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Influence of Sulphur and Potassium Applications on Yield, Uptake & Economics of Production of Garlic

M. Mudasir Magray[1*], M. A. Chattoo[2], S. Narayan[2], and S. A. Mir[3]

[1]Division of Vegetable sciences SKUASTKASHMIR-190025

[2]Division of Soil sciences SKUASTKASHMIR-190025

[3]Division of Agri-Stastics SKUASTKASHMIR-190025

*Corresponding Author E-mail: muzamilmagary@gmail.com

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ABSTRACT

The present study was conducted to examine the influence of sulphur and potassium applications on yield, uptake and economics of 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 yield, uptake and improved economics of production of garlic.Combined application of sulphur @45 kg ha^{-1}& potassium @ 100 kg ha^{-1} recorded significantly maximum values of equatorial diameter (5.29 cm), polar diameter (4.30 cm), average number of cloves bulb^{-1} (10.85), average clove weight (4.02 g), average bulb weight (41.96 g), total bulb yield (244.03 q ha^{-1}), total marketable yield (220.96) but slightly lower value of neck thickness (1.21cm),uptake of nitrogen (105.29 kg ha^{-1}), Phosphorus (30.84 kg ha^{-1}), potassium (83.90 kg ha^{-1}) and sulphur (38.73kg ha^{-1}). Economics of production of garlic revealed that highest cost of cultivation (Rs. 163087), maximum gross returns (Rs. 901,200), maximum net returns (Rs. 742,272) and maximum cost benefit ratio (5.67 Rs^{-1}) was registered with this treatment.

Key words: *Sulphur,Potassium,Yield,Uptake of nutrients parameters, Economics, Interaction effect.*

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[25]. 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[2]. In Jammu and Kashmir garlic is grown on an area of 540 hactares with a production of 460 metric tones respectively[2].

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} [19].

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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"[18].

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[6].

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"[5].

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[17]. Only a small portion of it becomes available to plants especially under temperate climatic conditions of Kashmir at its various altitudes[28].

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[11]. Continuous removal of S from soils through plant uptake has led to widespread S deficiency and affected soil S budget[3] 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[1].

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[12].

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[15]. 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[14]. Sulphur has a positive effect on vegetable crops[4]. Sulphur is an essential macronutrient and at an optimum concentration accelerates the plant growth[23]. The increased use of sulphur free N and P fertilsers, use of organic manures in small quantities and practically no application of potassium affects the reserves of potassium and sulphur in most of soils of Kashmir valley resulting in depletion of these nutrients thereby limiting the soil productivity[27]. Keeping in view above an investigation was conducted to assess impact of interaction effect of sulphur and potassium on yield, uptake of nutrients and economics of production of garlic

MATERIALS AND METHOD

An investigation was performed at the experimental field of Regional Research Station (RRS) & Faculty of Agriculture (FOA), Wadura, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-Kashmir) to find out the interaction effect of different levels of sulphur and potassium on yield, uptake of nutrients and economics of production 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}) whereas 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

Yield parameters

Yield parameters were recorded after harvesting of crop of ten bulbs by vernier caliper from each plot and mean value was calculated.

Total bulb yield (q ha^{-1}) was calculated from net plot area and weight of bulbs in each plot was recorded and expressed in q ha^{-1}. Based on size of bulbs, marketable yield was calculated from total bulb yield:

Plant analysis

Table 1: Methods employed for the analysis of plant samples

Estimation	Method employed	Reference
Total nitrogen	Micro-Kjeldahl's mehod	Tandon[22]
Total phosphorus	Vanadomolybdate phosphoric acid yellow colour method using spectrophotometer	Tandon[22]
Total potassium	Flame photometer method	Tandon[22]
Total sulphur	Turbidimetric method using spectrophotometer	Tandon[22]

Based on the nutrient concentration in plants the uptake of nitrogen, phosphorus, potassium and sulphur was worked out by multiplying dry matter content (kg ha^{-1}) with respective nutrient concentration (%) in plant samples.

Based on the prevailing prices of inputs at the time of their usage and market price of the produce at the time of their dispatch, the B:C ratio and net profit was worked out using the following formula;

Net profit per ha (Rs. ha^{-1}) = Gross income (Rs. ha^{-1}) **-** Cost of cultivation (Rs. ha^{-1}).

