fertilizers	7.76	0.31	0.64cd	18.67
N, P & K fertilizers	7.76	0.33	0.73c	17.55
Compost	7.75	0.34	1.28a	18.45
N, P & K + S @ 20 kg·ha^{-1}	7.63	0.38	0.96b	17.63
Compost + S @ 10 kg·ha^{-1}	7.61	0.36	1.41a	18.09
Compost + S @ 20 kg·ha^{-1}	7.54	0.38	1.28a	17.99
Compost + S @ 30 kg·ha^{-1}	7.46	0.39	1.20a	18.36
LSD $P \leq 0.05$	NS	NS	0.21	NS

*Means with different letter (S) in columns are significantly different at $P \leq 0.05$.

reported soil pH increase with compost consumption.

3.1.10. Soil Electrical Conductivity

The soil EC recorded after cop harvest were non significantly affected by sulphur applied with compost as shown in Table 4. It might be due to the reason that total soluble concentrations are statistically similar with each other. The results are in contrast with [63] who reported that EC was significantly affected by the addition of elemental S to calcareous soils. [64] mentioned that soil salinity increased with the constant use of the compost.

3.1.11. Soil Organic Matter Content

Analysis of data revealed that soil organic matter content was significantly affected by sulphur applied with compost as presented in Table 5. Highest Soil organic matter content of 1.41%, 1.28% and 1.20% were observed in the treatment plots of sulphur application with compost, which were statistically similar with each other's. The lowest organic matter content of 0.50% was noted in the control. It might be due to the reason that incorporation of organic manures enhances SOM content and soil organic carbon. The same results were obtained by [65] who noticed that organic matter content was improved with organic and inorganic fertilizers. [66] supported these results and found that application of rock phosphate through organic manure improved the organic matter content of soil. Our consequences are also supported by the findings of [67] [68] [69] [70] [71]. Comparable outcome were also supported by [72]. Comparable results were also obtained by [73]. Combination of organic fertilizer suggestively increased organic matter [35] and [74].

3.1.12. Soil Total Nitrogen Content

Post harvest soil total nitrogen as affected by sulphur applied with compost is given in Table 5.

Table 5. Post harvest soil N and P contents as affected by sulphur applied with compost.

Treatments	Total soil N	AB-DTP A extractable P
	Contents (mg·kg^{-1})	
Control (No fertilizers)	940d*	3.10f*
N & K fertilizers	1275c	3.859e
N, P & K fertilizers	1230c	4.193d
Compost	1101cd	4.580c
N, P & K + S @ 20 kg·ha^{-1}	1111cd	5.168b
Compost + S @ 10 kg·ha^{-1}	1477b	4.925b
Compost + S @ 20 kg·ha^{-1}	1613ab	5.567a
Compost + S @ 30 kg·ha^{-1}	1756a	5.704a
LSD $P \leq 0.05$	194.56	0.321

*Means with different letter (S) in columns are significantly different at $P \leq 0.05$.

Analysis of data indicated that soil total nitrogen content was considerably affected by sulphur applied with compost. Highest total soil N of 1756 mg·kg·ha^{-1} was observed with submission of compost and S at the rate of 30 kg·ha^{-1} followed by compost with S @ 10 kg·ha^{-1}. The lowest total soil nitrogen of 940 mg·kg^{-1} was noted in the control treatment. [41] reported the same results, who observed increased concentration in total soil nitrogen through application of organic materials with rock phosphate. Similar results have been shown by [16] who stated that the relevance of rock phosphate with organic manure have the capability to the soil nitrogen and phosphorus concentration and plant uptake. The same results were also presented by [75] found that maize yield and soil nitrogen were significantly increased when organic manure was applied in combination with NPK. These fallout are in line with [76], reported that after composting process the raise might be credited to a straight result of organic nitrogen resulting from the compost, which is gradually mineralized in soil [77]. Our results are also supported by [78].

