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IMPROVING MAIZE GROWTH AND DEVELOPMENT IN RELATION TO SOIL APPLIED ELEMENTAL SULFUR

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ABSTRACT

A field experiment was conducted to ascertain the effect of varying soil applied elemental sulfur (S) levels viz; 0, 10, 20, 30, 40 and 50 kg ha^{-1}, on maize growth and development. Experiment was conducted in randomized complete block design (RCBD) with three replicates. Growth and development parameters were computed; included leaf area per plant LAI, LAD, CGR, NAR and TDM and experimental results revealed that increasing S levels were pragmatic in improving maize performance. However, soil applied elemental S @ 30 kg ha^{-1} proved to be beneficial involved in growth and yield improvement. Maximum CGR (23.44 g m^{-2} d^{-1}), NAR (6.23 g m^{-2} d^{-1}) and LAI (4.85) was in plots where S was applied at 30 kg ha^{-1} while least LAI (4.40), LAD (193.45 days), TDM (1178.13 kg ha^{-1}) was in control treatment. Therefore, elemental S @ 30 kg ha^{-1} was noted to be most suitable for sustainable maize production amongst all other treatments.

Keywords: Elemental Sulfur, Growth, Maize, NAR, TDM

INTRODUCTION

Maize (*Zea mays* L.) is an annual, cross pollinated summer season crop that belongs to family Poaceae. Its grain is a rich source of many important nutrients. Its flour contains moisture (9.6%), carbohydrates (70.4%), protein (10.7%), oil (3-18%), crude fiber (2.2%), ash (1.7%) ether extracts (5.4%) and several important vitamins and minerals (Bressani *et al.,* 1990). It is regarded as an important profitable crop of higher agro-economic worth due to its extensive use in the agro-industries. In recent years, increased quantities of corn have been used in the manufacturing of soaps, varnishes, paints and other similar products (Craig *et al*., 2004). It accounts for approximately 5% of the total cropped area in Pakistan and an estimated area under maize is 1083 thousand hectares with annual production of 4271 thousand tons, change in the production over last year was 15.2% (GOP, 2012). Potential yield of maize is higher than that of either wheat or rice and we can expect maize to play a proportionally larger and more important role in world food security (Fischer and Palmer, 1984) whereas the yield of maize is getting lower due to poor land management practices, low organic matter, low soil productivity, conventional cropping system, imbalanced fertilization and inappropriate sowing methods.

Struggles are being made to enhance the production and diminish the space among the demand and supply for food. Land area under the farming of pulses, cereals and oilseeds is decreasing with increasing population. Now agricultural researchers are giving more attentions to maximize grain yield through correct nutrition of the crops, developing high yielding varieties and adopting the latest agronomic practices.

Sulfur (S) is emerging as a major plant nutrient for crops grown in the Indo-Gangetic plains spread over 13 million hectares in Pakistan, India and Bangladesh. The extent of Sulfur deficiency in soil in the region is continuously increasing with the adoption of high yielding cultivars of rice, wheat, maize, oil seeds and pulses and because of the increased use of fertilizers lacking Sulfur. Most of the alluvial soils of the indo-Gangetic plains were found deficient with respect to plant available Sulfur. Sulfur is considered fundamental nutrient for plant growth and development. Its demand for plants has become significant in Pakistan. However, the doses of S fertilizer should be recommended on the basis of available soil S and crop demand to attain the maximum crop yields. Plants need S equal to the amounts of phosphorus needed. Moreover, S has particular role in growth, enzymatic reactions and metabolism (Mengal and Kirkby, 1987). It is involved in the formation of amino acid like

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cystine, cysteine and methionine. Sulfur is also component of S-glycosides, coenzyme-A, vitamins i.e. thiamine and biotine (Mengel and Kirkby, 2001).

