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Effect of row spacing and nitrogen fertilization on growth, yield and composition of bulb in garlic *(Allium sativum* L.*)* cultivars

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Abstract

The field experiment to study the effect of row spacing and nitrogen fertilization on growth, yield and composition of bulb in garlic cultivars was conducted during *rabi* in 1998-99 and 1999-2000. All growth parameters, yield attributing traits, bulb yield and contents of the bulb increased significantly with the increasing level of nitrogen application and row spacing and these were maximum with nitrogen application of 200 kg ha^{-1} and a row spacing of 15 cm. However, the T.S.S. was higher in closer row spacing (10 cm). The cultivar, Jajavar local was significantly superior over the other two cultivars in all these characters. The interaction studies showed that the treatment combination of $N_4 S_2 V_2$. (Nitrogen @ 200 kg ha^{-1}, row spacing of 15 cm and cultivar Jajavar local) gave higher bulb yield (128 q ha^{-1}) with maximum net returns (Rs 77,236 ha^{-1}) and a B : C ratio (3.06:1).

Key words: *Allium sativum,* bulb contents, garlic, row spacing, nitrogen fertilization.

Introduction

Garlic (*Allium sativum* L.) is an important bulb crop next to onion. The cloves of garlic bulb are used in flavouring foods and in preparing chutneys, pickles, curry powder, tomato ketchuph etc. Garlic has higher nutritive value than other bulb crops. Although the crop is commercially important, its cultivation is handicapped by several factors and the yields are low. Among the cultural practices, nutrient supply and row spacing are of greater significance in garlic productivity. It is evident that among all the major plant nutrients found in various soils, nitrogen is the most deficient element, especially in coarse textured sandy soils (Arakery *et al.*1956) and nitrogen fertilization helps in increasing production and quality of the bulb crops (Singh & Tewari 1968; Singh *et al.* 1969; Maurya & Bhuyan 1982).

Spacing between rows of plants is another factor that affects the growth and yield of the crop. Evapotranspiration and weed infestation were found high in the crop grown with wider spacing and hence it is necessary to grow the crop at optimum spacing (Rahman & Talukdar 1986). Taking these into account, experiments were conducted to evaluate the effect of row spacing and nitrogen fertilization on yield and contents of bulb in three cultivars of garlic.

Materials and methods

The experiment was conducted at Horticulture Farm, S.K.N. College of Agriculture, Jobner during *rabi* season in 1998-99 and 1999-2000. The climate of Jobner is typically semi-arid,

with an average annual rainfall of about 500 mm. The soil of the experimental site was loamy sand, slightly alkaline, poor in organic carbon with low available N, P and S and medium in K status. The experiment was designed in a 4 x 2 x 3 factorial layout with four levels of nitrogen (N_1-50, N_2-100, N_3-150 and N_4-200 kg ha^{-1}) and two row spacings (S_1-10 cm and S_2-15 cm) and 7.5 cm between plants and three cultivars (V_1-Yamuna safed, V_2-Jajavar local and V_3-Mathani local) with four replications. The treatments were randomly allotted to different plots using Random Number Table of Fisher & Yates (1963). A basal dose of 60 kg P_20_5 and 60 kg k_20 ha^{-1} and 1/3 of nitrogen as per treatment was drilled at 5-7 cm deep through hand plough. Remaining dose of nitrogen was applied in two equal splits at 30 and 45 days after sowing with irrigation water. Cloves (8-10 mm diameter) were dibbled at 5.0-7.5 cm deep, keeping their distal ends upwards and covered with thin layer of soil. First irrigation was given just after sowing and subsequent irrigations were given at 10 day intervals. Observations on the growth parameters namely, plant height, number of leaves per plant, chlorophyll content of leaves and fresh weight of leaves were recorded at 100 days after sowing. At harvest, yield parameters namely, maturity period, neck thickness of bulb, bulb diameter, fresh weight of bulb, number of cloves per bulb, weight of 20 cloves, bulb yield and harvest index were recorded.

