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EFFECT OF LIME AND PHOSPHORUS FERTILIZER APPLICATIONS ON PERFORMANCE OF FRENCH BEANS IN UASIN GISHU DISTRICT, KENYA

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Abstract

Soil acidity and low phosphorus status are the key factors underlying low crop production in Uasin Gishu District. An on farm experiment was conducted during the 2007 and 2008 cropping season to test the effects of agricultural lime (20.8% CaO) and Triple superphosphate (TSP) (12-14% CaO) on some soil properties and two French bean varieties namely: Samantha and Amy. The bean varieties grown in acid soils (pH 5.0) at Kuinet, Uasin Gishu District received 0 and 2 t ha^{-1} lime and 0, 20 and 40 kg P ha^{-1} (TSP) and their combinations. Lime significantly increased soil pH from 5.5 to 6.3 and 5.4 to 6.0 for the first and second seasons, respectively at the end of the study period. P alone had no significant effect on soil pH, but increased soil available P between 8.7 and 14.7g/kg^{-1-}. Positive responses of the two crop varieties were observed. This gave GM of Kshs 84,200 and 44,200 respectively. The effects of lime and TSP (With Cao component) were attributed to a favorable positive change in soil pH which increased the availability of soil nutrients through organic matter decomposition or direct release from TSP and availability to the crop and subsequent uptake of the nutrients by the crop. Economic analysis of the crop yields reflected higher returns from both lime and P, particularly in the pods harvested seven weeks after planting. The study demonstrated the superiority of Samantha French bean variety over Amy despite being the most popular within the region. The need for complementary lime and phosphorus application is recommended for acid soil fertility improvement and high crop yields.

Key words: Increased soil pH. Lime. French bean. Residual effects. Soil acidity.

Introduction

Soil acidity and low plant available phosphorus (P) have been identified as major contributors to low soil fertility in many cropped soils of Kenya, particularly in western Kenya (Okalebo 2009). These soils are highly weathered, leached and are low in nutrients availability. Hence widespread nitrogen and phosphorus deficiencies occur in these soils (Neil, 1991). This situation is worsened by high rates of population growth in high potential areas which has resulted into land subdivision into small unproductive plots combined with continuous cultivation without replenishing depleted nutrients.

Uasin Gishu district falls within Western Kenya region whose soils are inherently acidic with pH range of 4.5-5.0 (Kisinyo et al 2009, Nekesa, 2007 and Jaetzold and Schmidt, 1983). In this region and some areas of Western Kenya, farmers maintain crop Production through continuous monocropping of mainly maize and wheat with minimal or no nutrient inputs, the practice which further enhances nutrient mining through harvest leading to agriculturally poorer soils than ever before (MOA, 1996). Acid soils cover about 13 % of the total land area cultivated with major crops in Kenya (Kanyanjua *et a*l., 2000). Among the factors contributing to soil acidity in this region are inherent nature of acidic parent material, nutrient leaching, excessive weathering and use of soil acidifying fertilizers such as DAP among others (Mburu *et al.*, 1999). While important crops like tea perform well on acid soils, other crops that are not tolerant to acidity perform poorly or only grow well after heavy investment in labour, fertilizers and lime.

Acid soils are generally infertile with plant growth being limited by one or more commonly interacting factors which include, build up of toxic levels of aluminium (Al) or manganese (Mn), effects on soil microbial activities and deficiencies of calcium (Ca), magnesium (Mg), potassium (K) and molybdenum (Mo). (Kamprath, 1984, Yamoah *et al.*, 1996), Ligeyo and Gudu, 2005,

Most of the Kenyan staple foods are sensitive to soil acidity. Maize, legumes and most of the horticultural crops perform poorly on acidic soils. Their poor growth and development leads to poor quality produce, low crop yields and low per capita food production, a situation which transforms into food shortages, recurrent hunger, malnutrition and loss of lives (Nekesa, 2007).

