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Influence of nitrogen and sulphur nutrition on growth and yield of garlic (*Allium sativum* L.)

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ABSTRACT

The experiment was carried out at Horticultural Research Station, Mondouri, BCKV during the rabi (winter) season of two consecutive years i.e. 2009-10 and 2010-11. In both the years, big to medium size cloves cv. Katki were planted during middle of October, in 2.0 m x 1.5 m plots, at 20 x 15 cm spacing accommodating 100 plants per plot. The experiment with four levels of sulphur (0, 20, 40 and 60 kg ha^{-1}) and five levels of nitrogen (50, 100, 150, 200 and 250 kg ha^{-1}) was laid out in split plot design with 3 replications assigning sulphur levels in main plot and nitrogen levels in sub-plots.The maximum plant height (76.16 cm), leaf number (11.96), equatorial diameter (3.92 cm), and number of cloves per bulb (34.27) were observed with $S_{60}N_{250}$. But the plants grown under $S_{60}N_{200}$ interaction recorded widest leaf (1.52 cm), maximum polar diameter (3.67 cm), weight of bulb (33.68 g), yield per plot (3.00 kg per 3m^2), projected yield (7.50 t ha^{-1}), maximum net return (Rs. 1,48,038/-) and B : C ratio (1.92). The minimum plant height (50.72 cm), leaf number (7.32), weight of bulb (19.15 g), projected yield (4.23 t/ha), net return (Rs. 52,736/-) and B:C ratio (0.71) were observed under S_0N_{50} treatment. From yield maximization and B:C ratio point of view 60 kg S ha^{-1} and 200 kg N ha^{-1} was found best when applied with 125 kg P_2O_5 and 150 kg K_2O ha^{-1}.

***Keywords*:** B:C ratio, garlic, nitrogen, sulphur

Garlic (*Allium sativum* L.) belongs to the family Alliaceae and is the second most widely used *Allium* next to onion (Rubatzky and Yamaguchi, 1997). It is highly accepted for its flavour enhancing capacity. It is widely used in Indian system of medicines (Ayurvedic, Unani and Siddha). Garlic possesses anti-microbial (Lawson and Hughes, 1991), anti-carcinogenic (Nitsche and Merz, 1962) and antimutagenic (Ishikawa *et al*., 1996) properties. Garlic is reported to act as antioxidant. It also reduces the levels of lipids, cholesterol and sugar in blood due to presence of *allicin.*

Garlic's volatile oil has many sulphur containing compounds that are responsible for the strong odour, its distinctive flavour and pungency as well as for its health benefit. It is a sulphur loving plant and sulphur is the fourth major nutrient for plants (Platan and Jennes, 1982). Insufficiency of sulphur is known to hamper N-metabolism and synthesis of S-containing amino acids and thus exerts adverse effects on both yield and quality of crop. Keeping this in view, the present investigation was undertaken to find out the effect of nitrogen and sulphur on growth and yield of garlic.

MATERIALS AND METHODS

The present investigation was carried out during the *rabi* (winter) season of two consecutive years *i.e.,* 2009-2010 and 2010-2011 at the Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The research station was located at 23.5º N latitude and 89º E longitude, with an altitude of 9.75 m above the mean sea level. The experimental plots have sandy clay loam soil with pH 6.9, organic carbon 0.63%, total nitrogen 0.084%, available phosphorus 18.07 kg ha^{-1}, available potassium 194.49 kg ha^{-1} and available sulphur 14.5 kg ha^{-1}. In both the years, big to medium size cloves cv. Katki were planted during middle of October, in 2.0 m x 1.5 m plots, at 20 x 15 cm spacing accommodating 100 plants per plot. The experiment with four levels of sulphur (0, 20, 40 and 60 kg/ha) and five levels of nitrogen (50, 100, 150, 200 and 250 kg ha^{-1}) was laid out in split plot design with 3 replications assigning sulphur levels in main plot and nitrogen levels in sub-plots. The doses of fertilizers were adjusted with the application of urea, single super phosphate, diammonium phosphate and muriate of potash. All the plots were received uniform dose of P and K at the rate of 125 kg P_2O_5 and 150 kg K_2O per hectare. Different doses of nitrogen in the treatments were given in 3 split doses , one third applied with full dose of phosphate, potash and sulphur and the remaining two third at 40 and 60 days after planting in two equal splits. Harvesting was done during the end of March in both the year. The observations on vegetative parameters were recorded at 120 days after planting from five

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randomly selected plants. The projected yield per hectare was calculated on the basis of yield per plot, considering 75% area occupied by garlic.