3.1.13. Post Harvest Soil P Content

Analysis of data revealed that post harvest soil P content was considerably affected by treatment combination of sulphur applied with compost is present in **Table 5**. Highest soil P content of 5.704 mg·kg·ha^{-1} was obtained by means of compost and S @ 30 kg·ha^{-1}, which was statically similar to compost and S @ 20 kg·ha^{-1} followed by N, P and K with S @ 20 kg·ha^{-1}, which was similar to compost and S at the rate of 10 kg·ha^{-1}. The lowest soil P content of 3.10 mg·kg^{-1} was recorded in the control treatment. The comparable results was obtained by [14] who found that it may be due to that sulphur reduced pH of the soil and making phosphorus and micronutrients more available. Similarly [79] and [80] and [81] found that sulphur has helpful outcome from the soil on releasing phosphorus and increased the yield of plant. Comparable results were also reported by [41] who found that concentration of P might be amplified when organic materials are mixed with rock phosphate. Comparable results were also reported by [48] and [67] who noticed that use of inorganic and organic manures increased the phosphorus availability in the soil. Over results are also supported by [71] [82] [83] [84].

3.1.14. Plant Nitrogen and Phosphorus Concentration

Data regarding plant N and P concentration as affected by sulphur applied with compost are presented in present in **Table 6**.

3.1.15. Plant N Concentration

Data regarding plant N concentration as affected by sulphur applied with compost are presented in **Table 6**.

Data regarding plant N concentration as significantly affected by the submission of sulphur applied with compost. Maximum plant N concentration of 1.29% was obtained with appliance of compost with S @ 20 kg·ha^{-1} followed by compost and S @ 30 kg·ha^{-1}. The lowest plant N concentration of 0.85% was

Table 6. Plant nitrogen and phosphorus concentration of wheat as affected by sulphur applied with compost.

Treatments	Plant N	Plant P
	Concentration (%)	
Control (No fertilizers)	0.85d*	0.07d*
N & K fertilizers	1.22b	0.10c
N, P & K fertilizers	1.12c	0.14b
Compost	1.25ab	0.13bc
N, P & K + S @ 20 $kg \cdot ha^{-1}$	1.13c	0.14b
Compost + S @ 10 $kg \cdot ha^{-1}$	1.23b	0.15ab
Compost + S @ 20 $kg \cdot ha^{-1}$	1.29a	0.18a
Compost + S @ 30 $kg \cdot ha^{-1}$	1.27ab	0.17a
LSD $P \leq 0.05$	0.06	0.03

*Means with different letter (S) in columns are significantly different at $P \leq 0.05$.

observed in the control treatment. This result is an agreement with [85] who observed that concentration of nitrogen in plant can be enhanced by the use of rock phosphate assorted with organic materials. [86] also supported our results that plant N concentration is able to raise by the combined submission of organic and inorganic sources of N. Further scientists [47] [48] and [67] in various plants also practical amplified concentration of nitrogen, phosphorus and potassium when organic and inorganic fertilizers were applied from different sources such as FYM, green manure and chemical fertilizers. Our results are also supported by [87].

3.1.16. Plant P Concentration

Wheat plant P concentration as affected by sulphur applied with compost is shown in **Table 6**. Plant P concentration was drastically affected by sulphur applied with compost. Highest plant P concentration of 0.24% was recorded with submission of compost and S @ 20 $kg \cdot ha^{-1}$, which was statistically comparable to compost and S at the rate of 30 $kg \cdot ha^{-1}$, followed by N, P and K with S @ 20 $kg \cdot ha^{-1}$. The lowest plant P concentration of 0.08% was observed in the control treatment. This might be due to that around the roots in small areas pH of the calcareous soil decreased by the addition of sulphur and absorption potential of phosphorus increases [88]. Composts prepared with rock phosphate out additional amounts of alkaline phosphates and acid in soil as compared to other common composts, improved phosphorus solubilization for longer time. During nitrogen fixation, legumes may be able to release supplementary phosphorus from RP by means of rhizosphere acidification [9]. [47] [48] [67] also observed better uptake of nitrogen, phosphorus and potassium concentration by plant were ominously inclined by organic manures. [71] [82] [87] and [89] founded that addition of naturals manures and compost to soil improved the Nitrogen, Phosphorus and potassium concentrations in plant.

3.1.17. Plant N Uptake

Wheat plant N uptake as affected by sulphur applied with compost is shown in Table 7.