In this respect, low yields of <200 kg/ha of the grain legumes and 3.5 tons/ha of fresh French bean pod yields, have been reported as reflected in the MOA Report, (2007) from Uasin Gishu district. These yields are low compared to the optimum of 8 tons/ha of fresh pods (MOA, 2000). This situation can be improved with soil acidity amendment measures that will encourage farmers into production for both local and export markets as a way of crop diversification. French beans grow well on well drained, silt loams to heavy clay soils high in organic matter and slightly acidic to slightly alkaline soils (pH 6.5-7.5), medium to high rainfall (900-1200) mm p.a. The climatic conditions within the region can favour French bean production because other factors are optimum for the crop apart from the acid soil conditions

Various options have been tried within the region to deal with soil acidity which includes high phosphorus rates; use of manures, fertilizer blends, breeding of crops tolerant to soil acidity (Ligeyo and Gudu, 2005, van Rheenen, 2001, Nekesa *et al.*, 2007). However, all these options have not offered complete solution to soil acidity problem as most of the crops grown within the region are highly sensitive to soil acidity, particularly legumes. Other options are rather expensive to a common farmer due to high costs involved in acquisition. It is therefore necessary to look into ways of dealing with this problem in order to promote the production of high value leguminous crop.

Recent work within the region has revealed the suitability of lime in dealing with soil acidity particularly on legume performance(Nekesa,2007,Kisinyo,2009).The main interest is due to its effect on improving crop responses to fertilizers by improving nutrient availability and uptake especially phosphorus, reducing aluminium(Al) toxicity and promoting the activities of such desirable organisms as rhizobia bacteria which fix nitrogen for legumes(Plaster,2003).Adoption of such cheaper soil amendment technologies may enhance profitable production of high value acid sensitive crops such as French beans on acid soils of Uasin Gishu district.

This study was conducted to: (i) investigate the effect of applying lime, phosphorus and their combinations on the performance of the two French bean varieties: Samantha and Amy. (ii) monitor changes in soil properties resulting from the use of specific lime and P treatments.(iii)assess the N and P nutrient uptake of the two French bean varieties from soil amendments.(iv)To assess the economic returns from fresh pods of the test French bean varieties due to treatment effects.

Methodology

Field studies

Field experiment was carried out at Kuinet village, situated 12 km N. of Eldoret town in Uasin Gishu District (lat.0043N, long. 35 18E, 2140 (m.a.s). This area receives between 900-1300 mm annual rainfall distributed between April and August, and average daily temperature of between 10^0C-25^0C. The soils are classified as Rhodic Ferrasols FAO1994 or Oxisols. Air–dry soil samples from the top 0.15cm at the study site was analyzed for pH, organic carbon, extractable P, Particle size and total N (Table 1).

The experimental treatments in the field were (i) Control (no input materials) (ii) lime at 2 t ha^{-1} (iii) 20 kg P (TSP) ha^{-1} (iv) 40 kg P (TSP) ha^{-1} (v) lime at 2 t ha^{-1}+ 20 kg P (TSP) ha^{-1} (vi) lime at 2 t $ha-^{1}$ + 40 kg P (TSP) ha^{-1}. These treatments were tested against yield performance of two French bean varieties: Samantha and Amy and the experiment laid out in a 2X6 factorial arrangement. Selection of P and lime rates was based on affordability and the two French bean varieties are the popular ones among the local farmers.

All the plots were hand hoed before the application of the treatments. The first and second crops were planted in 2007 and 2008, respectively. The plot applied with treatments in 2007 experiment was used to evaluate the treatments residual effects in 2008 on soil chemical properties and crop yields without any additional treatment application. A new experiment was set up in the 2008 season with similar treatment as in the previous year (2007).This experiment ran concurrently with the residual experiment. The soil amendment materials were broadcast and incorporated to a depth of 0-15cm before planting. The bean seeds were sown on 3mx3m plots at a spacing of 30x15cm with single seed per planting hole to give plant population of 101,111 plants ha^{-1}.

Hand weeding was done twice before flowering to avoid flower drop. Green pod harvesting started immediately after the pods started forming at week six after planting. This continued weekly up to week eight which is the optimum time for harvesting green pods. A separate portion of each plot was left for dry grain harvesting at full maturity.

Soil samples were taken between 0-15cm depth at 30 and 60 days after planting to monitor the changes in soil properties due to the treatments applied .The sampling depth represent the soil layer where most of the crop nutrients are concentrated after application and the zone occupied by the crop roots. Plant tissue samples consisted of the fresh harvested pods and the dry grains.

