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APPLICATION OF SULPHUR AND SULPHURIC ACID AND THE AVAILABILITY OF PLANT NUTRIENTS AND CHEMICAL COMPOSITION OF MAIZE

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In a pot study, application of fertilizer phosphorus, elemental sulphur or concentrated sulphuric acid to a calcareous sandy clay loam soil with initial pH of 8.1, significantly increased dry matter yield of maize plants. A significant increase in the plant phosphorus and calcium contents was recorded by the application of increasing rates of sulphur and sulphuric acid. However, at the highest rates, decline in plant phosphorus occurred. As the rate of application of these materials was increased, a significant decrease in soil pH and $CaCO_3$ contents and an increase in available soil phosphorus was observed.

INTRODUCTION

Most of the soils of Pakistan are alkaline calcareous in nature with a pH range of 7.5-8.5. Under such conditions soil nutrients such as phosphorus, copper, calcium, iron and zinc are rendered unavailable for plant use due to the formation of complex insoluble compounds. Acidification of soil by sulphur and sulphuric acid has been used for solubilizing and correcting the deficiencies of these elements in calcareous soils (Miyamoto *et al.*, 1975). Significant and drastic reduction in pH and increase in phosphorus availability have been reported by the addition of sulphur (Neller, 1956; Sengupta and Cornfield, 1964) and sulphuric acid (Ryan and Stroehlein, 1973 and Stroehlein *et al.*, 1978).

Acidifying materials when applied to soil are reported to have increased dry matter production and total nitrogen contents of alfalfa (Das and Datta, 1975), and phosphorus contents of alfalfa (Ryan and Stroehlein, 1973), whereas $CaCO_3$ contents of soil are decreased in correspondence to increasing application rates of these chemicals (Ryan *et al.*, 1974). However, application of higher

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doses of sulphur and sulphuric acid have been shown to decrease the solubility of phosphorus in calcareous soil due to the formation of insoluble compounds of iron and aluminium (Pratt, 1961), whereas rates of sulphur and sulphuric acid lower than acid titrable basicity are the best for increasing phosphorus availability (Ryan *et al.*, 1974). The present paper reports the effects of sulphur and sulphuric acid applications to an alkaline calcareous soil and on the growth of maize crop in a pot study.

MATERIALS AND METHODS

A normal productive alkaline calcareous soil (pH 8.1, $CaCO_3$ 2.81%), low in available P (4.51 ppm) with organic matter and nitrogen contents of 0.82% and 0.033%, respectively, was dug out upto 15 cm depth from the University Farms. The soil was air dried, ground, passed through 2mm seive and 10 kg of this soil were filled in each of the glazed pots with 25 cm diameter and 25 cm height. Requisite amounts of single super phosphate (SPP) using 40,80 and 120 kg P/ha and elemental sulphur at 163, 327, 490, 654 and 980 kg/ha rate were uniformly mixed into the soil in the pots. Sulphuric acid was applied to soil at three rates of 500, 1000 and 1500 kg/ha by two methods : 1) with irrigation water before planting maize; 2) direct injection into the soil by making holes and dropping acid into these holes by burette two weeks after seed germination.

In all there were 15 treatments including control, randomized completely with 4 repeats. A blanket application of 220 kg/ha urea-N was done in two split doses, one half at sowing and one half six weeks after planting maize. Seven healthy seeds of maize cultivar Pb. 7 were sown in each pot which were thinned to two after establishing of the seedlings. A uniform moisture level was maintained throughout the growing season. Plants were harvested at tasseling pot-wise close to the ground, dried, ground and analysed chemically for N by micro Kjeldahl's method. Plant phosphorus and calcium were determined, respectively, colourimetrically any by flame photometer in the plant material digested in 1:2 perchloric acid and nitric acid mixture. Soil samples after removal of the crop were collected, processed and analysed for pH of the saturated paste on Beckman Zeromatic pH meter. Available P was determined by the method described by Jackson (1962) and $CaCO_3$ by calcimeter (Moodie *et al.*, 1959).

RESULTS AND DISCUSSION

Effect of Chemicals on Maize Growth

Application of all rates of phosphorus, sulphur and H_2SO_4 resulted in increased plant height and dry matter production of maize (Table 1). However, 1600 kg/ha H_2SO_4 applied by soil injection produced minimum height and total dry matter of maize plants which was significantly lower when compared to control. Increase in dry matter production by sulphur application may be attributed to enhanced growth by increased availability of phosphorus and other nutrient elements (Sengupta and Cornfield, 1964; Gupta and Veinot, 1974), resulting from the solubilizing effect of H_2SO_4 generated by biological oxidation of sulphur. Favourable effects of H_2SO_4 application on plant height and dry matter production were explained by Ryan and Stroehlein (1973) due to accelerated availability and uptake of P, Ca, Cu and Mn released from soil, resulting from reduction of soil pH. However, reduction in plant height and total dry matter, by injection of H_2SO_4 at 1000 and 1600 kg/ha rates, might have been caused as a result of salt concentration in localized areas and hazardous effects of acid on plant roots (Ryan *et al.*, 1975).