Analysis of data shows that plant N uptake was significantly affected by sulphur applied with compost. Highest N uptake of 125.7 kg·ha^{-1} was recorded by the use of compost and S @ 20 kg·ha^{-1} which was 141% increase over control (Figure 4) and was statistically similar to compost with S @ 30 kg·ha^{-1} followed by N, P and K with S at the rate of 10 kg·ha^{-1}. The lowest plant nitrogen uptake of 51 kg·ha^{-1} was recorded in the control treatment. These results are conformity with [85] who observed that RP when assorted with organic materials can develop nitrogen uptake by plant. [86] also support our results that uptake of nitrogen by plant can be increased by the combined use of organic and inorganic sources of N. Further researchers [47] [48] [67] also observed improved uptake of nitrogen, phosphorus and potassium when organic and inorganic fertilizers were applied from different sources. Our results are also supported by [87] originate that plant nitrogen and phosphorus uptake were increased when rock phosphate was mixed organic fertilizers.

3.1.18. Plant P Uptake

Plant P uptake was significantly affected by sulphur applied with compost is shown in Table 7. The highest plant P uptakes of 17.5 kg·ha^{-1} was recorded with the application of compost and S at the rate of 20 kg·ha^{-1}, which was 272.3%, increase over control (Figure 5) and was statically similar to compost with S at the rate of 30 kg·ha^{-1}. The lowest plant P uptake of 4.3 kg^{-1} was noted in the control treatment. This may be due to that sulphur reduced pH of the soil and making phosphorus and micronutrients more available to the plant [79]. Our results were also supported by [90] who experiential that uptake of phosphorus by plant

Table 7. Plant N and P uptake of wheat as influenced by sulphur applied with compost.

Treatments	N	P
	Plant uptake (kg·ha^{-1})	
Control (No fertilizers)	57.0c*	4.7c*
N & K fertilizers	94.2d	7.9d
N, P & K fertilizers	101.5b	12.7b
Compost	103.7b	11.1b
N, P & K + S @ 20 kg·ha^{-1}	105.1b	13.0b
Compost + S @ 10 kg·ha^{-1}	106.8b	13.4b
Compost + S @ 20 kg·ha^{-1}	125.7a	17.5a
Compost + S @ 30 kg·ha^{-1}	122.9a	16.7a
LSD $P \leq 0.05$	6.73	2.73

*Means with different letter (S) in columns are significantly different at $P \leq 0.05$.

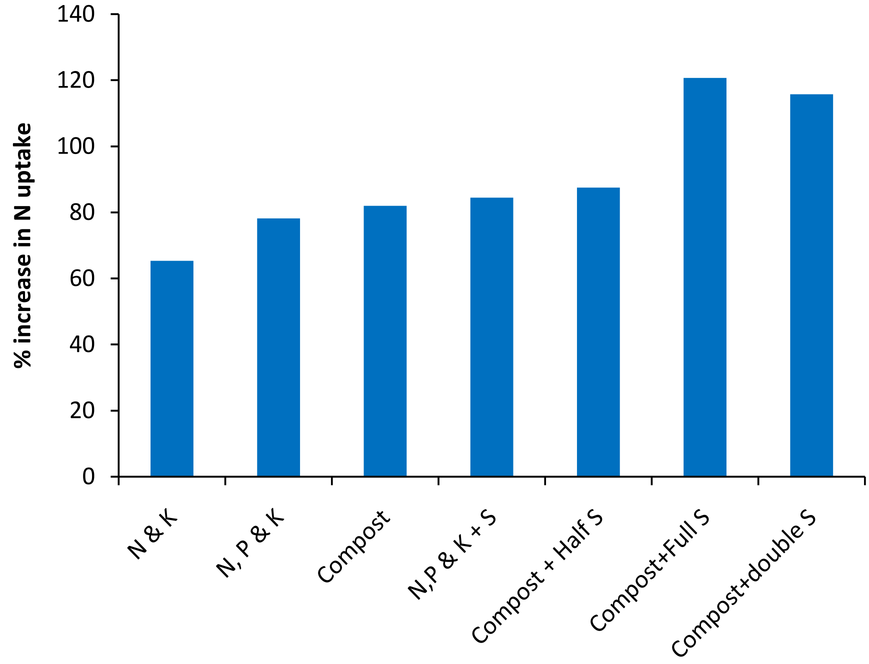

Figure 4. % increase in uptake of N over control as affected by S applied with compost.

