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EFFECT OF DIFFERENT SOURCES OF SULFUR ON SOIL PROPERTIES AND PHYSIO-CHEMICAL CHARACTERISTICS OF *CITRUS LIMON* L. (CV. LISBON) GROWN ON ALKALINE SOIL IN FATA

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ABSTRACT

Comparative studies on the effect of different sources of sulfur i.e. gypsum ($CaSO_4.2H_2O$), elemental sulfur (S) and ammonium sulfate {$(NH_4)_2 SO_4$}, were carried out on uniform trees grown in a well established 10 years old orchard of *Citrus limon* L. (cv. Lisbon) grown on alkaline soil with pH. 8.4-8.6 at lower Orakzai Agency FATA during 1999-2000. The results indicated that gypsum regulated soil pH significantly (8.5 - 7.5), TSS (0.131-0.208%), nitrogen (0.050 - 0.083 %), phosphorus (13.00 - 84.80 mg kg^{-1}), potassium (115 - 345 mg kg^{-1}), lime (15.50 - 11.00 %) and organic matter (0.71-1.67 %). It also resulted in significantly more fruit set (2.80 %), fruit weight (144 g) and vitamin C contents in fruit juice (46.20 %) and reduced fruit drop (20.60 %), total soluble solids (6.93 %) and acidity in fruit juice (4.77 %). As whole gypsum proved its superiority over other treatments and control.

INTRODUCTION

Pakistan is a citrus growing country where it is grown over an area of 0.196 million hectares with a production of 1.961 million tons and according to an estimate about 6.17 million hectare of land is affected by salinity and sodicity with high pH causing serious reduction in expected yield (Anonymous 2004). On the other hand to fulfill the fast growing food requirements of the increasing population, more food production per unit area and per unit time is the need of the day . Hence it is necessary to utilize each and every piece of land properly and proper utility of such degraded land is possible only either through reclamation or by growing the crops physiologically adapted to adverse soil environments (Mahmood *et al*. 1991). Lemon is an important sub division of citrus grown in subtropical regions of NWFP. The cultivar Lisbon is grown for processing as well as for table purpose. (Jan *et al.*1994). Citrus is sensitive to pH and is directly or indirectly depending on the mineral composition of the medium and hydrogen ion concentration (Bose *et al.* 1988; Bose and Mitra, 1990). Ideal pH for citrus is considered between 5.5-7.5 (Ford, 1963; Le Roux, 1965). It plays an important role in soil nutrients uptake by plants. The availability of plant nutrients is regulated by the acidity or alkalinity of the soil, and nitrogen and phosphorus is more available at soil pH 6.5-7.5 than at higher values (Hendrix, 1967; Hartmann *et al.* 1981). Koen and Smart (1984) compared the effects of pH ranging between 5.3- 7.7 on growth and Mn and Zn contents of avocado seedlings. The greatest top and root growth was obtained at pH 6.4. Mn and Zn declined as the soil pH rose. They suggested that plants grown in nursery soil with a pH above 6.0 should be sprayed with ZnO and $MnSO_4$, each at 150 g/100 liters. According to Bose *et al.* (1988) on soil having high pH and excess of sodium, natural salts which do not increase soil pH but amend soil structure are used. They stated that gypsum was the most common chemical material used for this purpose and reported that potash uptake at pH 8.7 was ten times less than uptake at pH 4.0. Subbiah and Singh (1970) evaluated the efficiency of gypsum as a source of sulfur to oilseed crops on soils deficient in sulfur and concluded that it was as effective as other sources, such as ammonium sulfate and sodium sulfate. Khosla and Abrol (1972) suggested that gypsum having size finer than 0.50 mm was more effective than coarse grades. Evidence of producing better result by surface soil application of gypsum as compared to deep soil application has been presented. (Rasmussen *et al.* 1972; Khosla *et al.* 1973). Pasricha and Randhawa (1973) concluded

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that sulfur application had significant effect on dry matter yield and it increased the oil contents of mustard by 12 %. They further reported that application of sulfur @ 60 mg kg^{-1} increased the uptake of sulfur in soybean. Reviewing the response of different crops i.e. wheat, potato, groundnut, ray, gram, lentil, moong and mash Aulakh *et al.* (1977) reported that application of sulfur not only increased the yield of the crops but also improved the quality. The authors observed increase in yield of potato tubers, protein contents and total soluble solids, due to soil application of sulfur and gypsum. Sulfur is the fourth major element required for profitable crop production and its uptake from the soil is of the same magnitude as that of phosphorus (Rehman and Ghani, 1989). They concluded that higher and continuous use of NPK may have a minimizing effect on the soil sulfur and it is specially true when high analysis fertilizers like urea and triple super phosphate have replaced ammonium sulfate and single super phosphate and in the absence of adequate supply of sulfur, potential crop yield may not be realized.

