IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 7, Issue 4 Ver. I (Apr. 2014), PP 32-37
www.iosrjournals.org

Comparative Effect of Soil and Foliar Application of Sulfur on Maize

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Abstract: *A field experiment was carried out to study the comparative effect of soil and foliar application of sulfur on maize at New Development Research Farm of The University of Agriculture Peshawar during 2012. The experiment was laid in randomized complete block design with three replications. For soil sulfur ammonium sulphate was applied at sowing @ 0, 20, 40, 60, 80 and 100 kg ha^{-1} while foliar sulfur was applied in two split doses @ 4, 8, 12, 16 and 20 kg ha^{-1}. Half dose at knee height and half at silking stage. Almost all the treatments have significantly affected all the agronomic and yield components of maize. Maximum grains yield (4060 kg ha^{-1}) was recorded in T6 and T11 i.e. 60 kg ha^{-1} sulfur application in soil. Similarly biological yield (12490 kg ha^{-1}) and ear weight (185.5 g ear^{-1}) were also significant at 60 kg ha^{-1}. The maximum sulfate concentration in leaves was recorded in T6 (0.390 %) and T11 (0.370 %) receiving sulfur @ 100 and 20 kg ha^{-1} via soil and foliar application. Sulfur application had significant effect on nitrogen and phosphorus uptake. Up to 60 kg ha^{-1} nitrogen was increased while above this become constant and finally declined and phosphorus up to 60 kg ha^{-1} increased but decreased drastically above it. On potassium uptake S has no significant effect. At post harvest soil samples maximum SO_4^--S contents were found in soil where S was applied @ 100 kg ha^{-1} and foliar application has little effect on soil sulfur. In foliar application maximum grains (3237 kg ha^{-1}) and biological yield (9340 kg ha^{-1}) was recorded in T11 which received S @ 20 kg ha^{-1}. Therefore it can be concluded that soil application of sulfur @ 60 kg ha^{-1} at sowing time can be practiced to get substantial growth and yield of maize. In foliar application maximum grain and biological yield (3237 and 9340 kg ha^{-1}) was found in T11 respectively. Plant height, ear weight, ear length, 1000 grains weight were also maximum in T11 where sulfur was applied @ 20 kg ha^{-1} by foliar application.*

Keywords: *maize, yield, sulfur, comparison, foliar, soil, spray*

I. Introduction:

Among cereals, maize (*Zea mays L.*) ranks third in the world, second only to wheat and rice and is an important food and feed crop. It is known as a huge agricultural economic value crop, because of its long-term use in agricultural industry. Corn in Pakistan, grown on of approximately 1.05 million hectares, the total output of 3.6 million tons and average grain yield of 1880 kg ha^{-1} is great far lower than other developing countries. This low productivity is due to a variety of reasons. Plant Nutrition mismanagement measurement is the main one. Accordingly, it is need to develop better this main component through technology to obtain high production and quality of corn [MINFAL, 2008-2009].

In crop production, sometimes sulfur is considered to be forgotten secondary nutrient. However it is most essential for activity of proteolytic enzymes and synthesis of amino acids. If adequate supply sulfur is ensured in the field it improves yield and quality of crops. The actual importance of sulfur has been noticed in the recent past due to exhaustive farming with high yielding varieties and the use of complex fertilizers, which led to sulfur deficiency in a lot of soils. In Tamil Nadu maize is one of the important commercial crops used as a constituent in poultry and cattle fee-d. Maize crop responds well to sulfur fertilization and it removes about 30-70 kg S ha^{-1}. Several workers have reported that uptake of major nutrients is also positively influenced by sulfur (Bharathi and Poongothai, 2008).

About 98% of total soil sulfur may be found in organic forms and is related with a diverse mixture of plant, animal residues and soil micro-organisms (Bloem, 1998). With depth the organic sulfur concentration is

usually on the pattern of organic matter concentration in soils (Probert, 1980). Soil organic sulfur is separated in two main groups: i.e, sulfur atoms with reduced and oxidized states. About 1 to 3% of the soil organic sulfur can be assumed the part of microbiological biomass (Stevenson, 1986), while from present study of Banerjee *et al*. (1993) soil microbial biomass sulfur is generally 1.5 -5% of total soil organic sulfur. In microbial cells amino acids and proteins are the most important type of sulfur (Banerjee and Chapman, 1996).

Inorganic sulfur is generally greatly in fewer amounts in most of the agricultural soils than organic sulfur (Bohn *et* a/., 1986). The mainly ordinary appearance of inorganic sulfur is sulfate and may be subdivided into mineral sulfur, SO_4^{2-} in soil and adsorbed SO_4^{2-} (Barber, 1995). Sulfur possibly precipitates with calcium, magnesium or sodium to form their sulfates. Great quantities of sulphide metals like pyrite accumulated in tidal marshlands. Once draining these areas, the sulfur holding complexes are oxidized to SO_4^{2-} attended by a drop off in pH. If adsorbed SO_4^{2-} is not willingly available to crop, every management causing a decline in retention and a resultant addition of SO_4^{2-} in soil solution must increase SO_4^{2-} availability to plants (Elkins and Ensminger. 1971).

