The Bioscan 12(1): 471-475, 2017 (Supplement on Agronomy)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.com

EFFECT OF SULPHUR AND POTASSIUM APPLICATIONS ON GROWTH AND CHEMICAL CHARACTERISTICS OF GARLIC

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KEYWORDS
Sulphur
Potassium
uality
nteraction effect

Received on :
02.03.2016

Accepted on :
04.01.2017

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ABSTRACT
The present study was conducted to examine the effect of sulphur and potassium applications on quality parameters and storage on garlic.Sulphur (S) was tested at rates of 0,15, 30, and 45 kg ha^{-1} in combination with potassium (K) applied at rates of 0, 50, 75, and 100 kg ha^{-1}.Increased rate of S and K applications enhanced the growth & quality paramaters and improved storage of garlic bulbs. Integration of sulphur @45 kg ha^{-1}& potassium @ 100 kg ha^{-1} recorded maximum values of plant height (110.55 cm) ,number of leaves $plant^{-1}$ (23.73) ,leaf length,(67.85 cm) and quality traits like T.S.S (35.67 ^{o}Brix), pyruvic acid (51.37 μmol g^{-1}), protein content (17.23 %) and vitamin C content (14.00 mg 100^{-1}g), besides recording minimum physiological weight loss, (16.07%), rotting (2.27%) and sprouting (2.62%), followed by $S_3 K_2$ treatment (45 kg ha^{-1}S+ 75 kg ha^{-1}K).

INTRODUCTION

Garlic (*Allium sativum* L.) is the second most important bulb vegetable crop in India. Garlic belongs to family Alliaceae and has originated from Central Asia (Vavilov, 1926). Garlic is a frost hardy, bulbous, herbaceous annual for bulb production.Garlic is used as a spice or condiment throughout India and has higher nutritive value than other bulb vegetable crops. The area and production of garlic in India is 248,000 hac and 1259.27 thousand metric tones respectively and productivity of 5.1 MT per hectare (Anonymous, 2013-14). In Jammu and Kashmir garlic is grown on an area of 540 hactares with a production of 460 metric tones respectively (Anonymous, 2013-14).

The edible portion of garlic is a composite bulb and contains 62.8% moisture, 6.3% proteins, 29 % carbohydrates, 13 mg 100^{-1} g vitamin C, 0.03 % calcium, 0.31% phosphorous, 0.0031 % iron and pyruvic acid content of 35-60 μmol g^{-1} (Schwimmer,and Weston 1961). Garlic is considered as "*Nectar of Life*" in Ayurveda. A colourless, odourless and water soluble amino acid "allin" present in garlic breaks down in to a sulphur containing product allium on injury or crushing. Allium is the anti-bacterial substance of garlic and has typical odour of fresh garlic. In allium principal ingredient is odoriferous "diallyl disulphide" (Rai and Yadav, 2005).

Among the major nutrients, potassium plays a vital role in plant metabolism such as photosynthesis, translocation of photosynthates, regulation of plant pores, activation of plant catalyst and resistance against pests and diseases. It is also considered as a quality element, as it improves quality parameters of many crops including garlic and onion. Potassium improves colour, glossiness and dry matter accumulation besides improving keeping quality of the garlic and onion (Subhani *et al.,* 1990; Dorais *et al.*, 2001).

Although K is not a constituent of any plant structures or compounds, it is involved early in all processes needed to sustain the plant life. Potassium in cell sap is involved in enzyme activation, photosynthesis, transport of sugars, protein and starch synthesis. It is known to help crop to perform better under water stress through the regulation of the rate at which plant stomata open and close. It is also known for its role to provide lodging resistance and insect/disease resistance to plants. Since potassium is involved in many metabolic pathways that affect crop quality, it is often called as "the quality element" (Dev, 1995).

The soils of Kashmir are thought to be rich in potassium due to presence of illite as the dominant clay mineral. But with the introduction of high yielding varieties and intensive cropping system, the soils have started depleting from high to medium and low potassium status as evidenced by soil testing (Prasad, 1990). Only a small portion of it becomes available to plants especially under temperate climatic conditions of Kashmir at its various altitudes (Wani *et al*., 2009).