The benefit cost ratio was determined as:

$$\text{Benefit cost ratio} = \frac{\text{Gross returns (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

Statistical analysis

In order to test the significance of results, the experimental data was subjected to statistical analysis as per the standard statistical procedure given by Gomez and Gomez[9]. Levels of significance used for 'F' and 'T' tests were p= 0.05 as given by Fisher[8].

RESULTS AND DISCUSSION

Yield Parameters

Effect of Sulphur

Sole applications of sulphur @ 45 kg ha^{-1} recorded maximum values for bulb yield and related attributes viz., equatorial diameter, polar diameter, average number of cloves $bulb^{-1}$, average clove weight and average bulb weight respectively.

Effect of potassium

Application of potassium (K_3) @ 100 kg ha^{-1} registered maximum values for bulb yield and yield related attributes viz., equatorial diameter, polar diameter, average number of cloves $bulb^{-1}$, average clove weight and average bulb weight but slightly lower values of neck thickness.

Interaction effect

Among integration of sulphur and

potassium K_3S_3 (K_3 @ 100 kg ha^{-1} and S_3 @ 45 kg ha^{-1}) recorded significantly maximum equatorial diameter (5.29 cm), polar diameter (4.30 cm), average number of cloves $bulb^{-1}$ (10.85), average clove weight (4.02 g) and average bulb weight (41.96 g) but slightly lower value for neck thickness (1.21 cm) was registered with same treatment.

Conjugation of K_3 @ 100 kg ha^{-1} and S_3 @ 45 kg ha^{-1} depicted significantly maximum total bulb yield (244.03 q ha^{-1}) and total marketable yield (220.96 q ha^{-1}) viz., Grade A (97.62 qha^{-1}), Grade B (86.74 q ha^{-1}), Grade C (36.61 q ha^{-1}) followed by K_2S_3 treatment as compared to lower potassium and sulphur interactions

Uptake of Nutrients

Significantly maximum values for uptake of N, P, K and S were recorded with sole applications of sulphur @45 kg ha^{-1} and potassium @ 100 kg ha^{-1} (S_3) as compared to rest of other treatments under study but exhibited at par results with K_2S_3 in case of phosphorus uptake during two consecutive seasons. Pooled analysis revealed that interaction of sulphur and potassium proved superior as compared to sole applications of sulphur and potassium in increasing uptake of nutrients viz., N, P, K and S. Treatment K_3S_3 (100 kg ha^{-1} K+45 kg ha^{-1} S) recorded significantly maximum value for uptake of N (105.29 kg ha^{-1}), P (30.84 kg ha^{-1}), K (83.90 kg ha^{-1}) and S (38.73 kg ha^{-1}).

Economics of production of garlic

Economics study revealed that treatment K_3S_3 registered maximum gross returns (Rs. 662,880 ha^{-1}), net returns (Rs. 527,774 ha^{-1}) and highest cost benefit ratio (4.91 Rs^{-1}) followed by K_2S_3 treatment recording gross returns (Rs 639,450. ha^{-1}), net returns (Rs. 504,886 ha^{-1}) and cost benefit ratio (4.75 Rs^{-1}) whereas lowest gross returns (Rs. 321,450 ha^{-1}), net returns (Rs. 193,761 ha^{-1}) and minimum cost benefit ratio (2.52 Rs^{-1}) was recorded with control (K_0S_0) before storage.

After storage of crop for 4 months, economic study revealed that maximum gross returns (Rs. 901,200 ha^{-1}), net returns (Rs. 742,272. ha^{-1}) and highest cost benefit ratio (5.67 Rs^{-1}) were also observed with K_3S_3 treatment followed by K_2S_3 treatment (5.29 Rs^{-1}) whereas lowest gross returns (Rs. 304,100 ha^{-1}), net returns (Rs. 161,875 ha^{-1}) and minimum cost benefit ratio (2.14Rs^{-1}) was recorded with control (K_0S_0).

