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Response of garlic (*Allium sativum*) to potassium application in loamy sand alluvial soil

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ABSTRACT

A 2-year experiment was conducted during *rabi* 2015–17 at Bathinda to study the response of garlic (*Allium sativum* L.) to basal application of potassium chloride and foliar application of KNO_3 (potassium nitrate) in a loamy sand alluvial soil. The basal application of K_2O (50 kg/ha) caused non-significant increase in number of leaves/plant, bulb weight, number of cloves/bulb, 50-clove weight and bulb yield, and significant but marginal increase in plant height (3.2%), bulb equatorial diameter (2.9%), benefit: cost ratio (12.0%) and A-grade bulb yield (13.7%) over control. The foliar application of KNO_3 gave better results in improving growth, bulb and yield parameters by low (4-5%), moderate (8-24%) and high magnitude (43-52%), respectively. The quantum of increase was higher at 3% concentration of KNO_3 than at 2% with equal number of sprays at same crop stage. The increase in cured bulb yield exhibited an upward trend with increasing number of sprays from two to five at both concentrations. Although, the highest increase over control in cured bulb yield (42.8%) and bulb weight (24.2%) was recorded by five sprays of KNO_3 @ 3% which was at par with four sprays at same concentration, the former gave higher benefit: cost ratio as it produced significantly higher grade-A bulb yield than the latter. Therefore, five sprays of KNO_3 @ 3% at 30, 45, 60, 75 and 90 days after sowing may be done to improve yield potential of garlic in loamy sand alluvial soil of South-Western Punjab.

Keywords: Bulb yield, Clove weight, Foliar spray, Garlic, Potassium nitrate

Garlic (*Allium sativum* L.) is one of the most important bulb vegetable crops of India. In Punjab, the area under its cultivation has increased from 1617 ha in 2007-08 to 7240 ha in 2017-18 (Anonymous 2018a, 2018b). Therefore, it is pertinent to improve garlic productivity by developing improved varieties and standardizing better production technologies. Balanced application of chemical fertilizers is necessary to obtain its best yield. The Punjab Agricultural University has recommended 125: 62.5: 0 kg/ha of N: P_2O_5: K_2O for garlic cultivation in Punjab (Anonymous 2018a). Depending upon the type of root system and surface area of roots, crops differ in their ability to take up potassium from a given soil (Armstrong 1998). Garlic crop responds well to potassium application (Yadav *et al.* 2007, El Sayed and El Morsy 2012) because of its shallow and unbranched root system (Diriba-Shiferaw 2016) and the important role played by potassium in activating over 80 different enzymes responsible for carbohydrate translocation from leaves to bulb, nitrate reduction, photosynthesis, etc. (Bidari and Hebsur 2011, Brady and Weil 2014). Although alluvial soils are considered rich in available potassium, this element is prone to leaching in loamy sand soils of semi-arid regions. Besides, high calcium and magnesium levels in the high pH soils may reduce potassium uptake by the plant as these cations tend to compete with one another for uptake by roots (Brady and Weil 2014).

Potassium can be applied as basal or foliar application. Basal application may be susceptible to leaching losses particularly in light textured soils. Foliar application is considered beneficial when there is a problem of salinization (cation competition), fixation and when peak demand exceeds the nutrient supply through the roots. Most of the studies conducted so far have concentrated on basal application of potassium and there is dearth of studies pertaining to foliar application of potassium in garlic. Therefore, the present study was conducted for two years to study the effect of basal application of potassium chloride and foliar application of potassium nitrate on growth, bulb and yield parameters of garlic in a loamy sand soil of semi-arid region having high pH values.