Table 1: Physical and chemical properties of soils at 0-15 cm depth taken before planting (start of 2007) at Kuinet site

Soil Properties	Kuinet Site
pH (H_2O, 1:2.5)	5.0
Olsen P mg P /kg	5.82
Total N (%)	0.21
%OC	2.14
C:N ratio	12.1
Soil physical properties	
Sand (%)	55
Silt (%)	23
Clay (%)	22
Soil Texture	Sandy clay loam
Soil Order	Ferralsol (Oxisols)

Laboratory and data analysis

Chemical analysis of the soil and plant material samples was carried out as outlined by Okalebo *et al* (2002). The SAS version 8 computer soft ware package was used for statistical analysis of data. The standard error of the differences (s.e.d) was used to compare the treatment means.

Results and Discussion

Initial Soil Characterization

Table1 gives initial soil parameters as measured from Kuinet study site. Thus the soils in the study site ranged from acidic to strongly acidic with low levels of organic carbon and Nitrogen giving a C: N ratio of 12:1. The soil of Kuinet measured a pH of 5.0 against 6.5-7.5 required for French bean production, the soil available P was 5.82 mg P/kg which is below the critical value of 10 mg P/ kg suggesting P application,(Okalebo *et al*., 2002). The low soil pH (Table 2) in Kuinet site indicates that the acidic level of the soil need to be corrected through suitable amendments such as lime or any other material that could work well on such acid soils. The soil pH below 5.5 according to Foth, (1990) suggests that the soils CEC is highly aluminium saturated. This high aluminium saturation in Kuinet soils has been reported elsewhere by Ligeyo and Gudu, (2005), causes decline in saturation of the CEC with basic cations mainly (calcium, magnesium and potassium). Hence intensive weathering has resulted in acid soils that are naturally infertile (Jaetzold and Schmidt, 1983) requiring supplemental fertilizer application for satisfactory crop production on these soils. The pH of Kuinet site is close to 5.0 (Table 1), the reduction of H^+ and ample supply of Ca by liming to pH 6.0 in this study could increase the mineralization of organic P (Robson and Abbot, 1989).To some extent, then liming an acid soil is an alternative to larger or more frequent phosphorus fertilizer applications (Troeh and Thompson, 1993). The low pH and low P levels could as well indicate the low nutrient levels of these soils and hence these soils are likely to respond to low minimum levels of input application especially phosphorus and calcium (Okalebo *et al.,* 2002). The low total N and organic carbon contents would suggest the addition of organic materials to supplement the low levels. The soil particle analysis reflects suitable soil texture which can hold nutrients, hence with proper fertilizer and liming applications the Kuinet soils can yield a good crop harvest

Soil pH.

Fig.1 shows the effects of different soil amendments and their combinations. Lime significantly increases soil pH (pH<0.01) from 5.5 to 6.3 and from 5.5 to 6.0, respectively for the first and second seasons from the soils sampled at the end of growing seasons. Increase in soil pH was also achieved with TSP alone which was above the control with respect to pH increases but generally lower than the values achieved by lime alone. These findings could be attributed to their different calcium contents of 21 % CaO and 19.2 % MgO for lime which have the combined neutralizing effect on soil acidity as compared to TSP calcium content of 12-14% CaO (Rick and Parker, 2004).These results concur with the findings of Tisdale *et al.,* (1990) who reported that phosphoric acid released from dissolving phosphate fertilizers such as triple superphosphate (Monocalcium phosphate) and Mono-ammonium phosphate can temporarily acidify localized zones at the site of application. They also found that TSP could lower the pH to as low as 1.5 while MAP could decrease pH to approximately 3.5.Their acidity is however rapidly neutralized, but the acidic reaction products may remain to influence the soil properties indicating the need for liming especially for such acid soils as an agronomic practice.