Table 2: Effect of different levels of sulphur and potassium on neck thickness (cm), equatorial diameter (cm) and polar diameter (cm) of bulbs

	neck thickness (cm)					equatorial diameter (cm)					polar diameter (cm)				
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	0.88	0.94	1.04	1.07	0.98	2.71	3.27	3.70	3.61	3.32	2.29	2.23	2.44	2.93	2.48
K_1	1.04	1.14	1.19	1.17	1.14	2.93	3.41	3.63	4.30	3.57	2.33	2.54	2.50	3.07	2.61
K_2	1.12	1.15	1.23	1.22	1.18	3.06	3.81	3.93	4.86	3.92	2.41	2.81	3.21	3.77	3.05
K_3	1.13	1.19	1.28	1.21	1.19	3.14	4.29	4.29	5.29	4.25	2.71	2.90	3.55	4.30	3.36
Mean	1.04	1.11	1.19	1.18	-	2.96	3.70	3.89	4.52	-	2.43	2.62	2.93	3.52	-
C.D($p \leq 0.05$)															
S			0.017					0.25					0.14		
K			0.017					0.25					0.14		
S x K			0.033					0.50					0.28		

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 average number of cloves bulb^{-1}, average clove weight (g) and average bulb weight (g)

	average number of cloves bulb^{-1}					average clove weight (g)					average bulb weight (g)				
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	6.02	6.14	6.11	7.24	6.32	2.16	2.96	3.00	3.29	2.85	25.89	30.52	34.80	38.07	32.32
K_1	6.08	6.15	6.61	8.51	6.84	2.92	3.02	3.04	3.58	3.13	29.21	34.06	36.13	38.27	34.42
K_2	6.74	6.78	7.13	8.89	7.39	3.03	3.12	3.23	3.74	3.28	31.68	35.83	37.85	41.06	36.61
K_3	6.80	6.83	8.63	10.85	8.28	3.08	3.19	3.42	4.02	3.43	34.20	37.36	40.91	41.96	38.61
Mean	6.42	6.47	7.12	8.87	-	2.80	3.07	3.17	3.66		30.25	34.45	37.42	39.84	-
C.D($p \leq 0.05$)															
S			0.11					0.041					0.88		
K			0.11					0.041					0.88		
S x K			0.22					0.082					1.76		

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 total bulb yield (q ha^{-1}), total marketable yield and uptake of nitrogen (kg ha^{-1}) of garlic

	total bulb yield (q ha^{-1})					total marketable yield (q ha^{-1})					uptake of nitrogen (kg ha^{-1})				
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	136.16	176.48	194.65	228.44	183.77	117.15	151.92	172.68	201.27	160.52	60.96	76.63	82.00	85.15	76.18
K_1	169.23	181.65	199.46	227.80	194.54	143.51	163.56	177.51	205.23	172.45	80.39	86.93	89.32	91.11	86.94
K_2	182.56	192.83	209.87	236.50	205.44	160.53	171.72	185.78	213.15	182.79	82.37	88.12	94.35	99.37	91.05
K_3	198.96	199.73	216.77	244.03	214.87	179.08	179.74	195.65	220.96	193.86	83.81	91.12	98.37	105.29	94.65
Mean	171.73	187.67	205.19	234.20	-	150.07	166.74	182.90	210.15		76.88	85.70	91.01	95.23	-
C.D($p \leq 0.05$)															
S			1.28					1.66					0.86		
K			1.28					1.66					0.86		
S x K			2.56					3.33					1.71		

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 5: Effect of different levels of sulphur and potassium on total uptake of phosphorus (kg ha^{-1}), potassium (kg ha^{-1}) and sulphur (kg ha^{-1})

	uptake of phosphorus (kg ha^{-1})					uptake of potassium (kg ha^{-1})					uptake of sulphur (kg ha^{-1}).				
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	18.67	21.56	25.00	25.12	69.86	51.52	71.78	76.11	79.7	69.86	21.80	23.46	27.08	28.09	25.10
K_1	21.50	24.76	26.85	26.94	74.47	66.90	73.73	76.84	80.43	74.47	23.48	26.75	28.09	33.62	27.98
K_2	23.52	25.27	27.63	28.92	75.71	69.00	74.56	77.94	81.32	75.71	23.97	27.76	31.49	36.42	29.91
K_3	25.19	27.31	28.33	30.84	77.00	69.87	75.44	78.77	83.90	77.00	25.80	28.62	32.70	38.73	31.46
Mean	22.21	24.73	26.95	27.91	-	64.40	73.88	77.42	81.33	-	23.76	26.65	29.84	34.22	-
C.D($p \leq 0.05$)															
S			0.84					0.60					0.82		
K			0.84					0.60					0.82		
S x K			1.68					1.20					1.64		