Sulfur is associated with synthesis of oil especially in oil seed crops. A dearth of S causes plants to be consistently chlorotic, under developed, week stemmed and etiolated. Intensive cropping systems require substantial amount of N, P, K and S for proper development. Reviewing the response of different crops i.e. wheat, potato, groundnut, gram, lentil, mung bean and mash bean have revealed that application of S not only increased the yield of the crops but also improved the quality of the produce (Aulakh *et al.,* 1977). S is the major element required for profitable crop production and its uptake from the soil is of the equal magnitude as that of phosphorus (Rehman and Ghani, 1989). In a study by Schonohf *et al.*, 2007, it was substantiated the growth promoter effects of S and indicated a significant increase in plant height upon S fertilization. S considerably enhanced crop growth and development by increasing net photosynthetic rate, net assimilation rate and S use efficiency, as revealed by Khan *et al.* (2005), S fertilization increased relative growth rate, net CO_2 assimilation and S use efficiency of mustard plants. Symptoms of S deficiency in plants are characterized by reduced plant growth and occurrence of uniform chlorosis on younger leaves (Havlin *et al.*, 2005). A study was therefore conducted to examine the nature and role of elemental S in improving maize growth and development under subtropical conditions of Faisalabad, Pakistan.

MATERIALS AND METHODS

A field study was carried out in randomized complete block design (RCBD) with three replications to evaluate the efficacy of different doses of elemental Sulfur (S^0) in respect of growth and development of maize crop at the Agronomic Research Area, University Of Agriculture, Faisalabad, Pakistan. The station is located between longitude 73°-74° East and latitude 30°-31.5° North, with an elevation of 184 meters above sea level. The maize hybrid Pioneer-32B33 was sown on 20th February 2012 on ridges with hand placement maintaining plant to plant distance 20 cm using seed rate of 25 kg ha^{-1}. Treatments under study (Table 1) were aimed to examine the effect of elemental S (S^0) on maize growth and development. Sulfur bentonite was employed to supply S^0 by broadcasting. NPK fertilization was done at the rate of 250, 125 and 125 kg ha^{-1} respectively. All of phosphorous, potash and half of the nitrogen were applied at the time of sowing in the form of DAP (Diammonium Phosphate), SOP (Sulphate of potash) and Urea. Remaining half nitrogen was applied in two splits, one at five leaf stage and second at tasseling stage and irrigation requirement. Five irrigations were applied to the crop according to the crop requirements. First irrigation was applied at 15 days after sowing whereas, subsequent irrigations were applied according to the need.The crop was harvested manually after its maturity on 10th of June 2012. Data were analyzed by using Fisher's analysis of variance technique. Least significant difference test at 5% probability level was applied to compare the treatment means (Steel *et al.*, 1997).

Observations regarding growth and development were computed via measuring leaf area per plant, leaf area index, leaf area duration, crop growth rate, net assimilation rate and final total dry matter according to following formulas:

Leaf area index (LAI) was calculated as the ratio of leaf area to land area (Watson, 1952).

$$LAI = Leaf\ area / Land\ area$$

Leaf area duration (LAD) for each sampling date was estimated according to Hunt (1978).

$$LAD = (LAI_1+LAI_2) \times (T_2 - T_1) / 2$$

Crop growth rate (CGR) was calculated as proposed by Hunt (1978) at each sampling date.

$$CGR = (W_2-W_1) / (T_2- T_1)$$

The mean net assimilation rate (NAR) was estimated by using the formula of Hunt (1978).

$$NAR = TDM / LAD$$

RESULTS AND DISCUSSION

Leaf area is a major factor determining canopy photosynthesis and ultimately crop yield. Fig. 1 showed that leaf area steadily increased in all the treatments and reached at maximum value at 70 days after sowing (DAS); thereafter leaf area declined until harvest. In the beginning, differences in leaf area among treatments were less visible, but with time these differences became progressively more visible and leaf area was maximum at 70 DAS (end of grand growth period) and declined thereafter as the crop progressed towards physiological maturity. S^0 had significant effect on leaf area per plant. Maximum leaf area per plant (8654.48 cm^2) was observed in S_3 treatment, while minimum leaf area per plant (7464.58 cm^2) was noted in S_1. The progressive increase in leaf area per plant was due to S^0application which leads to increase nutrient uptake which enhanced the rate of photosynthesis. Moreover, S has particular role in growth, enzymatic reactions and metabolism (Mengal and Kirkby, 2001). Findings were supported by Daniela *et al.* (2008) who reported that leaf area and LAI was significantly affected by the S application and showed the highest value. In another study, Khan *et al.* (2005) also corroborated that improvement in leaf area might be ascribed to S fertilization during its initial growth stages.