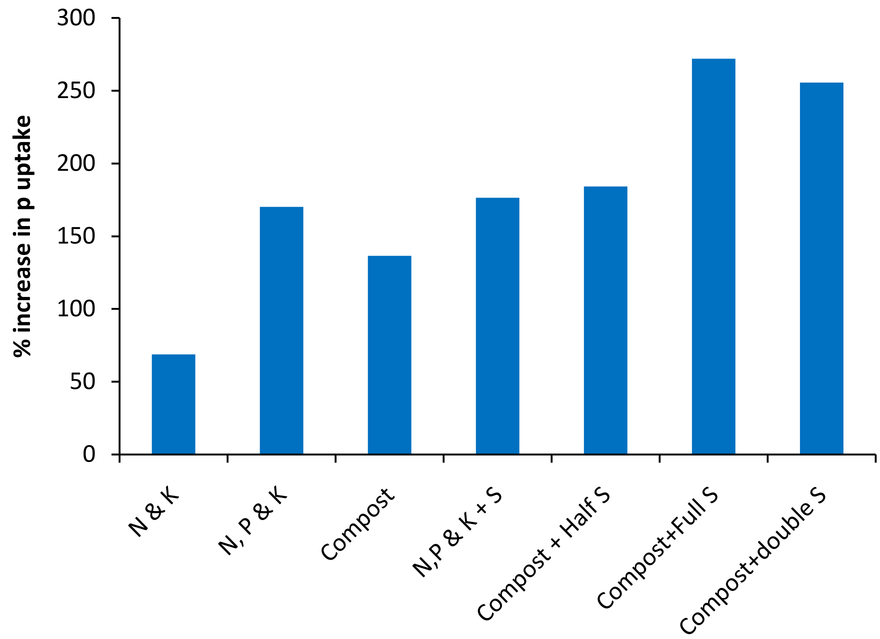

Figure 5. % increase in uptake of P over control as affected by S applied with compost

were significantly increased with residual effect of N-based compost. [87] also found that plant nitrogen and phosphorus uptakes were improved when RP was applied was mixed with organic fertilizers. [47] [48] [67] also observed N, P and K increased uptake by plant were ominously inclined by organic manures. [71] [82] [87] and [89] founded that addition of naturals manures and compost to soil improved the Nitrogen, Phosphorus and potassium concentrations in plant.

3.1.19. Plant Fe Concentration

Table 8 showed the mean data of plant micronutrients concentration as affected by sulphur applied with compost.

Table 8 showed the mean data of plant micronutrients concentration as affected by sulphur applied with compost. Results showed that Fe concentration in plant was significantly affected by sulphur applied with compost. Maximum plant Fe concentration of 58.1 mg·kg^{-1} was recorded with application of compost and S @ 20 kg·ha^{-1}, which was statistically similar to N, P, K with S @ 20 kg·ha^{-1} and N, P and K followed by compost and S @ 30 kg·ha^{-1}. The lowest plant Fe concentration of 38.2 mg·kg^{-1} was observed in the control treatment. The same results was obtained by [79] who found that it may be due to that sulphur reduced pH of the soil and making phosphorus and micronutrients more available to the plant. Our results were also supported by [80] who reported that utilization of sulfur in calcareous soil and with neutralizing lime improved accessibility of iron. [79] showed the same results.

3.1.20. Plant Zn Concentration

Table 8 showed the mean data of plant micronutrients concentration as affected by sulphur applied with compost. Results show that Zn concentration in plant was significantly affected by sulphur applied with compost. Maximum plant Zn concentration of 42.03 mg·kg^{-1} was recorded with application of compost and S at the rate of 20 kg·ha^{-1}, Which was statistically similar to N, P, K and S @ 20 kg·ha^{-1} and compost with S at the rate of 20 kg·ha^{-1} and N, P and K followed by compost and S @ 10 kg·ha^{-1}. The lowest plant zinc concentration of 25.07 mg·kg^{-1} was observed in the control treatment. [91] supported our results who reported that use of elemental sulphur improved zinc and cadmium solubilization in soil and amplified their uptake by plants. [92] reported that Fe, Zn and Cu concentration by plant were ominously inclined by compost. [93] reported

Table 8. Plant micronutrients concentration as affected by sulphur applied with compost.