RESULTS AND DISCUSSION

The pooled data presented in table 1, showed the significant variations in case of individual effect but not in interactions in respect of plant height. The increasing trend of plant height was observed (59.01 cm – 67.15 cm) with the increasing level of sulphur *i.e.* from zero to 60 kg ha^{-1} but in case of nitrogen plant height increased from 53.98 cm to 69.14 cm with the increasing level from 50 kg ha^{-1} to 200 kg ha^{-1} and thereby decreased. The maximum plant height was recorded in S_{60} N_{250} (74.16 cm) followed by S_{60} N_{200} (72.25 cm) and S_{40} N_{250} (71.68 cm) as compared to lowest height under S_0N_{50} (50.72 cm) combination.

Table 1: Effect of sulphur and nitrogen on growth and yield of garlic (Pooled of two years)

Treatment	Plant height (cm)	Number of leaves	Breadth of leaves (cm)	Diameter of bulb (cm)		Weight of bulb (g)	Number of cloves per bulb	Plot yield Kg per 3 m^2	Projected yield (t ha^{-1})
				Polar	Equatorial				
S_0	59.01	8.66	1.32	3.32	3.42	22.46	23.61	2.02	5.06
S_{20}	60.90	9.22	1.38	3.36	3.50	23.42	24.75	2.15	5.29
S_{40}	64.54	9.76	1.40	3.40	3.55	26.30	26.20	2.39	5.97
S_{60}	67.15	10.77	1.42	3.47	3.70	29.22	30.77	2.61	6.51
SEm (±)	**0.635**	**0.073**	**0.023**	**0.043**	**0.012**	**0.444**	**0.645**	**0.034**	**0.108**
LSD(0.05)	**1.957**	**0.225**	**NS**	**NS**	**0.037**	**1.368**	**1.987**	**0.105**	**0.333**
N_{50}	53.98	8.15	1.30	2.87	2.98	19.23	24.09	1.71	4.80
N_{100}	60.39	9.36	1.34	2.92	3.10	20.95	25.09	1.86	5.25
N_{150}	62.12	9.41	1.39	3.02	3.13	22.38	26.48	2.07	5.83
N_{200}	69.14	10.44	1.45	3.16	3.24	25.15	28.27	2.28	6.37
N_{250}	68.86	10.67	1.43	3.08	3.29	24.96	27.73	2.26	6.30
SEm (±)	**0.956**	**0.112**	**0.031**	**0.035**	**0.016**	**0.326**	**0.459**	**0.029**	**0.048**
LSD(0.05)	**2.704**	**0.317**	**0.088**	**0.099**	**0.045**	**0.922**	**1.298**	**0.082**	**0.238**
S_0N_{50}	50.72	7.32	1.21	3.12	3.25	19.15	22.16	1.69	4.23
S_0N_{100}	58.34	8.78	1.27	3.24	3.38	20.64	22.84	1.84	4.60
S_0N_{150}	55.14	8.24	1.36	3.36	3.47	22.75	23.27	2.08	5.20
S_0N_{200}	66.53	9.15	1.40	3.42	3.43	24.42	25.12	2.15	5.38
S_0N_{250}	64.30	9.83	1.36	3.44	3.56	25.34	24.65	2.36	5.90
$S_{20}N_{50}$	53.21	8.14	1.30	3.18	3.32	20.32	22.95	1.81	4.53
$S_{20}N_{100}$	59.26	8.67	1.36	3.29	3.47	21.78	23.16	1.97	4.93
$S_{20}N_{150}$	58.17	9.15	1.44	3.42	3.45	23.42	24.52	2.14	5.35
$S_{20}N_{200}$	68.55	9.84	1.44	3.51	3.56	23.74	27.94	2.27	5.68
$S_{20}N_{250}$	65.30	10.32	1.37	3.38	3.68	27.86	25.16	2.57	5.95
$S_{40}N_{50}$	55.18	7.96	1.29	3.29	3.38	22.93	24.32	2.03	5.08
$S_{40}N_{100}$	61.24	9.63	1.38	3.26	3.52	25.04	25.96	2.17	5.43
$S_{40}N_{150}$	65.36	9.48	1.40	3.38	3.48	24.62	25.72	2.42	6.05
$S_{40}N_{200}$	69.24	11.16	1.44	3.61	3.75	31.35	28.16	2.77	6.93
$S_{40}N_{250}$	71.68	10.56	1.48	3.47	3.63	27.57	26.82	2.55	6.38
$S_{60}N_{50}$	56.82	9.16	1.37	3.32	3.46	24.12	26.94	2.15	5.38
$S_{60}N_{100}$	62.70	10.35	1.35	3.36	3.59	26.80	28.38	2.41	6.03
$S_{60}N_{150}$	69.82	10.75	1.37	3.44	3.68	29.92	32.42	2.68	6.70
$S_{60}N_{200}$	72.25	11.62	1.52	3.67	3.84	33.68	31.85	3.00	7.50
$S_{60}N_{250}$	74.16	11.96	1.50	3.58	3.92	31.56	34.27	2.79	6.97
SEm (±)	**1.912**	**0.224**	**0.062**	**0.069**	**0.032**	**0.651**	**0.919**	**0.059**	**0.169**
LSD(0.05)	**NS**	**0.633**	**NS**	**NS**	**0.090**	**1.841**	**NS**	**0.167**	**0.486**

