Original Research Article

Effect of Sulphur and Micronutrients on Yield and Quality of Garlic (*Allium sativum* L.)

ABSTRACT

The field experiment was conducted at the Horticulture Farm, S.K.N. College of Agriculture, Jobner, Jaipur (Rajasthan) to find out the effect of sulphur and micronutrients on yield and quality of garlic during *Rabi* seasons 2019-20 and 2020-21. The experiment was carried out in factorial randomized block design with three replications and twenty treatment combinations with four levels of sulphur (S_0-control, S_1-sulphur 20 kg/ha, S_2-sulphur 40 kg/ha and S_3-sulphur 60 kg/ha) and five levels of micronutrients (M_0-Control, M_1-zinc sulphate @ 0.6%, M_2-ferrous sulphate @ 0.2%, M_3-borax @ 0.5 and M_4-Ammonium molybdate @ 0.5%). The sulphur was applied as soil application just before sowing and micronutrients (Zn, B, Fe and Mo) as foliar spray at 40 DAS. Recommended dose of inorganic fertilizers applied uniformly in whole experimental area. The results of the study have clearly indicated that among sulphur levels, application of sulphur 60 kg/ha significantly improved yield and quality parameters viz., average weight of clove, average weight of bulb, bulb yield per plot, per hectare, nitrogen content, phosphorus content, potassium content and sulphur content in bulb enhanced significantly by application of sulphur 60 kg/ha (S_3) in both the years as well as in pooled analysis. Although, sulphur application at 40 kg/ha along with foliar application of zinc at 0.6 % was found at par to it. Similarly, among micronutrients foliar application of zinc sulphate @ 0.6% significantly influenced all the yield and quality parameters viz., average weight of clove, average weight of bulb, bulb yield per plot, per hectare, nitrogen content, phosphorus content, potassium content and sulphur content in bulb of garlic in both the years as well as in pooled analysis.

Keywords: *Garlic, Sulphur, Micronutrients, yield and quality of garlic.*

1. INTRODUCTION

Garlic is an important bulbous vegetable crop used throughout India primarily as a spice or condiment. Botanically it is *Allium sativum* belonging to the family Alliaceae. It is originated from Central Asia and later spread to Mediterranean region [1] and [2]. The bulb of garlic is compound in nature, consisting of numerous bulblets, so called as cloves, of different size and whole is surrounded by layers of white scale leaves. Allicin is the main biologically active component of freshly crushed garlic cloves, which is produced by the degradation of alliin, from results of alliinase activity [3] and [4]. Having the medicinal properties it lowers blood cholesterol level and antiplatelet aggregation, produces anti-inflammatory activity and inhibits cholesterol synthesis. Moreover, it has long been known to have antibacterial, antifungal, anticancer, antioxidant and antiviral activities [5].

Besides, garlic also possesses insecticidal properties. Extract of garlic along with chilli and ginger has beneficial action against soil nematodes. Beneficial use of garlic extract has also been found against many fungi and bacteria [6]. Garlic oil or its juice is recommended to inhale in cases of pulmonary tuberculosis, rheumatism, sterility, impotency, cough and redness of eyes [7]. Garlic contains volatile oil known as diallel-disulphide which is the major flavouring component in garlic. Garlic has higher nutritive value as compared to other bulbous crops. It is a rich source of sugar, protein, fat, potassium, calcium, sulphur, phosphorus, fiber and iodine. Per 100 g of edible portion of garlic contains 59 % moisture, 6.4 g protein, 1469 k cal energy, 0.5 g fats, 33.1 g carbohydrates, 1.5 g fiber, 181 mg Ca, 153 mg P, 1.7 mg Fe, 17 mg Na, 401 mg K, 0.08 mg riboflavin, 0.25 mg thiamine, 0.06 mg nicotinamide and 10.8 mg ascorbic acid [8].

