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EFFECT OF LIME AND DIFFERENT SOURCES OF PHOSPHORUS ON TOTAL EXCHANGEABLE SOIL ACIDITY AND CROPS PRODUCTIVITY

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ABSTRACT: ***A field experiment was conducted on an acidic soil (Ferralsol humic) to evaluate the rates and sources of phosphorus with and without lime on total exchangeable acidity (Al + H) and crops yield. The sources of phosphorus were (I) diammonium phosphate (DAP), (ii) triple super phosphate (TSP) and (iii) dicalcium phosphate (DCP). The rates were 0, 60, 120 and 180 kg of P_2O_5 ha^{-1} with lime at rate 0 and 1Mg ha^{-1}. Sorghum (Sorghum bicolor L.) was planted in the first season. Potato (Solanum tuberasum L.) was planted in the second season without treatments to evaluate the residual effects. Then, the phosphorus treatments only were applied and wheat (Triticum aesstivum L.) was planted.***

Results indicated that relatively low rate of lime (1 Mg ha^{-1}) significantly increased the exchangeable basic cations at the expense of total exchangeable acidity. Phosphorus fertilizers slightly increased the mean values of total exchangeable acidity from 2.35 to 2.40 without lime, but with lime they decreased to 1.66 $cmol_c$ kg^{-1}. The calculated linear efficiencies values (B) **reflected** ***the relative high total exchangeable acidity for DAP than DCP, whereas the value was intermediate for TSP fertilizer. Also, the increasing of phosphorus rates increased total exchangeable acidity in the acid leached soil but not significantly.***

Results revealed that low rate of lime was adequate to sustain yields in a continuous sorghum, potato and wheat rotation and the combination with phosphorus fertilizers was more affective. Liming plus DAP produced the highest yield of sorghum, (1.638 Mg ha^{-1}). For evaluating the residual effect of lime and phosphorus fertilizers on potato, the highest yield was obtained with the lime residual effect with 120 kg of P_2O_5 ha^{-1}. The result for wheat was in harmony with those reported for sorghum and potato. The residual effect of lime after two seasons increased wheat yield by 25% from unlimed plots. Differences between wheat yield were insignificant with sources of phosphorus but, the response to phosphorus increment doses was almost linear.

Key words *: Acid soil, exchangeable acidity, lime, phosphorous, potato, sorghum, wheat.*

INTRODUCTION

In acid soils, phosphorus is often fixed in various compounds of aluminium and iron. It may be adsorbed by organic matter Al- complex, or precipitated as Al - hydroxyl - phosphate, like Al H_2 PO_4 (OH)[A1]$_2$. Crops growing in such soils show severe deficiency in available phosphorus as well as yields. Heavy applications of phosphorus fertilizers are then utilized to improve crop productivity in these soils. Numerous researchers, reported that certain fertilizers produced high rate of acidification (Fink ,1982, Hignett, 1985 and Van den Berghe *et al.* 1991). The problem of acidification action of the fertilizers makes part of the fertilizer efficiency. This efficiency includes the following aspects: the form, the dose, the placement and the application time.

The most important factor is the ammonium form of nitrogen. Ammonium containing fertilizers are oxidized by bacteria to form NO_3^- and hydrogen ions. For each NH_4^+ cation oxidized , two H^+ result. This reaction applies to any sources of NH_4^+, including urea after hydrolysis and mineralization of NH_4^+ from organic materials. Replacing the form NH_4 by NO_3 as source of N to avoid the acid effect put another problem such as losses by leaching (El Etreiby, 1986). As Burundi country is utilizing principally the DAP, there is certainly a risk that the soils become more acid at long term (Van den Berghe *et al.* 1991)

Lime application may increase the concentration of phosphate in the soil solution either by increasing the hydrolysis of phosphate compounds of aluminium and iron or by increasing the quantity of exchangeable phosphate or phosphate sorptivity (Coleman and Thomas, 1967; Holford, 1983; El Etreiby, 1992; Shehata *et al.*, 1996. and Shehata *et al.*, 1997).

This study was conducted in a leached acid soil, to find out the effect of phosphorus sources with and without relatively low rate of lime (1Mgha^{-1}) and their residual effects on the total exchangeable soil acidity and the yield of three field crops.