Sulphur also improves the yield and quality parameters of important vegetable crops. Sulphur requirement of crops is almost similar to that of phosphorous. Sulphur is a constituent of secondary compounds *viz*., allin, cycloallin and thiopropanol which not only influences the taste, pungency and medicinal properties of garlic and onion but impart resistance against pests and diseases.

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). Continuous removal of S from soils through plant uptake has led to widespread S deficiency and affected soil S budget (Aulakh, 2003) all over the world. Report is available which shows that apart from NPK fertilizer, sulphur can play a vital role in increasing the yield of garlic (Ahmed *et al.,* 1988).

Recently, studies have proved that amino acids can directly or indirectly influence the physiological activities in plant growth and development. Also, amino acids are well known as bio-stimulants which have positive effects on plant growth, yield and significantly mitigate the injuries caused by abiotic stresses (Kowalczyk and Zielony, 2008).

Sulphur is a constituent of enzyme nitrite reductase which is responsible for the reduction of NO_2 in chloroplasts and thus reduce accumulation of cancerous compounds like nitrates in vegetables (Paulsen, 2001). Non application of sulphur in sulphur deficient soils has often resulted in low yields of bulb crops. Sulphur deficient plants also had poor utilization of macro and micro nutrients. Lack of its optimum supply in different plant parts limits the crop growth and yield of onion (Nasreen and Haq, 2005). Sulphur has a positive effect on vegetable crops (Bloem and Ewald, 2004). Sulphur is an essential macronutrient and at an optimum concentration accelerates the plant growth (Thomas *et al.*, 2000). The increased use of sulphur free N and P fertilsers, use of organic manures in small quantities and practically no application of potassium affect the reserves of potassium and sulphur in most of soils of Kashmir valley resulting in depletion of these nutrients thereby limiting the soil productivity (Wani and Akhtar, 2009). Since a meager work was conducted under Kashmir conditions in this regard, the present research was conducted to assess the beneficial effects of sulphur and potassium on the garlic.

MATERIALS AND METHODS

An investigation was performed at the experimental field of Regional Research Station (RRS) and Faculty of Agriculture (FOA), Wadura, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-Kashmir) during *Rabi* 2012-13 and *Rabi* 2013-14 to find out the interaction effect of different levels of sulphur and potassium on quality and storage parameters of garlic.The experiment was laid out in Randomized completely block design with three replications of two factors with four levels of each factor. The two factors were S (sulphur) and K (potassium) with four levels as, S_0 (control or no sulphur), S_1 (15 kg ha^{-1}), S_2 (30 kg ha^{-1}) and S_3 (45 kg ha^{-1}) where as potassium levels as, K_0 (control or no potassium), K_1 (50 kg ha^{-1}), K_2 (75 kg ha^{-1}) and K_3 (100 kg ha^{-1}) .

Data collection

Plant height was measured with the help of measuring scale from the ground level to tip of the longest leaf by holding the plant vertically. The mean plant height (cm) was calculated. Average number of leaves $plant^{-1}$ was counted by counting all the normal and healthy leaves of ten plants and mean value was calculated. Average leaf length (cm) was measured of ten plants by a measuring scale, and mean value was calculated. Total soluble solids (TSS) content (°B) which is an index of total soluble solids with the help of a calibrated refractometer. Pungency (ì moles of pyruvic acid g^{-1} weight).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) for pungency.The protein content was calculated by multiplying a factor 6.25 (protein factor) with total nitrogen content in bulbs. Total nitrogen content in bulbs was determined by Kjeldahls method as outlined by Tandon (1993).Ascorbic acid, generally known as vitamin C is present in all fresh vegetables and fruits were then used for estimation of Vitamin C content in the laboratory following 2,6, dichlorophenol indophenol visual titration method (A.O.A.C. 1975) and expressed in milligrams 100 g^{-1} of fresh bulbs. For storage parameters 5kg onion was stored for five months and monthly following parameters were estimated as

$$\text{Physiological weight loss PWI}(\%) = \frac{\text{Initial weight - final weight}}{\text{Initial weight}} \times 100$$

$$\text{Sprouting}(\%) = \frac{\text{No.of sprouted bulbs}}{\text{Total No.of bulbs}} \times 100$$

$$\text{Rotting}(\%) = \frac{\text{No.of rotted bulbs}}{\text{Total No.of bulbs}} \times 100$$

