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Effect of sulphur on growth, yield and quality of garlic (*Allium sativum* L.)

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Abstract
Garlic (*Allium sativum* L.) is one of the important commercial vegetable crops of India. Sulphur has been recognised as an important nutrient for higher yield and quality of vegetable crops, including onion and garlic. Keeping this in view, a field experiment was conducted during rabi-2014-15 at Faculty of Agriculture, Wadura, Sopore, SKUAST-Kashmir to study the effect of varying levels of sulphur on growth, yield and quality of garlic cv. Local. The sulphur in the form of gypsum was tried at six levels, Viz., T_1= (0 kg ha^{-1}), T_2 = (15 kg ha^{-1}), T_3= (30 kg ha^{-1}), T_4= (45 kg ha^{-1}), T_5= (60 kg ha^{-1}) and T_6= (75 kg ha^{-1}) in a randomised block design with four replications. The results on growth, yield, quality attributes and shelf life of onion revealed significant variations among levels of sulphur. The results depicts an improvement/enhancement in all characters under study upto 45 kg ha^{-1} and thereafter exhibhited a decline. Sulphur @45 kg ha^{-1} (T_4) recorded maximum values for plant height (87.00 cm), No. of leaves per plant(17.33), leaf length(44.33),leaf width(2.55), polar diameter (3.08cm),equatorial diameter,(4.54 cm),average bulb weight(218.66g),no. of cloves (55),Average clove weight(188.33),total bulb yield(173.33qtls) marketable yield (125qtls) T.S.S.(30.81),pyruvic acid(47.62 µmol g^{-1}) Maximum uptake of nitrogen (78.00 kg ha^{-1}), phosphorus (22.61 kg ha ^{1}), potassium (66.08 kg ha^{-1}) and sulphur (24.13 kg ha^{-1}) was also recorded with 45 kg S ha $^{-1}$ (T_4) besides recording a minimum storage loss of 14.70%. Pseudo stem length (3.23cm), scape length (38.66 cm) were found maximum with treatment T_6 (75 kg ha^{-1}).

Keywords: Sulphur, garlic, growth, yield and quality

Introduction
Garlic (*Allium stavium* L.) is the second most important spice crop next to the onion and belongs to family *Alliacea* (Bose and Som, 1990) [8]. In India garlic is being cultivated on an area of 274000 ha with an annual production of 1271000Mtonnes (Anonymous, 2016-17).In Kashmir, It is being cultivated on an area of 0.54 000 hactares with an annual production of 0.85 tonnes per hectare (Anonymous, 2013-14). The reason for low productivity is mainly due to inadequate supply of nutrients, particularly sulphur. Sulphur is recognised as the fourth major nutrient after nitrogen, phosphorus and potassium. Sulphur deficiency in Indian soils have adversely affected the crop production even though crop is applied with recommended dose of N, P, K fertilisers. Onion and garlic are sulphur loving crops and the requirement is high for their proper growth, yield and better quality. Sulphur is recognised as an important nutrient for higher yield and quality of bulb crops. Severe sulphur deficiency during bulb development has detrimental effect on yield and quality of bulb crops

Pungency in garlic is attributed to presence of an alkaloid "allyl prophyl disulphide" in which sulphur is prime component. Sulphur application in crops is not only important from nutrient point of view but it also builds resistance against pest and diseases. Sulphur is essential for synthesis of amino acids, which are building blocks for essential proteins. It is essential for good vegetative growth and bulb development in bulb crops (Ahmad *et al*., 2007) [16]. Continuous removal of sulphur from soil by plants led to wide spread deficiency coupled with continuous use of sulphur free fertilisers, resulting a decline in the yield of bulb crops. In sulphur deficient soils plants exhibit a poor utilisation of both macro and micronutrients. Sulphur application has resulted in an improvement in growth, yield related attributes of garlic (Alam, 1995 and Nasrin *et al*, 2007) [2, 18]. Keeping in view the significance of sulphur in crop production, the present investigation was undertaken to study the "Effect of sulphur on growth, yield, quality and storage life of garlic (*Allium satvium* L).

Materials and Methods
A field experiment was conducted during *Rabi* 2014-15 at faculty of Agriculture and Regional Research station Wadura Sopre, SKUAST-Kashmir.