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 6: Cost of cultivation of garlic (per hectare)

	Preparatory tillage	**Rs. ha^{-1}**
A.	Two ploughings @ Rs. 3000 ha^{-1}	6000.00
	Clod breaking/levelling 30 labours @ Rs.150 labour^{-1}	4500.00
	Total	**10,500.00**
B.	Seed sowing (dibbling method)	
	Seed sowing 15 labours @ Rs.150	2250.00
	Total	**2250.00**
C.	Irrigation (five irrigations)	
	15 labours @ Rs.150	2250.00
	Total	**2250.00**
D.	After care operations	
	10 labours @ Rs.150	1500.00
	Total	**1500.00**
E.	Plant protection measures	2000.00
	Total	**2000.00**
F.	Cultural operations	7500.00
	Three weedings/hoeings 50 labours @ Rs.150	
	Total	**7500.00**
G.	Harvesting	
	20 labours @ Rs.150	3000.00
	Total	**3000.00**
H.	Post harvest management	
	20 labours @ Rs.150	3000.00
	Total (A+B+C+D+E+F+G) = 10,500 + 2250 + 2250 + 1500 +2000 + 7500+ 3000 + 3000	32,000 (working capital)
	Incidental charges @ 5% of the working capital	1012.50
	Total labour component involved in the cost of cultivation (working capital + incidental charge)	33,012.50
	Cost of seed	
	Cost of seed @ Rs.40 for 500 kg of seed required ha^{-1}	20,000.00
	Total	20,000.00
	Variable cost (labour + cost of seed)	**53,012.5**
	Land rent @ Rs.900.00 kanal^{-1}	18,000.00
	Land tax	80.00
	Depreciation on implements @ 5%	904.00
	Total	**18,984.00**
	Interest @ 6.5 on fixed factor	1233.96
	Total fixed cost (18,984 + 1233.96)	**20,217.96**

Table 7: Treatment-wise added cost

Treatment	Cost involved (Rs.)		No. of labourers involved @ Rs. 150 labour^{-1}	Amount involved on labour (Rs.)	Added cost (Rs. ha^{-1})
	Fertilizer	Manure			
T_1 (K_0S_0)	3259.00	50,000	8	1200	54459.00
T_2 (K_1S_0)	4351.00	50,000	10	1500	55851.00
T_3 (K_2S_0)	4884.00	50,000	10	1500	56384.00
T_4 (K_3S_0)	5426.00	50,000	11	1650	57076.00
T_5 (K_0S_1)	4759.00	50,000	10	1500	56259.00
T_6 (K_1S_1)	5851.00	50,000	11	1650	57501.00
T_7 (K_2S_1)	6384.00	50,000	12	1800	58184.00
T_8 (K_3S_1)	6926.00	50,000	12	1800	58726.00
T_9 (K_0S_2)	6259.00	50,000	11	1650	58059.00
T_{10} (K_1S_2)	7351.00	50,000	12	1800	59151.00
T_{11} (K_2S_2)	7884.00	50,000	12	1800	59684.00
T_{12} (K_3S_2)	8,426.00	50,000	13	1950	60376.00
T_{13} (K_0S_3)	7,759.00	50,000	12	1800	59559.00
T_{14} (K_1S_3)	8,851.00	50,000	13	1950	60801.00
T_{15} (K_2S_3)	9,384.00	50,000	13	1950	61334.00
T_{16} (K_3S_3)	9,926.00	50,000	13	1950	61876.00

Rate of fertilizers Rs.Gypsum = 12 kg^{-1}, Mop = 13.00 kg^{-1}, Urea = 5.80 kg^{-1}, DAP = 19 kg^{-1}, FYM =2000 ton^{-1}