RESULTS AND DISCUSSION

Growth Parameters

Perusal of table-1 revealed that growth parameters viz., plant height, average no.of leaves

$plant^{-1}$, leaf length significantly increased with increasing levels of sulphur whereas control treatment (S_0) recorded significantly lower values for growth parameters of garlic. Application of potassium (K_3) @ 100 kg ha^{-1} registered maximum values of plant height, average no. of leaves $plant^{-1}$,leaf length as compared to rest of treatments including control K_0 recording significantly lower values of growth parameters. (Table-1).

Pooled analysis revealed that combined application of sulphur S_3 (45 kg ha^{-1} and potassium K_3 @ 100 kg ha^{-1} registered maximum value Pooled analysis revealed that treatment combination K_3S_3 (K_3 @ 100 kg ha^{-1} and S_3 @ 45 kg ha^{-1}) recorded significantly maximum value for plant height (110.55 cm) ,for number of leaves $plant^{-1}$ (23.73) and (67.85 cm) for leaf length and was found significantly superior to lower levels of sulphur and potassium but statistically at par with K_2S_3 (Table 1).

Quality parameters

Perusal of (Table-1-3) reflected that higher applications of

Table-1: Initial status of experimental field with respect to available N, P, K, S, OC and soil pH

Character	Value	Range
Organic carbon (%)	0.54	Medium
pH	7.14	Neutral
Available N (kg ha^{-1})	312.13	Medium
Available P (kg ha^{-1})	17.87	Medium
Available K (kg ha^{-1})	157.31	Medium
Available S (kg ha^{-1})	18.23	low

Table 1: Effect of different levels of sulphur and potassium on growth parameters of garlic bulbs

	Plant height (cm) Pooled					No. of leaves/plant Pooled					Leaf Length (cms) Pooled				
Sulphur➔ Potassium⬇	S_0	S_1	S_2	S_3	Mean	S_0	S_1	S_2	S_3	Mean	S_0	S_1	S_2	S_3	Mean
K_0	61	62.74	66.36	71.76	65.46	12.4	12.5	12.83	15.67	13.35	34.65	39.03	42.03	54.78	40.88
K_1	67.38	69.95	70.62	79.33	71.82	13.18	13.5	13.83	17	15.92	36.92	42.55	51.12	61.05	47.91
K_2	71.72	80.21	84	107.71	85.94	13.68	14.52	16.67	21.65	16.63	39.79	46.33	53.28	67.17	51.65
K_3	73.24	82.01	100.76	110.55	91.64	13.85	15.33	18	23.73	17.73	43.83	47.68	59.83	67.85	54.8
Mean	68.33	73.73	80.44	92.36	-	13.27	13.96	15.33	19.51	-	38.75	43.9	51.57	62.71	-
C.D(p≤0.05)															
S	2.45					0.93					1.78				
K	2.45					0.93					1.78				
S x K	4.9					1.86					3.56				

Figures with same letters are statistically at par; Figures with different letters are significantly different ;S_0 (Control); S_1 (15 kg ha^{-1}); S_2 (30 kg ha^{-1}); S_3 (45 kg ha^{-1});K_0 (Control); K_1 (50 kgha^{-1}); K_2 (75 kg ha^{-1}); K_3 (100 kg ha^{-1})

Table 2: Effect of different levels of sulphur and potassium on T.S.S. (°Brix), pyruvic acid (μ mol g^{-1}) & protein content (%)