In respect of leaf number, the significant variations were observed in sole effect of both nutrients and their interactions also. The leaf number increased with the increasing level of both sulphur and nitrogen. The leaf number increased from 8.66 – 10.77 and 8.15 – 10.67 with S_0 – S_{60} and N_{50} – N_{250} respectively. In different combinations of sulphur and nitrogen the maximum leaf number of 11.96 was noticed in $S_{60}N_{250}$ followed $S_{60}N_{200}$ (11.62) and $S_{40}N_{200}$ (11.16) as compared to minimum number of leaves under S_0N_{50} (7.32). In case of individual effect of sulphur the leaf breadth increased from 1.32 cm to 1.42 cm with the increasing dose from zero to 60 kg ha^{-1} but for nitrogen the breadth increased from 1.30 cm to 1.45 cm with 50 kg ha^{-1} to 200 kg ha^{-1}. As per interaction, maximum leaf breadth was noticed with S_{60} N_{200} (1.52 cm) and minimum breadth with S_0N_{50} (1.21 cm) combination.

In response of polar diameter, significant variations were observed only in sole effect, not in interaction. The diameter increased from 3.32 cm to 3.47 cm with the increasing level of sulphur from zero to 60 kg/ha but the diameter increased from 2.87 cm to 3.16 cm when N level increased from 50 kg ha^{-1} to 200 kg ha^{-1}. Among the interactions, higher values were recorded with higher level of sulphur and nitrogen. But in case of equatorial diameter, significant variations observed both in individual effect and interaction. The diameter increased from 3.42 cm to 3.70 cm with increase in sulphur level from zero to 60 kg ha^{-1} and increased from 2.98 cm to 3.29 cm with the increase in N level from 50 kg ha^{-1} to 250 kg ha^{-1}. Among the interactions, the higher levels of sulphur along with higher levels of nitrogen generally produced bulb with more equatorial diameter. The

Table 2: Effect of sulphur and nitrogen on economics of garlic production (Mean)