Treatments	Fe	Zn	Cu	Mn
	mg·kg^{-1}			
Control (No fertilizers)	38.2e*	25.07d*	6.0e*	65.8e*
N & K fertilizers	42.5d	28.30c	8.4d	72.5d
N, P & K fertilizers	57.3a	40.57a	10.4c	93.7a
Compost	47.0c	34.13b	12.0bc	79.2c
N, P & K + S @ 20 kg·ha^{-1}	57.3a	40.87a	10.6c	94.6a
Compost + S @ 10 kg·ha^{-1}	51.1bc	35.73b	13.1b	86.6b
Compost + S @ 20 kg·ha^{-1}	58.1a	42.03a	16.3a	95.5a
Compost + S @ 30 kg·ha^{-1}	52.7b	39.03a	15.3a	90.2ab
LSD $P \leq 0.05$	4.05	3.043	1.80	6.16

*Means with different letter (S) in columns are significantly different at $P \leq 0.05$.

that using organic fertilizers the organic matter of the soil increases and thus increases the concentration of Fe, Zn, Cu, Mn, N, P, and K in plant.

3.1.21. Plant Cu Concentration

Concentration of Cu in wheat plant as affected by sulphur applied with compost is presented in **Table 8**. Data show that Cu concentration was significantly affected by treatment combination of sulphur applied with compost. Highest plant Cu concentration of 16.3 $mg \cdot kg^{-1}$ was observed with submission of compost and S @ 20 $kg \cdot ha^{-1}$ which was statistically similar to compost with S @ 30 $kg \cdot ha^{-1}$ followed, by compost and S @ 10 $kg \cdot ha^{-1}$. Lowest plant Cu concentration of 6.0 $mg \cdot kg^{-1}$ was noted in the control treatment. [93] reported that using organic fertilizers the organic matter of the soil increases and thus increases the concentration of Fe, Zn, Cu, Mn, N, P, and K in plant. [91] [94] [95] founded that pH reducing agents such as sulphur and sulphuric acid improves the properties of calcareous soils and enhanced the concentration of nutrients, including micronutrients.

3.1.22. Plant Mn Concentration

Concentration of Mn in wheat plant as affected by sulphur applied with compost is given in **Table 8**. Data show that Mn concentration was significantly affected by treatment combination of sulphur applied with compost. Highest plant Mn concentration of 95.5 $mg \cdot kg^{-1}$ was noticed by submission of compost and S at the rate of 20 $kg \cdot ha^{-1}$ that was statistically comparable to N, P and K fertilizers followed by compost and S @ 10 $kg \cdot ha^{-1}$. Lowest plant Mn concentration of 65.8 $mg \cdot kg^{-1}$ was observed in the control treatment. Our results are comparable with the result of [91] [94] [95] founded that pH reducing agents such as sulphur and sulphuric acid improves the properties of calcareous soils and enhanced the concentration of nutrients, including micronutrients. [93] reported that using organic fertilizers the organic matter of the soil increases and thus increases the concentration of Fe, Zn, Cu, Mn, N, P, and K in plant.

3.1.23. Plant Fe Uptake

Wheat plant Fe uptake as affected by sulphur applied with compost is present in **Table 9**. Data show that plant Fe uptake was significantly affected by treatment combination. Highest plant Fe uptake of 0.56 $kg \cdot ha^{-1}$ was recorded with application of compost and S @ 20 $kg \cdot ha^{-1}$ which was 124% increase over control (**Figure 6**), Followed by N, P and K with S @ 20 $kg \cdot ha^{-1}$. The lowest plant Fe uptake of 0.25 $kg \cdot ha^{-1}$ was recorded in the control treatment. This result was is in agreement with [79] who found that it may be due to that sulphur reduced pH of the soil and making phosphorus and micronutrients more available to the plant. [93], reported that using organic fertilizers the organic matter of the soil increases and thus increases the concentration of Fe, Zn, Cu, Mn, N, P, and K in plant. Our results were supported by [79] who reported that concentration of iron was increased in silage corn by with application of S. Similarly [96] supported our results in their findings that Fe and Zn uptake was increased in

Table 9. Plant micronutrients uptake as affected by sulphur applied with compost.