Mehlich (1964) originated that discharge of adsorbed SO_4^{2-} was related to the count of succeeding rise of Ca $(OH)_2$, that is believed the effect of increased pH. Therefore, small SO_4^{2-} adsorption is probable in upper soils which are sufficiently limed (Evans, 1986) and thus the combined application of limestone and gypsum consequences in an improved availability of SO_4^{2-} (Serrano *et al*, 1999).

Keeping in view the importance of sulfur in the production of maize, current work was designed to assess the possibility of sustaining high crop yield through the application of soil and foliar sulfur with these objectives: To study the effect of sulfur on NPK uptake by maize. To find out effect of sulfur on yield and yield components of maize.

II. Materials and Methods:

The research project "comparative effect of soil and foliar application of sulfur on maize" was conducted at New Developmental Farm (NDF) of The University of Agriculture, Peshawar during June, 2012. The experiment was carried out in Randomized Complete Block Design and replicated three times. Ammonium sulfate $[(NH_4)_2\ SO_4]$ was used to apply sulfur. The plot size was 3m x 5m and Azam variety of maize was sown. A basal dose 120, 90 and 60 kg ha^{-1} nitrogen, P_2O_5 and K_2O was applied to all plots respectively. All other cultural practices including hoeing, weeding, and irrigation were carried out to all plots uniformly. A composite soil sample was taken for physic-chemical properties, shown in Table 1.

Table 1. Physico-chemical properties of experimental site

Soil Properties	Unit	Value
Sand	%	16.00
Silt	%	52.40
Clay	%	31.60
Soil Texture	--	Silty Clay Loam
$pH_{(1:5)}$	--	8.42
$EC_{(1:5)}$	dS m^{-1}	0.16
Organic Matter	%	0.84
Total Nitrogen	%	0.09
AB-DTPA extractable P	mg kg^{-1}	3.20
AB-DTPA extractable K	mg kg^{-1}	103
Available Sulfate S	mg kg^{-1}	18.62

Soil application of was done at sowing time while foliar application of sulfur was applied in two split doses; half dose was applied at knee height stage and remaining half at silking stage. The application of sulfur levels to each treatment was mixed with small amount of detergents in water and was applied to each experimental unit with the help of spraying machine. Following treatment combinations soil and foliar T1 (0 kg ha^{-1}), T2 (20 kg ha^{-1}), T3 (40 kg ha^{-1}), T4 (60 kg ha^{-1}), T5 (80 kg ha^{-1}), T6 (100 kg ha^{-1}) and T7 (4 kg ha^{-1}), T8 (8 kg ha^{-1}), T9 (9 kg ha^{-1}), T10 (16 kg ha^{-1}), T11 (20 kg ha^{-1}) were applied respectively to maize.

III. Results and discussion:

Biological Yield

The results of biological yield are given in Table 2. The results showed that there were significant differences among all treatments. Maximum biological yield 12490 kg ha^{-1} was recorded in treatment where 60 kg ha^{-1} was applied in soil. The lowest biological yield 7470 kg ha^{-1} was observed in control which received no sulfur. Biological yield above 60 kg ha^{-1} was lower which shows antagonistic effects of S beyond 60 kg ha^{-1} application. This may be trait to lower pH in treatments, which helped in bio transformation of insoluble P to available. In comparing the foliar application highest biological yield was noted in T_{11} which was significantly at par with T8.

Table 1.Biological, grain yield, ear weight and 1000 grains weight as affected by different levels of soil and foliar application of sulfur

Treatment ($kgha^{-1}$)	Biological Yield	Grain Yield	Ear weight	1000 Grain weight
	kg ha^{-1}		G	
Soil				
T_1 Control	7470 f	1952 h	136.0 f	212.3 h
T_2 20	8770 de	2685 f	155.1 d	261.7 ef
T_3 40	10150 b	3668 b	164.1 c	277.7 b
T_4 60	12490 a	4060 a	185.2 a	300.7 a
T_5 80	10650 b	3938 a	173.0 b	294.0 a
T_6 100	9950 bc	3145 cd	170.0 b	264.3 c
Foliar				
T_7 4	8250 e	2373 g	146.0 e	244.0 e
T_8 8	8640 de	2859 e	160.0 c	254.0 d
T_9 12	8570 e	2874 e	161.0 c	268.7 c
T_{10} 16	8570 e	3007 de	162.3 c	277.7 b
T_{11} 20	9340 cd	3237 c	163.0 c	280.7 b
CV %	8.66	5.81	3.11	3.48
LSD value	720.7	158.7	4.472	8.25

In discussing the foliar application highest biological yield (9340 kg ha^{-1}) was noted in T11 which received sulfur @ 20 kg ha^{-1}. These results were similar to rerults of Hussain and Khan, (2003), Germaani *et al.* (2006) and Imran *et al.* (2007). The results were dissimilar to findings of Haqani *et al.* (1989) according to him peak production of maize was obtained by 72 kg ha^{-1} S fertilization. Similar results are shown by Baktash (2000).