Deficiency of micronutrients during the last three decades has become a major constraint to production and productivity of vegetables in general and garlic in particular. Thus, there is an urgent need for correction of individual nutrient deficiency and for arresting its further spread. The lower productivity of Indian garlic is primarily due to cultivation of low yield potential varieties, susceptibility to both biotic and abiotic factors. Therefore, imbalanced nutrition is treated as one of the major abiotic factors which adversely affects growth and yield of garlic. Keeping these points in view, foliar application of boron, zinc, iron and molybdenum as micronutrients and basal doses of sulphur as a macronutrient were used in the experimental crop to study the impact on growth, yield and storage of garlic. The foliar application of micronutrients reduces the cost of owing to the lesser requirement of nutrients and better absorption through the foliage. It has been observed that application of micronutrients are important in enhancing the translocation of carbohydrates from the site of synthesis to the storage organ. Among the macronutrients, sulphur is one of a major plant nutrient essential for building up sulphur containing amino acids namely cystine, cysteine &

methionine and is involved in synthesis of protein and sulphur containing vitamins like biotin, thiamine and some coenzymes.

2. MATERIALS AND METHODS

2.1 LOCATION OF EXPERIMENTAL SITE

The experiment was laid out at Horticulture farm, S.K.N. College of Agriculture, Jobner, District Jaipur (Rajasthan) during *Rabi* season 2019-20 and 2020-21. Geographically, Jobner is situated 45 km in West of Jaipur at $26^{\circ}5'$ North latitude,$75^{\circ}20'$ East longitude and at an altitude of 427 meters above mean sea level. This region falls under Agro-Climatic Zone-IIIA (Semi- Arid Eastern Plain Zone) of Rajasthan.

2.2 CLIMATE AND WEATHER

The climate of Jobner region is typically semi-arid characterized by extremes of temperature both in summer and winter, low rainfall and moderate relative humidity. The annual average rainfall varies between 250 to 500 mm, most of which is received in rainy season fall during July to early September, sporadic showers also received in winters. The maximum temperature ranges from 30 to $46^{\circ}C$ during month of May and June, while in December and January, it falls down below $-1^{\circ}C$ and evaporation ranges from 1.2-6.9 mm per day.

2.3 SOIL CHARACTERISTICS OF EXPERIMENTAL FIELD

To know the fertility status and other physical constraints of soil, samples were taken and analyzed in the department of Soil Science and Agricultural Chemistry, S.K.N. College of Agriculture, Jobner to evaluate physico-chemical characteristics of the soil before experimentation. The soil samples from 0-15 cm depth were collected from different locations of the experimental field before application of manures and fertilizers. A representative composite sample was prepared by processing and mixing them together and analysed for physical and chemical properties. The results of analysis presented in Table 3 showed that the soilof experimental site was loamy sand in texture, slightly alkaline in reaction, poor in organic carbon with low available nitrogen, phosphorus & sulphur and medium in potassium content. The underground water used for irrigation is partially saline in nature.

2.4 Quality of irrigation water

The irrigation water sample was taken from tube well of horticulture farm, SKN COA, Jobner and analysed in the department of soil science of S.K.N. College of Agriculture, Jobner. The irrigation water falls under classC_3S_1 to USDA Hand Book No. 60. The pH and EC were found to be 7.75 and 7.68 and 1.01 and 1.02 ds/m in the year 2019-20 and 2020-21 respectively. Water of Jobner area is little but saline in nature.

2.5 Treatments and design

A field experiment was carried out during *Rabi* season of 2019-20 and 2020-21 in factorial randomized block design with twenty treatment combinations viz., (S_0-control, S_1-sulphur 20 kg/ha, S_2-sulphur 40 kg/ha and S_3-sulphur 60 kg/ha, M_0-Control, M_1-zinc sulphate @ 0.6%, M_2-ferrous sulphate @ 0.2%, M_3-borax @ 0.5 and M_4-Ammonium molybdate @ 0.5%) and three replications. The sulphur was applied as a basal dose before sowing and micronutrients (Zn, B, Fe and Mo) as foliar spray. Recommended dose of inorganic fertilizers applied uniformly in whole experimental area.

2.6 Crop Management

The experimental land was prepared by ploughing and double harrowing to bring it to the fine tilth. Farm yard manure was applied at the rate of 25 t/ha before final harrowing and incorporated into the soil one week before sowing. The plots of required size were prepared. Bunds, irrigation channels and roads were laid out as per the plan. The seeds of cv. G -282 procured from NHRDF, Karnal (Haryana). The seeds (cloves) of garlic were first treated with Carbendazim @ 2 g/kg seed to control seed borne diseases. The seeds were sown on 16thOctober, 2019 and 22th October, 2020 manually with a seed rate of 500 kg /ha in row at 15 cm apart.

