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Effect of Lime and Potassium on Uptake of Nutrients by Soil and Tubers in Acid Soils

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Abstract: An experiment was conducted in strongly acidic sandy loam soil (pH: 4.5–5.2) to investigate the effect of lime and potassium on nutrient uptake by soil and tuber. Lime was applied at the rate of 0, 0.5, 1.0 and 2.0 t ha^{-1} and potassium at the rate of 0, 60, 80 and 100 K, kg ha^{-1}. The treatment combinations were allocated to the experimental plots in randomized complete block design. Application of lime and potassium significantly increased total dry matter yield as well as total uptake of nutrients by soil and plant. Lime slightly decreased Mg concentration in haulms and had no effect on tubers.

Key words: Acid soil, potato, nutrient uptake, lime, potassium

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INTRODUCTION

Acid soil in Bangladesh is one of the problem soils characterized by low in pH, deficiencies of organic matter, less content of Ca, Mg, P, K and high content of Fe, Al, Mn[1]. The potential of acid soil for crop production is limited due to less availability of phosphorus and high content (toxicity) of aluminium.

Potato is one of the most important vegetable crops in Bangladesh and may play a vital role to minimize food shortage. Total production of potato in the country is about 1.6 million tons[2] and annual average growth rate of potato production was 3.7% from 1987 to 1997[3]. But actual yield is quite low, 11.3 t ha^{-1}, compared to other countries like Republic of Korea (22 t ha^{-1}), Iran (19.7 t ha^{-1}), India (16.88 t ha^{-1}) and China (13.05 t ha^{-1})[3].

In our country, it is quite common to find soils used for potato production with pH values as low as 5.0. Crop yield on these soils increases with the increase in pH[4]. Optimum range of soil pH for potato production is 5.2 to 6.5 [5,6]. It is also found that K bearing minerals in these soils are low. Lime and potassium increase the yield of potato and improve the size of tuber (170-370 g). Liming on acid soils also increases resistance to bacterial soft rot and decreases the severity of internal brown spot[7]. This practice also makes phosphorus more available, reduce the aluminum toxicity, increases availability of nitrogen, potassium, calcium, magnesium and micronutrients, renders iron and manganese insoluble and harmless, increases fertilizer effectiveness and decreases plant diseases[8].

Continued use of acid forming fertilizers is leading to a decrease of pH with an accompanying decrease in crop yields. In acid soils organic matter decomposition and microbial activity are low. Farmers are applying unbalanced fertilizers for potato production and they have limited knowledge of lime and potassium requirements on potato. Very few studies have been conducted on liming on potato and their interaction with potassium in acid soil. The present study is needed to determine the effect of lime and potassium and their interaction on acid soil, consequence of nutrients uptake by tubers and farm soil.

MATERIALS AND METHODS

The study was conducted at the experimental field of Bangladesh Agricultural Research Station, Debigonj, Ponchagor, Bangladesh. The soil of the experimental site is very acidic, sandy loam and very poor in terms of nutrient availability.

The study was conducted in 4x4 factorial design (RCBD) with three replications for each of sixteen treatment combinations. Lime was applied at the rate of 0, 0.5, 1.0 and 2.0 t ha^{-1} and potassium at the rate of 0, 60, 80 and 100 K, kg ha^{-1}. Lime was applied in the form of $Ca(OH)_2$ as commercial grade before 15 days of planting. Urea, triple super phosphate, gypsum, zinc sulphate, magnesium sulphate and boric acid were applied at the rate of 260, 250, 100, 10, 100 and 10 kg ha^{-1}, respectively. Potassium in the form of muraite of potash was applied for each plot as per treatments. The variety “Cardinal” was selected for planting. Spacing was maintained as 60 cm row to row and 25 cm plant to plant.

Application of irrigation, earthing up, weeding and different intercultural operations were done whenever

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necessary. Preventive measure was taken to control pest and diseases. Harvesting was done after 90 days of planting. Data was recorded from the selected 3rd row of each plot to avoid the border effect. Potato was harvested manually at the time of physiological maturity.

For analysis soil samples were collected after 105 days of liming (crop maturity stage) at 0-15 cm of depth. Ten plant samples were randomly collected from each plot by cutting the plants at physiological maturity. Preparation and analysis of the samples were carried out following standard procedure.