Table 8: Treatment-wise comparative economics of cost of cultivation in garlic

Treatment	Fixed cost (Rs. ha^{-1}) (A)	Variable cost (Rs. ha^{-1})	Total Added cost (Rs.ha^{-1})	Total variable cost (Rs. ha^{-1}) (B)	Total cost of cultivation (Rs. ha^{-1}) (A+B)
T_1 (K_0S_0)	20217.96	53,012.50	68995.00	122007.00	142225.00
T_2 (K_1S_0)	20217.96	53,012.50	73114.00	126126.50	146344.00
T_3 (K_2 S_0)	20217.96	53,012.50	74924.00	127936.50	148135.46
T_4 (K_3S_0)	20217.96	53,012.50	78115.00	131127.50	151346.06
T_5(K_0S_1)	20217.96	53,012.50	74153.00	127165.50	147383.00
T_6(K_1S_1)	20217.96	53,012.50	76936.00	129948.50	150166.00
T_7(K_2S_1)	20217.96	53,012.50	77563.00	130575.50	150793.00
T_8(K_3S_1)	20217.96	53,012.50	79665.00	132677.50	152895.00
T_9(K_0S_2)	20217.96	53,012.50	77510.00	130522.50	150740.00
T_{10} (K_1S_2)	20217.96	53,012.50	78964.00	131976.50	152194.46
T_{11} (K_2S_2)	20217.96	53,012.50	80118.00	133130.50	153348.46
T_{12}(K_3S_2)	20217.96	53,012.50	81551.00	134563.50	154781.46
T_{13}(K_0S_3)	20217.96	53,012.50	81904.00	134916.50	155134.00
T_{14}(K_1S_3)	20217.96	53,012.50	83443.00	136455.50	156673.00
T_{15}(K_2S_3)	20217.96	53,012.50	84570.00	137582.50	157800.00
T_{16} (K_3S_3)	20217.96	53,012.50	85698.00	138710.50	158928.00

Total variable cost (Rs. ha^{-1}) = Variable cost (Rs. ha^{-1}) + Added cost (Rs. ha^{-1}), Total cost of cultivation (Rs. ha^{-1}) = Fixed cost (Rs. ha^{-1}) + Total variable cost (Rs. ha^{-1})

Table 9: Cost incurred due to storage for a period of 4 months

Treatment	Pooled marketable yield (q ha^{-1})	Room rent for 4 months (Rs.)	Labour involved (Rs.)	Rent on crates @ Rs. 15 per crate	Total cost incurred (Rs.)
T_1 (K_0S_0)	107.15	3500.00	3000.00	8036.00	14536.00
T_2 (K_1S_0)	143.51	3500.00	3000.00	10763.00	17263.00
T_3 (K_2S_0)	160.53	3500.00	3000.00	12040.00	18540.00
T_4 (K_3S_0)	179.08	3500.00	3000.00	13431.00	19931.00
T_5 (K_0S_1)	151.92	3500.00	3000.00	11394.00	17894.00
T_6 (K_1S_1)	163.36	3500.00	3000.00	12252.00	18752.00
T_7 (K_2S_1)	171.72	3500.00	3000.00	12879.00	19379.00
T_8 (K_3S_1)	179.74	3500.00	3000.00	13481.00	19981.00
T_9 (K_0S_2)	172.68	3500.00	3000.00	12951.00	19451.00
T_{10} (K_1S_2)	177.51	3500.00	3000.00	13313.00	19813.00
T_{11} (K_2S_2)	185.78	3500.00	3000.00	13934.00	20434.00
T_{12} (K_3S_2)	195.66	3500.00	3000.00	14675.00	21175.00
T_{13} (K_0S_3)	201.27	3500.00	3750.00	15095.00	22345.00
T_{14} (K_1S_3)	205.23	3500.00	3750.00	15392.00	22642.00
T_{15} (K_2S_3)	213.15	3500.00	3750.00	15986.00	23236.00
T_{16} (K_3S_3)	220.96	3500.00	3750.00	16572.00	23822.00

Storage rent including room (12 ×18) for 4 months @ 875 per month= 3500 Rs. (10,500 per year).