Grain Yield

Results of grain yield as affected by different concentrations of S are presented in Table 2. It can be seen from table that highest grain yield of 4060 kg ha^{-1} was obtained from T4 where S was applied @ 60 kg ha^{-1} in soil followed by 3938 kg ha^{-1} from T5 where 80 kg ha^{-1} S was applied along with 120, 90 and 60 kg ha^{-1} N, P_2O_5 and K_2O respectively. Higher levels beyond 60 kg ha^{-1} might have toxicity of S which may cause deficiency of other nutrients (P, K, Mo, and Zn). The lowest grain yield was obtained from treatment T1 which was control (0 kg ha^{-1} S). In foliar application of sulfur maximum grain yield was attained 3237 kg ha^{-1} in T11 when 20 kg ha^{-1} sulfur was applied. Although over all grain yield of maize was lower compared to potential yield of maize but treatment T4 indicated that S @ 60 kg ha^{-1} was beneficial and S application beyond 60 kg ha^{-1} may not be helpful for increasing yield of maize. Sulfur application along with nitrogen is the evidence by higher NUE. Sulfur effects on grain yield were more relevant showing the positive interaction. Gupta *et al.* (1997) accounted maximum yield with 60 kg ha^{-1} S application while 72 kg ha^{-1} was reported by Haq *et al.* (1980). Khan *et al.* (2006) reported 43% increase in grain yield when 60 kg ha^{-1} S was applied. Results are disagreed to the results of Sakal *et al.* (2000) who detected 0.99 t ha^{-1} increase in grain yield when 40 kg ha^{-1} S was applied.

Ear Weight

Results regarding to ear weight is shown in Table 2. It showed the significant difference among all treatments. Similar to other yield parameters, highest ear weight was recorded in T4 (185.2 g) when 60 kg ha^{-1} sulfur was applied to soil followed by 173 and 170.0 g produced with fertilization with 80 and 100 kg ha^{-1} S. Treatments T8, T9, T10 and T11 had no significant difference among their means and were not statistically comparable. The results are in confirmation with results of Mishra (1996) and Baktash (2000).

Thousand grain weight

The results on 1000 grains weight showed that maximum 1000 grains weight has been obtained in T4 which is at par with T5 where S was applied @60 and 80 kg ha^{-1} respectively. In case of foliar application highest 1000 grains weight was recorded in T11 which was not significantly different from T10 It is clear from the data that 60 kg ha^{-1} soil and 16 kg ha^{-1} foliar application gave maximum 1000 grains weight.

Sulfate sulfur concentration in leaves

The results on SO_4-S concentration in leaves are shown in Table 3. It showed the significant difference among treatments. Maximum concentration of SO_4-S (0.390 %) was recorded treatment where 100 kg ha^{-1} sulfur was applied by soil application while minimum (0.090 %) was recorded in control plot. In comparing foliar applications of sulfur maximum concentration (0.370 %) was calculated in t_{11} which was non-significant with T8. It was found by Mahapatra *et al.* (2000) that total sulfur uptake increased by increasing sulfur rate.

Table 2. SO_4-S concentration in leaves, SO_4-S uptake, and NPK uptake as affected by different levels of soil and foliar application of sulfur

Treatment ($kgha^{-1}$)	S Conc. in leaves	S uptake	N uptake	P uptake	K uptake
	%	kg ha^{-1}			
Soil					
T_1 Control	0.090 h	6.80 g	32.02 e	13.07 e	75.27
T_2 20	0.120 g	10.11 f	39.47 cd	19.87 c	93.60
T_3 40	0.230 d	23.54 d	46.57 bc	23.40 b	107.90
T_4 60	0.270 c	34.16 b	73.02 a	31.26 a	125.53
T_5 80	0.330 b	34.77 b	50.12 b	24.50 b	109.33
T_6 100	0.390 a	39.23 a	43.04 bcd	20.70 c	104.83
Foliar					
T_7 4	0.150 f	12.05 f	36.99 de	16.40 d	87.23
T_8 8	0.180 e	15.85 e	39.77 cd	16.80 d	92.17
T_9 12	0.270 c	22.73 d	39.82 cd	16.73 d	92.00
T_{10} 16	0.320 b	27.73 c	40.44 cd	17.43 d	91.83
T_{11} 20	0.370 ab	34.54 b	44.75 bc	20.30 c	99.53
CV %	11.46	14.37	18.80	13.41	16.15
LSD value	0.028	3.033	7.418	2.39	ns

Sulfate sulfur uptake by Maize

Data on sulfur uptake is shown in Table 3. It is clear from table that Sulfur uptake was significantly affected by different levels of sulfur application. Maximum uptake (39.23 kg ha^{-1}) of sulfur was noted in T6 where sulfur was applied in soil and minimum uptake was recorded in control plot. Treatments T4, T5 and T11 have same results at 5 % level of significance. Vijender *et al.* (1995) reported that plant sulfur uptake increased with 60 and 30 mg kg^{-1} in S deficient and medium S soils.

