

Response of Maize to Application of Sulfurea

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Abstract
To find out the effect of sulfurea on maize crop, an experiment was conducted at ARI Tarnab during Kharif, 2011. The experiment consisted of six treatments with three replications in RCB design. N, P and K were applied in the form of urea, Diammonium phosphate (DAP) and muriate of potash (MOP), respectively. The recommended dose of the sulfurea at the rate of 16L per hectare was applied in the first irrigation (half of the recommended i.e. 8L) and on the fourth irrigation (another half of the recommended i.e. 8L) when crop was at silking stage. The application of sulfur in the form of sulfurea significantly increased the yield of maize crop. The highest grain yield of 6090 kg ha^{-1} was obtained by the treatment where sulfurea was applied along with NPK fertilizers; whereas lowest grain yield was recorded in plots where no fertilizer was applied. Maximum dry matter yield was obtained when sulfurea was applied with NPK while minimum was obtained in control plots. The effect of sulfurea on the chemical properties of the soil was not very obvious and non-significant effect was observed. No effect on soil pH, electrical conductivity, organic matter and lime was observed which revealed that sulfurea has no effect on these chemical properties of soil. The post harvest soil analysis showed that nitrogen content was not significantly affected while phosphorus and sulfur content was significantly affected by the application of sulfur as sulfurea. Leaf analysis indicated the sulfur content was increased significantly also the uptake was increased significantly. These results indicated that the application of sulfur in the form of sulfurea should be encouraged to apply to the crops like maize, because it increased the yield and improved the soil nutrient content.

INTRODUCTION

One of the most vital food extensively grown all over the world for food is maize (*Zea mays L.*) (FAOSTAT, 2004). Corn sugar, corn oil, corn flakes and corn protein etc are produced by the raw materials of maize. Maize plays a major role in supplementing food supplies and is the most palatable feed for all types of livestock in countries like USA and Brazil (FAOSTAT, 2004). In year 2011, global production of maize exceeded 883 million tons (FAOSTAT,2011). Maize supplies an energy content of 365 Kcal/100g approximately (Nuss and Tanumihardjo, 2010). Nitrogen (N), phosphorus (P) and potassium (K) are the primary nutrients and plant needs them in soil in large quantities. Calcium (Ca), magnesium (Mg) and sulfur (S) are the secondary micronutrients. (Need reference) In reality, plants require sulfur and phosphorus in almost same amount (Tandon, 1986); but sulfur is still considered a secondary nutrient.

Nitrogen is a vital constituent of amino acids, which are the building blocks of proteins. Proteins can be structural, or they can be specialized workhouses called enzymes. Enzymes help reduce the energy barriers which keep many chemical reactions from occurring randomly in a plant. Deoxyribonucleic acid (DNA) molecule also contains nitrogen as its constituent so it plays an extremely vital function in reproduction and cell division. The chlorophyll molecule also contains nitrogen. (Need reference)

Sulfur is a building block of proteins and is essential for the production of chlorophyll (Duke and Reisenaue, 1986). Maximum potential in terms of yield or protein content cannot be achieved in crops that lack adequate S (Zhao *et al.* 1999). S plays an essential role in the growth and development of plant, in agricultural crops S deficiency was exceptional in wheat, (Withers *et al.* 1995). Sulfur additionally enhances efficiency of use of supplementary nutrients of plants, chiefly N and P. One of the major nutrients essential for plant growth, root nodules formation of legumes and plant protection mechanism is sulfur. Sulfur can additionally be utilized as an amendment for Pakistani soils. pH of soil is lowered by the application of sulfur. One of the main limitation in the production of crop in coarse textured soils is sulfur deficiency (Takkar *et al.* 1989) About 15% of Pakistani soils are deficient in sulfur (<10mg kg^{-1} SO_4), 30% fall in satisfactory range (11-30mg kg^{-1} SO_4), 33% are in adequate range (31-99mg kg^{-1} SO_4), and 22% qualify as high range as (100mg kg^{-1} SO_4) (NFDC, 1992).