Singh *et al.* (1970) applied gypsum, ammonium sulfate and sodium sulfate at different levels to groundnuts and mustard and concluded that total yield, protein, oil and methionine contests of both the crops increased significantly irrespective of the source of sulfur. However, they reported gypsum as a good source of sulfur especially for oilseed crops growing on alkaline soils. Using different soil amendments Chand *et al.* (1977) reported that when applied in equal quantities gypsum, ammonium sulfate and sulfuric acid were almost equally effective in improving the soil properties. Aulakh *et al.* (1980) indicated that maximum yield were obtained when nitrogen and sulfur were applied together to yellow mustard and suggested the application of 60 kg ha^{-1} of sulfur as an optimum dose for getting profitable yield .

While going through the literature, it has been felt that no work has been carried out in NWFP and FATA on fruit crops in general and on citrus fruits in particular evaluating the effect of different sources of sulfur on plants growing on alkaline soils, hence the study under review was initiated.

MATERIALS AND METHODS

Fortyeight trees of *Citrus limon* L. (cv Lisbon) with uniform vigor, planted at 20' x 20' at a private farm in Lower Orakzai Agency (FATA) were selected for the trial during 1999-2000. The selected trees were 10 years old. The treatments consisted of application of elemental sulfur (0.50 kg $tree^{-1}$), ammonium sulfate (2.00 kg $tree^{-1}$) and gypsum (2.50 kg $tree^{-1}$) and control. The quantity of doses was adjusted so that equal amount of active ingredients (500 g sulfur) could be supplied per plant. A randomized complete block design with four trees/treatment replicated three times was adopted. The inputs were applied as single dose in early March 1999, nine inches below the soil surface. Prior to the application of inputs, soil analysis of the samples collected at random were carried out giving the following results as average. (soil pH=8.5, TSS=0.131 %, nitrogen=0.05 %, phosphorus=13 mg kg^{-1}, potassium=115 mg kg^{-1}, lime=5.5 % and organic matter =0.74 %). Hoeing and irrigation was carried out after the application of inputs. The orchard was irrigated twice a month during summer and once a month during winter period. All cultural practices were uniformly followed for all the treatments to obtain judicious results.

The evaluation was based on soil analysis comprising soil pH, TSS, nitrogen, phosphorus, potassium, lime and organic matter and parameters regarding number of flowers, fruit set, fruit drop, fruit weight, acidity in fruit juice, vitamin C contents and total soluble solids. The soil samples were collected from the experimental trees on five different dates during the growth period at about four weeks intervals starting from early April and were chemically analyzed. The results of soil analysis are graphically presented in Figures 1-7. The data regarding yield components like flowering, fruit set, fruit drop, fruit weight, acidity of fruit juice, vitamin C contents and TSS are presented in Table-I.

RESULTS AND DISCUSSION

The chemical analysis of soil samples presented in Figures 1-7 indicate that the samples collected in April (4 weeks after the application of inputs) had no effect on soil pH. However, it has been observed that with the passage of time the effect on soil pH was very prominent (Fig.1). Gypsum reduced soil pH slowly from (8.5-7.5) in about 20 weeks followed by sulfur (8.5-7.7), ammonium sulfate (8.5-7.8) and control (8.5-8.2). As shown in Figure-2 the total soluble solids were the highest in plots treated with ammonium sulfate (0.224 %), followed by gypsum (0.208 %), sulfur (0.194 %) and control (0.174 %) 4 weeks after the application of inputs. However, it gradually decreased to 0.128, 0.110, 0.060 and 0.064 respectively after 20 weeks. Similarly it is indicated from the Figure-3 that in case of nitrogen, ammonium sulfate being a nitrogenous compound proved its superiority over all other treatments as the available nitrogen rose to 0.15 % after 4 weeks and 0.21 % after 8 weeks. However, it abruptly reduced to 0.122 % after 12 weeks, 0.117 % after 16 weeks and 0.100 % after 20 weeks of the application of inputs. The gypsum ranked second as the nitrogen availability was 0.035 % after 4 weeks, 0.083 % after 8 weeks, 0.080 % after 12 weeks, 0.073 % after 16 weeks and 0.065 % after 20 weeks. In case of sulfur, the available nitrogen was 0.047 % after 4 weeks and 0.073 % after 8 weeks, the supply was almost constant for the rest of the period of the trial and was 0.074 % after 20 weeks. In case of control it ranked between 0.050-0.067 % during the trial. The results are in confirmation with that of Hendrix (1967) and Hartmann *et al*. (1981) stating that nitrogen and phosphorus is more available at soil pH 6.5-7.5 than at higher values. Figure-4 depicts that the availability of the soil phosphorus raised by gypsum to 54.60 mg kg^{-1}, 62.80 mg kg^{-1}, 65.40 $^{-1}$, 84.80 mg kg^{-1} after 4, 8,12 and 16 weeks, respectively and fall to 35.00 mg kg^{-1} after 20 weeks. Almost the same pattern was adopted by ammonium sulfate and sulfur. However, it was reduced to 13.50 mg kg $^{-1}$, 13.00 mg kg $^{-1}$, 14.50 mg kg $^{-1}$ and 14.50 mg kg $^{-1}$ after 4, 8, 12 and 20 weeks in case of control. The results can be explained that as the soil pH dropped, the availability of plant nutrients increased (Ford 1963, Le Roux 1965).These are in agreement with the findings of Hendrix (1967) stating that hydrogen ion concentration plays an important role in soil nutrient uptake by plants.