Leaf Area Index

LAI is a major factor which determines radiation interception, canopy photosynthesis and crop yield. S^0 application significantly affected LAI of maize crop during spring season. Data related to LAI of maize are presented in Fig.2 which showed that LAI was increased with the increase in crop growth and attained maximum value at 70 days after sowing and again started declining when the crop reached to it maturity. Maximum LAI (4.85) was scored where S^0 was applied at the rate of 30 kg ha^{-1}.The minimum LAI (4.40) was observed in control treatment. The progressive increase in LAI was due to increase S^0 application which leads to increase the rate of photosynthesis which resulted in more LAI. Findings were supported by Daniela *et al.* (2008), they reported that LAI was significantly affected by the S application and showed highest value. As more LAI ensured the higher photosynthesis rate which further facilitates high dry matter accumulation, consequently more LAI could be attributed to significant development in leaf expansion. Moreover, the greater leaf expansion might be attributed to high rate of cell division and cell enlargement. As evidenced by Khan *et al.* (2005), reported that LAI is improved significantly due to S supplementation.

Leaf area duration

The effect of S^0 treatments on LAD is presented in Fig 3. The S^0 effect on LAD was positive for all treatments. Maximum LAD (212.86 days) was noted where S^0 was applied @ 30 kg ha^{-1}. The minimum LAD (193.45 days) was noted where S^0 was not applied. The progressive increase in LAD was due to increase in S^0 application which leads to increase the rate of photosynthesis, which resulted more LAI and LAD. The variation in TDM in response to agronomic treatment or S^0 rate may or may not be explained by variation in their maximum LAI. However, the differences in yield among treatments might be assessed based on their LADs. High LAD depicts that plant developed their leaves for long time, associated with delayed leaf senescence. The substantial increase in LAD at 30 Kg ha^{-1} might be ascribed to growth promontory effect of S^0, beyond this concentration both above or below, plant may exposed to S^0 toxicity and deficiency respectively. These results are in line with Khan *et al.* (2005) who reported S^0 fertilization enhanced the LAD. Furthermore, the relationship among TDM and LADs are strongly dependent on agro-climatic conditions that exist in particular conditions and environment in crop is sown (Monteith, 1981)

Total dry matter

TDM production increased steadily after crop establishment until maturity in all the treatments Fig 4. S^0 application significantly affected TDM of maize during growth. Maximum dry matter (1322.5 kg ha^{-1}) was noted where S^0 was applied @ 30 kg ha^{-1}.The minimum dry matter (1178.13 kg ha^{-1}) was noted in treatment where S^0 was not applied. The increase in TDM with application of S was due to better crop growth which gave maximum plant height, LAI and ultimately produced more biological yield. Findings are quite similar with Poonia (2000) and Daniela *et al.* (2008). Poonia (2000) reported that significant increase in dry matter of sunflower was observed when S was applied @ 25 kg ha^{-1} and according to Daniela *et al.* (2008), TDM was significantly affected by the S application and showed the highest value.

Crop growth rate

CGR is an important parameter which indicates how efficiently crop is using input resources and produces photosynthates which are used by plant for production of economic yield. Data related to CGR of maize are presented in Fig. 5 S^0 application significantly affected CGR of maize crop during spring season. CGR was increased with the increase in crop growth and attained maximum value at 70 days after sowing and again started declining when the crop reached to it maturity. Maximum CGR (23.44 g m^{-2} d^{-1}) was noted in the treatment where S^0 was applied @ 30 kg ha^{-1}. The minimum CGR (21.59 g m^{-2} d^{-1}) was noted in the treatment where S^0 was not applied. The increase in CGR was due to increase nutrients uptake which promoted better crop growth, gave maximum plant height, LAI and TDM with S^0 application. Findings are quite similar with Daniela *et al.* (2008), they reported that CGR (CGR) and RGR (relative growth rate) were significantly affected by the S application and showed the highest value. A higher CGR during anthesis period may be prerequisite to gain higher ultimately result in good crop production.

