Research Article

Effect of Sulphur supplementation on Yield and Quality Enhancement of Bolting Garlic (*Allium sativum* L. spp. *ophioscorodon*) in Indian Himalayan Long Day Temperate Climate

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Abstract

Although sulphur is a critical input for optimum bulb quality and higher yield, sulphur supplementation of garlic fields is largely unknown to the vegetable growers of Kashmir valley. This region located between Pir Panjal and Himalayan ranges mostly grows long day bolting garlic, which may require even higher dosage of sulphur compared to short day types. To address these issues, a pioneer study for determining sulphur dosage for bolting type-long day garlic was conducted. Basal application of sulphur at 30 kg/ha to 75 kg/ha resulted in significantly higher marketable bulb yield (t/ha) compared to no sulphur application and application of 15 kg/ha. Pyruvic acid content (µmol/g) was significantly higher at 30 kg/ha to 75 kg/ha sulphur than 0-15 kg/ha sulphur. Total soluble solids (%) were highest at 60-75 kg per hectare sulphur. The analysis of economics suggested the application of sulphur at 60 kg/ ha dosage is most beneficial to the region's garlic growers.

Keywords: Bolting garlic, temperate long days, sulphur supplementation, marketable bulb yield, pyruvic acid content, total soluble solids

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Introduction

Garlic (*Allium sativum* L.), a vegetable spice crop with sulphur compounds responsible for its aromatic and medicinal value, is grown throughout the world. According to FAO estimates of 2018, India was the second largest producer (17.21 lakh tonne) of garlic with a productivity of 5.68 t/ha, which is meager compared with productivity of producers down the line after India (Uzbekistan-26.62 t/ha, Haiti-26.47 t/ha, Egypt-22.39 t/ha etc). Among many factors, unsatisfactory cultivation practices are elementary reasons for low productivity in India. Majority of garlic growers in India, especially, those not from prime garlic cultivation zone (Maharashtra, Rajasthan, Gujarat and Madhya Pradesh) are not aware of the essentiality of sulphur supplementation to garlic. Same is true for Himalayan temperate zone with longer days compared to rest of the country, naturally endowed with capability to foster higher yields in garlic. In the valley of Kashmir, garlic subspecies *ophioscorodon* responsive to photoperiod of up to 14 hours and 30 minutes at bulb development stage is more commonly cultivated. Farming in this region is mostly on small land holdings with minimal refinement in production technologies and carried out by technologically less advanced growers. Although dosage of nitrogen, phosphorus and potassium has been standardized for the region, sulphur dosage has not been optimized and disseminated. Garlic productivity and quality in this region is compromised by shorter storage life, lower TSS, lower dry matter and milder pungency, which are key determinants of economic returns. In addition, opportunity to reap higher production is lost in the absence of the knowledge of sulphur supplementation to garlic fields since the uptake of other nutrients is compromised. Pyruvic acid content is another critical parameter that determines its quality. It is a measure of garlic's aroma (pungency) and an indirect measure of sulphur present in its tissue. It has also been shown to have positive impact on garlic dry matter, total soluble solids [1] and yield [2, 3].

The importance of sulphur supplementation in garlic crop is thus evident and must be done to ensure optimal productivity and quality. Therefore, a three years study was done to determine the dose of sulphur for garlic cultivation in the agro-ecology of Kashmir valley of the union territory of Jammu and Kashmir for the benefit of local garlic growers.

Material and Methods

The experiment was laid in Karewa soil characterized by silt clay with sand, low water holding capacity and coarse organic matter. The mean initial nitrogen, phosphorus, potassium, sulphur, iron, manganese, zinc, and copper concentrations in soil during the three years were 338.10 kg/ha, 13.27 kg/ha, 258.80 kg/ha, 15.01 kg/ha area, 16.92

mg/kg, 10.57 mg/kg, 4.67 mg/kg and 8.77 mg/kg soil.

A 10:00 - 11:50 hours day length during emergence, seedling growth and transplanting; 9:55 - 11:25 hours during dormancy and 11:30 - 14:30 hours during bulb development and growth were observed during the crop cycle all three years. In addition to the recommended dose of NPK fertilizers (110:40:60) kg/ha, sulphur in the form of sulphur bentonite (90% S) from Tata-Paras was provided at six levels starting from nil with consecutive addition of 15 kg per hectare (0, 15, 30, 45, 60 and 75 Kg/ha) as basal dose before planting. All treatments were in triplicates laid in randomized complete block design (RCBD). The influence of treatments was tested on adapted hard neck genotype CITH-G-13 selected and maintained at the ICAR-Central Institute of Temperate Horticulture, Srinagar (**Figure 1**). Harvesting of bulbs was done when whole plants displayed complete yellowing. Treatments were evaluated and compared with respect to marketable bulb yield (t/ha), pyruvic acid content (µmol/g), total soluble solids (TSS in °Brix), and nutrient (nitrogen, phosphorus, potassium and sulphur) uptake by the plants after proper curing of bulbs. Pyruvic acid content was determined by DNPH method described by [4] and TSS was measured by handheld refractometer. The N, P, K and S uptake by plants was analyzed by methods suggested by [5].

Figure 1 Genotype (CITH-G-13) used in the study

Results and Discussion

The three-year observations revealed significant effect of sulphur supplementation on yield and quality traits in garlic (**Table 1**), which has been discussed under the following subheadings.