Nitrogen uptake

Results in Table 3. showed that N uptake by maize crop is significantly affected by sulfur application by different methods. From the data it is clear that maximum N uptake (73.02 kg ha^{-1}) was resulted from the treatment where 60 kg ha^{-1} sulfur was applied by soil application followed by T3 and T5 where sulfur was applied @ 40 and 80 kg ha^{-1} respectively while lowest uptake (32.02 kg ha^{-1}) was calculated in control plot where sulfur was neither applied by soil nor foliar application. In comparing N uptake affected by soil and foliar application N was most affected by soil application instead of foliar application. All the foliar applications of sulfur have same results at 5 % level of significance showing non significant behavior on N uptake by maize crop in prevailing conditions. Taalab *et aL* (2008) revealed that combination of various phosphorus sources with sulfur resulted in better effect on N, P and K uptake by com than phosphorus sources alone. Fismes *et al.* (2000) stated that sulfur addition improves the N use efficiency and significantly affects the N uptake when applied @ 75 kg ha^{-1} to oilseed rape.

Phosphorus uptake

The results of sulfur application at different levels by different methods on P uptake are shown in Table 3. From the table it can be stated that P uptake was significantly affected by sulfur application. Maximum P uptake (31.26 kg ha^{-1}) was noted in T4 where S was applied @ 60 kg ha^{-1} by soil application followed by T3 and T5 receiving 40 and 80 kg ha^{-1} sulfur. Minimum P uptake (13.07 kg ha^{-1}) was recorded in control plot (no sulfur). Treatments T2, T6 and T11 have same effects on P uptake which received 20, 100 and 20 kg ha^{-1} by soil and foliar application respectively. In foliar application P uptake was not significantly affected by applying sulfur to plants except T11 which received S @ 20 kg ha^{-1} by foliar spray in two splits. Shamima and Haq

(2002) recorded increase in P concentration in plant tissues when sulfur was applied at rate of 60 kg ha^{-1} while sulfur beyond 60 kg ha^{-1} P uptake is antagonistically affected. In another study Aulakh *et al*. (1990) noted that phosphorus with sulfur was harmful when maximum dose of sulfur was applied that may have prevented P uptake in plant and in soil its concentration is enhanced.

Potassium uptake

The data on K uptake as affected by sulfur application at different doses and by methods are shown in Table 3. which showed that sulfur application has no significant difference on uptake of K by maize. Maximum K uptake (125.53 kg ha^{-1}) was noted in treatment T4 where sulfur was applied at rate of 60 kg ha^{-1} while minimum was recorded in control plot (75.27 kg ha^{-1}). From the data it is shown that in soil application with increasing levels of sulfur K also increased but not enough increase that can be differentiated @ 5 % level of significance. Singh, (1970) revealed this effect might be qualified to acidity caused by sulfur application, resulted in mobilization of nutrient inside the plant. Results in table 6. show that by foliar application of sulfur there is no major effect on K uptake.

IV. Conclusion and Recommendations:

Maximum yield of maize was achieved @ 60 kg ha^{-1} sulfur application in soil and it decreased beyond 60 kg ha^{-1}. This is optimal level of sulfur application in soil and above this level of sulfur yield and yield components are lowered causing toxicity. Maximum N and P uptake were recorded when sulfur was applied at 60 kg ha^{-1}, after this limit N uptake did not affect by S application and P uptake decreased when S exceed 60 kg ha^{-1}. K uptake was not significantly affected by S application by soil and foliar application. Addition of S fertilizer (Ammonium Sulfate) resulted in build up SO_4-S level of soil while foliar application has minor effect on soil sulfur. Highest SO_4-S was calculated in leaves when S was applied in soil @ 60 kg ha^{-1} and 20 kg ha^{-1} by foliar application.

Based on findings of present study following recommendation are suggested

To get maximum yield of maize 60 kg ha^{-1} sulfur should be added to sulfur deficit soils along with NPK fertilizers. Foliar application of sulfur may attain yield comparable with soil application if it should applied in three or four splits instead of two. The experiment may be repeated to confirm these results of soil Vs foliar application of sulfur on maize.

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