Treatments	Fe	Zn	Cu	Mn
	Plants uptake (kg·ha^{-1})			
Control (No fertilizers)	0.26g*	0.17f*	0.04f*	0.44d*
N & K fertilizers	0.33f	0.22e	0.06e	0.56c
N, P & K fertilizers	0.53b	0.38b	0.10b	0.88b
Compost	0.39e	0.28d	0.10d	0.66b
N, P & K + S @ 20 kg·ha^{-1}	0.53b	0.38b	0.10b	0.88b
Compost + S @ 10 kg·ha^{-1}	0.44d	0.31c	0.11c	0.75b
Compost + S @ 20 kg·ha^{-1}	0.56a	0.41a	0.16a	0.93a
Compost + S @ 30 kg·ha^{-1}	0.50c	0.38b	0.15b	0.87a
LSD $P \leq 0.05$	0.03	0.02	0.02	0.04

*Means with different letter (S) in columns are significantly different at $P \leq 0.05$.

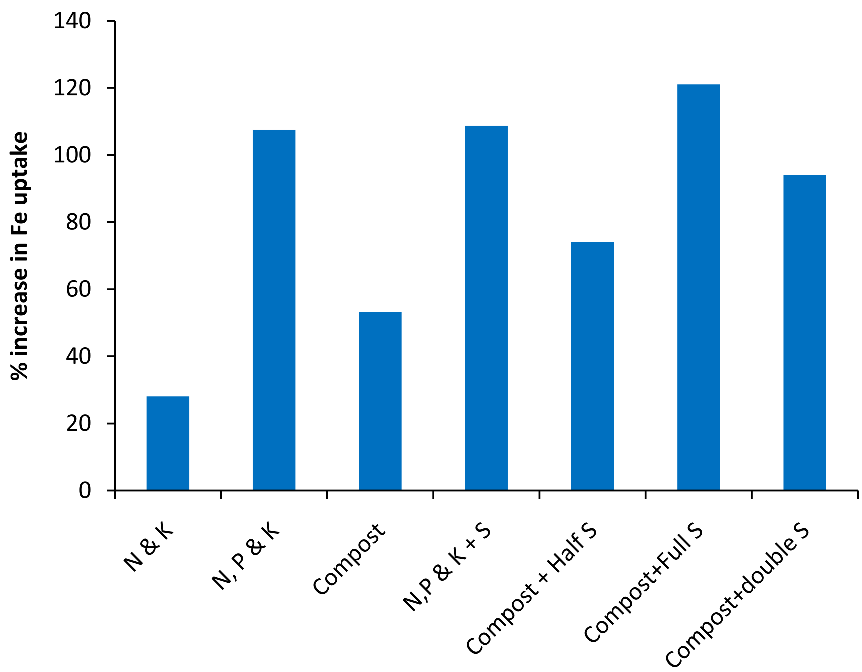

Figure 6. % increase in plant uptake of Fe over control as affected by S applied with compost.

calcareous soils by sulphur application.

3.1.24. Plant Zn Uptake

Wheat plant Zn uptake as affected by sulphur applied with compost is shown in Table 9. Data show that plant Zn uptake was significantly affected by treatment combination. Highest plant Zn uptake of 0.41 kg·ha^{-1} was recorded with application of compost and S at the rate of 20 kg·ha^{-1}, which was 143% increase over control (Figure 7) followed by N, P and K and S @ 20 kg·ha^{-1} and compost with