	Pooled (T.S.S.)					Pooled (pyruvic acid)					Pooled (protein content)				
Sulphur➔ Potassium⬇	S_0	S_1	S_2	S_3	Mean	S_0	S_1	S_2	S_3	Mean	S_0	S_1	S_2	S_3	Mean
K_0	19.01	26.11	27.2	30.92	25.81	28.81	33.79	36.08	45.5	36.05	9.52	13.00	14.74	15.78	13.26
K_1	26.79	26.72	27.58	32.66	28.44	31.94	34.73	36.88	48.7	38.06	10.41	13.53	14.97	16.09	13.75
K_2	27.05	28.38	31.08	34.45	30.24	32.72	34.84	37.98	49.45	38.75	11.46	13.92	15.51	16.33	14.31
K_3	27.43	30.45	32.96	35.67	31.63	32.73	36.29	39.19	51.37	39.89	12.2	14.32	15.59	17.23	14.83
Mean	25.07	27.92	29.71	33.43	-	31.6	34.91	37.53	48.75	-	10.9	13.7	15.2	16.36	
C D (p≤0.05)															
S	0.58					0.68					0.29				
K	0.58					0.68					0.29				
S x K	1.16					1.37					0.57				

S_0 (Control); S_1 (15 kg ha^{-1}); S_2 (30 kg ha^{-1}); S_3 (45 kg ha^{-1}) K_0 (Control); K_1 (50 kgha^{-1}); K_2 (75 kg ha^{-1}); K_3 (100 kg ha^{-1})

Table 3 : Effect of different levels of sulphur and potassium on Physiological Weight loss (%) and Rotting (%)

Sulphur➔ Potassium↓	Physiological Weight loss Pooled S_0	S_1	S_2	S_3	Mean	Rotting (%) Pooled S_0	S_1	S_2	S_3	Mean
K_0	26.24	22.8	23.24	22.13	23.6	4.01	3.35	3.15	2.73	4.07
K_1	25.44	22	22.73	21.14	22.83	3.21	3.15	3.06	2.68	3.26
K_2	24.61	21.61	21.22	17.74	21.3	3.15	3.03	2.98	2.33	2.8
K_3	23.93	20.89	19.92	16.07	20.2	3.09	2.98	2.86	2.27	2.54
Mean	25.05	21.82	21.78	19.27	-	3.36	3.13	3.02	2.4	-
C.D(p≤0.05)										
S	0.56					0.05				
K	0.56					0.05				
S x K	1.11					0.1				

S_0(Control); S_1(15 kg ha^{-1}); S_2(30 kg ha^{-1}); S_3(45 kg ha^{-1}); K_0 (Control); K_1 (50 kgha^{-1}); K_2(75 kg ha^{-1}); K_3(100 kg ha^{-1})

Table 4: Effect of different levels of sulphur and potassium on Vitamin C (mg 100^{-1}g) **and Rotting (%)**

Sulphur➔ Potassium↓	Vitamin C Pooled S_0	S_1	Rotting Pooled S_2	S_3	Mean	S_0	S_1	S_2	S_3	Mean
K_0	8.91	10.31	10.67	12.66	10.64	4.17	3.12	3.05	2.95	3.32
K_1	9.76	11.06	11.94	13.02	11.44	3.34	2.96	2.98	2.89	3.03
K_2	10.43	11.18	12.44	13.60	11.91	3.12	2.93	2.92	2.78	2.93
K_3	10.57	11.61	12.61	14.00	12.20	2.94	2.88	2.87	2.62	2.83
Mean	9.92	11.04	11.91	13.32	-	3.39	2.98	2.95	2.81	-
C.D(p≤0.05)										
S	0.32							0.05		
K	0.32							0.05		
S x K	0.64							0.11		

S_0(Control); S_1(15 kg ha^{-1}); S_2(30 kg ha^{-1}); S_3(45 kg ha^{-1}); K_0 (Control); K_1 (50 kgha^{-1}); K_2(75 kg ha^{-1}); K_3(100 kg ha^{-1})

sulphur @ 45 kg ha^{-1} significantly enhanced T.S.S (°Brix) content, Pyruvic acid, Protein content and Vitamin C content of bulbs besides reducing physiological weight loss,rotting % and sprouting % of garlic bulbs after 5 months of storage.Perusal of (Table 1-3) revealed that application of potassium K_3 @ 100 kg ha^{-1} recorded significantly maximum value of T.S.S (°Brix) content, Pyruvic acid, Protein content and Vitamin C content of bulbs while reducing physiological weight loss,rotting % and sprouting % of garlic bulbs after 5 months of storage as compared to lower levels of potassium including control treatment (K_0).

