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Yield and nutrient uptake of garlic (*Allium sativum* L.) as influenced by sulphur nutrition

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Abstract
Field experimentation to the effect of different levels of sulphur (S) nutrient on yield, storability as well as nutrient uptake in garlic was carried out at Vegetable Research Farm, C.S.A. University of Agriculture and Technology, Kalyanpur, Kanpur during *rabi* season of two consecutive years in 2015-16 and 2016-17. Results revealed that application of sulphur @ 45 kg ha^{-1} significantly produced maximum marketable and total bulb yield of 78.86 q ha^{-1} and 86.07 q ha^{-1}, respectively in T_4 followed by application of sulphur @ 60 kg ha^{-1} was recorded in T_6 (85.94 q ha^{-1} and 77.58 q ha^{-1}). The storage weight loss was minimum record by T_3 with the application of sulphur @ 30 kg ha^{-1}. The results on total nutrient uptake by plant indicated maximum nitrogen and potassium was obtained in T_4 with the application of sulphur @ 45 kg ha^{-1} and significantly uptake of phosphorus and sulphur was recorded in T_5. Thus, it may be concluded that application of sulphur @ 45 or 60 kg ha^{-1} increases the bulb yield but also higher uptake of nutrients in garlic.

Keywords: Sulphur, yield, nutrient, garlic

Introduction
Garlic (*Allium sativum* L.) belongs to the family Alliaceae and is the second most widely used *Allium* next to onion. Garlic possesses typical pungent flavor which makes it useful mainly as a spice, seasoning and flavoring agent for foodstuff. In garlic the flavour is due to the presence of chemical content *diallyl disulphide*. The balanced use of all the nutrients along with sulphur is necessary for better yields, quality as well as nutrient uptake of garlic. Sulphur is an essential plant nutrient and its role in balanced fertilization and consequently in crop production is being increasingly appreciated. However, sulphur is the fourth major plant nutrient after nitrogen, phosphorus, and potassium. It is essential for the synthesis of amino acids like cystine (27%), cysteine (26%) and methionine (27%) a component of vitamin A and activates certain enzyme systems in plants (Havlin *et al*., 2004) [3]. Continuous removal of S from soils through plant uptake has led to widespread S deficiency and affected soil S budget (Aulakh, 2003) [1] all over the world. Sulphur is a constituent of enzyme nitrite reeducates which is responsible for the reduction of NO_2 in chloroplasts and thus reduce accumulation of cancerous compounds like nitrates in vegetables (Paulsen, 2001) [5]. Non application of sulphur in sulphur deficient soils has often resulted in low yields of bulb crops. Sulphur is an essential macronutrient and at an optimum concentration accelerates the plant growth (Thomas *et al*., 2000) [9]. Hence the present study was carried out to evaluate the effect of different levels of sulphur nutrition on bulb yield, quality, storage loss as well as total nutrient uptake of garlic.

Material and Methods
The investigation was carried out at the Vegetable Research Farm, C.S.A. University of Agriculture and Technology at Kalyanpur, Kanpur on garlic cv.G-282 during *rabi* season of two consecutive years in 2015-16 and 2016-17. The experiment site is located at 26° 29 N latitude and 80° 18 E longitudes with an altitude of 125.9 m above from mean sea level. The initial soil fertility status of experimental plot was well drained clay loam with pH 7.29 and EC 0.22 dS/m. Furthermore, the available N, P_2O_5 K_2O and S content of the soil were 214.0, 19.5, 186.0, and 19.8 kg ha^{-1}, respectively. The experiment was carried out in a Randomized Block Design with four replications. The treatments consisted of six level of sulphur viz., T_1: No sulphur, T_2: 15 kg S ha^{-1}, T_3: 30 kg S ha^{-1}, T_4: 45 kg S ha^{-1}, T_5: 60 kg S ha^{-1} and T_6: 75 kg S ha^{-1} were used in the experiment. The same treatments were used for both years of experimentation in the same field. The cloves were planted manually in flat beds of 3x2 m size at a spacing of 15x10 cm. Well decomposed farm yard manure at the rate of 15 tons ha^{-1} was applied at the time of land preparation. The common fertilizer schedule adopted for all the treatments were 75:40:40 kg NPK ha^{-1} in the form of urea, diammonium phosphate and

muriate of potash, respectively. One third of N and full doses of P, K and S were applied at the time of sowing and remaining two third of nitrogen was top dressed in two equal splits 30 and 45 days after planting when hand weeding was carried out in the experimental plots. Recommended cultural and plant protection practices were followed equally in all the plots as and when required. The crop was harvested both years in the first week of April when the leaves turned yellowish. The observation of total soluble solid (TSS) was estimated using hand refractometer and the percent TSS was noted down. The 5 kg bulbs for each treatment were kept for storage studies of total storage losses after 120 days. The plant samples were collected for analysis of N, P, K and S based on the nutrient concentration in plants. The uptake of nitrogen, phosphorus, potassium and sulphur was calculated by multiplying nutrient concentration (%) with dry matter yield. The mean data over the years were subjected to statistical analysis according to standard procedure.

