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Response of tomato (*Lycopersicon esculentum* Mill.) to lime and potassium under acidic soil condition

LALHRUAIZELI, Y.K. SHARMA* AND S.K. SHARMA

Department of Agricultural Chemistry and Soil Science, SASRD, Nagaland University, Medziphema - 797106, Nagaland

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ABSTRACT

A greenhouse experiment was conducted in the Department of Agricultural Chemistry and Soil Science, SASRD, Nagaland University, Medziphema during rabi season of 2014-16 to study the response of tomato to lime and potassium application in acidic soils of Nagaland. The experiment was laid out in complete randomized design with three levels of lime (control, 15, and 30% lime of LR) and four levels of potassium (0, 40, 80 and 120 kg K_2O ha^{-1}) and three replications. Results revealed that the application of 30% lime of LR significantly enhanced the plant height, number of branches $plant^{-1}$, number of fruits $plant^{-1}$, fruit and stover yields, nutrients content and nutrients uptake of tomato over 15% lime of LR and control. While days require for first fruit setting reduced significantly with lime application. Application of 30% lime of LR increased fruit and stover yields by 83.4 and 116.2%, respectively over control. Potassium application significantly enhanced the growth, yield attributes and yield of tomato. Application of 120 kg K_2O ha^{-1} increased the fruit and stover yields by 30.3 and 50.6%, respectively over control. Uptake of nutrients by fruit and stover and total uptake by the crop increased significantly with K application. Lime and potassium application improved TSS and vitamin C contents of tomato. Lime application significantly enhanced soil pH, cation exchange capacity and base saturation and status of available nutrients (N, P and K) in post harvest soil. Exchangeable acidity and total potential acidity decreased significantly with lime application. Potassium application improved only CEC and content of available K in soil significantly over control.

Keywords: Lime, potassium, tomato, yield, nutrient uptake, CEC, base saturation, soil acidity

INTRODUCTION

Tomato is the world's largest vegetable crop after potato and sweet potato. Tomato is universally treated as protected food and is being extensively grown as an annual plant all over the world. It is a very good source of income of small and marginal farmers and contributes to the nutrition of the consumers. Gentle hill slopes with shallow soil depths and sufficient soil moisture regime gives the hill areas in the North-East enough potential for horticultural development. In Nagaland tomato is grown as a major crop during winter and a minor crop during summer. Soil acidity is a base unsaturated soil which has got enough of adsorbed exchangeable H^+ ions and probably Al^{+3} ions which give it a pH lower than 7. In certain cases this acidity may also exist in the form of free organic acids especially in soils rich in organic matter (peat soils) and organic matter rich sandy soils. Liming is an important practice to achieve optimum yields of all crops grown on acid soils. According to Kaitibie *et al.* (2002), liming is the most widely used long-term method of soil acidity amelioration, and its success is well documented. Application of lime at an appropriate rate brings several chemical and biological changes in the soils, which are beneficial or helpful in improving crop yields on acid soils. Potassium maintains the ionic balance and water status within the plant. It is involved in the production and transport of sugars in the plant, enzyme activation and synthesis of proteins. Potassium is also required for pigment synthesis, notably lycopene. Application of potassium causes firmness in fruits, development of fruits and improvement in ripeness. Potassium is a key nutrient for enhancing productivity of vegetable crops and its content in vegetables has significant positive relationship with quality attributes (Bidari and Hebsur 2011). Potassium is an activator of enzymes involved in protein and carbohydrates metabolism, helps in carbohydrate translocation, stomatal opening, and membrane permeability and enhances the plants ability to resist diseases. Cultivation of crops without K application results in poor yield and quality of produce along with depletion of inherent

*Corresponding author
Email: yk2310sharma@rediffmail.com

potassium in the soils. Scanty information is available on effect of lime and potassium on performance of tomato in Nagaland. Therefore an attempt was made to assess potassium requirement of tomato under acidic soil condition.