Net assimilation rate

The average NAR of a crop represents the net photosynthetic production per unit LAD (Hunt, 1978). Data related to CGR of maize are presented in Fig. 6. Maximum NAR (6.23 g $m^{-2}d^{-1}$) was noted where S^0 was applied @ 30 kg ha^{-1}. The minimum NAR (6.09 g m^{-2} d^{-1}) was noted in treatment where no S^0 was applied. The increase in NAR with application of S^0 was due to better crop growth which gave the maximum plant height, LAI, TDM and LAD. The improvement in NAR may be attributed to more vegetative growth due to increasing rate of N fertilizer. TDM accumulation during growth especially earlier than flowering is considered to be very essential for determination TDM as sink capacity (Andrade, 1995). Therefore, the formation of large sink size may be a requirement to higher TDM production during growth, are prerequisite for higher yield and finally higher economic return.

Table 1: Treatments and application rate of S^o

Treatment no.	Application rate
S_o	Control (no S^0 application)
S_1	Soil application at sowing @ 10 kg ha^{-1}
S_2	Soil application at sowing @ 20 kg ha^{-1}
S_3	Soil application at sowing @ 30 kg ha^{-1}
S_4	Soil application at sowing @ 40 kg ha^{-1}
S_5	Soil application at sowing @ 50 kg ha^{-1}