Urea is a commonly used fertilizer for nitrogen deficiency. The highest grade of urea contains 46 per cent of nitrogen, while some other grades contain 42 per cent of nitrogen. Its pH is alkaline (8.0). It is readily soluble in water and is well suited for use in solution fertilizer or foliar spray. It is available in white prill form. (Need reference) but I think this para graph should be deleted. No need to say about urea.

Sulfurea is an acidic nitrogenous fertilizer which serves as urea thiosulfate and supplies nitrogen and sulfur to plant. It contains 10%S and 9.2%N. Its pH ranges from 3-4. Due to acidic pH, it supplies nutrients present in soil to the plants. In sulfurea nitrogen and sulfur are dissolved in solution of fulvic acid. So, sulfur and fulvic acid solution prevents volatilization of nitrogen (Pamphlet on sulfurea by life technologies private limited).

Losses from N fertilizers and animal slurries by nitrate leaching, denitrification and ammonia volatilization have long been a concern to soil scientists. To the farmer, such losses are uneconomical and to the environmentalists they are seen as having major impact on atmospheric and water quality (Jarvis et al, 1995). Nitrate levels, in rivers and groundwater, are increasing in certain regions of Ireland (Stapleton, 1996) and there are chances of nitrate vulnerable zones being declared where the use of N fertilizers will be restricted in future. Emissions of ammonia from cattle feedlots are particularly high and it has been estimated that 75% of the N excreted by animals is lost under current waste management systems, (Power et. al. 1994) which effects environment in its worst way. Besides the environmental consequences of leaching and volatilization, large quantities of N are lost which could be used in plant production. In the mid to late 80's, research at North Dakota State University by Dr. Jay Goos indicated that ATS (Thio-Sul) has an inhibitory effect on nitrification and urease activity (Goos 1985; Goos *et al* 1986).

Fulvic acids, humic acids, and humin are the functions of humic substances found in soil and sediments. (Need reference) A colloidal solution of humic acid and fulvic acid is extracted from soil and other solid phase sources into a strongly basic aqueous solution of potassium hydroxide or sodium hydroxide. (Need reference) By the addition of hydrochloric acid, pH of the solution is adjusted to 1.0 which results in the precipitation of humic acid, leaving the fulvic acids in solution. It is a highly soluble organic phenol found in humus that chelates elemental mineral nutrients and are soluble independent of pH (Baigorri *et al*. 2009). Fulvic acid enhances uptake of fertilizers and promotes ecological balance.

It is beneficial for sugar cane, tobacco and orchards. The sulfur present in sulfurea reaches every portion of plant by absorbance. Therefore, use of sulfurea increases the immunity of plant to diseases and insects (Pamphlet on sulfurea by life technologies private limited).

Fulvic acid makes fertilizers more effective for plant growth and yield, and makes them stronger. It improves soil structure, soil moisture content, soil aeration, and the availability of nitrogen, phosphorus and other nutrients. (Need reference, specially fulvic acid)It helps in development of rhizosphere from where plant can get water and nutrients. It also neutralizes the harmful effects of pesticides and poisonous residues (Pamphlet on sulfurea by life technologies private limited).

MATERIALS AND METHODS

This experiment was conducted at ARI Tarnab during Kharif, 2011 on maize crop. There were 6 treatments with three replications. Half N and all P and K were applied at first irrigation as urea, DAP and MOP. The remaining half N was applied at knee height stage. The recommended dose of the sulfurea (6.5 %) at the rate of 16L per hectare was applied in the 1st irrigation (half of the recommended i.e. 8L) and 4th irrigation (another half of the recommended i.e. 8L) when crop was at silking stage. In one recommended dose of sulfurea, there was 1.6 litre of nitrogen and 1.5 litre of sulfur. Plot size was kept as (4.65 x 5.4) m^2. Design was RCB. The recommended dose on plant basis i.e. 40.16mL was dissolved in 618mL of water and was applied to the soil surface uniformly through water sprayer. Composite soil sample was collected before sowing for complete physiochemical analysis. Similarly plant and post harvest soil samples from each plot was also collected for various chemical analysis.