MATERIALS AND METHODS

A greenhouse experiment was conducted with tomato (cv. Pusa Ruby) as the test crop. The experimental site is located at 25°45ʹ45”N latitude and 93°51ʹ45ʺE longitude at an elevation of 310 m above mean sea level. Mean temperature ranges from 21°C to 30°C during summer and rarely goes below 8°C during winter due to high atmospheric humidity. The average rainfall varies between 2000-2500 mm. The experimental soil was sandy clay loam in texture and acidic in reaction (pH 5.50). The soil organic carbon content was 17.0 g kg^{-1}, and available N, P and K contents were 276.0, 10.4 and 190.0 kg ha^{-1}, respectively. The cation exchange capacity, base saturation percentage, exchangeable acidity, total potential acidity and lime requirement were 10.1 (cmol kg^{-1}), 15.1%, 1.25 (cmol kg^{-1}) 7.0 (cmol kg^{-1}), and 2.43 t ha^{-1} respectively. The experiment was laid out in complete randomized design (CRD) with three replications. The treatments consisted of three lime levels (control, 15 and 30 % lime of LR) and four potassium levels (control, 40, 80 and 120 kg K_2O ha^{-1}). Earthen pots of 30 cm diameter size were filled with 10 kg of soil. Lime levels were supplied through calcium carbonate. Recommended doses of 100 kg N and 60 kg $P_2O_5ha^{-1}$, respectively were supplied through urea and single superphosphate. Full dose of potassium as muriate of potash and phosphorus were applied one day before transplanting while nitrogen was supplied in two equal splits, *viz.* half at transplanting time and rest half after 30 days of transplanting. Lime was applied 15 days before transplanting. Thirty days old tomato seedlings were transplanted in each pot on 17 October, 2015. Weeding was done at regular intervals. Crop was irrigated as and when required. The data on plant height, number of branches and fruits $plant^{-1}$, days required for first fruit setting and fruit and stover yields were recorded. Fruit samples were analyzed for total soluble solids (brix) and vitamin C using standard procedures (A.O.A.C. 1984). The fruits and stover were analyzed for N, P, K and Ca contents. The N content was analysed by Kjeldahl method. Phosphorus and potassium were determined in diacid (HNO_3-$HClO_4$) dighest by adopting standard procedures (Jackson 1973). Calcium in acid digest was determined by versenate titration method. The soil samples were analyzed for pH, CEC, base saturation using standard methods (Chapmam and Pratt1961). Soil organic carbon, available nitrogen and available potassium were determined using standard methods (Jackson 1973). For estimation of available P, soil samples were extracted with NH_4F (Bray and Kurtz 1945). The lime requirement of the soil was determined by Shoemaker *et al.* (1961) method. Exchangeable acidity was determined by Sokolov’s method and total potential acidity by Peech’s method as described by Black (1965). The data were analyzed statistically to compare the treatment effects.

RESULTS AND DISCUSSION

Growth, yield and quality

The plant height, number of branches per plant, and number of fruits per plant of tomato increased and days require for first fruit setting decreased significantly by lime and potassium application (Table 1). Each increasing level of lime significantly enhanced the plant height of tomato over preceding lower level of lime and maximum plant height (86.77 cm) was recorded with 30% lime of LR. Potassium application enhanced the plant height from 73.22 cm to 84.24 cm. Number of branches increased markedly with lime and potassium application. Highest number of branches (17.58) per plant was recorded with the application of 30% lime of LR and 120 kg K_2O ha^{-1}. Maximum number of fruits was recorded with the application of 30% lime of LR. It was also recorded that 15% lime of LR increased number of fruits per plant significantly over control. In case of potassium application, highest number of fruits was recorded with 120 kg K_2O ha^{-1} which was at par with 80 kg K_2O ha^{-1}. Lime application improved the soil pH and decreased different soil acidity ultimately enhanced nutrient availability in soil solution resulted more plant growth. Potassium application enhanced enzymatic and metabolic activities within plant system resulted enhanced plant growth. These results are in accordance with the findings of Koesrini *et al.* (2014).

Table 1: Effect of lime and potassium on growth, yield and quality of tomato (mean of 2 years)

Treatment	Plant height (cm)	Branches plant^{-1}	Days require for first fruit setting	Fruits plant^{-1}	Yield (g pot^{-1})		TSS ($^{\circ}$Brix)	Vitamin C (mg 100 g^{-1})
					Fruit	Stover		
Lime levels (% of LR)								
0	70.62	14.25	29.66	7.66	374.00	8.22	6.04	37.58
15	77.92	15.41	27.83	10.41	521.50	12.00	6.93	42.71
30	86.77	17.58	26.83	12.91	686.03	17.77	7.77	51.15
SEm±	0.54	0.23	0.31	0.24	12.10	0.41	0.04	0.64
CD (P=0.05)	1.85	0.78	1.06	0.92	40.62	1.39	0.14	2.17
Potassium (kg ha^{-1})								
0	73.22	14.77	30.66	9.11	456.64	10.38	6.56	40.57
40	76.55	15.11	27.88	9.88	6506.64	11.80	6.76	43.26
80	79.10	15.66	28.00	10.77	550.49	12.85	6.97	44.97
120	84.24	17.44	25.00	11.55	594.96	15.63	7.35	46.44
SEm±	0.63	0.26	0.36	0.31	13.87	0.41	0.04	1.28
CD (P=0.05)	2.12	0.90	1.23	1.06	46.91	1.39	0.16	4.35