2.7 **STATISTICAL ANALYSIS**

The experimental data recorded for growth, yield, quality and storage characters were subjected to statistical analysis in accordance with the 'Analysis of variance' technique suggested by Fisher. The critical difference (CD)was calculated wherever the difference was found significant. Assuming homogeneity in the experimental data of two years, pooled analysis was done. The analysis of variance of different components for all parameters discussed is given in the annexures at the end.

3. RESULTS AND DISCUSSION

3.1 Effect of Sulphur on yield parameters

The perusal of data in the table (1, 2 and 3) reveals that all the sulphur levels (20, 40 and 60 kg ha^{-1}) significantly increased the average weight of clove, average weight of bulb, bulb yield per plot and per hectare as compared to control during both the years and in pooled mean. The maximum average weight of clove (1.49, 1.46 and 1.47g), average weight of bulb (26.65, 24.84 and 25.75g), bulb yield per plot (3.20, 2.98 and 3.09 kg/plot) and per hectare (177.68, 165.62 and 171.65 q/ha) was recorded with 60 kg S ha^{-1} that was at par with 40 kg S ha^{-1}. Where as the minimum average weight of clove (1.29, 1.27 and 1.28 g), average weight of bulb (21.17, 19.78 and 20.48 g), bulb yield per plot (2.54, 2.37 and 2.46 kg/plot) and per hectare (141.15, 131.86 and 136.51 q/ha) was recorded with control.

The yield attributing characters namely average weight of clove, average weight of bulb and bulb yield per plot and per hectare increased significantly with the application of sulphur (S_3) sulphur @ 60 kg/ha over control. Pooled mean basis, the maximum values of yield and yield attributes *i.e.*, average weight of clove (1.47 g), average weight of bulb (25.75 g), bulb yield per plot (3.09 kg/plot) and bulb yield per hectare (171.65 q/ha) were recorded with application of 60 kg S/ha (S_3) which at par with 40 kg S/ha (S_2) and minimum under control (S_0). Further, sulphur being an integral constituent of certain amino acids of which nitrogen is also essential constituent, might have helped in increasing net assimilation rate of nitrogen along with other nutrients. Thus, it might have resulted in increased yield attributes. Increase in yield of garlic due to sulphur application may be due to low initial available sulphur content in experimental soil and better development and thickening of xylem and collenchyma fibers because of higher rate of protein synthesis and enhanced photosynthetic activity of the plant with increased chlorophyll synthesis due to fertilization with sulphur which in turn resulted in more yield attributes and yield of plant. These results are agreement with findings of [9] in onion and garlic, [10] in onion, [11], [12] in garlic, [13] and [14] in onion.

3.2 Effect of Sulphur on quality parameters

Data (Table 2) indicated that the nitrogen content was significantly increased by the application of increasing levels of sulphur fertilization during both the years as well as pooled mean. The maximum nitrogen content (0.821, 0.850 and 0.836 per cent), phosphorus content (0.302, 0.339 and 0.321 per cent) and potassium content (0.522, 0.542 and 0.532 per cent) was recorded under treatment S_3 (Sulphur @ 60 kg/ha) and minimum nitrogen content (0.942, 1.020 and 0.981 %), phosphorus content (0.260, 0.292 and 0.276 per cent) and potassium content (0.439, 0.461 and 0.450 per cent) under control during 2019-20, 2020-2021 and in pooled mean. The treatment S_3 where Sulphur @ 60 kg/ha was applied observed as significantly superior over control but remained statistically at par with treatment S_2 (Sulphur @ 40 kg/ha).

Application of sulphur resulted in significant increase in chlorophyll content of leaves, which might have enhanced the rate of photosynthesis which further increased vegetative growth and provided more site for translocation of photosynthates which might have resulted in increased accumulation of carbohydrate, thus increased TSS content in garlic bulb. These results are in accordance with the findings of [15] in onion and [16] in onion, [17] in onion, [18] in garlic, [19] in garlic, [20] in garlic and [21] in onion.