Collection of soil and plant sample

Soil sample from each plot was collected after the harvest. Soil sample was dried at room temperature, grinded and sieved through less than 2mm sieve and was packed in labeled plastic bag for laboratory analysis. Leaf samples at silking stage below and opposite the ear was also collected. Plant samples after air drying was dried in oven at 70° C.

Soil analysis

Electrical conductivity (E.C) (McClean, 1982)., pH, (McClean, 1982). organic matter, lime (Page *et al.,* 1982), soil texture (Koehler *et al*. 1984), total nitrogen (Bremner and Mulvaney, 1982), AB-DTPA extractable P (Soltanpour and Schwab, 1977), and available sulfur (Williams and Steinbergs, 1959) were analyzed in a composite soil sample.

Leaf analysis

Analysis of leaves samples was done by the wet digestion of leave samples using procedure of Rashid *et al.* (1995), with minor modification. Spectrophotometer was used to measure the absorbance of SO_4–S using standard solution at 470 nm (Bardsley and Lancaster, 1960).

Nutrient uptake by maize crop

After chemical analysis of plant samples, the nutrient contents were calculated and the value of nutrient uptake was also calculated by the following formula (Jackson, 1965).

Nutrient uptake (kg ha^{-1}) = $\frac{\text{Nutrient content (\%) x yield (kgha}^{-1}\text{)}}{100}$

Yield parameters
Stalk yield and grain yield was determined in the study. Following formula was used to record the grain yield:

$$\text{Grain yield (kg ha}^{-1}) = \frac{X \times 10000\,m^2}{\text{Row length} \times \text{Row - Row distence} \times \text{No. of Rows harvested}}$$

Where X= Grain yield (kg plot^{-1})

Value Cost Ratio
Value Cost Ratio was calculated to check the difference of input and output costs and also its feasibility for farmers. Need reference

$$\text{VCR} = \frac{\text{Value of Increased Yield}}{\text{Cost of Fertilizer}}$$

Statistical analysis
All the data recorded on different parameters of plant yield, plant analysis and soil analysis was subjected to statistical analysis for comparison as suggested by Steel and Torrie (1980). LSD was used for mean comparison and orthogonal contrast used to compare the effect of different groups.

RESULTS SND DISCUSSIONS
To find out the effect of sulfurea on the yield of maize, a field crop experiment was conducted in Agricultural Research Institute, Peshawar with six treatments during 2010-2011. Before conducting the experiment, a composite soil sample was collected at the depth of 0-30 cm and analyzed for physic-chemical properties. The data is presented in Table 4.1 and the results showed that the soil was clay loam in texture, alkaline in reaction, low in organic matter and slightly calcareous. The soil was poor in total nitrogen and available phosphate. Available sulfur was also marginal.

Table 4.1. Physico-chemical properties of soil

Parameter	Values	Units
Textural class	Clay loam	---
Lime	11.25	%
Organic Matter	0.44	%
pH (1:5)	8.1	---
EC (1:5)	0.51	dS m^{-1}
AB-DTPA Extractable P	10.0	mg kg^{-1}
AB-DTPA Extractable K	105	mg kg^{-1}
Total Nitrogen	0.022	%
Available Sulfate	15.7	mg kg^{-1}

Grain Yield
Data on grain yield is tabulated in table 4.2. The data indicated that there was significant variation in yield by the application of sulfur. The highest yield of maize (6090 kg ha$^{-1)}$ was obtained by T_6 where sulfurea was applied along with NPK fertilizers whereas lowest grain yield was recorded by T_1. Grain yield can be obtained by the application of sulfur at the rate of 40, 60 and 72 kg ha^{-1} (Gupta *et al.* 1997), (Sakal *et al.* 2000) and (Haq *et al.* 1989).