Data was analyzed by using SPSS and MSTAT standard package (Excel). Treatment means for different parameters were separated using Duncan's multiple range test (DMRT) at 95% confidence level. Regression analysis was done for related parameters.

RESULTS AND DISCUSSION

Uptake of nitrogen: Uptake of nitrogen by both haulms and tuber was differed significantly according to the application of lime and potassium (Table 1 and 2). Interaction effect of lime and potassium was found significant on tuber but not in haulms. Liming increase soil nitrogen and hasten disappearance of NH_4^+-N from soil by the uptake in tubers[4,9,10,11]. A light rainfall during the growing season of potato is insufficient for leaching the urea into soil, may actually increase NH_3 volatilization by supplying moisture for urea dissolution and hydrolysis[12].

Total nitrogen uptake (haulms + tubers) was highest 95.25 kg ha^{-1} and 94.08 kg ha^{-1} by applying 1 t ha^{-1} lime and 100 kg ha^{-1} of potassium, respectively. Lowest uptake (58.32 kg ha^{-1}) obtained from control plot (Table 3).

Uptake of phosphorus: Uptake of phosphorus was observed significantly higher with increasing level of lime application (Table 4). Liming increases phosphate availability and decreases adsorption[13]. Lime might have reduced the concentration of soluble and exchangeable iron which otherwise react with added phosphorus fertilizer to form sparingly soluble Fe-phosphate[14]. Actually the farm soil is very rich in phosphorus due to heavy phosphate fertilizer application for a long time. Interaction effect of lime and potassium was found in tuber (Table 5 and 6). Phosphorus uptake was lowest in control plots 5.29 kg ha^{-1} and highest 10.34 kg ha^{-1} in higher level of lime and potassium (Table 4).

Table 1: Effect of lime and potassium on nitrogen uptake by haulms (Kg ha^{-1})

Lime t ha^{-1}	0	0.5	1	2	Mean
K kg ha^{-1} 0	11.56±0.43	13.00±0.10	13.79±1.00	13.72±0.30	13.02±0.46c
60	12.2±0.48	14.61±1.04	15.82±0.37	15.33±0.84	14.5±0.68b
80	13.24±0.27	15.92±0.48	17.05±0.41	18.43±0.40	16.16±0.39a
100	13.92±0.43	16.50±0.55	17.86±0.75	17.86±0.75	16.54±0.59a
Mean	12.73±0.40c	15.01±0.54b	16.13±0.60a	16.33±0.57a	

Statistically significant at 0.05 probability*, Lime *, Potassium*, Limex potassium ns (Non significant)

Table 2: Effect of lime and potassium on nitrogen uptake by tubers (Kg ha^{-1})

Lime t ha^{-1}	0	0.5	1	2	Mean
K kg ha^{-1} 0	46.76±0.14	62.48±0.05	70.45±0.30	68.26±0.20	61.99±0.17d
60	55.78±0.47	69.14±0.30	76.26±0.11	73.38±0.07	68.49±0.24c
80	60.76±0.77	73.71±0.13	82.38±0.19	84.33±0.22	75.29±0.33b
100	69.15±0.24	75.25±0.29	83.38±0.08	86.30±0.06	78.55±0.17a
Mean	58.11±0.41c	70.17±0.19b	78.12±0.17a	78.07±0.14a	

Lime*, Potassium*, Limex potassium*

Table 3: Combined effect of lime and potassium on total nitrogen uptake (Kg ha^{-1})

Lime t ha^{-1}	0	0.5	1	2	Mean
K kg ha^{-1} 0	58.32a	75.48b	84.25b	81.98b	75.01
60	67.98b	83.75b	96.08b	88.71b	84.13
80	74.01b	89.63b	99.43b	102.76b	91.46
100	83.07b	89.85b	101.24b	104.16b	94.08
Mean	70.85	84.68	95.25	94.40	

Lime*, Potassium*, Limex potassium*

Table 4: Combined effect of lime and potassium on total phosphorus uptake (kg ha^{-1})