MATERIALS AND METHODS

The present investigation was conducted at Regional Research Station, Punjab Agricultural University, Bathinda (30º 9’ 36’’ N, 74º 55’ 28’’ E, 211 m altitude) for two consecutive years *rabi* 2015–16 and 2016–17. The climate of

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the site is semi-arid having average annual rainfall of about 410 mm most of which occurs during monsoon period. The soil type was alluvial, loamy sand having 79.9% sand, 11.9% silt and 8.2% clay. The initial properties of the experimental soil at 0-15 cm depth were recorded as *p*H (8.4 and 8.3), electrical conductivity (0.204 and 0.188 dS/m), organic carbon (0.19 and 0.21%), available P (25.2 and 30.4 kg/ha) and available K (242.0 and 267.0 kg/ha) during first and second year, respectively. There were ten treatments replicated thrice in a randomized complete block design. The treatments included T_0: control, T_1: Basal application of K_2O (50 kg/ha), T_2: foliar application of KNO_3 (potassium nitrate) @ 2% at 30, 45, 60, 75 and 90 DAS, T_3: foliar application of KNO_3 @ 2% at 45, 60, 75 and 90 DAS, T_4: foliar application of KNO_3 @ 2% at 60, 75 and 90 DAS, T_5: foliar application of KNO_3 @ 2% at 75 and 90 DAS, T_6: foliar application of KNO_3 @ 3% at 30, 45, 60, 75 and 90 DAS, T_7: foliar application of KNO_3 @ 3% at 45, 60, 75 and 90 DAS, T_8: foliar application of KNO_3 @ 3% at 60, 75 and 90 DAS, T_9: foliar application of KNO_3 @ 3% at 75 and 90 DAS. Non-experimental plots were also sown on both sides of the experimental plots in each replication. The cloves of garlic cultivar PG-17 and PG-18 were sown on 13th October during 2015 and on 14th October during 2016, respectively. The sowing was done at a spacing of 15 cm × 7.5 cm and net plot size was 1.50 m × 1.80 m. Each plot accommodated 12 rows and 20 cloves were planted in each row. Phosphorus @ 62.5 kg/ha in the form of diammonium phosphate (DAP) was added into the soil as basal dose. A total of 100.5 kg/ha of nitrogen in the form of urea was added as top dressing in three equal splits at 30, 45 and 60 days after planting. Muriate of potash (potassium chloride) was used as a source of potassium for basal application in T_1. For treatments T_2 to T_9, water soluble potassium nitrate containing 13% nitrogen and 45% potassium was used for foliar application along with a sticker for proper spread and absorption by garlic plants.

Plant height and number of leaves/plant were recorded on 10 randomly selected plants per plot at 120 days after planting. Ten competitive rows of bulbs leaving two border rows per plot were harvested. Freshly harvested bulbs along with leaves were cured at room temperature and bulb yield after curing was recorded after removing the leaves. Bulbs obtained from each plot were graded into A-grade (>3 cm equatorial diameter) and B-grade (<3 cm equatorial diameter), weighted separately and their cumulative weight was considered as total cured bulb yield. A-grade bulb yield was represented as per cent of total bulb yield. Ten bulbs were randomly chosen and their equatorial diameter and weight were recorded with the help of a Vernier Calliper and electronic weighing balance, respectively. Afterwards, these 10 bulbs were broken into cloves which were counted to estimate number of cloves/bulb. Of these, 50 cloves were taken randomly and weighed on an electronic balance to estimate 50-clove weight (g). Economic analysis was done as per the cost of different treatments and the prevailing market value. The benefit: cost ratio (B: C ratio) for different treatments was estimated by dividing gross returns with total cost of cultivation. Data were analyzed for individual years and pooled over years for analysis of variance using computer software program CPCS-1 (Cheema and Singh 1999).

RESULTS AND DISCUSSION

Analysis of variance: The mean sum of squares due to treatment was significant for all the traits during individual years and pooled over years revealing significant differences among treatments for all the traits. The pooled analysis showed that Treatment × Year interaction was significant for five traits, viz. plant height, number of leaves/plant, bulb equatorial diameter, number of cloves/bulb and A-grade bulb yield which meant that the performance of treatments for these traits was significantly different during both the years, whereas for other traits the performance of treatments was on a par during both the years. This might be due to the use of a different clone and different field during two years of study. The variance due to years was significant for all the traits and the average values of all eight traits during second year were significantly higher than in first year (Table 1). This might be due to the reason that the soft-neck (non-bolting) clone 'PG-18' used in second year trial was higher yielder (Dhall and Brar 2016) than the hard-neck clone 'PG-17' used in first year trial.