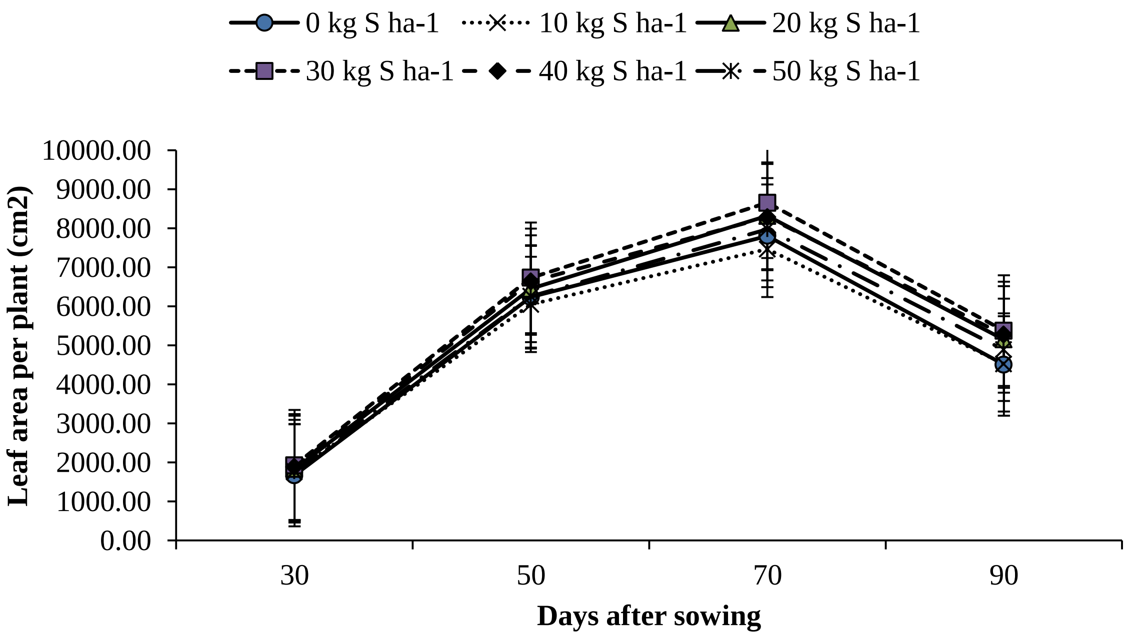

Fig. 1: Change in leaf area per plant in response to elemental sulfur

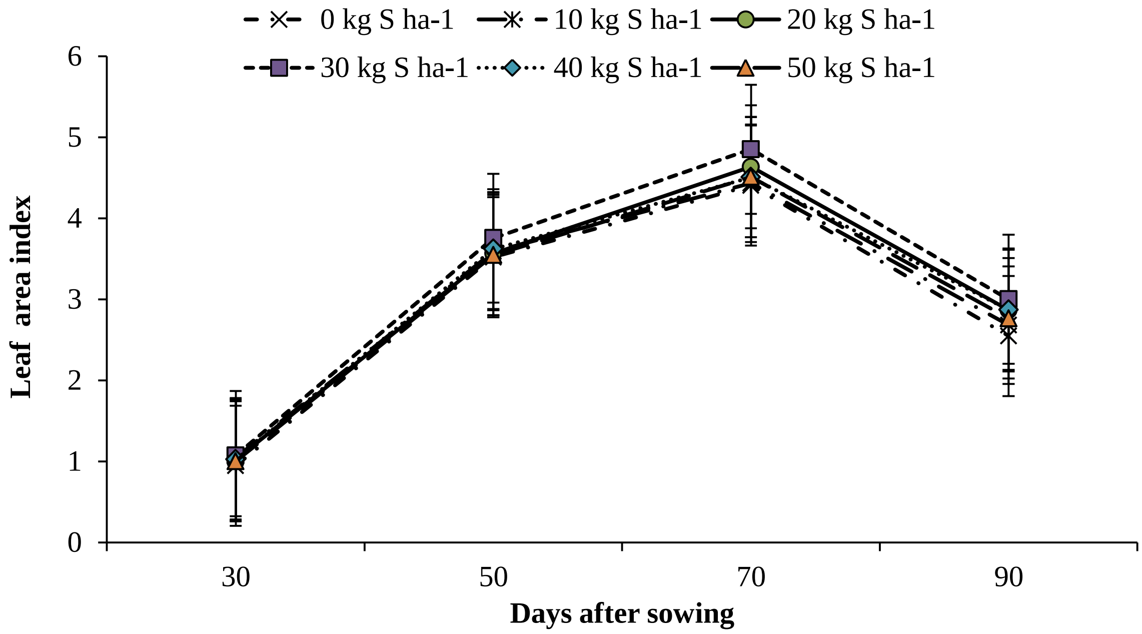

Fig. 2: Change in leaf area index in response to elemental sulfur

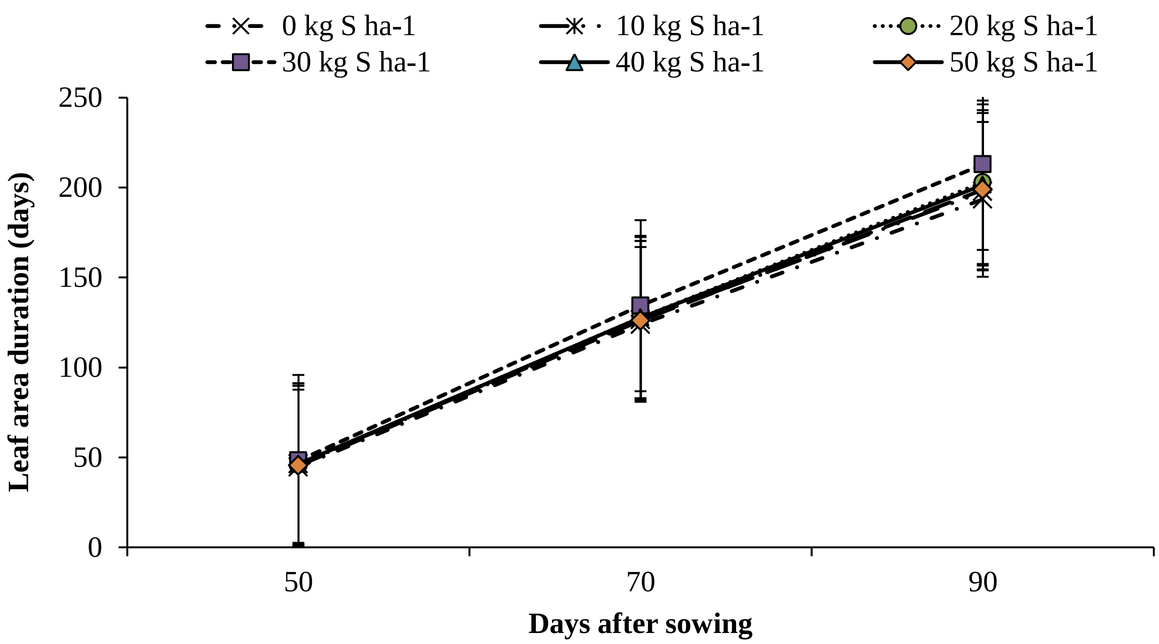

Fig. 3: Change in leaf area duration in response to elemental sulfur

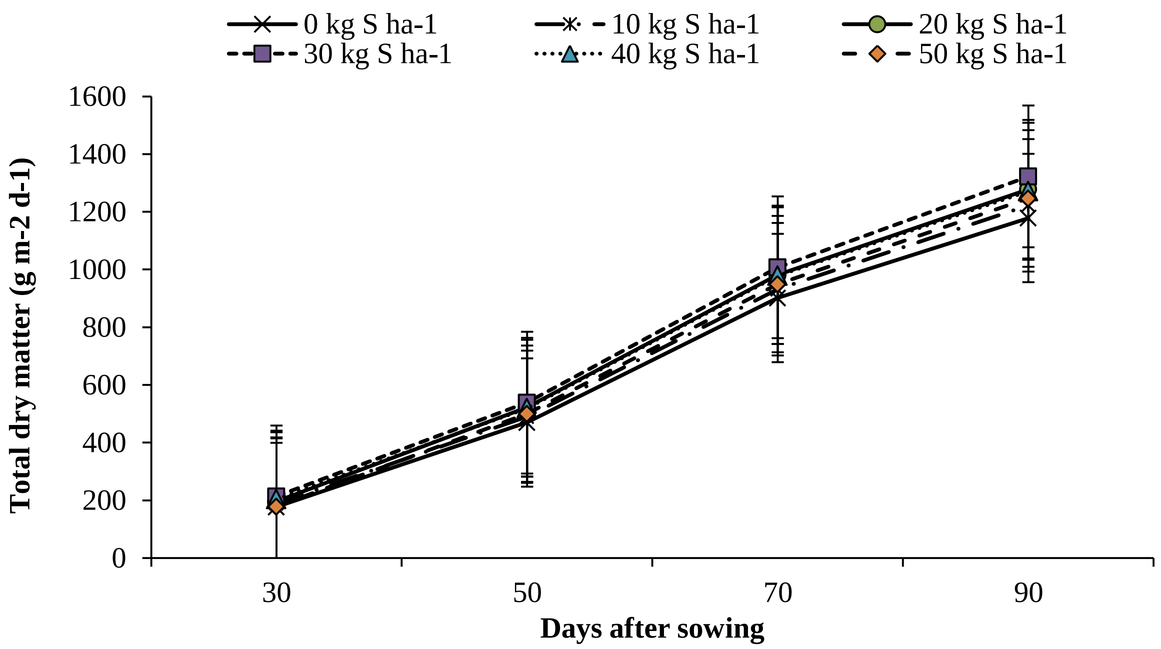

Fig. 4: Change in total dry matter in response to elemental sulfur