Figure-5 reveals that availability of potassium as affected by the different sources of sulfur indicates that gypsum, ammonium sulfate and sulfur all increased its availability. In case of gypsum it was available at the rate of 191 mg kg $^{-1}$ 294 mg kg $^{-1}$, 309 mg kg $^{-1}$ 345 mg kg $^{-1}$ and 180 mg kg $^{-1}$ after 4, 8, 12, 16 and 20 weeks respectively. In case of ammonium sulfate it was available @ 145 mg kg $^{-1}$, 200 mg kg $^{-1}$, 281 mg kg $^{-1}$, 270 mg kg $^{-1}$ and 262 mg kg $^{-1}$ after 4, 8, 12, 16 and 20 weeks respectively after the application of inputs. The availability of potassium as effected by sulfur was nearly identical to the ammonium sulfate being 136 mg kg $^{-1}$, 248 mg kg $^{-1}$, 273 mg kg $^{-1}$, 227 mg kg $^{-1}$ and 262 mg kg $^{-1}$ respectively after 4, 8, 12, 16, and 20 weeks. The availability of potassium to the untreated plants was the lowest of all the treatments through out the duration of the trial being 118 mg kg $^{-1}$, 150 mg kg $^{-1}$, 227 mg kg $^{-1}$, 170 mg kg $^{-1}$ and 120 mg kg $^{-1}$ after 4, 8, 12, 16, and 20 weeks respectively after the application of inputs. As is evident from Figures-3-5 nitrogen, phosphorus and potash which are scarcely available to the plants growing on alkaline soils were made available after the application of sulfur containing compounds like gypsum, ammonium sulfate and sulfur. The reason can again be explained that due to decrease in soil pH by the application of gypsum, ammonium sulfate and sulfur, the availability of these elements increased. Figure-6 indicates that the availability of lime dropped from 15.5 % to 10.25 %, 11.00 %, 11.00 %, 12 % and 11 % due to gypsum after 4, 8, 12, 16 and 20 weeks respectively. The availability was almost the same in case of ammonium sulfate and sulfur. However, in case of control the lime dropped to 8 %, 7 %, 6 % and 6 % after 8, 12, 16 and 20 weeks. Figure-7 reveals that with the application of gypsum, the organic matter was in the soil was 0.71 %, 1.67 %, 1.46 %, 1.28 % and 1.60 % after 4, 8, 12, 16 and 20 weeks and in case of ammonium sulfate, it was 1.53 %, 1.50 %, 1.12 %, 1.19 % and 1.12 % after 4, 8, 12, 16 and 20 weeks. It was 0.95 %, 1.46 %, 1.46 %, 0.93 % and 1.30 % in case of sulfur. The controlled plots showed the lowest organic matter i.e. 0.75 %, 0.75 %, 0.50 %, 0.85 %, and 0.85 % respectively after 4, 8, 12, 16 and 20 weeks. No work of this nature seems to have been conducted in the past specifically in this area hence, there are no findings to support these results.

Data presented in Table-I reveals that different treatments had no significant effect on number of flowers and fruit set percentage, however, maximum flowers were opened per plant in control (9904) and maximum fruits were set in the plants treated with gypsum (2.80%). The reason can be explained that treatments were applied in March hence they could not affect the flowering and fruit set. The data on fruit drop indicate that maximum fruit drop was recorded in control (36.66%) followed by sulfur (22.38%), gypsum (20.60%) and ammonium sulfate (19.20%). The decrease in the number of fruit drop due to the sulfur containing compounds can be attributed to the decline in soil pH, which might have resulted in the availability of most of the essential elements leading to decrease in fruit drop. Data regarding fruit weight show increased fruit weight in the plants treated with gypsum (144.00 g) followed by sulfur (143.16 g), ammonium sulfate (142 16 g) and control (94.16 g). However, the differences among the treatments are not significant. Here the reason can be explained again that the nutrients availability to the plants was regulated by lowering soil pH which resulted in vigorous growth to produce quality fruits. Significantly high acidity (6.79%) was in fruits born on untreated plants while the least acidity was due to application of ammonium sulfate (5.33%), gypsum (4.77%) and sulfur (4.60%). Similarly vitamin C contents were significantly increased by application of gypsum (46.20%) sulfur (44.00%) ammonium sulfate (44.00%) and control (37.00%). The total soluble solids were significantly more with the application of ammonium sulfate (7.43%), sulfur (7.33%), control (7.00%) and gypsum (6.93%). Similar results have also been reported by different authors like Singh *et al*. (1970), Aulakh *et al.* (1977), Chand *et al*. (1977) and Aulakh *et al.* (1980) who obtained more yields and improved quality produce by the application of gypsum and other sulfur containing compounds to their trials and stated that gypsum was a good source of sulfur specially for oilseed crops growing on alkaline soils.

CONCLUSIONS AND RECOMMENDATIONS

Gypsum is cheaper and available; hence its use is recommended on alkaline soils.

Further research may be conducted to standardize the doses and methodology for different crops grown on soils having different levels of alkalinity.

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