3.3 Effect of Micronutrients on yield parameters

Data (Table 3) also showed that significant improvement in average weight of clove (1.45, 1.44 and 1.44 g), average weight of bulb (25.70, 24.84 and 25.75 g), bulb yield per plot (3.08, 2.92 and 3.00 kg/plot) and bulb yield per hectare (171.34, 162.14 and 166.74 q/ha) of garlic was recorded with foliar application of micronutrients wherein zinc sulphate @ 0.6% produced significantly maximum average weight of clove, average weight of bulb, bulb yield per plot and bulb yield per hectare compared to control (M_0). While, micronutrient treatments viz., zinc sulphate @ 0.6%, ferrous sulphate @ 0.2%, borax @ 0.5% and ammonium molybdate @ 0.5% remaining at par with each other also proved significantly superior to control.

The average weight of clove, average weight of bulb, bulb yield per plot and bulb yield per hectare increased significantly with foliar application of micronutrients (zinc sulphate @ 0.6%) over control. Pooled mean basis, the maximum values of yield and yield attributes *i.e.*, average weight of clove (1.44 g), average weight of bulb (25.01 g), bulb yield per plot (3.00 kg/plot) and yield per hectare (166.74 q/ha) was recorded with the foliar application of zinc sulphate @ 0.6% (M_1) and minimum under control. These results are in conformity with the findings of [22] in garlic, [23] in garlic, [24] in garlic, and [25] in onion.

The increase in yield and yield attributes by the application of micronutrient (Zn) might have influenced the formation of some growth hormones in the plant as it is associated with water relation in the plants and also involved in auxins metabolism like tryptophane synthetase, tryptomine metabolism, influence the activity of dehydrogenase enzymes Pyridine nucleotide, glucose-6 phosphate and triose phosphate and also synthesis of tryptophane, a compound of proteins and needed for the production of growth hormones such as IAA and GA. Similar finding were recorded by [26] in tomato, [27] in okra, [28] in garlic and [29] in onion.

3.4 Effect of Micronutrients on quality parameters

The data regarding the foliar application of micronutrients on nitrogen content, phosphorus and potassium content presented in the table 2. The perusal of data revealed that the nitrogen was significantly increased by foliar application of micronutrients during both the years as well as pooled mean. The nitrogen content (0.922, 0.986 and 0.954 per cent), phosphorus content (0.295, 0.335 and 0.315 per cent) and potassium content (0.505, 0.531 and 0.518 per cent) was recorded maximum under treatment M_1 (zinc sulphate @ 0.6%) whereas, the minimum nitrogen content (0.825, 0.865 and 0.845 per cent), phosphorus content (0.267, 0.293 and 0.280 per cent) and potassium content (0.453, 0.470 and 0.462 per cent) was recorded under the treatment M_0 (control). The treatment M_1 was observed as significantly superior over control and remained statistically at par with treatment M_2 (ferrous sulphate @ 0.2%), M_3 (borax @ 0.5%), M_4 (ammonium molybdate @ 0.5%) during both the years and in pooled mean. It might be due to adequate nutrient availability in the feeding zone which ultimately increased the uptake of nutrients, photosynthetic rate and finally the greater growth of plant by enhancing the quality of bulb. Zinc plays an important role in metal activator of different enzymes and essential trace elements in various function of the plant like increases the rate of chlorophyll, antioxidant enzymes and essential components of many proteins and improving the mineral status (TSS, ascorbic acid, protein and sugar content) as well as increasing crop yield and quality. Similar results were also recorded by [30] in cauliflower, [31] in garlic, [32] and [33] in onion, [34] in onion, [35] in tomato and [36] in tomato, [37] in onion, [38] in garlic.

4. CONCLUSION

Based on the results of two years experiments, it may be concluded that soil application of sulphur at 60 kg/ha combined with foliar spray of Zinc sulphate at 0.6% proved the most superior treatment combination in garlic fetching the significantly higher yield. Although, sulphur application at 40 kg/ha along with foliar application of zinc at 0.6 % was found at par to it.