Treatment	Cost of production (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit : cost ratio
S_0	75416.00	151860	76444.00	1.01
S_{20}	75989.40	154874	78884.20	1.04
S_{40}	76118.60	179220	103101.00	1.35
S_{60}	76473.04	195420	118947.00	1.55
N_{50}	74590.75	144113	69521.80	0.93
N_{100}	75533.00	157425	81892.00	1.08
N_{150}	76050.50	170042	93991.50	1.24
N_{200}	76677.75	191175	114497.00	1.49
N_{250}	77144.31	188963	111818.00	1.45
S_0N_{50}	74164.00	126900	52736.00	0.71
S_0N_{100}	74577.00	138000	63423.00	0.85
S_0N_{150}	75311.00	156000	80689.00	1.07
S_0N_{200}	76282.00	161400	85118.00	1.12
S_0N_{250}	76746.00	177000	100254.00	1.31
$S_{20}N_{50}$	74256.00	135900	61644.00	0.83
$S_{20}N_{100}$	75705.00	147900	72195.00	0.95
$S_{20}N_{150}$	76181.00	141668	65487.00	0.86
$S_{20}N_{200}$	76662.00	170400	93738.00	1.22
$S_{20}N_{250}$	77143.00	178500	101357.00	1.31
$S_{40}N_{50}$	74419.00	152400	77981.00	1.05
$S_{40}N_{100}$	75849.00	162900	87051.00	1.15
$S_{40}N_{150}$	76234.00	181500	105266.00	1.38
$S_{40}N_{200}$	76805.00	207900	131095.00	1.71
$S_{40}N_{250}$	77286.00	191400	114114.00	1.48
$S_{60}N_{50}$	75524.00	161250	85726.00	1.14
$S_{60}N_{100}$	76001.00	180900	104899.00	1.38
$S_{60}N_{150}$	76476.00	201000	124524.00	1.63
$S_{60}N_{200}$	76962.00	225000	148038.00	1.92
$S_{60}N_{250}$	77402.22	208950	131548.00	1.70

Note: Cost of inputs: *Seed bulb (HYV): Rs. 60.00 kg^{-1}; Seed bulb (Local): Rs. 50.00 kg^{-1}; FYM: Rs. 700.00 ton^{-1}; Labour: Rs. 81.00 day^{-1}; Urea: Rs. 5.80 kg^{-1}; SSP: Rs. 3.80 kg^{-1}; MOP: Rs. 5.40 Kg^{-1}; DAP: Rs. 10 Kg^{-1}.* ***Selling price of garlic :*** *Rs. 30.00 kg*

maximum diameter was recorded with $S_{60}N_{250}$ (3.92 cm) followed by $S_{60}N_{200}$ (3.84 cm) and $S_{40}N_{200}$ (3.75 cm) combination as compared to minimum diameter in S_0N_{50} (3.25 cm).

In case of bulb weight the significant variations were observed both in individual and interaction effects. The bulb weight increased from 22.46 g to 29.22 g with increasing level of sulphur (0 to 60 kg ha^{-1}) and increased from 19.23 g to 25.15 g with increasing N level from 50 kg ha^{-1} to 200 kg/ha. In interactions, the response of nitrogen was observed upto 250 kg ha^{-1} with zero and 20 kg ha^{-1} sulphur but with rest two levels of sulphur (S_{40} and S_{60}), nitrogen upto 200 kg ha^{-1} exhibited the positive response. The maximum bulb weight was recorded in $S_{60}N_{200}$ (33.68 g) followed by $S_{60}N_{250}$ (31.56 g) and $S_{40}N_{200}$ (31.35 g) as compared to least bulb weight in S_0N_{50} (19.15 g).

The number of cloves per bulb varied significantly with individual effects only. The clove number increased from 23.61 to 30.77 with increased level of sulphur from zero to 60 kg ha^{-1}. The increasing level of nitrogen from 50 kg ha^{-1} to 200 kg ha^{-1} caused increase in number from 24.09 to 28.27. In interactions, nitrogen levels with S_0, S_{20} and S_{40}, clove number generally increased upto 200 kg ha^{-1} and further increase of nitrogen level caused reduction in number. The maximum number of cloves was noticed in $S_{60}N_{250}$ (34.27) followed by $S_{60}N_{150}$ (32.42) as compared to minimum number (22.16) in S_0N_{50} combination.

Perusal of data presented in table 1, clearly demonstrated that plot yield varied significantly in individual effects of nutrients and in interactions. The positive response of sulphur was noticed upto its highest level (60 kg ha^{-1}) but increasing trend in yield was recorded upto 200 kg N ha^{-1}. Plot yield increased from 2.02 kg per $3m^2$ to 2.61 kg per $3m^2$ and 1.71 kg per $3m^2$ to 2.28 kg per $3m^2$ with increasing level of sulphur from zero to 60 kg ha^{-1} and nitrogen from 50 kg ha^{-1} to 200 kg ha^{-1}. In interactions, maximum plot yield of 3.00 kg per $3m^2$ was recorded in $S_{60}N_{200}$ combination followed by $S_{60}N_{250}$ (2.79 kg per $3m^2$) and $S_{40}N_{200}$ (2.77 kg ha^{-1}), though the later two combinations were *at par*. The minimum yield of 1.69 kg per $3m^2$ was recorded in S_0N_{50} combination.

