Lime and Potassium (K) Interaction Effect on Soil acidity and K availability in an upland acidic soil of Eastern India

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Abstract

In order to investigate the effect of liming on potassium (K) dynamics at various levels of K fertilizer application in an acid soil growing groundnut one laboratory incubation study was conducted for 5 weeks with 4 levels of lime (0, 0.1 LR, 0.2 LR, 0.3 LR) and 3 levels of potassium (0, 10 ppm, 20 ppm K) on a soil collected from an upland located in the Central Farm of Odisha University of Agriculture and Technology (OUAT)at Bhubaneswar . At weekly interval, soil samples were analysed for pH, exchange acidity, various forms of K (water soluble, Exchangeable and non-exchangeable), water soluble Ca^{++} and Mg^{++} and activity ratio. Liming significantly increased soil pH but effect of application of potassium on soil pH was nonsignificant up to 5 weeks. Exchangeable acidity and exchangeable Al^{3+} got significantly reduced with liming at 0.1 LR and at higher levels there was complete neutralisation of exchangeable Al^{3+}. Liming at 0.1 LR significantly raised the water soluble K content which decreased with liming at higher levels of 0.2 LR and 0.3 LR. Application of K increased both exchangeable and non-exchangeable K significantly but liming effect was non significant. The intensity of K measured in terms of activity ratio also increased with periods of incubation. The intensity increased with increase in K level, with increased liming the intensity decreased. From the results it may however be suggested that in acidic red and lateritic soils more benefit from applied K fertilizer can be obtained by liming @0.1 LR and increased lime level requires increase in K fertilizer dose for greater availability of K to plants.

Key Words: K Dynamics, ws-K, Exchangeable K, Non-exchangeable-K, Activity ratio, Buffering capacity

Introduction

Acid soils particularly acidic upland is the main area of production of pulses, oilseeds and coarse cereals. Liming increases the soil pH, improves availability of plant nutrients and crop growth, increases nutrient uptake, stimulates biological activity, decreases 3+ extractable Al and reduces toxicity of some elements

Acid soils that occupy more than 70% of the total cultivated area of Odisha have many soil related production constraints. Liming is the single most important technology developed and tested multilocationally to enhance crop yield in acidic uplands. Liming along with fertilization has significantly increased the productivity of acid soils (Annual Progress Report, NAE, 2009-10).

Potassium as a nutrient element plays many a vital role in plant growth. It is essential in nearly all processes involved to sustain plant life. The average nutrient consumption of Odisha was 59.78 kg/ha of cropped area which consisted of 33.65 kg N, 17.11 kg P_2O_5 and 9.02 kg K_2O (Anonymous, 2004). The consumption rate is far less than the national average. Although requirement of K_2O is almost same or more than that of N in most crops, the consumption rate of K_2O is only 27% of that of N. Mishra and Mitra (2001) reported that crop removal of K_2O from the soils of Odisha was 282.34 thousand tonnes and addition as fertilizer only 39.47 thousand tonnes, which left a huge negative balance of 242.87 thousand tonnes. This accounted for a negative balance of 29.16 kg K_2O/ha. In Odisha, as compared to N and P much less work has been done on K. This is because of the general impression that soils are well supplied with this element and that in most of the cases there is little need for potash fertilizer. Much of the works on response of crops to K in the state have been restricted to rice only.

Groundnut is an important oilseed crop of the state. There is huge potential to increase the area and productivity of groundnut by covering upland acid soils of the state through crop substitution and providing adequate nutrition. Acid soils that occupy more than 70% of the total cultivated area have many soil related production constraints. Liming when used along with adequate nutrition is the single most important technology developed and tested multilocationally to raise the productivity of acid soils in the state. Application of liming either directly or indirectly influences various soil processes responsible for nutrient availability in soil.

Effects of liming on K availability are not well documented. The efficiency of fertilizer K use in a particular soil under a particular crop requires understanding of K-lime interactions. Considering the importance of potassium in groundnut nutrition and liming in increasing crop productivity in the acid soils of the country and the state of Odisha in particular, the present investigation was carried out.