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Table 1 Effect of sulphur and micronutrient on average weight of clove and average weight of bulb

Treatments	Average weight of clove			Average weight of bulb		
	2019-20	**2020-21**	**Pooled**	**2019-20**	**2020-21**	**Pooled**
Sulphur levels						
S_0	1.29	1.27	1.28	21.17	19.78	20.48
S_1	1.40	1.36	1.38	24.31	22.46	23.38
S_2	1.47	1.45	1.46	26.22	24.51	25.36
S_3	1.49	1.46	1.47	26.65	24.84	25.75
SEm ±	0.03	0.03	0.02	0.46	0.46	0.32
CD (P = 0.05)	0.07	0.08	0.05	1.32	1.31	0.91
Micronutrients						
M_0	1.33	1.29	1.31	21.81	20.04	20.93
M_1	1.45	1.44	1.44	25.70	24.32	25.01
M_2	1.43	1.40	1.42	25.19	23.34	24.27
M_3	1.45	1.42	1.43	25.58	23.97	24.77
M_4	1.41	1.38	1.39	24.66	22.81	23.73
SEm ±	0.03	0.03	0.02	0.52	0.51	0.36
CD (P = 0.05)	0.08	0.09	0.06	1.48	1.46	1.02

Table 2 Effect of sulphur and micronutrient on average weight of bulb per plot and yield of bulb per hectare of garlic

Treatments	**Bulb yield (kg/plot)**			**Bulb yield (q/ha)**		
	2019-20	**2020-21**	**Pooled**	**2019-20**	**2020-21**	**Pooled**
Sulphur levels						
S_0	2.54	2.37	2.46	141.15	131.86	136.51
S_1	2.92	2.70	2.81	162.05	149.73	155.89
S_2	3.15	2.94	3.04	174.79	163.39	169.09
S_3	3.20	2.98	3.09	177.68	165.62	171.65
SEm $\pm$	0.05	0.05	0.04	3.07	3.22	2.23
CD (P = 0.05)	0.16	0.15	0.11	8.80	9.22	6.27
Micronutrients						
M_0	2.62	2.41	2.51	145.39	133.63	139.51
M_1	3.08	2.92	3.00	171.34	162.14	166.74
M_2	3.02	2.80	2.91	167.94	155.62	161.78
M_3	3.07	2.88	2.97	170.54	159.78	165.16
M_4	2.96	2.74	2.85	164.37	152.07	158.22
SEm $\pm$	0.06	0.06	0.04	3.44	3.60	2.49
CD (P = 0.05)	0.18	0.17	0.12	9.84	10.31	7.01

Table 3 Effect of sulphur and micronutrient on number of cloves per plant of garlic

Treatments	N content (%)		
	2019-20	**2020-21**	**Pooled**
Sulphur levels			
S_0	0.821	0.850	0.836
S_1	0.870	0.920	0.895
S_2	0.912	0.980	0.946
S_3	0.942	1.020	0.981
SEm $\pm$	0.013	0.018	0.011
CD (P = 0.05)	0.037	0.050	0.031
Micronutrients			
M_0	0.825	0.865	0.845
M_1	0.922	0.986	0.954
M_2	0.895	0.955	0.925
M_3	0.905	0.970	0.937
M_4	0.885	0.937	0.911
SEm $\pm$	0.014	0.020	0.012
CD (P = 0.05)	0.041	0.056	0.034

Table 4 Effect of sulphur and micronutrient on phosphorus and potassium content in garlic bulb

Treatments	Phosphorus content (%)			Potassium content (%)		
	2019-20	**2020-21**	**Pooled**	**2019-20**	**2020-21**	**Pooled**
Sulphur levels						
S_0	0.260	0.292	0.276	0.439	0.461	0.450
S_1	0.282	0.312	0.297	0.481	0.502	0.492
S_2	0.295	0.331	0.313	0.511	0.533	0.522
S_3	0.302	0.339	0.321	0.522	0.542	0.532
SEm ±	0.004	0.006	0.004	0.007	0.008	0.005
CD (P = 0.05)	0.013	0.018	0.011	0.021	0.023	0.015
Micronutrients						
M_0	0.267	0.293	0.280	0.453	0.470	0.462
M_1	0.295	0.335	0.315	0.505	0.531	0.518
M_2	0.287	0.320	0.303	0.495	0.516	0.506
M_3	0.292	0.329	0.311	0.503	0.524	0.514
M_4	0.283	0.316	0.299	0.485	0.506	0.496
SEm ±	0.005	0.007	0.004	0.008	0.009	0.006
CD (P = 0.05)	0.014	0.020	0.012	0.023	0.026	0.017