The T.S.S. percent of bulb was determined with the help of hand refractometer. Protein content of bulb was calculated by multiplying percent nitrogen content in bulb with the factor 6.25 (A.O.A.C. 1960). Nitrogen content of bulb was estimated by the method suggested by Snell & Snell (1939), phosphorus content by the method of Jackson (1967), potassium content by flame photometric method (Jackson 1967), sulphur content by turbidometirc method (Tabatabai & Bremner 1970), essential (volatile) oil content using essential oil distillation assembly (A.O.A.C. 1970) and ascorbic acid content by the method advocated by A.O.A.C. (1960). The data were subjected to statistical analysis and the economics and benefit cost ratio were also calculated.

Results and discussion

The data recorded on growth attributes are presented in table 1. The results showed that the growth parameters were affected by nitrogen level and were significantly higher at higher nitrogen level N_4 (200 kg ha^{-1}). However, the crop matured early with low level of nitrogen N_1 (50 kg ha^{-1}). This may be attributed to better nutritional environment in the root zone as well as in the plant system. The response to nitrogen fertilization in terms of overall improvement in growth parameters is further supported by the fact that the soil of experimental field was low in nitrogen status and its early supply corrected the deficiency and improved overall crop growth considerably. This result agrees with the findings of Buwalda (1986), Pal & Pandey (1986), Borabash & Kochina (1987) and Grad *et al.* (1993) who reported that growth parameters increased significantly with the nitrogen fertilization.

The growth parameters varied significantly, except number of leaves per plant in the cultivars tested (Table 1). The mean maximum plant height (52.19 cm), chlorophyll content of leaves (1.046 mg g^{-1}) and fresh weight of leaves per plant (26.35 g) were recorded in cultivar Jajavar local. The number of days for maturity was lowest in cultivar Yamuna safed.

The results further indicated that the cultivars differed significantly in the composition of the bulb. The mean maximum nitrogen (3.33 %), phosphorous (0.37 %), potassium (0.73 %), sulphur (1.39 %), T.S.S. (33.03 %), moisture (55.95 %), protein (20.85 %), ascorbic acid (13.88 %) and volatile oil (0.65 %) content of garlic bulb were recorded in cultivar Jajavar local.

The positive influence of nitrogen fertilization on N, P, K and S contents of the bulb appears to be due to improved nutritional environment both in the root zone and the plant system. Increased availability of nutrients in the root zone coupled with increased metabolic activity at the cellular level might have increased the

Table 1. Effect of nitrogen, row spacing and cultivars on growth, yield and yield attributes in garlic (Pooled data of two years)

Treatment	Plant height (cm)	No. of leaves plant^{-1}	Chlorophyll content of leaves (mg g^{-1})	Fresh weight of leaves plant^{-1} (g)	Maturity period (days)	Neck thickness of bulb (cm)	Diameter of bulb (cm)	Fresh weight of bulb (g)	No. of cloves bulb^{-1}	Weight of 20 cloves (g)	Bulb yield hectare^{-1} (Q)	Harvest index (%)
Nitrogen												
N_1	38.05	8.02	0.617	16.02	154.00	0.73	3.52	21.45	22.91	15.58	88.75	56.25
N_2	50.01	9.48	0.940	23.93	158.91	0.91	3.75	29.32	31.16	25.33	106.25	60.80
N_3	56.06	9.62	1.198	28.46	162.58	1.04	3.85	36.00	35.83	28.58	119.58	68.54
N_4	56.15	9.68	1.269	29.57	169.00	1.07	4.0	36.93	37.41	29.41	124.83	69.80
SEm ±	0.195	0.134	0.004	0.164	0.117	0.008	0.032	0.159	0.074	0.113	0.286	0.163
CD 5%	0.558	0.382	0.011	0.469	0.335	0.022	0.092	0.454	0.212	0.324	0.817	0.465
Row Spacing												
S_1	49.48	9.15	0.992	27.07	160.87	0.91	3.75	30.12	30.66	23.87	113.16	65.80
S_2	50.65	9.25	1.020	24.92	161.37	0.97	3.88	31.73	33.00	25.58	106.54	61.90
SEm ±	0.138	0.095	0.003	0.116	0.183	0.005	0.022	0.112	0.052	0.080	0.202	0.115
CD 5%	0.395	NS	0.008	0.332	NS	0.016	0.062	0.321	0.150	0.229	0.578	0.329
Cultivar												
V_1	47.71	9.09	0.961	22.51	158.68	0.91	3.76	29.31	29.81	22.68	105.68	63.27
V_2	52.19	9.30	1.046	26.35	164.12	0.97	3.87	32.32	34.00	26.81	114.00	67.15
V_3	50.30	9.21	1.011	24.61	160.56	0.94	3.81	31.14	31.68	24.68	109.87	61.13
SEm ±	0.221	0.130	0.004	0.055	0.289	0.004	0.018	0.076	0.111	0.138	0.092	0.074
CD 5%	0.624	NS	0.012	0.156	0.819	0.011	0.051	0.216	0.314	0.390	0.261	0.210