Growth parameters: The various treatments exerted minor effect on growth parameters of garlic. On the basis of pooled data, the highest increase of 4.89% and 4.27% over control in plant height and number of leaves/plant was exhibited by T_2 and T_7 treatments, respectively. Basal application of potassium (T_1) had number of leaves at par with control, but plant height significantly and marginally higher (3.22%) than control (Table 1). Yadav *et al.* (2007) also observed marginal increase (4.29%) over control in number of leaves of garlic with basal application of potassium (50 kg/ha) in light textured soils of Rajasthan, India. El Sayed and El Morsy (2012) also reported non-significant increases (3.00% and 4.07%) over control in plant height and number of leaves, respectively, of garlic with basal application of potassium (60 kg/ha) in clay loam soils of Egypt. The maximum plant height (59.60 cm) was recorded by T_2 treatment which was at par with T_6, T_7, T_3, T_4 and T_8, whereas, the control (T_0) exhibited the lowest plant height (56.82 cm) which was at par with T_9 (57.02 cm). The T_7 treatment recorded maximum number of leaves/plant (7.33) and was at par with T_6, T_9, T_2, T_8, T_1 and T_4. On the other hand, the lowest number of leaves (7.03) was recorded in T_0 and T_3 which were at par with T_5, T_4 and T_1 (Table 1).

Bulb parameters: The different treatments moderately improved the bulb parameters of garlic. On the basis of pooled data, the maximum increase over control was exhibited by T_6 treatment in respect of bulb weight (24.17%), 50-clove weight (12.38%) and equatorial diameter of bulb (7.89%), and by T_8 treatment in respect of number of cloves/bulb (18.75%). Bulb weight, number of cloves/

Table 1 Growth, yield and bulb parameters of garlic as influenced by basal and foliar application of potassium at Bathinda

Treatment	Plant height (cm)			No. of leaves per plant			Equatorial diameter of bulb (cm)			Bulb weight (g)		
	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled	Y_1	Y_2	Pooled
T_0	57.17	56.47	56.82	6.83	7.23	7.03	3.76	3.84	3.80	17.38	20.08	18.74
T_1	58.30	59.00	58.65	6.93	7.43	7.18	3.94	3.88	3.91	17.76	21.85	19.81
T_2	58.37	60.83	59.60	7.07	7.43	7.25	3.93	4.01	3.97	18.05	24.90	21.48
T_3	58.27	60.17	59.22	7.10	6.97	7.03	3.87	4.05	3.96	18.31	23.42	20.87
T_4	58.30	59.87	59.08	7.13	7.20	7.17	3.98	4.06	4.02	18.38	22.63	20.50
T_5	56.63	59.27	57.95	7.13	7.13	7.13	3.92	4.00	3.96	17.92	22.44	20.18
T_6	58.67	60.27	59.47	6.93	7.67	7.30	3.96	4.24	4.10	19.58	26.96	23.27
T_7	58.60	60.03	59.32	7.20	7.47	7.33	3.87	4.14	4.00	18.77	26.15	22.46
T_8	57.80	60.03	58.92	7.23	7.20	7.22	3.84	4.10	3.97	18.52	24.13	21.32
T_9	57.57	56.47	57.02	7.30	7.27	7.28	3.82	4.07	3.95	18.13	22.44	20.29
Mean	57.97	59.24	58.60	7.09	7.30	7.19	3.89	4.04	3.96	18.28	23.50	20.89
CD (T) ($P \leq 0.05$)	0.93	1.60	0.89	0.22	0.33	0.19	0.12	0.15	0.09	1.08	3.60	1.82
CD (Y) ($P \leq 0.05$)			0.40			0.09			0.04			0.81
CD (T × Y) ($P \leq 0.05$)			1.27			0.27			0.13			NS
	No. of cloves per bulb			*50-clove weight (g)*			*Cured bulb yield (t/ha)*			*A-grade bulb yield (%)*		
	Y_1	Y_2	*Pooled*	Y_1	Y_2	*Pooled*	Y_1	Y_2	*Pooled*	Y_1	Y_2	*Pooled*
T_0	17.9	17.2	17.6	41.80	58.03	49.91	4.50	6.01	5.26	34.9	33.6	34.2
T_1	18.2	18.5	18.3	44.81	60.90	52.85	5.12	6.48	5.80	37.9	39.9	38.9
T_2	18.1	19.4	18.7	43.85	62.45	53.15	5.15	7.70	6.42	46.4	48.4	47.4
T_3	18.3	19.5	18.9	38.64	62.24	50.44	5.64	7.64	6.64	48.9	47.8	48.4
T_4	18.4	19.3	18.9	39.09	56.77	47.93	5.56	7.08	6.32	45.3	48.8	47.1
T_5	19.2	19.5	19.4	38.00	56.78	47.39	5.39	7.04	6.21	41.1	43.6	42.3
T_6	19.0	22.2	20.6	45.64	66.53	56.09	6.04	8.97	7.51	54.2	55.0	54.6
T_7	18.9	22.4	20.7	40.89	57.68	49.29	5.88	8.69	7.28	43.0	54.5	48.8
T_8	19.2	22.5	20.9	40.66	56.46	48.56	5.50	7.62	6.56	41.4	57.2	49.3
T_9	19.0	19.1	19.0	40.78	57.98	49.38	5.47	7.22	6.34	37.8	51.2	44.5
Mean	18.6	20.0	19.3	41.41	59.58	50.50	5.42	7.44	6.43	43.1	48.0	45.5
CD (T) ($P \leq 0.05$)	0.6	2.6	1.3	4.80	4.97	3.33	0.75	1.26	0.71	6.6	6.2	4.4
CD (Y) ($P \leq 0.05$)			0.6			1.49			0.32			2.0
CD (T × Y) ($P \leq 0.05$)			1.8			NS			NS			6.2