Materials and methods

In order to fulfil the objectives of the present investigation, the incubation study was conducted in the laboratory of the Department of Soil Science and Agricultural Chemistry, Orissa University of Agriculture and Technology, Bhubaneswar. The laboratory incubation study was laid out in complete randomized design (CRD) with 12 treatments (table 1) replicated thrice. The study was conducted for a period of 5 weeks. The treatments consisted of 4 levels of lime (L_0=No lime, L_1=0.1LR, L_2=0.2LR, L_3=0.3LR) and 3levels of potassium (K_0=No potassium, K_1=10 ppm potassium, K_2=20 ppm potassium).The source of liming material was $CaCO_3$ and potassium source was MOP fertilizer. The treatment details are given below:

Table 1. Description of treatments of the incubation study

Treatments	Treatment details
L_0K_0	CONTROL
L_0K_1	10 PPM K
L_0K_2	20PPM K
L_1K_0	0.1 LR
L_1K_1	0.1 LR+10 PPM K
L_1K_2	0.1LR+20 PPM K
L_2K_0	0.2 LR
L_2K_1	0.2 LR+10 PPM K
L_2K_2	0.2 LR+20 PPM K
L_3K_0	0.3 LR
L_3K_1	0.3 LR+10 PPM K
L_3K_2	0.3 LR+20 PPM K

The soil for incubation study was collected from an upland located in the Horticulture orchard of OUAT .The soil was a moderately well drained red soil. It was air dried under shade, crushed and shieved (10 mesh) and stored .Then approximately 1Kg of soil was taken in each of the 36 nos. of wide mouth bottles. After maintaining field capacity moisture bottles were incubated at room temperature for 5 weeks. One set of samples were used for estimation of soil moisture by gravimetric method and the moisture content was used for the calculation of different nutrients.

The fresh soil samples were subjected to various physical and chemical analysis following standard methods such as Soil pH(Jackson, 1967), Soil EC(Jackson, 1967), Exchangeable Acidity and Exchangeable Al^{3+} **(**Yuan 1959), Water Soluble potassium and Neutral-Normal Ammonium Acetate (NH_4OAc) Extractable Potassium(Hanwayard Heidel, 1952), 1N HNO_3 Extractable K(Wood and De Turk, 1940), Exchangeable Ca^{2+} and Mg^{2+} (Perkins Elmer Atomic Absorption Spectrophotometer), Activity Ratio (AR_0^K) and Potential buffering capacity (PBC^K). Statistical Analysis was done by the method given by Gomez and Gomez (1976).

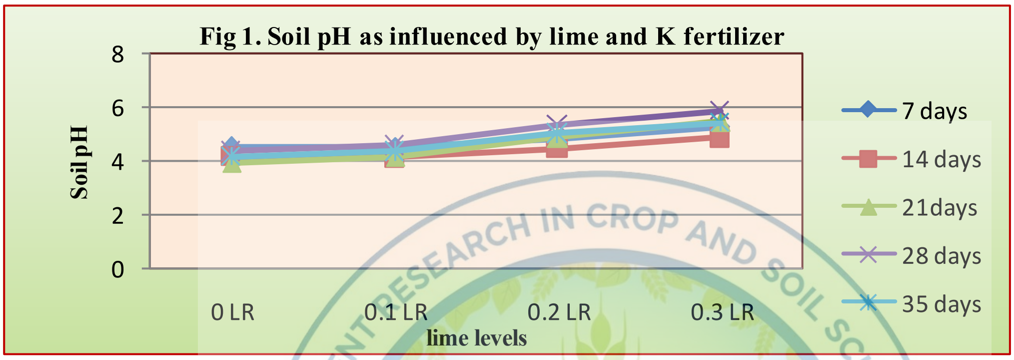
Result and Discussion

Results on effect of liming and potassium levels on some important soil physical and chemical properties are presented and discussed below:

Soil pH

Data pertaining to soil pH as influenced by different levels of liming and K application to the test soil under incubation revealed that soil pH varied between 4.05 and 5.90 which was slightly below and above the initial soil pH of 4.83. The pH was inconsistent over the period of 35 days.