Table 4.2. Effect of Sulfurea on grain yield and dry matter yield of maize

Treatments					Grain yield	Dry matter yield
	N	P	K	Sulfurea	Kg ha^{-1}	
T_1	0	0	0	0	3636 d	7360 c
T_2	0	0	0	Y	3812 cd	7886 bc
T_3	60	45	60	0	4556 bc	8149 bc
T_4	60	45	60	Y	5257 b	8850 ab
T_5	120	90	60	0	5345 ab	8850 ab
T_6	120	90	60	Y	6090 a	9901 a
LSD ($P \leq 0.05$)					795.0	1296
CV (%)					9.14	8.38

Total Dry Matter Yield
Dry matter yield is influenced by the application of sulfur as presented in table 4.2. It is showed by the data that sulfur application has increased the dry matter yield significantly. Maximum dry matter yield was obtained when

sulfurea is applied with NPK followed by T_4 which is statistically similar to T_5. Minimum dry matter yield is obtained by T_1. With 30 kg ha^{-1} increase in dry matter was also reported by Mandal and Sikder (1999) and Singh *et al.* (1997).

pH

Results of pH are presented in Table 4.3. Data on pH showed that pH is not affected by the application of sulfur. pH is constant for all treatments. Experimental field was alkaline before and after the experiment. There was almost no variation in pH of all treatments. Although sulfurea is acidic in nature but there was no effect on pH of soil. It was due to the buffering capacity of the soil. Buffering capacity of the soil is very high and it resists any change in its pH. Sulfur coated urea has less effect on pH and electrical conductivity (Zhang *et al.* 2007).

Electrical Conductivity

Results on electrical conductivity are presented in Table 4.3. Data on electrical conductivity revealed that sulfur has no effect on electrical conductivity of soil. It was almost constant for all treatments. Experimental field was non-saline before and after the experiment. Sulfur coated urea has less effect on pH and electrical conductivity (Zhang *et al.* 2007).

Organic Matter

These results are shown in Table 4.3. Data on organic matter showed that organic matter was not affected by sulfur. The experimental field was deficient in organic matter before and after the experiment. It is shown by the experiment that sulfur has no effect on the organic matter of the soil.

Lime Content

These results are shown in Table 4.3. Data on lime revealed that lime content was constant for the field before and after the experiment. Lime content of the field was not affected at all which shows that lime content is independent of sulfur application. The variation in lime content for all treatments was non-significant.

Table 4.3. Effect of sulfur on pH, EC, Lime and O. M

Treatments					pH	EC (dS m^{-1})	Lime (%)	O. M (%)
	N	P	K	Sulfurea				
T_1	0	0	0	0	8.1	0.37	12.8	0.40
T_2	0	0	0	Y	8.1	0.35	12.8	0.42
T_3	60	45	60	0	8.2	0.35	15.75	0.49
T_4	60	45	60	Y	8.1	0.35	12.7	0.47
T_5	120	90	60	0	8.1	0.30	12.9	0.48
T_6	120	90	60	Y	8.1	0.29	11.8	0.41
LSD ($P \leq 0.05$)					NS	NS	NS	NS
CV (%)					0.85	8.38	10.48	15.39

Nitrogen

Data on nitrogen is presented in Table 4.4. It was showed by data that nitrogen content of soil was not affected by the application of sulfur. The experimental field was deficient in nitrogen content before and after the experiment. Sulfur has no effect on the total nitrogen content of the field. The nitrogen content of the soil was almost same for all the treatments.

Phosphorus

Data on phosphorus is presented in Table 4.4. It was revealed by the data that phosphorus was affected significantly by the application of sulfurea. The highest value of phosphorus was obtained for T_6 ant the lowest value of phosphorus was obtained for T_1. Sulfur application at the rate of 60 to 80 kg ha^{-1} increased the phosphorus concentration as reported by Haq and Nasreen (2002). Aref (2007) reported that the amount of soil P enhanced because of some residual P addition to soil in form of a fertilizer as phosphorous became unavailable in soil.

Soil Sulfate Sulfur

Result of sulfate sulfur concentration in soil at harvesting stage is presented in Table 4.4. It shows that the application of sulfurea significantly affected the soil's sulfate sulfur concentration. It has highest value for T_6 and lowest value for T_1. T_1, T_3 and T_5 are statistically same whereas T_2, T_4 and T_6 are statistically same. SO_4 –S builds up in soil with increasing sulfur addition has also been noted by Barbora (1995) and Sreemanarayana and Raju (1994). These results are in agreement with the finding of Barbora (1995), who found that available SO_4 – S increased by 4 mg kg^{-1} per annual application of 20 kg ha^{-1}, and with Sreemanarayana and Raju (1994), reported that application of S beyond 20 kg ha^{-1} significantly improved SO_4–S status of soil.