Table 10: Benefit cost ratio (economics of production of garlic Rs. ha^{-1} after 4 months of storage)

Treatment	Treatment details	Total cost of cultivation (Rs.ha^{-1})	Remaining yield of marketable storage (q ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Return per rupees invested ratio
T_1	(K_0S_0)	142225.00	60.82	304100	161875	2.14
T_2	(K_1S_0)	146344.00	96.78	483900	337556	3.31
T_3	(K_2 S_0)	148135.46	110.47	552350	404195	3.73
T_4	(K_3S_0)	151346.06	124.34	621700	470354	4.11
T_5	(K_0S_1)	147383.00	106.35	531750	384367	3.61
T_6	(K_1S_1)	150166.00	116.69	583450	433289	3.89
T_7	(K_2S_1)	150793.00	124.29	621300	470507	4.12
T_8	(K_3S_1)	152895.00	131.53	657650	504755	4.30
T_9	(K_0S_2)	150740.00	124.89	624450	477710	4.14
T_{10}	(K_1S_2)	152194.46	125.69	628450	476250	4.13
T_{11}	(K_2S_2)	153348.46	135.71	678550	525202	4.42
T_{12}	(K_3S_2)	154781.46	146.60	733000	578219	4.74
T_{13}	(K_0S_3)	155134.00	143.63	718150	563016	4.63
T_{14}	(K_1S_3)	156673.00	149.16	745800	589127	4.76
T_{15}	(K_2S_3)	157800.00	167.03	835150	677350	5.29
T_{16}	(K_3S_3)	158928.00	180.24	901200	742272	5.67

Gross return (Rs. ha^{-1}) = Yield (q ha^{-1}) × cost of garlic (Rate q ha^{-1}), selling price of garlic = 5000 Rs. per quintal
Net return (Rs. ha^{-1}) = Gross return (Rs. ha^{-1}) – Total cost of cultivation (Rs. ha^{-1})
Return per rupees invested ratio (Benefit cost ratio) = Gross return (Rs. ha^{-1})/Total cost of cultivation (Rs. ha^{-1})

Table 11: Benefit cost ratio (economics of production of garlic, Rs. ha^{-1})

Treatment	Treatment details	Total cost of cultivation (Rs.ha^{-1})	Total Mar Yield of (q.ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Return per rupees invested ratio
T_1	(K_0S_0)	127,689.0	107.15	321,450	193,761	2.52
T_2	(K_1S_0)	129,081.0	143.51	430,530	301,449	3.33
T_3	(K_2 S_0)	129,614.0	160.53	481,590	351,976	3.72
T_4	(K_3S_0)	130,306.0	179.08	537,240	406,934	4.12
T_5	(K_0S_1)	129,488.0	151.92	455,760	326,272	3.52
T_6	(K_1S_1)	130,731.0	163.56	490,680	359,949	3.75
T_7	(K_2S_1)	131,413.0	171.72	515,160	383,747	3.91
T_8	(K_3S_1)	131,956.0	179.74	539,220	407,264	4.09
T_9	(K_0S_2)	131,289.0	172.68	518,040	386,751	3.95
T_{10}	(K_1S_2)	132,381.0	177.51	532,530	400,149	4.02
T_{11}	(K_2S_2)	132,914.0	185.78	557,340	424,426	4.19
T_{12}	(K_3S_2)	133,606.0	195.65	586,950	453,344	4.39
T_{13}	(K_0S_3)	132,789.0	201.27	603,810	471,021	4.55
T_{14}	(K_1S_3)	134,031.0	205.23	615,690	481,659	4.59
T_{15}	(K_2S_3)	134,564.0	213.15	639,450	504,886	4.75
T_{16}	(K_3S_3)	135,106.0	220.96	662,880	527,774	4.91

Gross return (Rs. ha^{-1}) = Yield (q ha^{-1}) × cost of garlic (Rate q ha^{-1}),
Selling price of garlic = 3000 Rs. per quintal
Net return (Rs. ha^{-1}) = Gross return (Rs. ha^{-1}) – Total cost of cultivation (Rs. ha).