Lime t ha^{-1}	0	0.5	1	2	Mean
K kg ha^{-1} 0	5.29a	7.47b	7.83b	8.85b	7.38
60	6.06a	8.19b	8.84b	9.23b	8.08
80	7.26b	8.74b	9.32b	9.92b	8.81
100	7.6b	9.42b	9.75b	10.34b	9.28
Mean	6.55	8.46	8.94	9.59	

Lime*, Potassium*, Limex potassium*

Table 5: Effect of lime and potassium on phosphorus uptake by haulms (kg ha^{-1})

Lime t ha^{-1}	0	0.5	1	2	Mean
K kg ha^{-1} 0	0.54±0.40	1.05±0.011	1.16±0.072	1.14±0.032	0.97±0.13b
60	0.87±0.04	1.14±0.082	1.30±0.041	1.39±0.095	1.18±0.06a
80	1.02±0.02	1.27±0.023	1.39±0.010	1.52±0.025	1.3±0.021a
100	1.08±0.04	1.31±0.036	1.42±0.045	1.57±0.070	1.35±0.050a
Mean	0.88±0.12b	1.19±0.039a	1.32±0.042a	1.41±0.055a	

Lime*, Potassium*, Limex potassium*

Table 6: Effect of lime and potassium on phosphorus uptake by tuber (kg ha^{-1})

Lime t ha^{-1}	0	0.5	1	2	Mean
K kg ha^{-1} 0	4.75±0.03	6.42±0.02	6.67±0.11	7.71±0.09	6.39±0.062d
60	5.19±0.01	7.05±0.05	7.54±0.11	7.84±0.08	6.89±0.063c
80	6.24±0.02	7.47±0.03	7.93±0.02	8.39±0.18	7.51±0.059b
100	6.52±0.01	8.11±0.06	8.32±0.06	8.77±0.10	7.93±0.057a
Mean	5.68±0.016c	7.26±0.04b	8.18±0.073a	8.18±0.11a	

Lime*, Potassium*, Limex potassium*

Uptake of potassium: Uptake of total potassium was observed significantly higher with increasing level of lime and potassium application as well as their interaction (Table 7). Potassium is mineral fertilizer, which is readily available and was easily taken up by potato. The lowest potassium uptake was observed from control plot and the highest from higher level of lime and potassium, 41.51 and 115.79 kg ha^{-1}, respectively (Table 7).

Uptake of calcium: Total calcium uptake was found significantly higher with increasing level of lime and potassium as well as their interactions (Table 8). Lowest

Table 7: Combined effect of lime and potassium on total potassium uptake (kg ha^{-1})

Lime t ha^{-1}	0	0.5	1	2	Mean
K kg ha^{-1} 0	45.51a	53.89a	56.42a	48.72a	50.14
60	54.47a	67.6b	77.78b	77.70b	69.39
80	73.05b	93.99b	98.35b	97.52b	90.73
100	87.74b	112.21b	111.05b	115.79b	106.70
Mean	64.19	81.92	85.9	84.93	

Lime*, Potassium*, Limex potassium*

Table 8: Combined effect of lime and potassium on total calcium uptake (kg ha^{-1})

Lime t ha^{-1}	0	0.5	1	2	Mean
K kg ha^{-1} 0	17.95a	32.16b	36.07b	40.81b	31.75
60	21.15b	34.17b	40.17b	47.56b	35.79
80	23.17b	37.15b	43.26b	53.84b	39.36
100	24.45b	39.82b	42.73b	53.18b	40.05
Mean	21.68	35.83	40.56	48.87	

Lime*, Potassium*, Limex potassium*

Table 9: Combined effect of lime and potassium on total magnesium uptake (Kg ha^{-1})

Lime t ha^{-1}	0	0.5	1	2	Mean
K kg ha^{-1} 0	11.35a	14.81b	14.6b	13.4b	13.54
60	12.67a	15.58b	16.6b	16.31b	15.29
80	14.55b	17.16b	17.21b	17.72b	16.66
100	15.61b	17.85b	17.94b	17.91b	17.33
Mean	13.55	16.35	16.59	16.54	

Statistically significant at 0.05 probability*, Lime*, Potassium*, Limex potassium ns (Non significant)

calcium uptake (17.95 kg ha^{-1}) was observed in control treatment and the highest (53.84 kg ha^{-1}) was from the treatment with 2 t ha^{-1} of lime and 80 kg ha^{-1} of potassium (Table 8).