Similar trend of effect like plot yield was reflected in projected yield also. In sole effects, the maximum yield of 6.51 t ha^{-1} was recorded with 60 kg S ha^{-1} but nitrogen at the rate of 200 kg ha^{-1} gave highest yield of 6.37 t ha^{-1}. In case of interactions the maximum yield of 7.50 t ha^{-1} was recorded in $S_{60}N_{200}$ followed by $S_{60}N_{250}$ (6.97 t ha^{-1}) and $S_{40}N_{200}$ (6.93 t ha^{-1}). The lowest yield was recorded with S_0N_{50} (4.23 t ha^{-1}).

The findings obtained from table 2, indicated the marked variations among treatments in respect of cost of cultivation, gross and net return and B:C ratio. The maximum cost of production was recorded in $S_{60}N_{250}$ (Rs. 77,402.22) followed by $S_{40}N_{250}$ (Rs. 77,286.00) and $S_{20}N_{250}$ (Rs. 77,143.00) as compared to lowest cost of production in S_0N_{50} (Rs. 74,164.00) combination. The highest gross return was associated with $S_{60}N_{200}$ (Rs. 2,25,000.00) followed by $S_{60}N_{250}$ (Rs. 2,08,950.00) and $S_{40}N_{200}$ (Rs. 2,07,900.00) as compared to lowest return in S_0N_{50} (Rs. 1,26,900.00).

In case of net return, the maximum value of Rs. 1,48,038.00 was registered under $S_{60}N_{200}$ combination followed by $S_{40}N_{200}$ (Rs. 1,31,548.00) and $S_{40}N_{200}$ (Rs. 1,31,095.00) against lowest net return in S_0N_{50} (Rs. 52,736.00). Highest B:C ratio was noticed in $S_{60}N_{200}$ (1.92) followed by $S_{40}N_{200}$ (1.71) and $S_{60}N_{250}$ (1.70) as compared to lowest B:C ratio in S_0N_{50} (0.71).

Significantly more plant height, number of leaves per plant, weight of bulb, polar and equatorial diameter of bulb were observed upto 60 kg S ha^{-1}. The increase in growth characters with the application of sulphur might be due to its use in the manufacture of chlorophyll (Nagaich *et al.*, 1999). The results are in conformity with those of Farooqui *et al.* (2009). The application of 200 kg N h^{-1} a significantly increased the growth attributes like plant height, leaf number, breadth of leaf and yield parameters like bulb weight, number of cloves per bulb, diameter of bulb and yield. The findings of this investigation are in close conformity with those of Naruka and Dhaka (2001), Yadav (2003) and Farooqui *et al.* (2009). Availability of nitrogen is of prime importance for growing plants as it is major and indispensable constituent of protein and nucleic acid molecules. An adequate supply of nitrogen is associated with vigorous vegetative growth and more efficient use of available inputs finally leading to higher productivity.

In our experiment, we got the response of nitrogen upto 200 kg N ha^{-1} and adverse effect of higher dose of nitrogen *i.e.,* 250 kg ha^{-1} has been observed. The adverse effect of N beyond 150 Kg N ha^{-1} also reported by Buwalda and Frederikson (1985) and Ruiz (1986). Response of garlic to higher dose of nitrogen also reported from different parts of the world. Maksoud *et al.* (1984) from Egypt also reported significant

favourable effects of nitrogen application on yield. These workers observed that the addition of N at 360 kg ha^{-1} increased the yield of cured marketable bulbs from 12.4 to 20.5 t ha^{-1}. In Chile, Ruiz (1986) reported that increasing rate of applied nitrogen from 0 to 150 kg ha^{-1} increased bulb yield from 4.6 to 10.6 t ha^{-1}. From yield maximization and B:C ratio point of view 60 kg S ha^{-1} and 200 kg N ha^{-1} was found best when applied with 125 kg P_2O_5 and 150 kg K_2O ha^{-1}.

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