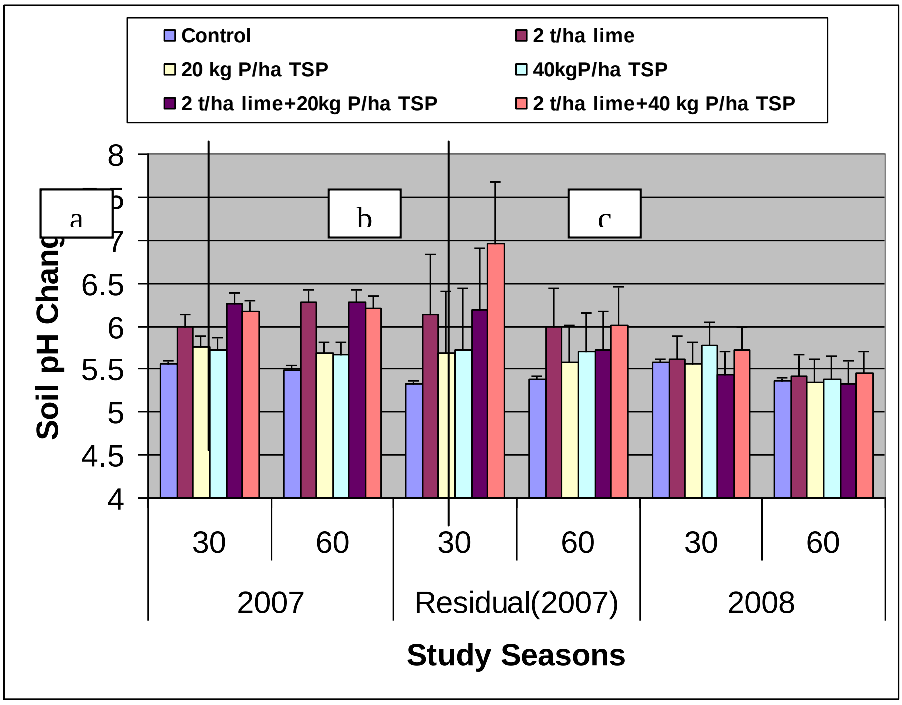

Fig 1: pH changes due to soil improvement materials application over the study period. Bars represent standard errors

Effect of P on Soil extractable P .

The effects of applying both lime and P on the Olsen extractable or soil available P. during the two cropping seasons (2007 and 2008) including the2007 residual effects are presented in Fig 2.In general the values were very low, Nevertheless, The application of P. as TSP significantly (p<0.01) increased the amount of extractable P. With respect to the rates of P applied from 15.78 to 20.93 to 25.97 (mg P kg^{-1}) for 0, 20, and 40 kg P ha^{-1} applied during the first sampling at 30 days after planting. The trend however changed during the second sampling at 60 days after planting where the soil P values measured were not consistent with the rates applied giving 18.28, 16.05 and 20.81 (mg P kg^{-1}) respectively as above. This could be attributed to rapid uptake by the vigorously growing crop during the second sampling period.

The same positive trend was obtained in the second growing season where the P. values increased with the P. rates applied as indicated in fig.2.The P values for the residual were not consistent across the rates applied which could be due to crop uptake depending on the previous nutrient applied and possible P. fixation by the soil colloid.

The solubility of phosphorus ions depends greatly on pH because pH influences both the kind of phosphorus ion present and the concentration of the precipitating ions. According to Troeh and Thompson, (1993), the influence of soil pH on phosphorus solubility is one of the reasons for liming acid soils. Liming acid soil will precipitate Al^{3+} as Al $(OH)_3$ which is dominant in acid soils such as those in Kuinet site as indicated by pH of the soils in the area (Table 1), thus increasing plant available P as echoed by Havlin *et al.*, (2005). Phosphorus occurs in the soil in both mineral and organic forms. The phosphorus in organic matter is tied into the structure of the compounds. Such phosphorus may participate in chemical reactions but it is held firmly in place and unavailable to plants until the organic material decomposes (Troeh and Thompson, 1993). Lime with the active CaO component contributed to the release of fixed and precipitated phosphorus by creating favorable pH hence increasing available P, suggesting the need for liming acid soils such as those in Kuinet site as a means of enhancing P. availability.