The soil of the experimental plot was clay loam in texture having a pH 7.14, available NPK and S 312:87:157.31:18.23 kg ha^{-1}respectively.The experiment was laid out in randomised block design with four replication. The sulphur was applied in the form of gypsum with six levels each representing a treatment. The levels/treatments include T_1=control (0 kg S ha^{-1}), T_2 =15 kgS 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 S kg ha^{-1}. A uniform recommended dose of NPK and FYM 75:40:40+15 kg ha^{-1} N: P_2O_5: $K_2O$was applied to all the plots. Garlic variety local was planted in plots of size 3.00×2.00 m at a spacing of 15 cm × 10 cm on 30th November 2014. Crop was raised as per the cultural practices recommended by SKUAST-Kashmir. The crop was harvested on ending June 2015.The observation on growth, yiled, uptake and quality attributes were taken from randomly selected 10 plants from each plot using standard procedures. Storage data was recorded from well cured/compact garlic bulbs 5 kg from each plot/treatment of each replication for a period of four months. Pungency develops when allianase enzyme interacts with precursors collectively known as S allyl cysteine sulfoxide, after cutting or crushing of garlic tissue following the procedure of Ketter and Randle (1998) [15] for pungency. The data recorded on various parameters was subjected to statistical analysis as per the procedure suggested by Panse and Sukhatme (1978) [19].

Results and Discussion

Growth and yield

Data on growth and yield given in table-1 reveal that growth & yield related attributes exhibited an increase upto 45 kg S ha^{-1}, thereafter a decline was observed with higher doses of sulphur. Maximum plant height (87.00 cm) was recorded with T_4(45 kg ha^{-1}) which was significantly superior to T_1 (0 kg S ha^{-1}),T_2 (15 kg S ha^{-1}) and T_3(30 kg ha^{-1}) but was stastically at par with T_5(60 kg ha^{-1}) and T_6 (75 kg ha^{-1}).Significantly highest number of leaves (17.33),leaf length (44.33 cm) and leaf width (2.55 cm) was recorded with T_4 (45 kgS ha^{-1}) as compared to T_1,T_2,T_3 and T_6 but exhibited at par results with T_5 treatment. Treatment T_6 (75 kg ha^{-1}) and T_5(60 kg ha^{-1}) recorded maximum pseudo stem length of 3.23 cm, which was significantly higher than T_1,T_2&T_3 but was at par with T_4.Scape length registered maximum value of 46.16 cm was registered with T_1 which received no sulphur applications, lowest scaple length 29.56cm was recorded with 45 kg S ha^{-1} (T_4). A significant influence was observed on yield and yield related attributes of garlic due to sulphur application. Maximum equatorial diameter (5.00 cm) and polar diameter (3.14cm) was recorded with treatment T_4, and were significantly superior to the values recorded with other treatments except treatment T_5 in case of polar diameter.

Highest average bulb weight (260.00gms) of ten bulbs was recorded with T_4 (45 kg S ha^{-1}) which was significantly superior to the bulb weight recorded with other treatments, except T_3 (30 kg Sha^{-1}) where it exhibited stastically at par results. No. of cloves (per 5 bulbs) also exhibited significant variations, recording maximum number of 55.00 cloves with T_4, which was significantly superior to T_1,T_2 and T_6 but exhibited at par results with T_3 and T_5.Average clove weight (per 50 cloves) responded differently to various levels of sulphur, recording maximum weight of 188.83 gms which was significantly superior to the values recorded with T_1,T_2 and T_3 but exhibited at par results with T_5 and T_6.Significant variations were observed both for total and marketable bulb yield recording maximum values of 173.33 and 153.33 q ha^{-1} for total bulb and marketable bulb yield respectively and were found significantly superior to all other treatments under study. Application of 45 kg S ha^{-1} produced an additional bulb yield of 27.56 q ha^{-1} over control (T_1).

Table (2) revealed significant variations among various levels of sulphur were observed with respect to quality parameters and nutrient uptake. Treatment T_4 (45 kg ha^{-1}) recorded maximum values of 30.81Brix° which was significantly superior to T_1 and T_2 but was statically at par with T_3,T_5 and T_6.Maximum pyruvic acid content of 30.81 µ $molg^{-1}$ was recorded with T_4 and was significantly superior to all the treatments under study.