MATERIALS AND METHODS

A field experiment was carried out at Agricultural Experiment Station of Mahwa, Institute Agric. Res. Burundi (IASBU), altitude 1980 m above sea level (ASL),, maximum and minimum annual temperatures are 22.5 and 14°C, respectively. The total annual rainfall is about 1635 mm (Bultot, 1950). The studied soil is classified as ferralsol humic soil developed on schist quartizitic parent materials according to INEAC classification (1960), Its organic carbon and total N were 4.04 and 0.34 %, respectively. Some chemical properties of the soil surface (0-30 cm) are presented in Table (1).

Table 1: Some chemical properties of the studied Soil (0-30 cm).

pH		Exchangeable Cations							available	
H_2O	1N KCl	Ca	Mg	Na	K	Al	H	ECEC*	P	m**
(1:5)		----------	----------	----------	$cmol_c\ kg^{-1}$	----------	----------	----------	$mg\ kg^{-1}$	%
4.32	4.22	0.39	0.25	0.04	0.07	1.50	0.85	3.11	58	48.23

* Effective cations exchange capacity.

** (m) Kamprath = Exchangeable Al X 100 / ECEC

Lime and Fertilizers treatments:

Lime of Moso (33% CaO 22% MgO) at two rates 0 and 1 Mg ha^{-1} was applied to the soil and plowed down 15 cm 3 wks prior to sowing at the first season. The phosphorus sources were (i) diammonium phosphate (DAP), 18% N and 46 % P_2O_5 (ii) triple super phosphate (TSP) 48 % P_2O_5 and (iii) dicalcium phosphate (DCP) 37 % P_2O_5. The forms of phosphorus were banded at four rates 0, 60, 120, and 180 kg of P_2O_5 ha^{-1}. The experiment was arranged in a split-split plot design with four replicates. Main plots were the lime rates, sub-plots were the P- fertilizers and phosphate doses as sub-sub plots. The net area for each plot was 44 m^2 (4 x 11 m).

Experimental Procedure:

Sorghum *(Sorghum bicolor L.)* seeds *c.v. local* were sown and all plots were fertilized with 60 kg ha^{-1} of N as urea (45%N) and K Cl (60% K_2O) at the rate of 49.8 kg $ha^{-1}$of K_2O as a basic treatment at the recommended practices in consideration the quantity of N in DAP treatments. For evaluating the residual effect of lime and phosphorus fertilizers, the soil in the second seasons was plowed and received only 49.8 kg ha^{-1} of K_2O banded at planting time and 30 kg ha^{-1} of N as urea was applied 10 days after planting. Then, potato tubers *(Solanum tuberasum L.) cv. Ndinamagra* were planted at spacing of 0.75 x 0.33m. Later in the third season, wheat grains *(Triticum aesstivum L.) c.v. Cowbird* were sown in plot consisted of 20 rows, 20 cm apart, within rows with hand drill at a rate of 120 kg seeds/ ha. The plots were fertilized with 60 kg ha^{-1} of N and 41.5 kg ha^{-1} of K. Phosphorus fertilizers were applied at the rates as described above. Weeds were controlled using hand pulling throughout the growing seasons. At harvest, weight of sorghum grain and biological yield (panicles + straw), potato and wheat grains yield were recorded. The data obtained were statistically analyzed using personal computer according to Dagnelie (1975).

Soil Analysis:

Composite soil samples representing each of the experimental plots were taken before cultivation and at the end of the study, air dried and analyzed for pH (1:5 soil: water ratio) and exchangeable cations as described by Black (1965). Available P was determined by Olsen's method, (Jackson, 1958). Organic carbon and total N were determined as mentioned by Black (1965).

Exchangeable acidity (Al+H) were extracted with 1N KCl and measured by successive titration by sodium hydroxide and HCl in presence of sodium flouride (Black, 1965). Effective CEC as defined by Kamprath (1970) was taken as the sum of exchangeable acidity and exchangeable cations.