Uptake of magnesium: Total uptake of magnesium was observed significantly increased with increasing rate of potassium and lime application. Lime increases magnesium availability in soil. This might be due to adsorption of Ca^{++} and Mg^{++} ions replacing H^+ ions from the exchange complex. Similar results were observed by other researchers[4,13,15,16,17]. The lowest uptake of magnesium was obtained by control plot 11.35 kg ha^{-1} and highest was 17.94 kg ha^{-1} from the plot where lime 1 t ha^{-1} and potassium 100 kg ha^{-1} were applied (Table 9).

Relationship between total dry matter yield and total uptake of different nutrients: The relationship between total dry matter yield and total nutrient uptake was described by a common second order polynomial function that best fitted to the data points. In each relationship, the intercept was set to zero assuming that at zero uptakes no dry matter yield was expected.

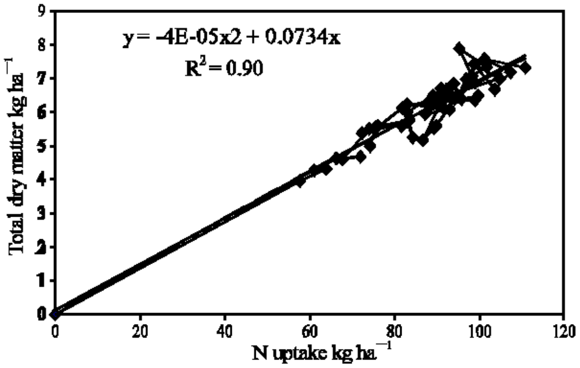

Fig. 1: Relationship between total dry matter yield and nitrogen uptake

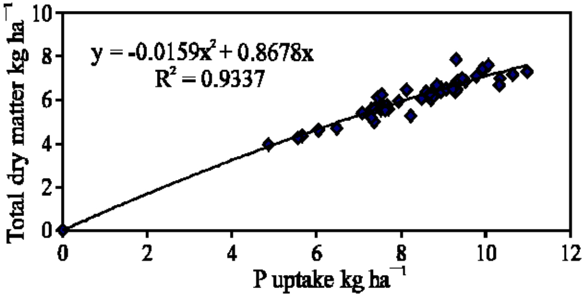

Fig. 2: Relationship between total dry matter yield and phosphorus uptake

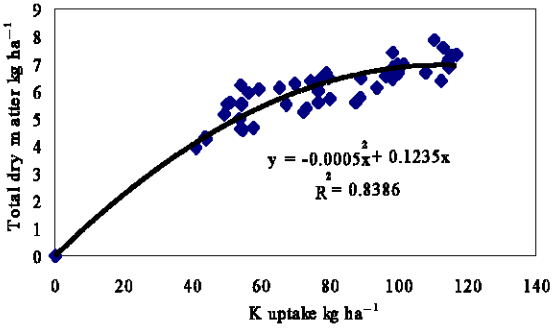

Fig. 3: Relationship between total dry matter yield and potassium uptake

Total dry matter yield (t ha^{-1}) as a function of total N uptake (kg ha^{-1}): Relationship between uptake of total nitrogen and dry matter yield by the tubers has been presented in Fig. 1. The dry matter production increased with increasing uptake of nitrogen. The basic regression equation is $Y= 0.0734\,X - 0.00005X^2$ ($R^2= 0.90$).

Where Y is total dry matter yield (t ha^{-1}) and X is total nitrogen uptake (kg ha^{-1}). The regression equation indicates that for 1 kg of nitrogen uptake the dry matter yield is increased by 73.4 kg. The near linear yield uptake relation indicates that nitrogen is a limiting growth factor of potato.

Total dry matter yield as a function of total P uptake: Figure 2 depicts that the dry matter production in relation to P uptake. The Positive correlation ($R^2= 0.93$) indicates the lime responsiveness to the crop. The regression equation is given by $Y= 0.8678\,X - 0.0159\,X^2$ ($R^2= 0.93$).