Plant Sulfate Sulfur
The data on plant sulfur is tabulated in table 4.5. Sulfate sulfur content of plant was calculated. The data showed that sulfur uptake of plant was affected by the application of sulfur. T_1, T_3 and T_5 are statistically same whereas T_2, T_4 and T_6 are statistically same. Sulfur content was highest for T_6 and lowest for T_3. Increased rates of sulfur application increased the sulfur concentration in plant in other studies (Khan *et al.* 1992 and Mandata *et al*. 1994).). Islam *et al.* (1990) reported that S uptake in rice was enhanced by S application. Dixit *et al.* (2006) analyzed that S addition brought significant enhancement in S uptake by hybrid rice straw however uptake of S enhanced on subsequent increment of 15 kg Zn per ha, after this minimized on greater quantities due to negative influence of Zn on S.

Table 4.4. Effect of Sulfurea on soil nitrogen, soil sulfur, soil phosphorus and plant sulfur

Treatments	Nitrogen	Soil Sulfur	Plant Sulfur	Phosphorus
	%			mg kg^{-1}
T_1	0.019	5.7 c	0.09 b	6.1 d
T_2	0.021	18.43 b	0.23 a	7.3 cd
T_3	0.024	6.58 c	0.08 b	9.1 bc
T_4	0.024	21.52 ab	0.24 a	10.4 ab
T_5	0.024	6.09 c	0.09 b	10.4 ab
T_6	0.020	24.24 a	0.25 a	12.2 a
LSD ($P \leq 0.05$)	NS	3.3134	0.0645	1.9691
CV (%)	15.81	13.23	0.49	11.67

Analysis of Sulfurea
Sulfurea was analyzed for the concentration of sulfur and nitrogen. It contained 9 % nitrogen and 10 % sulfur (Pamphlet on sulfurea by life technologies private limited).

Value Cost Ratio
Value Cost Ratio for all treatments is given in Table 4.5. We obtained highest VCR ratio for treatment 2 but the net grain yield was very low and it was not economical as it did not give us a lot of output. For treatment 4 and 6, VCR was almost equal and it was much higher than treatment 3 and 5 consecutively. VCR of treatment 4 and 6 shows that benefit was more than two times than the cost. So it can be concluded that the use of sulfurea is economical for farmers.

Table 4.5. Value to Cost Ratio

	Grain Yield (Kg ha^{-1})	Increase In yield (Kg ha^{-1})	Value of Increase Yield (Rs ha^{-1})	Cost Of Fertilizer (Rs. ha^{-1})	Net Return (Rs ha^{-1})	VCR
T1	3636					
T2	3812	176	4752	1360	3392	3.4:1
T3	4546	920	24840	15441.9	9398.1	1.6:1
T4	5257	1621	43767	15407.8	28359.2	2.8:1
T5	5345	1709	46143	22908	23162	2.0:1
T6	6090	2454	66258	24306.5	41951.5	2.7:1

CONCLUSIONS
After this experiment it can be concluded that application of sulfurea can affect the yield and nutrient balance of the maize crop. Maximum maize yield was achieved by the application of sulfurea along with the basal dose of NPK. Dry matter yield was significantly increased by the application of sulfurea. Phosphorus concentration in soil was significantly increased by the application of sulfurea. Sulfurea application has significantly increased the sulphur concentration in both soil and plant. Sulfurea has no effect on the chemical properties of the soil. Nitrogen content of the soil is not affected by the application of sulfurea. It is recommended from the present study that sulfurea should be applied with basal dose of NPK to get the maximum yield of maize crop. Effect of sulfurea on different crops should be investigated in different agro-ecological environment to get optimum yield of crops. Effect of different doses of sulfurea should be investigated in different areas to get maximum optimum yield.

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