RESULTS AND DISCUSSIONS

Soil Chemical Properties:

Table (1) shows the chemical properties of the soil. It was acid soil with pH 4.32 and total exchangeable acidity was 2.35 $cmol_c\ kg^{-1}$; hydrogen and aluminium accounting for 0.85 and 1.50 $cmol_c\ kg^{-1}$, respectively. The soil (m) Kamprath was 48.23. The results of soil chemical properties from the three seasons experiment indicated that relatively low rate of lime (1Mg ha^{-1}) considerably increased the exchangeable basic cations Ca, Mg, Na and K at the expense of total exchangeable acidity (Al + H). Contribution of lime decreased the mean values of total exchangeable acidity from 2.35 to 1.66 and increased the sum of exchangeable basic cations from 0.75 to 1.39 $cmol_c\ kg^{-1}$, (Tables 2 and 3). Regarding to the total exchangeable acidity data, the results revealed that the DCP had lower value than the DAP, whereas the value was intermediate for TSP fertilizer in the acid leashed soil.

In other words, linear regression, Y=A + B X was definitely the more suitable to describe the increase of total exchangeable acidity (Al+ H) $cmol_c\ kg^{-1}$ as functions of phosphorus rates with or without lime, respectively:

The form of DAP:

$Y_{limed.}$ = 1.506 +1.3500E-03 X 0 < X > 180 $R^2 = 0.9742$ (1)

$Y_{unlimed.}$ = 2.364 +5.6666E-04 X 0 < X > 180 $R^2 = 0.9802$ (2)

The form of TSP:

$Y_{limed.}$ = 1.506 +1.3500E-03 X 0 < X > 180 $R^2 = 0.9438$ (3)

$Y_{unlimed.}$ = 2.367 +5.3333E-04 X 0 < X > 180 $R^2 = 0.8391$ (4)

The form of DCP:

$Y_{limed.}$ = 1.500 +1.1666E-03 X 0 < X > 180 $R^2 = 0.9761$ (5)

$Y_{unlimed.}$ = 2.334 +4.0000E-04 X 0 < X > 180 $R^2 = 0.7580$ (6)

Where, "Y" is the total exchangeable acidity (Al+ H) $cmol_c\ kg^{-1}$, X is unit of applied phosphorus fertilizer, A is the obtained (Al+ H) $cmol_c\ kg^{-1}$ with X=0 and B is the linear coefficient. The B of the equations are indicative of the increases of total exchangeable acidity with the P treatments. The previous equations indicated that for each unit of applied phosphorus fertilizer, the total exchangeable acidity (Al+ H) $cmol_c\ kg^{-1}$ is increased with residual effect of lime by 1.3500E-03, 1.3500E-03 and 1.1666E-03 $cmol_c\ kg^{-1}$ for DAP, TAP and DCP, respectively. The corresponding values without lime were 5.6666E-04, 5.3333E-04 and 2.1666E-04 $cmol_c\ kg^{-1}$, respectively. Also, the slope values reflect the relative high total exchangeable acidity for DAP than DCP. This was apparently due to NH_4^+ and Ca^{++} compositions of the two forms, respectively.

Table 2: Sum of exchangeable cations ($cmol_c\ kg^{-1}$) of the soil after the three successive seasons as affected by phosphorus and lime treatments.

P_2O_5 Kg/ha	Unlimed				Limed				Mean
	DAP	TSP	DCP	Mean	DAP	TSP	DCP	Mean	
0	0.75	0.78	0.71	0.75	1.17	1.34	1.26	1.26	1.03
60	0.65	0.78	0.80	0.74	1.63	1.51	1.59	1.58	1.18
120	0.75	0.80	1.00	0.85	1.57	1.40	1.66	1.54	1.19
180	0.82	0.78	1.00	0.87	1.30	0.94	1.44	1.26	1.06
Mean	0.74	0.78	0.88	0.80B	1.41	1.30	1.49	1.39A	1.11

Effect of lime F. obs .05 = 84.0**
Effect of P doses F. obs .05 = 2.91*
Effect of interaction P doses X lime F. obs .05 = 3.49*
Effect of interaction P doses X P form F. obs .05 = 4.49*

Table 3: Effect of different sources of phosphorus on the total exchangeable acidity of soil (Al+ H), cmol kg^{-1}, after three growing seasons.