Effect of Chemicals on Composition of Maize

Plant compositional data presented in Table 2 revealed that the plant P content increased significantly by increasing rates of SSP, S and H_2SO_4. Increased P concentrations in the plants explain its higher availability due to reduction in pH by the application of S and H_2SO_4. Similar results were reported by Brauen *et al.* (1977), Ryan and Stroehlein (1973, 1979) and Stroehlin *et al.* (1978). However, at the highest application rate of 980 kg/ha sulphur and 1600 kg/ha of H_2SO_4 applied by both the methods showed a decline in the P content of plants which may be attributed to the formation of complex iron and aluminium phosphates under the intense acidification of soil by these two chemicals at such high rates. This is in conformity with the findings of Sengupta & Cornfield (1964) and Ryan *et al.* (1975).

Table 1. *Effect of soil application of fertilizer phosphorus, sulphur and sulphuric acid on maize growth (mean of 4 repeats)*

T. No.	Amendment applied	Rate (kg/ha)	Plant height (cm)	Dry matter yield(gm/pot)
1.	Control	–	67.0_{c}	30.20_{bc}
2.	P	40	76.2_{abc}	35.57_{abc}
3.	,,	80	79.5_{abc}	43.05_{abc}
4.	,,	120	82.0_{abc}	49.12_{a}
5.	Sulphur	163	78.1_{abc}	34.62_{abc}
6.	,,	327	82.6_{abc}	37.95_{abc}
7.	,,	490	85.6_{a}	39.32_{abc}
8.	,,	654	83.4_{abc}	44.02_{ab}
9.	,,	980	84.0_{ab}	41.47_{ab}
10.	Sulphuric acid (with water)	500	81.1_{abc}	42.20_{abc}
11.	,,	1000	79.7_{abc}	36.82_{abc}
12.	,,	1500	77.1_{abc}	35.87_{abc}
13.	,, (as soil injection)	500	71.1_{abc}	28.67_{bc}
14.	,,	1000	67.6_{bc}	26.35_{c}
15.	,,	1500	47.7_{d}	8.20_{d}

Figures followed by the same letter are statistically similar at 5% probability level.

Table 2. *Effect of soil application of fertilizer phosphorus, sulphur and sulphuric acid on chemical composition of maize plant (mean of 4 repeats)*

T. No.	Amendment applied	Rate (kg/ha)	N%	P%	Ca%
1.	Control	–	1.65 d	0.156 j	0.418 gh
2.	P	40	1.68 c	0.160	0.458 f
3.	,,	80	1.70 bc	0.187 h	0.342 j
4.	,,	120	1.69 bc	0.194 g	0.449 f
5.	Sulphur	163	1.69 bc	0.167 j	0.392 i
6.	,,	327	1.70 bc	0.180 i	0.452 f
7.	,,	490	1.68 c	0.194 g	0.464 ef
8.	,,	654	1.71 b	0.205 e	0.470cde
9.	,,	980	1.70 bc	0.198 f	0.497 c
10.	Sulphuric acid (with water)	500	1.75 a	0.177 i	0.344 j
11.	,,	1000	1.71 b	0.227 c	0.406 hi
12.	,,	1500	1.70 bc	0.214 d	0.486 cd
13.	,, (as soil injection)	500	1.65 d	0.205 e	0.429 g
14.	,,	1000	1.71 b	0.281 a	0.518 b
15.	,,	1500	1.63 d	0.258 b	0.608 a

Figures followed by the same letter are statistically similar at 5% probability level.

With regard to the plant calcium content, it can be seen in Table 2 that the effect of phosphorus application was not consistent, whereas increasing application rate of sulphur and H_2SO_4 caused corresponding increase in the calcium content of maize plants. Application of H_2SO_4 to the soil and its generation from sulphur through biological oxidation might have increased calcium availability with a concomitant enhanced absorption by the plants. This concept is further strengthened by a decreasing trend of $CaCO_3$ content of soil by increasing rates of sulphur and H_2SO_4 application. The mean values of nitrogen content of maize plants were inconsistent and no definite conclusions could be drawn from the data as to the effects of various chemicals applied in this study.

Effect of Chemicals on Soil Characteristics

The results showed that the highest value of available soil *P* and the lowest values of soil pH and $CaCO_3$ contents were recorded in the case of 1500 kg/ha H_2SO_4 application made by injection technique. The data, in general, reveal that reduction in $CaCO_3$ content and pH of the soil are positively correlated with increasing rates of sulphur and H_2SO_4 application. Similar results were reported by Stroehlein *et al.* (1978). This may be explaind due to reaction of acid with lime and its dissolution. The increase in the availability of soil phosphorus by sulphur and H_2SO_4 may be due to acidification of soil by these chemicals. Application of acid by injection technique caused more pronounced increase in available phosphorus contents of soil. This was explained by Ryan and Stroehlein (1979) as being due to the formation of highly acid zone in soil low in pH which resulted in an increase in phosphorus availability.

It appears from the data presented, that soil applications of acidifying materials such as sulphur and H_2SO_4 promoted dissolution of $CaCO_3$ and availability of phosphorus through reduction in pH of a normal alkaline calcareous soil which eventually resulted in increased crop growth. It is worthwhile to undertake further research in order to fully establish the fertilizing potential of such like acidifying materials on soils varying in texture and lime contents under field conditions.

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