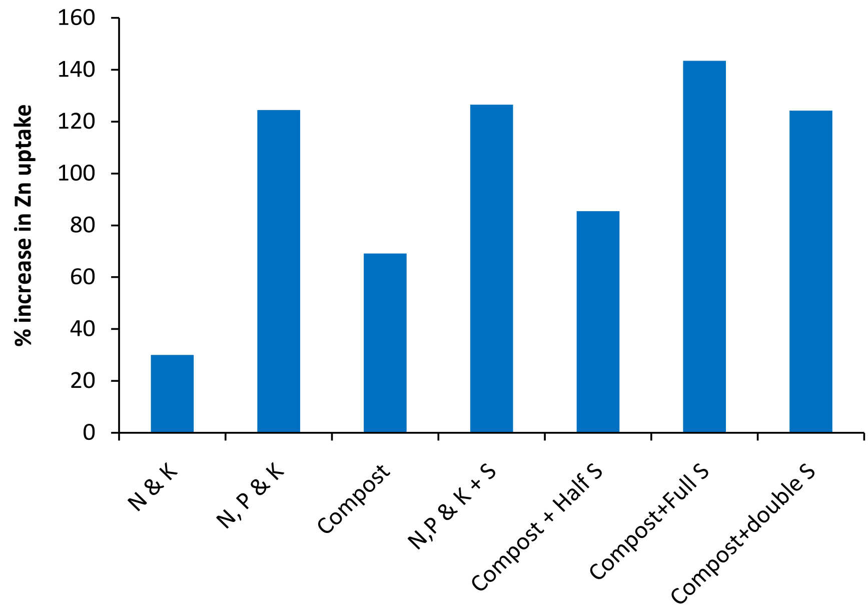

Figure 7. % increase in plant uptake of Zn over control as affected by S applied with compost.

S at the rate of 30 kg·ha^{-1}. The lowest plant Zn uptake of 0.17 kg·ha^{-1} was recorded in the control treatment. [93], reported that using organic fertilizers the organic matter of the soil increases and thus increases the concentration of Fe, Zn, Cu, Mn, N, P, and K in plant. Similarly [96] supported our results in their findings that Fe and Zn uptake was increased in calcareous soils by sulphur application.

3.1.25. Plant Cu Uptake

Table 9 showed mean data of Cu uptake by wheat as influenced by sulphur applied with compost. Plant Cu uptake was significantly affected by treatment combinations of sulphur applied with compost. Highest plant Cu uptake of 0.16 kg·ha^{-1} was noted with application of compost and S @ 20 kg·ha^{-1}, which was 300% increase over control (**Figure 8**), followed by compost with S @ 30 kg·ha^{-1} and N, P and K fertilizers. Lowest plant Cu uptake of 0.04 kg·ha^{-1} was practical in the control treatment. [93] reported that using organic fertilizers the organic matter of the soil increases and thus increases the concentration of Fe, Zn, Cu, Mn, N, P, and K in plant. [92] reported that Fe, Zn and Cu concentration by plant were ominously inclined by compost.

3.1.26. Plant Mn Uptake

Table 9 showed mean data of Mn uptake by wheat plant as influenced by sulphur applied with compost. Plant Mn uptake was significantly affected by treatment combinations of sulphur applied with compost. Highest plant Mn uptake of 0.93 kg·ha^{-1} was noted with application of compost and S @ 20 kg·ha^{-1}, which was 111% increase over control (**Figure 9**), followed by N, P and K with S @ 20 kg·ha^{-1} and was statistically similar with compost with S @ 10 kg·ha^{-1}. Lowest