P_2O_5 Kg/ha	Unlimed				Limed				Mean
	DAP	TSP	DCP	Mean	DAP	TSP	DCP	Mean	
0	2.37	2.38	2.35	2.37	1.51	1.52	1.51	1.51	1.94
60	2.39	2.39	2.34	2.37	1.57	1.55	1.55	1.56	1.97
120	2.43	2.41	2.37	2.40	1.69	1.68	1.65	1.67	2.03
180	2.47	2.48	2.42	2.46	1.74	1.73	1.71	1.73	2.09
Mean	2.42	2.41	2.37	2.40A	1.63	1.62	1.60	1.66B	2.01

Effect of Lime F. obs .05 = 66.6***

Sorghum

Tables (4) and (5) and Fig.(1) show that both lime and phosphorus doses had a significant effect on panicles sorghum yield. But for grain yield, only phosphorus doses showed a significant effect. Sources of phosphorus had insignificant effect on both panicles and grain yield and the interaction lime x phosphorus was insignificant. Grain yield of sorghum maintains a linear response to phosphorus increments (Fig.1). This indicated that phosphorus could be a limiting factor for sorghum crop growing in leached acid soil. While lime application had a slight effect on sorghum yield. However, application of 1 Mg ha^{-1} lime combined with DAP produced higher mean grain yield, (1.64 Mg ha^{-1}) than DAP alone (1.16 Mg ha^{-1})This confirmed the importance of liming with acid fertilizer effect.

Table 4: Yield of sorghum panicles (Mg ha^{-1}) as affected by rates and sources of phosphorus with and without lime.

P_2O_5 Kg/ha	Limed				Unlimed				Mean
	DAP	TSP	DCP	Mean	DAP	TSP	DCP	Mean	
0	1.552	1.479	1.406	1.479	0.953	0.771	1.094	0.939	1.209d
60	2.344	2.084	2.063	2.163	1.554	1.851	1.573	1.659	1.912c
120	2.740	2.240	2.500	2.493	1.847	2.271	2.385	2.174	2.331b
180	3.323	2.845	3.042	3.073	2.663	2.496	2.448	2.536	2.804a
Mean	2.490	2.164	2.253	2.302A	1.754	1.847	1.875	1.826B	2.064

Means follow by different letters are significant at 0.05 level of probability

Table 5: Grain yield of sorghum (Mg ha^{-1}) as affected by rates and sources of phosphorus with and without Lime.

P_2O_5 Kg/ha	Limed				Unlimed				Mean
	DAP	TSP	DCP	Mean	DAP	TSP	DCP	Mean	
0	0.771	0.843	0.781	0.799	0.677	0.427	0.479	0.528	0.663d
60	1.521	1.365	1.177	1.354	1.125	1.188	0.833	1.049	1.202c
120	1.781	1.396	1.427	1.535	1.094	1.594	1.271	1.320	1.427b
180	2.479	1.865	1.896	2.080	1.729	1.875	1.469	1.691	1.886a
Mean	1.638	1.367	1.320	1.442	1.156	1.271	1.013	1.147	

Means follow by different letters are significant at 0.05 level of probability

Effect of phosphorus doses F.obs= 47.9***

Potato

As shown in Table (6) and Fig. (2), the residual effect of phosphorus doses had a significant effect on potato yield, but lime residual effect had not effect even when combined with phosphorus application. The highest tubers yield (6.92 Mg ha^{-1}) was obtained by residual effect of both lime and TAP. Therefore, an increase of 1.56 % in the mean value of potato yield was obtained by residual effect of combined lime (1 Mg ha^{-1}) with phosphorus fertilizers.

Table 6: Potato yields (Mg ha^{-1}) as affected by residual effect of lime and phosphorus.