Lime and potassium application significantly improved tomato fruit yield. Highest fruit and stover yields were recorded with the application of 30% lime of LR. Application of 30% lime of LR increased the fruit and stover yields by 83.4% and 116.2 %, respectively over control. Application of 120 kg K_2O ha^{-1} increased the fruit and stover yields to the extent of 30.3 and 50.6%, respectively over control. Lime and potassium application improved growth and yield attributes which ultimately resulted in higher fruit as well as stover yields of tomato. Similar result was also obtained by Colpan *et al.* (2013) and Koesrini *et al.* (2014). Application of lime and potassium had significantly effect on quality of tomato. Application of lime 30% of LR recorded the maximum total soluble solids (7.77) and vitamin C (51.15) contents. Similarly, maximum total soluble solids (7.35 brix) and vitamin C (46.44 mg 100g^{-1}) were recorded with application of 120 kg K_2O ha^{-1}. Increased TSS in tomato fruits may depend on a higher sugar import and accumulation. Potassium involved in enzymatic and metabolic activities in plant system resulted in improved quality of tomato fruits (El-Nemr 2012).

Table 2: Effect of lime and potassium on nutrient content (%) of tomato (mean of 2 years)

Treatment	Nitrogen		Phosphorus		Potassium		Calcium	
	Fruit	Stover	Fruit	Stover	Fruit	Stover	Fruit	Stover
Lime levels (% of LR)								
0	1.49	2.69	0.31	0.56	2.22	3.37	0.16	2.15
15	1.54	2.73	0.37	0.62	2.29	3.60	0.21	2.64
30	1.58	2.77	0.43	0.68	2.34	3.99	0.26	3.20
SEm±	0.002	0.002	0.002	0.002	0.01	0.02	0.002	0.02
CD (P=0.05)	0.007	0.007	0.007	0.009	0.03	0.07	0.008	0.07
Potassium (kg ha^{-1})								
0	1.52	2.72	0.35	0.59	2.19	3.31	0.23	2.82
40	1.53	2.73	0.37	0.61	2.30	3.66	0.22	2.73
80	1.54	2.74	0.38	0.63	2.32	3.77	0.21	2.62
120	1.56	2.75	0.40	0.64	2.34	3.87	0.20	2.48
SEm±	0.002	0.002	0.002	0.003	0.01	0.02	0.002	0.02
CD (P=0.05)	0.009	0.008	0.008	0.01	0.04	0.09	0.009	0.09

Content and uptake of nutrient

Lime and potassium application remarkably affected the mineral composition of tomato (Table 2). Nitrogen, phosphorus, potassium and calcium contents in fruits and stover of tomato increased significantly with application of lime and potassium as compared to control as well as their lower levels. However, calcium content in fruit and stover of tomato reduced significantly with potassium application. It was also reported that tomato stover contained more nutrients than tomato fruits. Lime addition reduced Al^{3+} and increased Ca^{2+} concentration on the soil clay complexes which increased nutrient solubility in the soil solution resulted plants absorbed more nutrients from the soil. Furthermore, higher concentrations of potassium within plant system catalyze the metabolic activities ultimately plant absorbed more nutrients. Total N uptake of tomato enhanced significantly with increasing levels of lime and potassium (Table 3).

Table 3**:** Effect of lime and potassium on nutrient uptake (mg pot^{-1}) by tomato (mean of 2 years)

Treatment	Nitrogen			Phosphorus			Potassium			Calcium		
	Fruit	Stover	Total	Fruit	Stover	Total	Fruit	Stover	Total	Fruit	Stover	Total
Lime levels (% of LR)												
0	332.2	22201	554.4	71.9	46.8	118.8	468	279	780	37.0	175.9	211.5
15	482.2	326.2	808.4	118.6	74.2	192.8	719	433	1152	66.9	314.2	381.2
30	652.9	452.4	1146.2	182.0	122.3	304.4	971	718	1689	108.9	561.7	670.7
SEm±	11.1	21.4	1.4	2.80	2.55	3.84	22.7	14.0	21.9	1.5	9.8	9.7
CD (P=0.05)	37.6	72.3	4.4	9.47	8.62	12.99	76.9	16.2	74.08	5.23	33.1	32.8
Potassium (kg ha^{-1})												
0	418.5	383.9	701.4	100.2	63.4	163.7	560	345	950	65.8	306.7	372.5
40	469.5	323.1	792.6	116.2	74.0	190.2	703	441	1144	70.1	336.8	407.0
80	506.5	296.7	857.7	131.6	82.7	214.3	771	499	1265	72.6	349.7	420.5
120	562.0	431.6	993.6	148.7	104.2	253.0	843	625	1469	75.3	409.2	484.5
SEm±	12.8	24.7	1.6	3.23	2.94	4.04	26.2	47.6	25.2	1.78	11.3	11.2
CD (P=0.05)	43.4	83.5	5.1	9.47	9.96	15.00	88.8	54.9	148.1	6.04	38.3	37.8

