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Response of Soybean [*Glycine max* (L.) Merrill] to Lime and Phosphorus Fertilizer Treatments on an Acidic Alfisol of Nigeria

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Abstract: Liming and phosphorus (P) fertilization are often required for sustainable crop production on acid mineral soils. Here, P-release in an acidic Typic Paleustalf incubated with lime, crystallizer (CRYS), single superphosphate (SSP) and organic fertilizer (O.F) was evaluated. Short-term and residual effects of lime (2 tha^{-1}) and P (88 $kgPha^{-1}$) treatments (Control, lime, CRYS, O.F, lime+O.F, lime+CRYS, O.F+CRYS and lime+O.F+CRYS) on performance of two soybean (*Glycine max*) varieties (early maturing TGx1485-ID and late maturing TGx1844-18E) were also evaluated, using completely randomized design with three replicates. Lime treatments gave highest soil pH increases (7.4-7.7). Sole and combined applications of P-fertilizers led to pH range of 5.0-5.8 compared with control (5.2) while the tendency of SSP to acidify the soil became obvious. After 5 weeks of growth, O.F+RP and O.F treated TGx1485-ID plants were taller (28.50 and 27.66 cm, respectively) than control (20.03 cm) and sole lime (19.33 cm) treated plants. During 2nd cropping, lime treatment produced plants of similar vigor as O.F and O.F+CRYS treatments. The same trend was observed for TGx1844-18E plants. Phosphorus- uptake by TGx1485-ID plants was highest with the application of O.F or O.F+CRYS, being 9.57 or 9.62mg pot^{-1} and 3.66 or 5.28mg pot^{-1} in the 1st and 2nd cropping, respectively. The potency of O.F and CRYS as alternative acid soil ameliorants for sustainable agriculture was evident. The liming effectiveness of O.F (applied alone or in combination with other amendments) might be sufficient, especially on long-term basis when soil acidification by the conventional-SSP would have reached an alarming proportion.

Key words: Lime effectiveness, typic paleustalf, short-and long-term effects, sustainable crop production

Introduction

Soil is an important factor in crop production and its degradation is one of the limiting factors for sustainable agriculture (FAO, 2004). With the ever-growing population, soil fertility management by long fallow periods is practically impossible. The application of mineral fertilizer as sole soil fertility management method under intensive continuous cropping is also no longer feasible due to scarcity, high cost (Akinrinde and Okeleye, 2005) where available and the numerous side effects on the soil. Farmers using mineral fertilizers for years often notice signs of soil exhaustion shown by the sick appearance of plants, leaf discolouration, retarded growth and low yields (Neil and Ray, 1999). Acid soils result from leaching of basic cations (in areas of high rainfall), leaving behind the more resistant Al^{3+}, which predominates. Poor farming practice has more often acidified agricultural soils in developing countries. According to Hoekenge *et al.* (2003), continuous use of ammonia fertilizers under intensive agriculture is capable of further acidifying the soil.

All over the world, poor growth of soybean in acid soils has been attributed to a number of factors that include: low pH, high level of Al, Mn, and H, low levels of Ca, Mg, P, K, micronutrients like B, Zn etc. (Fageria, 1994), low population of beneficial micro-organisms like rhizobia, vesicular arbuscular (VAM) fungi and inhibition of root growth (Maddox and Soileux, 1991).

For successful soybean production, large quantities of lime and Phosphorus (P) fertilizers may be required (Fageria *et al.*, 1995). Liming improves microbiological activities of acid soils, which in turn increases N fixation by legumes, and also promotes mineralization of organic materials. However, over liming may reduce crop yield by inducing P and micronutrient deficiencies (Fageria, 1984).

Combined applications of organic materials and phosphate rock have been reported to be suitable for humid tropical soils (Agboola *et al*., 1982) and to improve soil physical and chemical properties by enhancing biological activity and soil organic carbon accumulation (FAO, 2004). This is in relation to the resulting benefits of improved availability of nitrogen, phosphorus and sulphur, improved soil organic matter contents and soil texture of sandy soils as well as promotion of sustainable agriculture (Eliott *et al*., 1993). The ultimate objective of this research effort is to determine the effects of lime, rock phosphate, RP (CRYS) and organo mineral fertilizer, (OF) on soil pH changes, P release, as well as on P nutrition, growth and yield of two soybean cultivars as influenced by sole and combined applications of organic fertilizer, lime, crystallizer and single super phosphate in an acid soil from Ikenne, Ogun state, Nigeria.