P_2O_5 Kg/ha	Limed				Unlimed				Mean
	DAP	TSP	DCP	Mean	DAP	TSP	DCP	Mean	
0	4.61	2.65	3.11	3.46	4.41	4.31	3.18	3.30	3.97b
60	7.85	7.12	6.04	7.00	6.77	5.34	8.02	6.71	6.86a
120	8.23	7.50	7.39	7.71	7.06	7.59	7.80	7.48	7.60a
180	7.00	8.65	8.16	7.94	7.42	7.52	7.75	7.56	7.75a
Mean	6.92	6.48	6.18	6.53	6.42	6.19	6.69	6.43	6.48

Effect of phosphorus doses F.obs = 25.54**

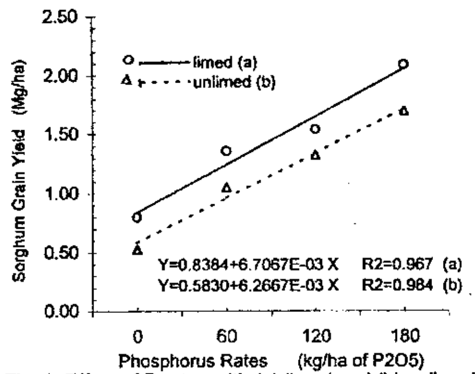

Fig. 1: Effect of P rates with (a) limed and (b) unlimed treatments on grain yield of sorghum.

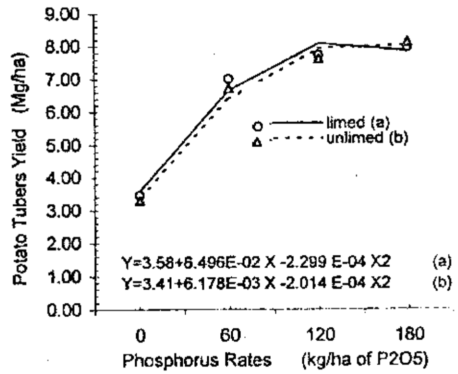

Fig.2: Effect of P residual effect with (a) lime residual effect and (b) unlimed treatment on potato yield.

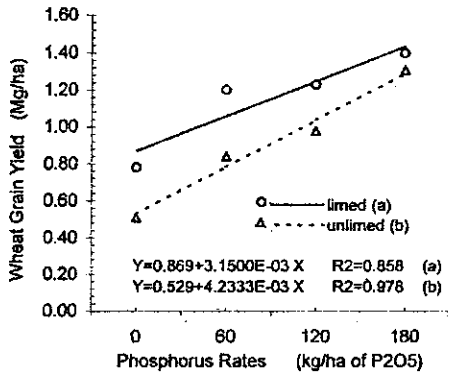

Fig.3: Effect of P rates with (a) lime residual effect and (b) unlimed treatment on grain yield of wheat.

Wheat

Tables (7 and 8) and Fig.(3) show that wheat yield significantly increased with the residual effect of lime treatment as well as phosphorus doses increment. The results are in harmony with those reported for potato and sorghum. The results, also indicated that the residual effect of lime significantly increased wheat yield planted after two seasons. Regardless of P dose and sources, lime increased grain yield more than unlimed plots by 27.34%. Wheat yield response to phosphorus increment doses is almost linear. But the different forms of phosphorus had an insignificant effect on wheat yield. The results had the same trend as pointed out by Winkler (1977) and Shehata (1986).

Table 7: Wheat biological yield ($Mg\ ha^{-1}$) as affected by rates and sources of phosphorus with and without the residual effect of lime.

P_2O_5 Kg/ha	Unlimed				Limed				Mean
	DAP	TSP	DCP	Mean	DAP	TSP	DCP	Mean	
0	0.81	0.67	1.01	0.83	1.44	1.24	1.06	1.25	1.04c
60	0.97	1.21	1.20	1.13	2.05	1.58	1.43	1.69	1.41b
120	1.16	1.35	1.74	1.42	1.58	1.88	1.47	1.64	1.53a
180	1.89	1.56	1.84	1.76	1.88	2.12	1.88	1.96	1.86a
Mean	1.21	1.20	1.45	1.28B	1.74	1.70	1.46	1.63A	1.60

Effect of lime: F.obs. .05= 24.33^{***}

Effect of phosphorus doses : F.obs= 21.86^{***}

Effect of interaction lime x phosphorus sources = 5.34^{*}

Table 8: Wheat grain yield ($Mg\ ha^{-1}$) as affected by rates and sources of phosphorus with and without the residual effect of lime.