Nutrient uptake depicted significant variations among levels of sulphur. Treatment T_4(45 kg S ha^{-1}) recorded maximum values of 78.00,22.61,66.08 and 24.13 kg ha^{-1} for nutrient uptake of nitrogen, phosphorus, potassium and sulphur respectively and were found significantly superior to all other treatments under study. Shelf life of garlic was also influenced by various levels of sulphur. Treatment T_4, recorded minimum storage loss of 14.76 % and was found significantly lower that the values recorded with other treatments.

The overall increase in growth and yield attributes of garlic may be due to role of sulphur in balanced fertilisation, performs many physiological functions like synthesis of sulphur containing amino acids and development of profuse roots system in plants. which might have increased uptake of nutrients, ultimately increasing the rate of photosynthesis. Storage life of garlic may have been enhanced due to firmness in membrane structures and increase of dry matter thereby increasing shelf life. Similar findings were also reported by Jaggi (2005) [13] in onion, Tripathy *et al*., 2013 (onion), Farooqui *et al*, 2009, Hore *et al*., 2014 and Magray *et al*., 2017 [10, 11, 16] in garlic.

Conclusion

The application of 45 kg ha^{-1} through gypsum was found to be advantageous for better growth, yield, quality and improved storage life of garlic cv. local under Kashmir conditions.

Table1: Effect of various levels of sulphur on growth and yield attributes of garlic (*Allium sativum L.)*.

Treatment	Plant height (cms)	No. of leaves	Leaf length (cms)	Leaf width (cms)	Pseudostem length (cms)	Scaple length (cms)	Polar diameter (cms)	Equatorial diameter (cms)	Average Bulb Weight (gms) (10 bulbs)	No. Of cloves (5 Bulbs)	Average Clove weight (50 cloves)	Total Yield Q ha^{-1}	Marketable Yield Qha^{-1}
T_1 = 0 kg ha^{-1}	65.33	13.00	32.33	1.72	2.40	46.16	2.62	4.38	218.66	45.00	149.00	145.77	94.74
T_2 = 15 kg ha^{-1}	70.00	14.00	34.33	2.09	2.65	40.86	2.73	4.44	221.87	48.00	156.00	147.91	105.39
T_3 = 30 kg ha^{-1}	78.33	15.33	39.00	2.35	2.91	34.34	2.81	4.78	240.33	51.00	168.33	160.21	121.03
T_4 = 45 kg ha^{-1}	87.00	17.33	44.33	2.55	3.10	29.56	3.14	5.00	260.00	55.00	188.33	173.33	153.00
T_5 = 60 kg ha^{-1}	86.00	17.00	42.66	2.55	3.23	38.66	3.08	4.54	236.00	50.00	185.00	157.33	125.00
T_6 = 75 kg ha^{-1}	84.66	17.00	40.66	2.36	3.23	36.00	3.01	4.52	228.66	49.00	180.33	152.44	116.58
C.D	2.81	1.22	3.10	0.42	0.15	2.01	0.08	0.03	20.25	5.35	10.83	10.83	9.75

Table 2: Effect of various levels of sulphur on quality and nutrient uptake of garlic (*Allium sativum* L.).

Treatment	T.S.S. (Brix)	Pyruvic Acid (µmol g^{-1})	Uptake of Nitrogen	Uptake of Phosphorus (kg ha^{-1})	Uptake of Potassium) (kg ha^{-1})	Uptake of Sulphur (kg ha^{-1})
T_1= 0 kg ha^{-1}	24.81	30.78	65.83	18.96	55.60	20.33
T_2= 15 kg ha^{-1}	26.37	33.84	66.59	19.29	56.33	20.60
T_3= 30 kg ha^{-1}	29.43	35.86	72.12	20.89	61.16	22.30
T_4= 45 kg ha^{-1}	30.81	47.62	78.00	22.61	66.08	24.13
T_5= 60 kg ha^{-1}	28.64	42.52	70.84	20.54	60.24	21.86
T_6= 75 kg ha^{-1}	28.56	40.65	68.62	19.91	58.33	21.17
C.D	3.17	0.80	4.92	1.42	3.98	1.51

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