Y_1 = 2015-16, Y_2 = 2016-17

bulb and 50-clove weight obtained from basal application of potassium (T_1) was at par with control (T_0), however, its equatorial diameter (3.91 cm) was marginally but significantly higher (2.89%) than control (3.80 cm) (Table 1). El Sayed and El Morsy (2012) have also reported marginal increase of 5.70%, 11.07% and 7.58% in bulb weight, clove weight and bulb diameter, respectively, of garlic with basal application of potassium (60 kg/ha) over control in clay loam soils of Egypt. The treatment T_6 recorded the maximum bulb equatorial diameter (4.10 cm), bulb weight (23.27 g) and 50-clove weight (56.09 g). Besides, it also produced 20.6 cloves per bulb that was at par with treatment T_8 that had maximum number of cloves per bulb (20.9). On the other hand, the minimum values of all these bulb parameters were recorded by control (T_0) (Table 1). The increase in number of cloves/bulb may have led to increase in bulb diameter which ultimately enhanced bulb weight. This was corroborated by significant and positive correlation between number of cloves and bulb diameter (0.727), number of cloves and bulb weight (0.829), bulb diameter and bulb weight (0.869).

Yield parameters: The various treatments improved the yield parameters of garlic by a considerable margin. On the basis of pooled data, the maximum increase over control was exhibited by T_6 treatment in respect of A-grade bulb yield (59.65%) and cured bulb yield (42.78%). Basal application of potassium (T_1) yielded (5.80 t/ha) at par with control (5.26 t/ha), however, its A-grade bulb yield was significantly higher (13.74%) than control (Table 1). The present findings are in agreement with those of Yadav *et al.* (2007) who have also observed marginal and non-significant increase (7.55%) over control in bulb yield with basal application of potassium (50 kg/ha) in light textured soils of Rajasthan, India. El Sayed and El Morsy (2012) have also reported marginal increase of 5.61% in total yield of garlic with basal application of potassium (60 kg/ha) over control in clay loam soils of Egypt.