nutrients uptake and accumulation in the vegetative plant parts, which improved metabolism and greater translocation of these to reproductive organs (bulb) of the crop. The increase in N, P, K and S contents were also observed by Bhati *et al.* (1988) in fennel. Since protein content of bulb is essentially a manifestation of nitrogen content, application of nitrogen significantly increased the yield of volatile oil. The increase in volatile oil with the increase in nitrogen application was also reported in fennel (Bhati *et al.* 1989).

Ascorbic acid, T.S.S. and moisture content significantly increased with nitrogen fertilization. Application of nitrogen helps in vigorous vegetative growth and imparted deep green colour to the foliage, which favoured photosynthetic activity of the plants, resulting in greater accumulation of food material i.e. carbohydrates in the bulb due to more synthesis of ascorbic acid, T.S.S. and moisture contents. A similar trend was also reported by Verma *et al.* (1996) in garlic.

Increase in the level of nitrogen significantly increased the yield and yield attributing traits of the garlic (Table 1). The mean maximum neck thickness of bulb (1.076 cm), diameter of bulb (4.02 cm), fresh weight of bulb (36.93 g), number of cloves per bulb (37.41), weight of 20 cloves (29.41 g), bulb yield per hectare (124.83 q) and harvest index (69.80 %) were recorded with higher level of nitrogen N_4 (200 kg ha^{-1}). The present trend of increase in bulb yield with application high level of nitrogen is in close conformity with the findings of Cardenas (1986), Gunadi & Asandhi (1986), Pal & pandey (1986) and Kumar & Singh (1996). It is also evident that row spacing significantly affected the yield and yield attributes. The mean maximum neck thickness of bulb (0.973 cm), diameter of bulb (3.88 cm), fresh weight of bulb (31.73 g), number of cloves per bulb (33.00) and weight of 20 cloves (25.58 g) were recorded in wider row spacing (15 cm), while the mean maximum bulb yield per hectare (113.16 q) and harvest index (65.80 %) were recorded with the closer row spacing (10 cm).

Results showed that yield attributing parameters increased at wider row spacing. This might have been due to less number of plants in a given area with low competition for nutrients and sunlight, increasing food assimilatory efficiency and thereby more food reserve in bulbs thereby increasing neck thickness, bulb diameter, fresh weight of bulb, number of cloves per bulb and weight of 20 cloves. The results obtained are in close conformity with the findings of Nieuwhof (1969), Janseen (1983) and Sande & Jaurissen (1986) who reported that the size and weight of knobs in knol knol decreased with increasing the plant density. Decrease in head size in cabbage at closer spacing was observed by Lawande *et al.* (1986). By increasing the row spacing, bulb yield per hectare and harvest index decreased significantly. It was perhaps due to reduction in number of bulbs harvested in a given area. These results agree with the findings of Rahman & Das (1985), Rahman & Talukdar (1986), Pandey *et al.* (1992), Garcia *et al.* (1992) and Singh *et al.* (1995).