Increase in nitrogen uptake by tomato due to application of 15 and 30% lime of LR was 45.8 and 106.7%, respectively over control. Application of 40, 80 and 120 kg K_2O ha^{-1} increased N uptake by 11.5, 22.3 and 41.6% over control, respectively. Phosphorus uptake by tomato increased significantly with lime and potassium application. Phosphorus uptake by tomato enhanced from 118.8 mg pot^{-1} in control to 304.4 mg pot^{-1} at 30% lime of LR. Potassium application enhanced P uptake from 163.7 mg pot^{-1} to 253.0 mg pot^{-1}. Phosphorus uptake enhanced by 156.2 and 54.5% over control with application of 30% lime of LR and 120 kg K_2O ha^{-1}, respectively. Potassium uptake by tomato increased significantly with the application of lime and potassium. Maximum K uptake was recorded at 30% lime of LR application. Potassium uptake enhanced by 47.7 and 116.5%, respectively over control with of 15 and 30% lime of LR. Increase in potassium uptake by tomato due to application of 40, 80 and 120 kg K_2O ha^{-1} was 27.7, 44.4 and 80.9%, respectively over control. Calcium uptake by tomato improved remarkably with lime and potassium application. Application of 30% lime of LR enhanced calcium uptake to the extent of 217.1% over control. Calcium uptake increased by 30.1% over control with application of 120 kg K_2O ha^{-1}. Lime and potassium application enhanced yield as well as nutrient contents in fruits and stover which ultimately increased nutrient uptake. These results are in confirmatory with those of De Almeida *et al.* (2015).

Soil properties

Liming significantly improved the pH of the soil (Table 4) over no liming. Application of 15 and 30% lime of LR enhanced the soil pH significantly over preceding lower levels. The soil pH and organic carbon were not affected significantly by lime and potassium application. Lime application increased significantly CEC and base saturation of post harvest soil. CEC was also improved significantly by potassium application. Lime application significantly decreased exchangeable and total potential acidities of the soil. Exchangeable acidity was reduced from 0.98 to 0.58 cmol kg^{-1}, while total potential acidity was reduced from 8.35 to 7.13 cmol kg^{-1} with 30% lime of LR. Lime application replaced Al^{3+} and H^+ from clay complexes which ultimately increased CEC and base saturation and reduced soil acidities. Lime application significantly enhanced available N, P and K contents of the soil. It might be due to increased soil pH resulted reduced nutrient fixation in the soil. Potassium application did not affect markedly base saturation, exchangeable and total potential acidities, and available nitrogen and phosphorus contents of the soil. However available potassium status of the soil improved significantly with potassium application and maximum available potassium content was recorded at 120 kg K_2O ha^{-1}. These finding are in accordance with those of Halim *et al.* (2014).

Table 4**:** Effect of lime and potassium on the soil properties

Treatment	pH	Organic carbon (g kg^{-1})	CEC (cmol kg^{-1})	Base saturation (%)	Exchangeable acidity (cmol kg^{-1})	Total potential acidity (cmol kg^{-1})	Avail. nutrients (mg kg^{-1})		
							N	P	K
Lime levels (% of LR)									
0	5.48	17.5	10.5	12.3	0.98	8.35	141.0	5.0	87.8
15	5.68	17.3	12.5	13.1	0.72	7.53	147.9	5.3	99.8
30	5.81	17.3	13.3	15.0	0.58	7.13	150.5	5.6	110.1
SEm±	0.002	0.08	0.09	0.42	0.02	0.05	0.96	0.02	2.89
CD (P=0.05)	0.007	NS	0.32	1.42	0.09	0.17	3.25	0.07	9.79
Potassium (kg ha^{-1})									
0	5.61	17.3	11.8	13.5	0.78	7.80	144.2	5.3	88.3
40	5.70	17.5	12.1	12.8	0.74	7.66	146.9	5.3	97.0
80	5.64	17.3	12.3	13.6	0.77	7.60	147.7	5.3	100.7
120	5.69	17.3	12.7	13.9	0.74	7.62	147.0	5.2	110.7
SEm±	0.002	0.06	0.11	0.48	0.03	0.06	1.11	0.03	3.34
CD (P=0.05)	NS	NS	0.37	NS	NS	NS	NS	NS	11.3

From the results, it may be concluded that lime application improved significantly the growth, yield attributes, yield and quality of tomato. Application of 30% lime gave best results over other levels of lime. Application of potassium also enhanced and yield of tomato. Nutrient content and their uptake enhanced markedly with lime and potassium application. Lime application increased pH and reduced acidities of the soil. Application of lime improved the nutrient status of post harvest soil. Application 30% lime of LR along with 120 kg K_2O was proved to be the optimum dose for getting better yield of tomato under acidic soil condition of Nagaland.

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