P_2O_5 Kg/ha	Unlimed				Limed				Mean
	DAP	TSP	DCP	Mean	DAP	TSP	DCP	Mean	
0	0.52	0.61	0.41	0.51	0.75	0.77	0.81	0.78	0.68c
60	0.86	0.88	0.77	0.84	1.39	1.07	1.14	1.20	1.02b
120	0.93	1.34	0.93	0.98	1.27	1.18	1.24	1.23	1.15b
180	1.39	1.42	1.11	1.31	1.39	1.38	1.43	1.40	1.35a
Mean	0.93	1.06	0.81	0.93B	1.20	1.10	1.16	1.15A	1.04

Effect of lime : F.obs= 13.12^{*}

Effect of doses of phosphorus: F. obs = 22.13^{***}

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تأثير إضافة الجير ومصادر مختلفة من الفسفور على الحموضة المتبادلة الكلية للأرض وإنتاجية المحاصيل

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الملخص العربي

أجريت تجربة حقلية على أرض حامضية لتقييم معدلات ومصادر الفوسفور مع معدل منخفض من الجير والأثر المتبقي لهما على الحموضة المتبادلة الكلية للأرض (ألومنيوم+ هيدروجين) والمحاصيل الناتجة. وكانت مصادر الفوسفور المستخدمة هى:

(١) فوسفات ثنائي الأمونيوم (DAP) (٢) تربل سوبر فوسفات (TSP) (٣) فوسفات ثنائى الكالسيوم (DCP) بمعدلات إضافة صفر، ٦٠، ١٢٠، ١٨٠ كجم فو٢ أ٥ / هكتار مع الجير بمعدل صفر، ١ميجا جرام/ هكتار. وقد زرع الذرة السكرية في الموسم الأول ثم البطاطس في الموسم الثاني بدون إضافة للمعاملات لدراسة التأثير المتبقي وبعد ذلك أضيفت معدلات الفوسفور مرة ثانية وتمت زراعة القمح .

أوضحت النتائج إلى أن المعدل المنخفض من الجير ١ميجا جرام/ هكتار قد زاد معنويا من القواعد المتبادلة على حساب الحموضة المتبادلة الكلية حيث انخفضت الأخيرة إلى ١,٦٦ لمعاملة الجير بينما كانت ٢,٤٠ سنتي مول/ كجم بدون إضافة لجير. أشارت القيم المحسوبة لميل الخط المستقيم الارتفاع النسبى للحموضة المتبادلة الكلية فى حالة فوسفات ثنائي الأمونيوم عن فوسفات ثنائى الكالسيوم بينما تربل سوبر فوسفات وسط بينهما. وبينت أيضا أن زيادة معدل التسميد الفوسفورى يزيد من قيمة الحموضة المتبادلة الكلية فى الأرض الحامضية.

وقد بينت النتائج أن المعدل المنخفض من الجير كان كافيا لاستمرارية والمحافظة على إنتاجية المحاصيل فى دورة تشمل الذرة السكرية والبطاطس والقمح وأن إضافة الأسمدة الفسفورية معه كان أكثر فاعلية حيث أعطى الجير بمعدل ١ ميجا جرام/هكتار مع فوسفات ثنائى الأمونيوم أعلى إنتاجية من الذرة السكرية (١,٦٣٨ميجا جرام/ هكتار) في الموسم الأول. ولتقييم الأثر المتبقي للجير والأسمدة الفسفورية على البطاطس فإن أعلى إنتاجية قد تحققت

نتـــيجة للأثـــر المتبقي لمعاملة الجير مع ١٢٠ كجم فو٢ أ٥ / هكتار. أما الأثر المتبقي للجير بعد موسمين متتاليين فقد زاد إنتاجية محصول القمح ٢٥% مقارنة بالمعاملات التى لم يضاف لها الجير. وكانت نتائج القمح متماثلة مع تلك المتحصل عليها للذرة السكرية والبطاطس. وعلى الـــرغم من أن الفروق بين مصادر الفوسفور على إنتاجية محصول القمح كانت غير معنويا إلا أنهـــا معـــنوية مع معدلات التسميد وكانت العلاقة خطية . الاتجاه العام لهذه النتائج يوضح أن التسميد الفوسفاتى مع الجير قد أعطى نسبيا أعلى محصول.