Materials and Methods

A laboratory incubation study and 2 pot experiments were conducted using loamy sand Alfisol collected from International Institute for Tropical Agriculture (IITA) trial site at Ikenne, Nigeria. Analysis of the soil prior to cropping revealed its characteristics to be: pH (H_2O) =4.7, organic carbon=10.9g kg^{-1}, total N=9.4g kg^{-1}, available P =2.91mg kg^{-1}, exchangeable Ca, Mg, Na and K = 0.38, 0.09, 0.29 and 0.48 c mol kg^{-1}, respectively. Soil physical properties determination gave sand=918 g kg^{-1}, clay =14.0 g kg^{-1} and silt=68.0 g kg^{-1}. Thus, it was an acid loam sand alfisol –Typic Paleustalf (Soil Survey Staff, 1994) formed on sandstones (Akinrinde, 1987).

The laboratory experiment involved the use of 50 g samples of the experimental soil in 48 custom laboratory cups and incubated for 7, 14 and 21 days. However, the following 16 sole and combined treatments were replicated three times in completely randomized design (CRD): control (C), lime (L), single super phosphate SSP, 18 % P_2O_5 crystalliser (CRYS - blend of Sokoto RP and talc having 20.21 % P_2O_5), organic waste-fertilizer OF, (0.55 % P_2O_5), L+SSP, L+CRYS, L+OF, CRYS+SSP, CRYS+OF, OF + SSP, CRYS+OF+SSP, L+CRYS+OF, L+SSP+OF, L+CRYS+SSP and L+OF+CRYS+SSP. Soil pH and available P were subsequently determined to know the effectiveness of these treatments in correcting soil acidity and releasing P with time.

Two pot experiments (first and second cropping) with 8 lime and P – fertilizer treatment combinations laid in a factorial using CRD were conducted behind the department of Agronomy, University of Ibadan, Nigeria. Each of the eight treatment combinations (Control, (C), Lime (L) crystallizer (CRYS) organic fertilizer (OF), L+ OF, L+ CRYS, OF+ CRYS and L+OF+ CRYS) were mixed with two-kilogram soil sample at the rate of 2 t ha^{-1} Ca $(OH)_2$ ha^{-1} and 88 kg P ha^{-1}. They were replicated three times to give twenty-four experimental units each and six seeds of early soybean variety (TGx1485-ID) and late maturing variety (TGx1844-18E) were sown into 24 polybags each. They were moistened in order to equilibrate prior to sowing 6 seeds of each of early (TGx1485-ID) and late (TGx184418E) maturing soybean varieties and later thinned to two seedling/polybag at 2 weeks after planting (WAP). Data were collected after 5 weeks of growth on plant height, number of leaves, number of nodules, leaf area and stem girth. Fresh weights of the soybean plants were taken after which it was partitioned into root and shoot weights. Dry weights were recorded after oven drying at 65°C (to constant weight). Soil pH, available P, Fe, Mn, Zn, Ca, Mg and Al contents were determined in the soils after cropping.

Second cropping: For the second cropping, the soils in each of the 24 pots were air dried, sieved and resown with six seeds of soybean. No treatment was added so as to evaluate the residual effect of the P fertilizers. The plants were grown till they produced seed yield. The same parameters like the first were observed in addition to pod and seed yield. The data obtained were analyzed like that of the first cropping using SAS. Relative agronomic efficiency (RAE) of the P sources was then determined to imply their lime effectiveness (LE) relative to the conventional lime.

The RAE or LE was computed as the ratio of the pH value obtained with a specific soil amendment minus pH value of untreated soil to pH value obtained with conventional treatment minus pH value of untreated soil i.e.

RAE or LE =

$$\frac{\text{Soil pH (test liming material) - soil pH (control)}}{\text{Soil pH (conventional lime) – soil pH (control)}} \times \frac{100\%}{1}$$

Plant analysis: Oven dried ground dried plant materials were digested with a mixture of three acids (perchloric acid, nitric acid and sulphuric acid). The P concentration in the digest was determined colorimetrically, while other elements were determined by atomic absorption spectrophotometer (Udo and Ogunwale, 1986) and soil pH was determined using pH meter.

Results and Discussion

Summarily, soil amendments involving lime gave a range of 7.5-7.7 (Table 1) but decreased with increasing incubation time to a range of 6.8-7.4 by the last sampling period (21 days). This is an indication of lime depletion through adsorption by soil colloids with time, hence the need for regular lime application (Kotur, 1991). For lime and lime combinations (L, L+CRYS, L+OF, L+CRYS+SSP etc), pH increases above the control were observed up to the third week of incubation indicating a tendency for some liming materials to have a long term effect as reported by Follett *et al*. (1981). For treatments without lime (CRYS, OF, OF+CRYS, OF+CRYS+SSP etc), appreciable increases in soil pH and available P greater than the control were obtained. This is in line with the explanation of Wright *et al.* (1991) that increase in soil pH could be attributed to consumption of protons during acidulation of rock phosphate and subsequent neutralization of bases released. These treatments (OF and CRYS) involved materials that supplied fertilizer P in addition to P release through their liming ability as explained by Lelei *et al*. (2000). FAO (2004) and Eghball (1999) reported that RP and organic fertilizer possess some liming ability. The low soil pH of SSP after 7 days of incubation relative to control supports the result of previous work of Opara–Nadi *et al*. (2000) that inorganic fertilizer treatments either maintained same or decreased soil pH compared with control. The high available P contents associated with this inorganic P source (Table 1) are attributed to the fact that it is water-soluble (Akinrinde *et al*., 1999; Siddaramappa *et al*.,