The maximum cured bulb yield (7.51 t/ha) was obtained with T_6 treatment which was at par with T_7 (7.28 t/ha) and significantly higher than all other treatments. The T_6 treatment also gave maximum A-grade bulb yield (54.6%) which was significantly higher than all other treatments (Table 1). In general, foliar application of KNO_3 at higher concentration (3%) gave higher bulb yield than at lower concentration (2%) with equal number of sprays at same crop stage. This improvement in yield and bulb parameters of garlic with foliar application of KNO_3 may be due to better absorption of potassium by the plant as compared with basal application of potassium which is prone to fixation and leaching. Although the potassium ion does not enter in to permanent organic combinations in plants, but apparently exists as soluble inorganic and organic salts (Bidari and Hebsur 2011). Potassium participates in activation of important enzyme reactions, promotes photosynthesis, speeds up the flow of assimilates and intensifies the storage of assimilates. Secondly, potassium nitrate also contains 13% nitrogen which could be utilized by the plant and transformed into high yield in the presence of high K levels as potassium improves the effect of nitrogen fertilizer by favouring the rapid turnover of inorganic nitrogen (NO_3^-) into proteins (Armstrong 1998, Yadav *et al.* 2007).

Economics: The lowest gross returns (220078 ₹/ha), net returns (55088 ₹/ha) and benefit: cost ratio (1.33) was recorded by control (T_0). Basal application of potassium (T_1) caused 12.74%, 48.19% and 12.03% increase in gross returns, net returns and benefit: cost ratio, respectively, over control (Table 2). However, foliar application of KNO_3 proved much better than basal application of potassium chloride. Moreover, foliar application of KNO_3 at higher concentration (3%) gave higher economic benefit than at lower concentration (2%) with equal number of sprays at same crop stage. But this benefit was the highest when five sprays were done and it kept on decreasing with reduction in number of sprays. Maximum gross returns (344859 ₹/ha), net returns (172494 ₹/ha) and benefit: cost ratio (2.00) was registered by T_6 treatment (five sprays of KNO_3 @ 3%) closely followed by T_7 treatment.

The results obtained from the present study have revealed that basal application of potassium (T_1) did not have any significant effect on growth, bulb and yield parameters of garlic as compared to control during both the years. The proneness of potassium to leaching and fixation, less uptake by the plant due to competition with other cations and shallow root system of the crop may be some of the reasons for poor response of garlic to basal application of potassium chloride. On the contrary, foliar application of KNO_3 improved the growth, bulb parameters and yield of garlic over control by low (4-5%), moderate (8-24%) and high magnitude (43-52%), respectively. This improvement was numerically higher at 3% concentration of KNO_3 than at 2% concentration with equal number of sprays at same stage of crop. The high magnitude of increase in cured bulb yield with foliar application of KNO_3 was primarily due to increase in proportion of A-grade bulbs and secondarily due to increase in number of cloves/bulb which ultimately improved bulb equatorial diameter and weight as revealed by significant values of correlation coefficients among these traits. Moreover, this improvement showed an upward trend with increasing number of sprays from two to five at both the concentrations. Although, five sprays of KNO_3 @3%

Table 2 Economics of garlic cultivation as influenced by basal and foliar application of potassium at Bathinda

Treatment	Cost of cultivation (₹)			Gross returns (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
	Fixed cost (₹/ha)	Treatment cost (₹/ha)	Total cost (₹/ha)			
T_0	164990		164990	220078	55088	1.33
T_1	164990	1500	166490	248124	81634	1.49
T_2	164990	5500	170490	285562	115072	1.67
T_3	164990	4400	169390	296675	127285	1.75
T_4	164990	3300	168290	280734	112444	1.67
T_5	164990	2200	167190	269887	102697	1.61
T_6	164990	7375	172365	344859	172494	2.00
T_7	164990	5900	170890	325853	154963	1.91
T_8	164990	4425	169415	294282	124867	1.74
T_9	164990	2950	167940	278326	110386	1.66

(T_6) showed at par cured bulb yield with four sprays at same concentration (T_7), the former gave higher economic benefit as it produced significantly higher grade-A bulb yield than the latter. Therefore, five sprays of KNO_3 @3% at 30, 45, 60, 75 and 90 days after sowing may be opted to improve yield potential of garlic in loamy sand alluvial soils of South-Western Punjab.

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