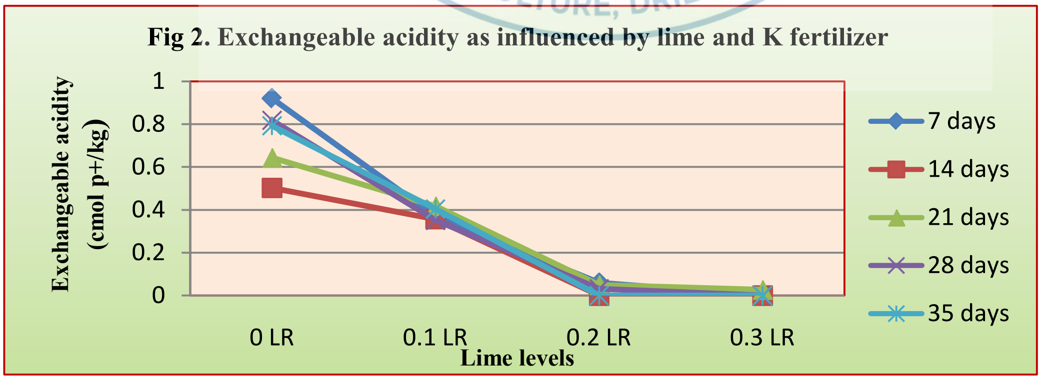
Application of lime at or above 0.2LR significantly increased the soil pH. At 0.1LR the pH however was lower than no lime situation particularly in 1st 2weeks after which it increased. Inspite of liming the pH remained within moderately acidic range. Application of K had no significant effect on soil pH. The interaction effect was also non significant.



Exchangeable acidity

Liming significantly influenced the exchangeable acidity that significantly decreased to a lower value at 0.1LR and to almost nil at or above 0.2LR which is illustrated in fig 2.

In relation to pH, the exchangeable acidity decreased with increase in pH and reduced to almost zero when pH became more than 4.84. This has also been reported by the workers at OUAT (Annual Report, NAE-2009). Application of K and the interaction effect of lime and K were non significant.



Exchangeable Al^{3+}

Similar to exchangeable acidity, the lime application significantly decreased the exchangeable Al^{3+} at 0.1LR level and to almost nil at 0.2LR and above which corresponds to pH values of about

4.84 and above. The decrease in Al^{3+} exchangeable acidity. Application of K and the interaction effect of K and lime were non significant.

Water soluble K

Application of lime increased the ws-K and the measured increase was significant at 14th and 28th day irrespective of the levels of K applied. Out of the 3 levels of lime applied, 0.1 LR recorded almost highest ws-K at each stage of incubation. With higher levels of lime application ws-K either remained almost constant or slightly decreased. Decrease with increased levels of lime application has also been reported by (Cutin and Smillie, 1983). The decrease is due to more fixation of K at higher pH (Grewal and Kanwar, 1967).

Application of K fertilizer significantly increased the ws-K at each stage of incubation. With increased level of application, the ws-K increased. No significant interaction effect of lime and K on ws-K was observed. However, at higher levels of liming, ws-K was more at higher levels of K application. This suggests that increased lime level requires increase in K fertiliser dose for greater availability of K to plants. Similar findings have also been reported by Raychaudhuri and Raychaudhuri (2009).

Exchangeable K

Unlike ws-K, exchangeable K showed a sharp decrease during 7-14 days, followed by a slight fall at 21 day and a progressive increase thereafter. Exchangeable K varied from a lowest of 14-60 ppm in L_2K_2 treatment that received lime @ 0.2LR and 20ppm K. The exchangeable K values measured for incubated acid soil were much lower than the ws-K values which might be due to low CEC associated with the soil that has low kaolinite as the dominant mineral with little of illite mixed with it (Tisdale *et. al*., 1985) and no leaching of K^+ as soil is at FC moisture and soil is under a closed system.