The results further indicated significant differences in the yield and yield attributes in various cultivars. The mean maximum neck thickness (0.971 cm), diameter of bulb (3.87 cm), fresh weight of bulb (32.32 g), number of cloves per bulb (34.00), weight of 20 cloves (26.81 g), bulb yield per hectare (114.00 q) and harvest index (67.15 %) were recorded in cultivar Jajavar local.

Thus the cultivar Jajavar local was significantly superior to cultivar Mathani local and Yamuna safed with respect to growth, yield and yield attributing traits. This might be due to difference in their genotypic potential and adaptability to soil and climate. The higher value for growth parameters recorded in cultivar Jajavar local might be one of the reasons as these parameters contribute directly or indirectly towards yield and yield attributing characters. Such differential behaviour in garlic cultivars was also reported by Singh *et al.* (1988) and Pandey (1996).

The data on the composition of garlic bulbs are presented in table 2. The bulb composition was significantly affected by the nitrogen level. The mean maximum nitrogen (3.49 %), phosphorous (0.40 %), potassium (0.76 %), sulphur (1.44 %), T.S.S (33.04 %), moisture content (61.45 %), protein (21.86 %), ascorbic acid (13.11 mg/100 g pulp) and volatile oil content (0.64 %) of the garlic bulbs were recorded with 200 kg N ha^{-1}.

The data revealed that all growth parameters namely, mean maximum plant height (50.65 cm), chlorophyll content of leaves (1.020 mg g^{-1}) and fresh weight of leaves per plant (24.92 g) increased significantly in higher row spacing (15 cm), except the number of leaves per plant and maturity period (Table 1). Similar results were also reported by Singh *et al.* (1995). This might be due to the fact that wider row spacing facilitated less competition for space and more availability of light and nutrients to the plants. The increase in growth and chlorophyll content of leaves due to wider spacing in coriander (Bhati 1988b) and in fenugreek (Bhati 1988a) was also reported.

All the contents in bulb were also significantly affected by row spacing (Table 2). The mean maximum nitrogen (3.29 %), phosphorus (0.37 %), potassium (0.73 %), sulphur (1.32 %), moisture (54.21 %), protein (20.42 %), ascorbic acid (11.96 %) and volatile oil (0.61 %) content of garlic bulb were significantly higher with wider row spacing (15 cm), whereas the T.S.S content (32.78 %) was higher under closer row spacing (10 cm).

The economics of various treatment combinations with benefit : cost ratio are given in Table 3. The gross return from the sale of garlic bulbs was calculated at an average price of Rs 800 per quintal. Maximum net profit of Rs 77596 ha^{-1} was obtained under the treatment combination of $N_4S_1V_2$ which was closely followed by $N_4S_2V_2$ with a net profit of Rs 77236 ha^{-1}. Whereas, the minimum net profit Rs 41580.50 ha^{-1} was under the treatment combination of $N_1S_2V_1$. Further, $N_4S_2V_2$ treatment combination resulted in the highest B : C ratio of 3.06 : 1 which was closely followed by $N_4S_2V_3$. The treatment combination

Table 2. Effect of nitrogen, row spacing and cultivars on different contents of garlic bulb (Pooled data of two years)