Pooled data revealed that combined application of sulphur @ 45 kg ha^{-1} and potassium @100 kg ha^{-1} (K_3S_3) recorded significantly maximum value (35.67 °Brix) for T.S.S content, maximum value (51.37 μmol g^{-1}) for pyruvic acid content of bulb, maximum protein content of 17.23%, and maximum vitamin C content of 14.00 mg 100^{-1}g,which was significantly maximum as compared to rest of other treatments including control treatment (K_0S_0) recording significantly lower value of 19.01°Brix for T.S.S (°Brix), lower value of Pyruvic acid content (28.81 μmol g^{-1}, significantly lower value of Protein content (9.52 %) and vitamin C content of 8.91 mg 100^{-1}g (Table 1,2and3).

Storage characterists of bulbs

Pooled analysis revealed that combined application of sulphur S_3 @ (45 kg ha^{-1} and potassium K_3 @ 100 kg ha^{-1}) recorded significantly lowest value (16.07%) for physiological weight loss, significantly lowest value (2.62 %) for sprouting per cent and recorded lowest value (2.27%) for rotting after 4 months of storage as compared to rest of other treatments.Significantly maximum value for physiological weight loss (26.24%), Rotting % (4.17%), and Sprouting % (4.01%) was observed with treatment K_0S_0 treatment as compared to all other treatments.(Table 2 &3).

Integration of sulphur (45 kg ha^{-1}) and potassium (100 kg ha^{-1}) has proved superior as compared to their sole effects.Pooled analysis showed that treatment K_3S_3 (100 kg K S_3 + 45 kg S ha^{-1}) recorded significantly maximum values of plant height (110.55 cm), number of leaves $plant^{-1}$ (23.73) , leaf length, (67.85cm), T.S.S (35.67 °Brix), Pyruvic Acid (51.37 μmol g^{-1}), Protein content (17.23%), for Vitamin C content (14.00 mg 100^{-1}g) besides showed lowest values of physiological weight loss (26.24%), rotting % (4.17%) and sprouting % (4.01%).

This might be possible due to synergistic relationship between sulphur and potassium applications as a result of which thereby increased uptake of N, P, K and S by crop and better translocation of photosynthates from source to sink occurred which improved growth parameters like plant height, no. of leaves $plant^{-1}$, leaf length and quality traits of garlic such as TSS, Vitamin C, protein and pyruvic acid content.The improvement regarding storage qualities could be possible by synergistic relationship between sulphur and potassium and resulted in increased uptake of nutrients like N, P, K and S which enhanced dry matter content of garlic bulbs. The reason may be due to increased synthesis of primary sulphur compounds such as S-allyl cysteine compounds which are positively correlated with keeping quality of bulb as has also been reported by Diriba-Shiferaw (2012) in garlic.Similar findings were reported by researchers like Praminck *et al.* (1999), Poornima (2007) in onion and Nabi *et al.* (2010) and

El Sayed *et al*. (2012) in garlic,Yadav *et al*. (2002) and Verma and Singh (2012) in onion.Similar findings were revealed by authors like Patel *et al*.(2013) in corainder and Kalpana *et al*.(2016) in tomato.

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be distinguished in the text and in the references by letter arranged alphabetically followed by the citation of the years eg. 2004a, 2004b.

Standard abbreviations and units should be used, SI units are recommended. Abbreviations should be defined at first appearance and their use in the title and abstract should be avoided. Generic names of chemical should be used. Genus and species names should be typed in italics.

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