Marketable bulb yield

There was no significant difference between yields obtained without the application of sulphur and with the application of sulphur at 15 kg/ha. Thereafter, yield (12.88 – 14.07 t/ha) at consecutively higher dosages of sulphur (30, 45, 60 and 75 kg/ha) was significantly higher than the check (no sulphur). Sulphur is a secondary macronutrient required for normal growth and development of plants. However, in case of garlic and onion, which are cultivated and consumed only for their sulphurous nature, sulphur supplementation is necessary. Sulphur increases yields and especially marketable yields in crops mainly by enhancing protein synthesis because sulphur is central element in essential amino acids; cysteine, cystine and methionine. Sulphur is also required for chlorophyll synthesis, which makes it critical for photosynthesis and therefore for optimal yield. Therefore, in the present study, a marked increase was observed in marketable yield of garlic when sulphur supplementation was done.

Table 1 Effect of sulphur supplementation on garlic yield and quality traits and nutrient uptake

Treatment	MBY* (t/ha)	B:C** ratio	Pyruvic acid (µmol/g)	TSS (°Brix)	Nutrient uptake (Kg/ha)			
					N	P	K	S
T1: 0 Kg S/ ha	10.74^{a}	1.86	61.28^{a}	38.44^{ab}	128.07^{a}	12.49^{a}	127.29^{a}	13.37^{a}
T2: 15 Kg S/ ha	11.01^{a}	1.91	62.27^{a}	37.82^{a}	136.37^{ab}	14.80^{ab}	142.75^{b}	15.83^{b}
T3: 30 Kg S/ ha	12.88^{b}	2.37	66.17^{bc}	38.63^{ac}	144.76^{bc}	16.89^{bc}	151.17^{cd}	16.29^{b}
T4: 45 Kg S/ ha	13.57^{b}	2.51	69.25^{c}	40.18^{bd}	153.21^{c}	20.06^{d}	163.15^{e}	17.20^{bc}
T5: 60 Kg S/ ha	14.07^{b}	2.61	67.64^{c}	40.81^{d}	150.97^{c}	18.14^{cd}	157.63^{de}	17.74^{c}
T6: 75 Kg S/ ha	12.96^{b}	2.29	66.70^{b}	40.50^{c}	137.13^{a}	15.26^{ac}	146.81^{c}	16.55^{bc}
*CD****	*1.86*	-	*1.67*	*1.99*	*13.12*	*3.13*	*8.31*	*1.40*
CV (%)	*7.75*	-	*1.38*	*2.75*	*3.52*	*7.31*	*2.14*	*3.28*

* Marketable bulb yield, ** Benefit : Cost ratio. *** Critical difference at 5% level of significance
Values with same superscript are not significantly different

Pyruvic acid content (µmol/g)

Pyruvic acid content of garlic was significantly affected by the application of sulphur. The accumulation of pyruvic acid in response to sulphur supplementation was not observed at 15 kg/ha when compared with check. But it was significant at 30 kg/ha and higher dosages. However, the highest pyruvic acid was found at 45 – 60 kg/ha sulphur. Pyruvate content was again brought to the lower level at 75 kg/ha (66.70). Since pyruvic acid content is the function of sulphur content, it follows that pungency can be increased with the addition of sulphur to garlic field.

Total soluble solids (°Brix)

Application of sulphur to garlic had significant effect on its total soluble solid content. There was a general trend of increase in TSS, which reached its highest (40.81-40.50) at 60-75 kg sulphur per hectare. There were no significant differences among rest of the treatments for TSS. Since sulphur is involved in the chlorophyll synthesis and enzymatic activities in plant systems, its optimum concentration in plant physiological processes increases photosynthesis and thus sugars, which are the main constituents of TSS. Hence, up to a particular degree, the presence of sulphur enhances TSS of garlic cloves, thereby, increasing their quality.

Nutrient uptake by the crop

Sulphur has been documented to improve nutrient uptake by plants besides being beneficial for plant growth, development and productivity [6]. In this study, effect of sulphur supplementation was observed on nitrogen, phosphorus and potassium uptake (kg/ha) by garlic plants. For nitrogen, the uptake was significantly higher at sulphur dosages of 30 kg/ha to 60 kg/ha (144.76 – 153.21) when compared with that of the check (128.07). The uptake of phosphorus (18.14 – 20.06) and potassium (157.63 – 163.15) was also significantly higher than that of check (127.29) and highest uptake was observed at the dosage of 45 to 60 kg/ha sulphur. Uptake of sulphur was found to be significantly highest (16.55 – 17.74) at 45 to 75 kg/ha sulphur supplementation, which was significantly higher than check (13.37). The results strongly recommend application of sulphur basal dose for improved nutrient uptake by the crop. The higher nutrient concentrations in plant body results in more synthesis of metabolites and thus more yield and quality of the produce.

Economics of production

An addition of sulphur to the garlic field has undoubtedly enhanced its performance ranging from yield to quality parameters. In most of the cases, significant improvements started to happen at 30 kg sulphur per hectare and further increases in parameters were observed at higher dosages. However, on analysis of cost and benefit, sulphur supplementation at 60 kg/ha was found to be most profitable to the garlic growers because of highest marketable yield in terms of tones reaped per unit area. Also this treatment was one of the treatments that gave highest values for all the quality traits and nutrient uptake.

Conclusion

Sulphur supplementation was tested against the traditional mode of garlic cultivation that involved no sulphur application to the field. All traits were significantly affected by supplementation. However, most of them started responding at 30 kg/ha and attained peak at or around 60 kg sulphur per hectare. The benefit-cost ratio also suggests treatment of sulphur at 60 kg/ha is most beneficial to the garlic growers of the valley.

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