DISCUSSION

Pooled analysis revealed that combined application of sulphur S_3 (45 kg ha and K_3(100 kg ha^{-1} (K_3S_3) recorded significantly highest values for yield related parameters viz., bulb weight (41.96g), average clove weight (4.02g), average number of cloves bulb^{-1} (10.85 g), polar diameter (4.30 cm), equatorial diameter (5.29 cm) and slightly lower value of neck thickness (1.21 cm) in most parameters followed by K_2S_3 combination as compared to other treatment combinations. Thus interaction effect of sulphur and potassium on yield related parameters proved superior as compared to their sole effects. This might be due to synergistic effect of sulphur and potassium in accumulating and translocating photosynthesis in bulb yield related parameters of garlic. Although marginal decrease in neck thickness was observed due to increase in dry matter content of bulbs. Similar findings have also been reported by Hariyappa[10], Poornima[16] & Verma and Singh[26] in onion.

Pooled analysis revealed that conjugation of sulphur (45 kg ha^{-1}) and potassium (100 kg ha^{-1}) depicted significantly higher total bulb yield (244.03 qt ha^{-1}) and marketable yield (220.96 q ha^{-1}) as compared to rest of other treatments. The per cent increase in K_3S_3 was 79.22 per cent in total bulb yield and 88.60 per cent in marketable yield over control. The interaction effect proved superior as compared to main effects of sulphur and potassium. This might be due to synergistic effect of sulphur and potassium on growth and yield parameters of garlic. Similar findings have been reported by Singh[20] in garlic and Farhad *et al*[7]., in soyabean.

Combined application of sulphur and potassium proved beneficial for enhancing nutrient uptake. Pooled analysis revealed that integration of sulphur and potassium resulted an increase in uptake of nutrients and significantly maximum uptake of N (105.29 kg ha^{-1}), P (30.84 kg ha^{-1}), K (83.90 kg ha^{-1}) and S (38.73 kg ha^{-1}) was recorded with K_3S_3 treatment followed by K_2S_3. The per cent increase for nitrogen uptake (72.72 %), phosphorus uptake (65.18%), potassium uptake (62.85%) and Sulphur uptake (77.66%) was recorded with K_3S_3 treatment over control treatment. This might have been possible due to synergistic effect of sulphur and potassium in augmenting uptake of all nutrients. The better crop vigour and growth due to enhanced nutrient utilization and translocation of photosynthates from source to sink augmenting bulb yield of garlic might be possible reason for increased uptake of nutrients as reported by Poornima[16], Singh *et al*[21]., in Brown sarson & Verma and Singh[26] in onion.

Economics of production of garlic before storage revealed that maximum gross returns (Rs. 662,880 ha^{-1}), net returns (Rs 527,774. ha^{-1}) and highest cost benefit ratio (4.91 Rs^{-1}) were registered with K_3S_3 treatment followed by K_2S_3 treatment (4.75 Rs^{-1}) whereas lowest gross returns (321,450 Rs ha^{-1}), net returns (193,761 Rs. ha^{-1}) and lowest cost benefit ratio (2.52 Rs^{-1}) were recorded with control (K_0S_0).

After storage of crop for 4 months' economic study revealed that maximum gross returns (901,200 Rs ha^{-1}), net returns (742,272 Rs. ha^{-1}) and highest cost benefit ratio (5.67 Rs^{-1}) were recorded with K_3S_3 treatment followed by K_2S_3 treatment (5.29 Rs^{-1}) whereas lowest gross returns (304,100 Rs ha^{-1}), net returns (161,875 Rs. ha^{-1}) and lowest cost benefit ratio (2.14 Rs^{-1}) was depicted with control (K_0S_0). Treatment K_3S_3 registered an increase of 78.19 per cent of net returns over control. The results of economic study might be due to higher bulb yield and marketable yield associated with K_3S_3 (45 kg S ha^{-1} + 100 kg K ha^{-1}) followed by K_2S_3 (45 kg S ha^{-1} + 75 kg K ha^{-1}) whereas lowest total bulb yield and lowest marketable yield was associated with control treatment (K_0S_0). Our results are in line with those of Mozumder *et al*[13]., & Poornima[16], Ullah *et al*[24]., in onion, Zaman *et al*[29]., in garlic and Singh *et al*[21]., in potato.

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