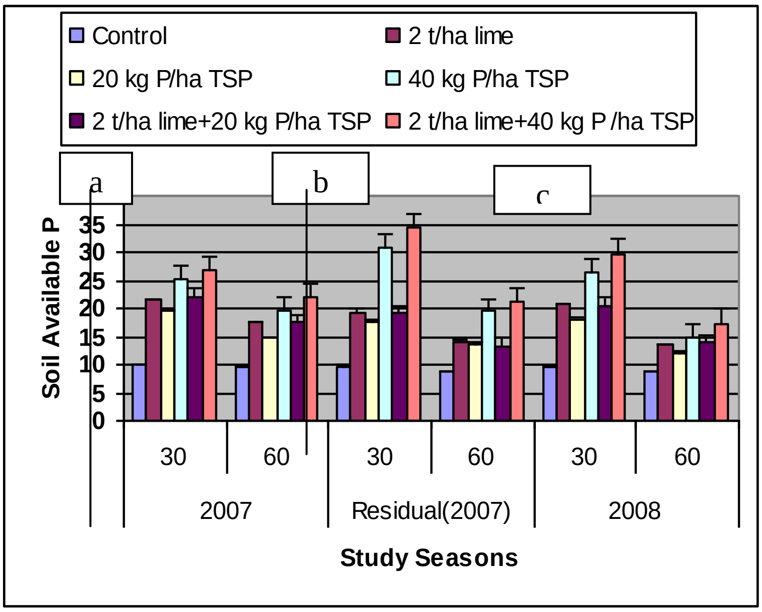

Fig 2: Changes in available P (mg kg^{-1}) as affected by soil improvement material application over the study period. Bars represent standard errors.

Effect of liming and P on Fresh pod bean yield of two French bean varieties.

Table 1a, 1b and 1c give fresh pod weight of French beans. On average during the study period, the application of 2 t ha^{-1} lime, 20 kg P^{-1} and 40kg ha-^{1} P. as TSP increased the fresh pod yields above the control by 6.87, 5.35 and 6.91timess respectively, these were for the Samantha French bean variety, the corresponding values for the Amy variety as follows:3.23, 2.99 and 2.38 across the treatments applied. The combination of lime and P (TSP) had variable effects on fresh pod bean yields of the two French bean varieties. The highest fresh pod yields increase was obtained in the 2007 residual experiment, where an application of 2 t ha^{-1} lime with 40 kg P ha^{-1} produced 9.3 t ha^{-1} fresh pod yields from Samantha variety compared to 6.29 t ha^{-1} obtained with a application of 40kg P ha^{-1} alone. Amy variety however gave its highest fresh pod yields of 8.87 t ha^{-1} when 2 t ha^{-1} lime were combined with 20kg P ha^{-1} compared with 20kg P ha^{-1} which gave 6.24t-ha fresh pod yields. There were positive interaction effects between lime and the application of P. on fresh pod yields of both French bean varieties. Amy variety was however responding poorly to the treatments applied when compared to Samantha at the corresponding rates of materials applied. The high French bean yields both fresh and dry from P or Lime or both in combination for two seasons, as compared to the control, show that French bean responded to the addition of P and CaO to the soil. According to Troeh and Thompson, (1993), calcium is a structural component of cell walls and is therefore vital in the formation of new cells; hence the Ca supply through liming in the present study could have had a favorable effect on bean crop yield in the limed plots. According to Adams and Early, (2005) beneficial soil organisms are affected by soil acidity and liming. Calcium sometimes improves soil structure and soil stability. This could be due to its effect on organic matter decomposition yielding humus and promotes root activity. Havlin *et al.*, (2005) and Troeh and Thompson, (1993) agree on the fact that legumes are known to use more calcium and magnesium; this could partly explain the French bean varieties yield response to liming of the Kuinet acid soils in this study. These researchers also note that most calcium in fertilizers is associated with phosphorus compounds and is applied for the benefit to be derived from the phosphorus as observed from the plots receiving the P and lime treatment combinations. Use of Lime alone or TSP in combination with lime increased soil nutrients P and Ca required for plant growth either from direct release from the inputs or improving the solubility of phosphorus from insoluble Al and Fe compounds which are commonly associated with acid soils such as those in Kuinet site. This could have contributed to higher French bean yields obtained from the treatments applied in the present study.

Table: 1a Treatment effects on V1 (Samantha) & V2 (Amy) fresh pod yields (t /ha) as harvested during 2007 of the study period

2007								
French bean varieties	Samantha V1				Amy V2			
Treatments	Po	P20	P40	Means Lime	Po	P20	P40	Mean Lime
Lime t ha^{-1}								
0	1.21	6.47	7.91	**5.19**	1.64	4.91	3.90	**3.48**
2	8.31	6.99	7.69	**7.66**	5.30	5.86	4.39	**5.18**
Means P	**4.76**	**6.74**	**7.80**		**3.47**	**5.39**	**8.29**	
Overall Mean				**6.43**				**4.33**
CV (%)				**13.22**				**24.16**
$LSD_{0.05}$ P L P*L				 **0.54** **0.44** **0.76**				 **0.73** **0.87** **0.71**

1 b Table:

Table 1b: Treatment effects on V1 (Samantha) & V2 (Amy) fresh pod yields (t /ha) as harvested during 2007 Residual of the study period