Lime application caused a sharp increase in exchangeable K particularly during 1st and 2nd week of incubation upto 0.1LR. At higher levels of lime (0.2LR) application the exchangeable K suddenly dropped which might be due to absence of pH dependent charges and more fixation of desorbed K. More K fixation at higher lime levels (≥0.2LR) in acid soils (pH <5.5) has been reported by Grewal and Kanwar, (1967). Raychaudhuri and Raychaudhuri (2009) reported a fall in exchangeable K at 0.25 to 0.75 LR. The exchangeable K when averaged over K levels increased from 36.30ppm at L_0 or no lime application to 74.88ppm at 0.1LR level followed by a sharp fall to 46.64ppm at 0.2LR. The increase within 1st week and drop there after might be due to initial adsorption followed by gradual desorption for establishment of a new equilibrium among all the forms.

Application of K also caused an increase in exchangeable K at all the stages of measurement except the 2nd week. The increase with application of 10ppm and 20ppm K was higher in the first week than later periods indicating more adsorption in the early period followed by fast release and fixation. The interaction effect of lime with K on exchangeable K was significant on 2nd, 4th and 5th week.

Non exchangeable K

Data related to non exchangeable/ fixed K showed an increase in the 1st week followed by a decrease in the 2nd week. Again there was an increase in 5th week. The decrease in fixed K observed at the end of 1st week and there after might be due to the direct release into solution K pool of the soil which is evidenced by an increase in soil solution K due to low CEC, low pH dependent charge and restriction to leaching. This result was supported by the increase in soil solution K.

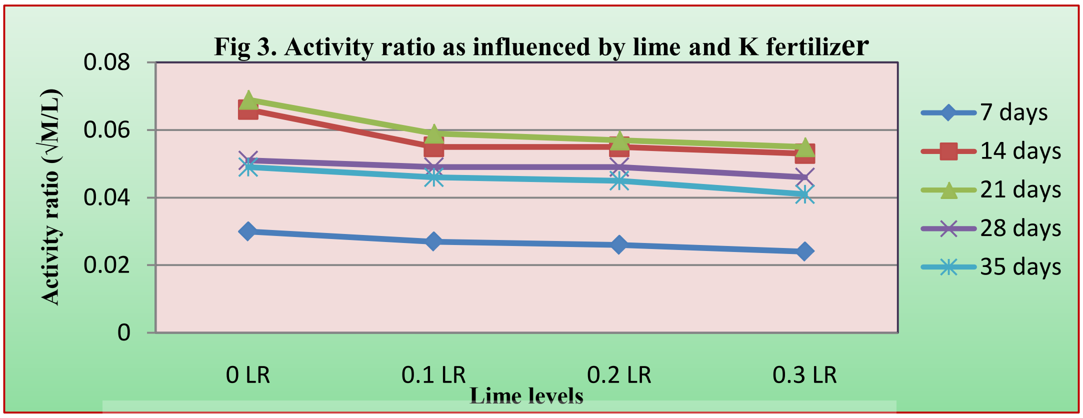
Under no lime condition, the fixed K measured highest particularly in 1st and 2nd week. With liming @0.1LR it dropped sharply followed by an increase with increased levels of liming *i.e.,* at 0.1LR. The soil maintains a low level fixed K that gradually increased with increase in lime level. Increase in K fixation at higher levels of liming has been reported by Grewal and Kanwar, (1967). Thus liming had significant effect on the fixed K level of such an acid soil.

It is also interesting to note that with increased level of K application there is decrease in fixed K measured up to 5 weeks. With period the level gradually falls. This is in contrast to the result of exchangeable K that increased with K level. The interaction effect was non significant.

Activity ratio

Results on activity ratio or intensity of potassium measured for soil under incubation at different liming and K levels shows variation between 0.024 and 0.066√M/L. With period of incubation the intensity showed an upward trend up to the 3 weeks after which it decreased. The intensity was higher in 2nd week (0.057√M/L) and at 3rd week (0.060 √M/L) as compared to other weeks.