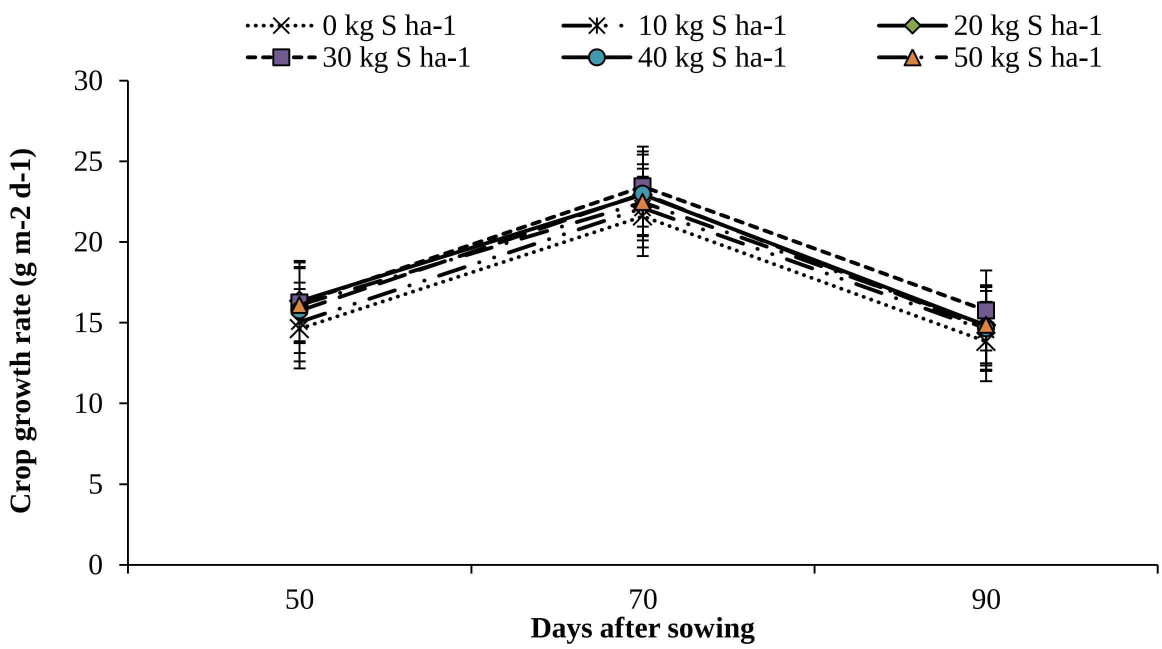

Fig. 5: Change in crop growth rate in response to elemental sulfur

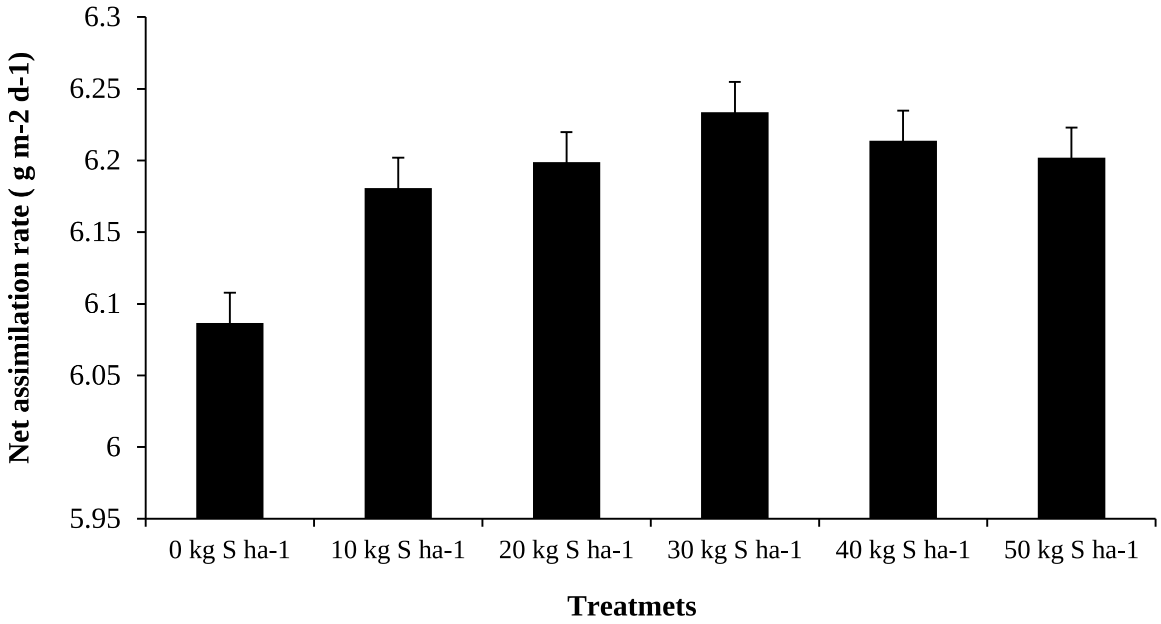

Fig. 6: Change in net assimilation rate in response to elemental sulfur

CONCLUSION

Good growth and development of any plant results in better productivity. However, numerous factors affect productivity also. It is concluded that elemental sulfur significantly boosted maize performance by increasing growth and development. However, application of elemental sulfur (S^0) @ 30 kg ha^{-1} has more influence on growth, rather beyond this rate, plant may get stressed. Further investigation particularly for maize should be related to depth of S application and method for improving S use efficiency.

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