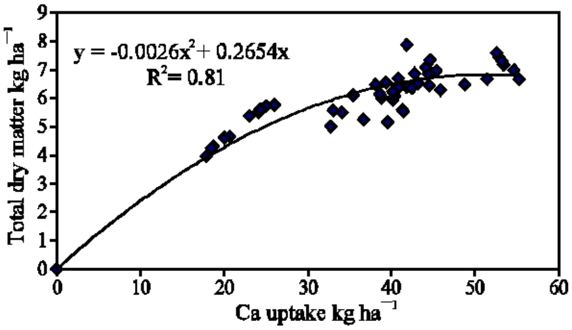

Fig. 4: Relationship between total dry matter yield and potassium uptake

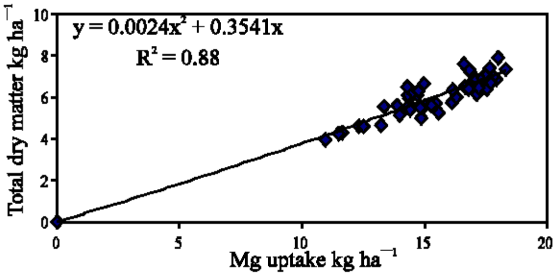

Fig. 5: Relationship between total dry matter yield and magnesium uptake

Where Y is total dry matter yield (t ha^{-1}) and X is the total uptake (kg ha^{-1}). It was observed that total P uptake increased with the application of lime. The initial efficiency of P uptake was high (867.8 kg). It means for 1 kg uptake of P the dry matter yield was increased 867.8 kg.

Total dry matter yield as a function of total K uptake: Uptake of total potassium and the relationship with total dry matter yield is presented in Fig. 3. The regression equation for the relationship is given by $Y=0.1235X-0.0005X^2$ ($R^2= 0.81$).

Here Y is total dry matter yield (t ha^{-1}) and X is total K uptake (kg ha^{-1}). Potassium application positively affected its concentration in haulms, tubers, soil as well as dry matter and consequently K uptake was also affected. The positive effect indicates the higher relationship between K uptake and total dry matter yield. The regression equation indicates that for 1kg of K uptake the dry matter yield is increased by 123.5 kg. So potassium is a limiting growth factor of potato. The lowest yield was obtained in control plots, which had lowest total K uptake and significantly differ than other treatments receiving lime and potassium.

Total dry matter yield as a function of Ca uptake: Figure 4. shows the uptake of total calcium as a function of total dry matter. The regression equation is given by $Y=0.2654X-0.0026X^2$ ($R^2=0.81$).

Where Y is total dry matter yield (t ha^{-1}) and X is total Ca uptake (kg ha^{-1}). The initial slope of the equation is 265.4, it indicates that 1 kg Ca uptake increased the dry matter yield by 265.4 kg. It is less limiting factor compared to potassium. However, it is also limiting growth factor of potato.

Application of calcium positively affected its concentration in haulms and tubers, soil as well as total dry matter and consequently Ca uptake was also affected. Calcium uptake increased with the application of lime. The lowest yield was obtained in control plots, which had lowest total Ca uptake and significantly differ than other treatments receiving lime and potassium.

Total dry matter yield as a function of Mg uptake: Figure 5 indicates the uptake of total magnesium as a function of total dry matter. The regression equation is $Y=0.3541X+0.0024X^2$ ($R^2=0.88$).

Where Y is total dry matter yield (t ha^{-1}) and X is total Mg uptake (kg ha^{-1}). It was found that Mg uptake has been increased with the application of lime. The initial slope of total Mg uptake had higher initial efficiency yielding 354.1 kg total dry matter per kg of Mg uptake where as Ca was 265.4 kg. Therefore Mg is less limiting growth factor than calcium.

Application of lime and potassium significantly increased total dry matter yield as well as total uptake by plant. Total dry matter was increased from 4.18 t ha^{-1} to 7.43 t ha^{-1} due to the application of lime and potassium. Lime increased the total uptake of N, P, K, Ca in both haulms and tubers.

From the study it was found that optimum requirement of lime and potassium on potato in acidic sandy loam soils are 2 t ha^{-1} and 100 kg ha^{-1}, respectively.

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