Between liming and K levels the latter had significant effect on the intensity after 1st week onwards. Liming resulted in decrease in activity ratio. With increased in liming levels the activity ratio showed a decreasing trend at all stages of incubation, but the decrease was non significant. Sparks and Liebhardt (1981) while investigating the effect of lime on K equilibrium in soils, found that the amount of labile K estimated from Q/I parameters decreased with liming. Raychaudhuri and Sanyal (1999) also reported similar result.



This indicates that at one stage the unlimed soil supplies more K to plant followed by liming at 0.1LR level than the soil with higher levels (0.2LR and 0.3LR) of liming. Thus it may be concluded that liming decrease availability of K to crop plants and with increased liming the availability decreases further. Sudhir (1983) reported antagonistic effect of calcium on K uptake where high levels of calcium were accompanied by low levels of K. In a recent study conducted on the acid soil of Odisha. Raychaudhuri and Raychaudhuri (2009) reported a decrease in water soluble K, exchangeable K and non-exchangeable K with increased doses of liming from 0.25 LR to 0.75 LR.

The intensity increased with K level showing least intensity at no K application and maximum at 20ppm K indicating higher availability in soil which received K. This result is in conformity with the findings of Grewal and Kanwar, (1967).

Potential buffering capacity

For describing the K supplying power of soils the quantity, intensity and buffering capacity of a soil proposed by Beckett (1964) are very useful. The potential buffering capacity (PBC^K) indicates how the K-level in soil solution (intensity) varies with the amount of labile form of K (quantity). The wider the PBC^K more buffered is the soil which has higher capacity to replenish the depleted soil solution K (intensity).

Results on PBC^K calculated by Q/I show a range between 0.67 to 18.40 cmol (p+)/kg/√M/L. On the 7th day of incubation the buffering capacity was highest and it ranged between 6.23 and 18.40 cmol (p+)/kg√/M/L that sharply fell down to 0.67 to 5.51 cmol (p+)/kg/√M/L on 14 day and 1.31 to 3.16 cmol (p+)/kg/√M/L 0n 21 day and to 1.80 to 8.75 cmol (p+)/kg/M/L on 28 day and to 1.66-5.06 cmol 0n 35 day. In general, buffering capacity of soil increased with liming at 0.1LR level. But with higher levels of liming at 0.2LR and 0.3LR it decreased.

Thus highest buffering capacity is maintained with liming at 0.1L. Sengupta (1982) and Nanda (1977) reported low buffering capacity of soils to be associated with low pH and liming of acid soils increased the buffering capacity but lowered K activity in soil solution. In contrast application of K had no significant effect on PBC^K. The interaction effect was also non significant.

CONCLUSION

From the findings of the present study it may be concluded that liming significantly increased soil pH but the effect of application of potassium on soil pH was non significant up to 5 weeks. Liming significantly influenced the exchangeable acidity and exchangeableAl^{3+} that significantly decreased to a lower value at 0.1LR and to almost nil at or above 0.2LR. In relation to pH the exchangeable acidity decreased with increase in pH and reduced to almost zero when pH became more than 4.84, the interaction effect of K and lime were non significant. Highest content of water soluble K is measured at 0.1LR and 0.2 LR in incubation study the contents are high because of low CEC and lack of K fixing minerals in the red soil tested. Optimum amount of calcium results in an increase in the availability of exchangeable and water soluble potassium. Excessive addition of calcium to soil often decreases the availability to plants. The exchangeable K values measured for incubated acid soil were much lower than the ws-K values which might be due to low CEC associated with the soil. Activity ratio which is a measure of K intensity was found be inversely related to levels of liming. There was –ve correlation between AR^K and ws-K. In contrast PBC^K which is a measure of the replenishing or buffer power of soil to supply K to crop is positively correlated with ws-K and exchangeable. At lower liming level of 0.2 LR PBC^K measured higher value. Thus it may be suggested that in acedic red and lateritic soils more benefit from applied K fertilizer can be obtained by liming @ 0.2 LR and increased lime level requires increase in K fertilizer dose for greater availability of potassium to plants.

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