Treatment	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Sulphur (%)	TSS (%)	Moisture (%)	Protein (%)	Ascorbic acid (mg/100g pulp)	Volatile oil (%)
Nitrogen									
N1	2.79	0.32	0.67	1.17	32.06	42.98	17.57	10.75	0.55
N2	3.20	0.34	0.71	1.28	32.48	49.41	19.78	11.10	0.59
N3	3.45	0.38	0.74	1.35	32.73	58.79	21.50	12.20	0.61
N4	3.49	0.40	0.76	1.44	33.04	61.45	21.86	13.11	0.64
SEm ±	0.001	0.003	0.002	0.000	0.091	0.131	0.067	0.049	0.002
CD 5%	0.003	0.009	0.005	0.001	0.259	0.375	0.192	0.140	0.007
Row spacing									
S1	3.18	0.35	0.71	1.29	32.78	52.11	19.96	11.62	0.59
S2	3.29	0.37	0.73	1.32	32.37	54.21	20.42	11.96	0.61
SEm ±	0.001	0.002	0.001	0.000	0.064	0.093	0.048	0.035	0.002
CD 5%	0.002	0.006	0.003	0.001	0.183	0.265	0.136	0.099	0.005
Cultivar									
V1	3.11	0.35	0.70	1.22	32.10	50.27	19.55	10.28	0.56
V2	3.33	0.37	0.73	1.39	33.03	55.95	20.85	13.88	0.65
V3	3.26	0.36	0.72	1.32	32.60	53.25	20.18	11.21	0.59
SEm ±	0.004	0.003	0.002	0.001	0.103	0.053	0.069	0.056	0.003
CD 5%	0.012	0.008	0.006	0.004	0.291	0.149	0.194	0.159	0.008

Table 3. Benefit-cost ratio of different treatments in garlic

Treatment combination	Yield ha^{-1} (q)	Cost of cultivation (Rs ha^{-1}) (including the cost of treatments)	Gross return ha^{-1} @ Rs 800 q^{-1}	Net profit (Rs ha^{-1})	Benefit : Cost ratio
$N_1S_1V_1$	88.500	26859.50	70800.00	43940.50	1.63:1
$N_1S_1V_2$	95.500	26859.50	76400.00	49540.50	1.84:1
$N_1S_1V_3$	91.500	26859.50	73200.00	46340.50	1.72:1
$N_1S_2V_1$	82.000	24019.50	65600.00	41580.50	1.73:1
$N_1S_2V_2$	89.500	24019.50	71600.00	47580.50	1.98:1
$N_1S_2V_3$	85.500	27241.00	68400.00	44380.50	1.84:1
$N_2S_1V_1$	104.500	27241.00	83600.00	56359.00	2.06:1
$N_2S_1V_2$	112.500	27241.00	90000.00	62759.00	2.30:1
$N_2S_1V_3$	110.000	27241.00	88000.00	60759.00	2.23:1
$N_2S_2V_1$	100.500	24401.00	80400.00	55999.00	2.29:1
$N_2S_2V_2$	106.500	24401.00	85200.00	60799.00	2.49:1
$N_2S_2V_3$	103.500	24401.00	82800.00	58399.00	2.39:1
$N_3S_1V_1$	119.500	27622.50	95600.00	67977.50	2.46:1
$N_3S_1V_2$	128.000	27622.50	102400.00	74777.50	2.70:1
$N_3S_1V_3$	124.500	27622.50	99600.00	71977.50	2.60:1
$N_3S_2V_1$	111.500	24782.50	89200.00	64417.50	2.59:1
$N_3S_2V_2$	120.000	24782.50	96000.00	71217.50	2.87:1
$N_3S_2V_3$	114.000	24782.50	91200.00	66417.50	2.68:1
$N_4S_1V_1$	124.000	28004.00	99200.00	71196.00	2.54:1
$N_4S_1V_2$	132.000	28004.00	105600.00	77596.00	2.77:1
$N_4S_1V_3$	127.500	28004.00	102000.00	73996.00	2.64:1
$N_4S_2V_1$	115.000	25164.00	92000.00	66836.00	2.65:1
$N_4S_2V_2$	128.000	25164.00	102400.00	77239.00	3.06:1
$N_4S_2V_3$	122.500	25164.00	98000.00	72836.00	2.89:1

of $N_4S_1V_2$ gave Rs 2.77 returns per rupee of the cost incurred with the maximum net profit per hectare, however it was inferior in terms of benefit cost ratio as compared to $N_4S_2V_2$ due to the additional cost of planting material (seed). Therefore, it may be inferred from that above findings that $N_4S_2V_2$ was the most economical combination as it gave the highest benefit cost ratio (3.06 : 1) and it was found that application of 200 kg N ha^{-1} with wider row spacing (15 cm) for cultivar Jajavar local was the best combination for increasing the production of garlic.

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