2007 Residual								
French bean varieties	Samantha V1				Amy V2			
Treatments	Po	P20	P40	Means Lime	Po	P20	P40	Means Lime
Lime t ha^{-1}								
0	2.53	6.87	6.29	**5.23**	1.76	6.24	4.89	**4.29**
2	8.71	9.02	9.30	**9.01**	6.20	8.87	3.77	**6.28**
Means P	**5.62**	**7.95**	**7.80**		**3.98**	**7.56**	**4.33**	
Overall Mean				**7.12**				**5.19**
CV (%)				**10.28**				**24.08**
$LSD_{0.05}$ P L P*L				 **0.57** **0.46** **0.78**				 **0.87** **0.71** **1.23**

Table: 1c Treatment effects on V1 (Samantha) & V2 (Amy) fresh pod yields (t /ha) as harvested during 2008 of the study period

2008								
French bean varieties	Samantha V1				Amy V2			
Treatments	Po	P20	P40	Means Lime	Po	P20	P40	Means Lime
Lime t ha^{-1}								
0	2.08	6.66	7.75	**5.49**	1.91	6.30	6.34	**4.85**
2	8.03	6.67	9.39	**8.03**	6.50	4.59	4.62	**5.24**
Means P	**5.06**	**6.67**	**8.57**		**4.21**	**5.45**	**5.48**	
Overall Mean				**6.76**				**5.04**
CV (%)				**21.07**				**34.88**
$LSD_{0.05}$ P L P*L				 **0.55** **0.45** **0.78**				 **0.73** **0.77** **0.71**

Residual effects of the treatments on crop yields

During the second season (LR 2008), treatments were not re-applied in the previous plot of (2007 LR) in order to study their residual effects on subsequent crop and the overall economic findings from each treatment. Thus, the residual (2007) treatment experiment performance of the crop varieties depended upon the residual effects of lime, phosphorus and their combinations applied in the first season of (2007). French bean, both fresh and dry grain yields, generally increased with increasing rates of materials applied though as in the fresh treatment application, the yields tended to reduce with higher level of P (40 kg P/ha) applied in combination with 2 tons of lime for (Amy). The variety (Samantha) was still performing better under the treatments applied as compared to (Amy).The increased yields could be explained according to the findings of Cooke (1967) who noted that residues of fertilizers left in the soil often raise yields that are difficult to imitate with fresh fertilizer dressings. According to Havlin *et al*., (2005) plant nutrients must be in the soil in available forms if they are to be taken up and used by plants. Soil pH is especially important for maintaining fertilizer nutrients in the available forms. Hence the availability of Ca, phosphorus from the materials applied and other nutrients released from organic matter mineralization and improved uptake could have been a major contributing factor to higher yields in the residual experiment due to lime components in both lime and TSP materials applied. For a given soil, molybdenum availability and uptake by the plants increases as the soil pH increases. According to Norman *et al*., (1995), one of the benefits of liming soils is increasing available molybdenum which is the main factor that enhances growth of legumes on acid soils such as those under this study. Thus this could partly explain the high crop yields obtained from the soil amendment treated plots.

Conclusion

Soil analyses results confirmed that the problem of high soil acidity and low nutrient N and P contents is considerable at the Kuinet site. In general continuous maintenance of optimum P fertilizer rates to the soil is required so as to maintain an appropriate level of soil available phosphorus**.**

High soil acidity levels within the Kuinet area require application of suitable soil amendment materials to correct this situation to enable production of acid sensitive crops such as legumes. This can be done through annual applications of small quantities of agricultural lime in order to improve utilization of the applied fertilizers for better crop returns.

The results of P analysis have shown that, application of materials with both P and CaO (TSP*LIME) to the highly acidic and P-fixing soils of Kuinet site greatly improves P availability. However, for long term crop yield improvement, application of these recommended materials would be profitable if applied in larger quantities to ensure higher residual effects on subsequent crop.

The trials have also shown that French bean production on acid soils is possible with appropriate soil acidity amendment techniques. This however should take into consideration Varietal differences as regards crops response to the applied acid soil improvement material. In this study Samantha French bean response to the applied inputs can form a basis for its recommendation for production on acid soils.

On average, the performance of the input materials in terms of yield responses particularly the residual effects on subsequent season and the net benefit was superior as compared to the freshly applied materials.

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