Results and Discussion

The results on marketable and total bulb yield of garlic revealed that significant variations due to different treatments of sulphur. The data indicated in Table-1 showed that application of sulphur up to 45 kg ha^{-1} from the different level of sulphur increased bulb yield of garlic. However, the maximum pooled mean values of marketable and total bulb yield (78.86 and 86.07 q ha^{-1}, respectively) were obtained with the application of sulphur @ 45 kg ha^{-1} in T_4 followed by T_5 with the value of (77.58 and 85.94 q ha^{-1}, respectively). The increase in bulb yield of onion in sulphur applied plots might be due to higher production of metabolites and increase in meristematic activity. Besides, it could be attributed to improvement in nutritional environment in crop root zone and ultimately resulted in better vegetative growth and finally the bulb yield reported by Pradhan *et al.*, (2015) [6]. Similar results were also recorded by Zaman *et al.*, (2011) [11] who found that application of sulphur @ 45 kg ha^{-1} recorded significantly higher bulb yield in garlic. On the other hand, the quality parameter of total soluble solids was significantly influenced by different levels of sulphur application. The maximum pooled mean value (41.62 %) was recorded with the application of sulphur @ 45 kg ha^{-1} in T_4 which is statistically at par with T_3 with the value of (41.16 %) than the control (40.47 %). Similar findings were reported by researchers like Ghotekar *et al.*, *(*2015) [2] in onion and Magray *et al.*, (2017) [4] in garlic. The results of total storage weight loss revealed that sulphur application to present study was showed that significant effect on storage life. The total storage losses have been reduced in sulphur applied treatments as compare to control after four months of storage. However, the maximum total weight loss was obtained in control plots with the value of (19.65 %) whereas minimum total weight loss was obtained with the application of sulphur @ 30 kg ha^{-1} in T_3 with the value of (14.04 %) which is followed by T_4 (15.23 %) with the application of sulphur @ 45 kg ha^{-1}. This indicates that the sulphur has role in reducing storage losses in garlic bulbs. Beneficial effect of sulphur on storage quality of onion bulbs has been reported by Tripathy *et al*., (2013) [10].

In response of total nutrient uptake of N, P, K and S varied significantly effect of garlic presented in Table-2. The significant increased in total uptake of N in garlic plants were noticed with the application of increased level of sulphur up to 45 kg ha^{-1} and decrease in application of sulphur @ 60 kg ha^{-1} and 75 kg ha^{-1}, respectively. However the maximum pooled mean data of nutrient uptake (57.57 kg ha^{-1}) of N was recorded with the application of sulphur @ 45 kg ha^{-1} in T_4 which was statistically *at par* with application of sulphur @ 60 kg ha^{-1} in T_5. Therefore the increase in N uptake was mainly due to increase in bulb yield. Similar reports were reported by Pradhan *et al*., (2015) [6]. The corresponding increase in N uptake by plants was mainly due to greater production of garlic bulb. The availability of phosphorus in garlic plant increased significantly with application of sulphur over control. The maximum P uptake to the extent of 7.4 kg ha^{-1} was observed with the application of sulphur @ 60 kg ha^{-1} in T_5 which is followed by T_4 with the application of sulphur @ 45 kg ha^{-1} of P uptake with the value of (6.6 kg ha^{-1}). Once again, application of sulphur increased up to 45 kg ha^{-1} was uptake of potassium by plants significantly over control indicating a synergistic effect of sulphur on K nutrition in garlic. The maximum total potassium uptake of 39.00 kg ha^{-1} was attained in treatment T_4 followed by treatment T_3 (35.90 kg ha^{-1}) with the application of sulphur @ 30 kg ha^{-1} which was significantly higher than rest of treatments. Similar findings were also reported by Sankaran *et al*., (2005) [7]. The trend of uptake of sulphur under treatment of 60 kg ha^{-1} application of sulphur nutrition was the same as that of phosphorus and was significantly higher than different level of sulphur treatment. Among that maximum total uptake of sulphur by garlic crop was recorded in T_5 with the value of (8.0 kg ha^{-1}) over control treatment. However, the uptake of sulphur in either of the plant parts during the whole growth period decreased at the higher levels of sulphur possibly due to imbalance and antagonistic effect caused due to raising sulphur level without increase in the other fertilizer, which could not be over come through dry matter production. The results of the studies by Sharma and Gupta (1992) [8] for addition of sulphur decreased the sulphur uptake due to the antagonistic effect of higher doses of sulphur on sulphur uptake.

Conclusion

On the basis of two years experiment result, it may be concluded that maximum bulb yield and nutrient uptake can be achieved by the application of sulphur @ 45 kg ha^{-1} which is followed by application of sulphur @ 60 kg ha^{-1} for better garlic production under central Uttar Pradesh condition.

Table 1: Effect of sulphur application on bulb yield, total soluble solids, and storage weight loss in garlic (pooled)

Treatment details		Marketable bulb yield (q/h)	Total bulb yield (q/h)	Total Soluble solids (%)	Total storage weight loss (%)
T_1	No Sulphur	53.96	64.09	40.47	19.65
T_2	15 kg S/ha	64.03	74.90	38.28	15.40
T_3	30 kg S/ha	72.52	80.69	41.16	14.04
T_4	45 kg S/ha	78.86	86.07	41.62	15.23
T_5	60 kg S/ha	77.58	85.94	39.38	17.01
T_6	75 kg S/ha	60.89	70.01	40.70	17.30
CD ($P = 0.05$)		1.13	1.01	1.88	0.99
CV %		9.21	7.31	3.10	3.99

Table 2: Total uptake of nutrients in garlic as influenced by sulphur application (pooled)

Treatment details		Nutrient uptake (kg ha^{-1})			
		N	**P**	**K**	**S**
T_1	No Sulphur	40.82	4.4	16.45	5.6
T_2	15 kg S/ha	46.02	5.5	27.37	5.0
T_3	30 kg S/ha	52.47	6.4	35.90	7.2
T_4	45 kg S/ha	57.57	6.6	39.00	7.1
T_5	60 kg S/ha	57.00	7.4	30.17	8.0
T_6	75 kg S/ha	49.44	5.4	31.47	5.9
CD ($P = 0.05$)		9.05	0.83	5.08	1.30
CV %		11.88	9.29	11.23	13.30

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