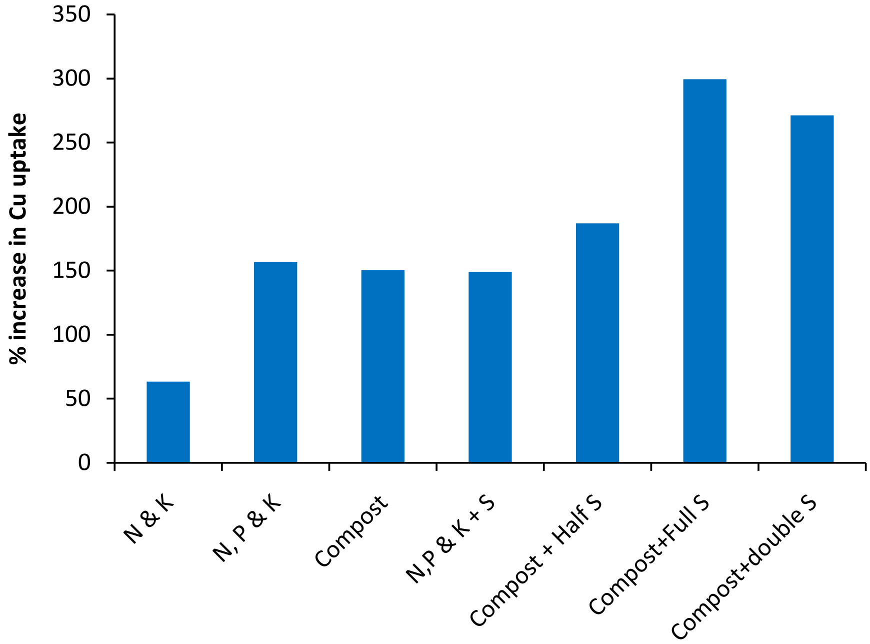

Figure 8. % increase in plant uptake of Cu over control as affected by S applied with compost.

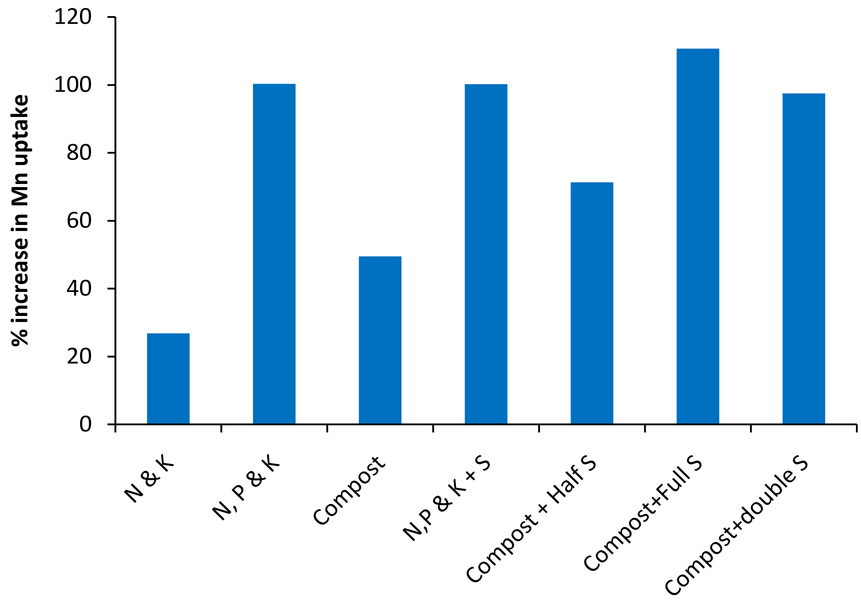

Figure 9. % increase in plant uptake of Mn over control as affected by S applied with compost.

plant Mn of 0.44 kg·ha^{-1} was observed in the control treatment. [93] reported that using organic fertilizers the organic matter of the soil increases and thus increases the concentration of, Zn, Cu, Fe, Mn, N, P, and K in plant. [91] [94] [95] founded that pH reducing agents such as sulphur and sulphuric acid improves the properties of calcareous soils and enhanced the concentration of nutrients, including micronutrients.

4. Conclusions

Following conclusions are drawn from the results of the conducted research work.

- Sulphur application with compost prepared from farm yard manure and rock phosphate significantly increased grain (4076 kg·ha^{-1}), total dry matter yield (9721 kg·ha^{-1}) and straw yield (5644 kg·ha^{-1}) of wheat crop.
- Maximum plant height, thousand grains weight and spike length of wheat were recorded by the application of sulphur with compost.
- Plant N and P uptake of wheat crop improved significantly by the addition of S with compost.
- Micro nutrients (Zn, Cu, Fe and Mn) uptake by wheat plants significantly increased by S application with compost.
- Post harvest soil total N, OM, and AB-DTPA extractable P contents improved by the addition of S with compost.

Recommendations

Following recommendations could be drawn on basis of findings of the conducted research work.

- Sulphur application with compost prepared with RP has the potential to improve yield, yield components and nutrients uptake of crops.

Further research work is needed to conduct experiment on sulphur application with composts of different crops and organic materials at various agroecological conditions of Pakistan

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