Table 1: The influence of lime, phosphorus (P) fertilizer and their combinations on the pH and available P contents of soils incubated for 7, 14 and 21 days

Treatment	Incubation period (Days)					
	7		14		21	
	pH	Available-P (mg kg^{-1})	pH	Available-P (mg kg^{-1})	pH	Available-P (mg kg^{-1})
Control	5.29	11.75	4.93	11.02	4.83	12.40
Lime (L)	7.22	12.47	7.15	13.05	7.21	13.42
Crystalliser (CRYS)	5.52	21.18	5.06	19.58	5.10	25.90
Organic Fertilizer (O.F)	5.53	38.88	5.25	42.00	4.74	42.44
Single super (SSP)	5.04	47.23	5.36	40.41	5.20	45.34
L+SSP	7.56	32.21	7.23	17.77	6.82	17.99
L+OF	7.67	25.24	7.49	26.26	7.18	4.52
CRYS+SSP	5.82	34.96	4.87	35.18	4.94	30.90
CRYS+OF	5.69	48.89	5.24	46.50	5.03	44.25
OF+SSP	5.73	20. 40	5.05	29.02	5.00	32.13
CRYS+OF+SSP	5.55	15.38	4.91	15.38	4.91	17.19
L+CRYS+OF	7.71	30.83	7.55	25.90	7.47	23.94
L+SSP+OF	7.48	39.32	7.54	46.43	7.34	45.27
L+CRYS+SSP	7.57	29.23	7.46	26.19	7.29	19.44
L+OF+CRYS+SSP ± S.E.	7.58±0.26	31.34±3.03	7.41±0.29	27.13±2.98	7.41±0.29	24.44±2.80

Values with the same letter (s) along columns are not significantly different at p=0.05 by Duncan multiple range test.

1991) while subsequent decrease could have been caused by P fixation (Saranganath *et al.*, 1997). CRYS, OF, CRYS +OF, OF+SSP, L+CRYS+OF and CRYS+ SSP soil amendments similarly increased available P throughout the incubation periods in consonance with the work of Minhas and Tripathi (1986) and Marwaha and Kanwar (1981) that RP (e.g. crystalliser) in combination with SSP or farmyard manure (OF) can be as effective as SSP.

Influence of lime and P fertilizer treatments on soybean growth and yield: The experimental soil was highly acidic (pH 4.7) with medium organic carbon (10.9 g kg^{-1}), low available P (2.91mg kg^{-1}), high total N (9.47 g kg^{-1}) and adequate K (0.48 cmolkg^{-1}) (Adeoye and Agboola, 1985).

The effect of lime and P fertilizer on the height of soybean is shown in Fig. 1.The other growth parameters - leaf area, stem girth and number of leaves responded similarly.

After 5 weeks of growth for the first cropping, untreated TGx1485-1D had (24.50 cm) and sole lime treated plants (23.00 cm). They were significantly shorter than OF treated plants (28.16 cm) and OF+CRYS treated plants (28.50 cm), which were not significantly different. For TGx1844-18E, OF+CRYS and OF treatments still encouraged the production of the tallest plants (27.83 and 28.70 cm, respectively) while, control and sole lime treatments still led to the shortest plants (20.03 and 19.33 cm, respectively). Data on residual cropping at 4 WAP indicated that liming effect was more prominent in plant height, stem girth, leaf area and number of leaves compared to the first cropping

P and lime application in the first cropping significantly increased dry shoot and root yield of both TGx1485-1D and TGx1844-18E (Table 2). OF+CRYS and O.F treatment gave the highest dry shoot yield for both varieties however; they were not significantly different from L+OF treatment. Dry shoot yield obtained from O.F+CRYS, O.F and L+O.F treatments increased approximately 2 times over control, while, control and sole lime treated plants produced the lowest dry matter yield. This is evident from the poor growth performance from control and sole lime treated plants. Root dry weight of TGx1485-1D treated with OF gave 3 times increase over control with OF+CRYS increasing by 2 fold. However, L+O.F and L+O.F+CRYS treated TGx1485-1D increased by 1. Mamaril *et al*. (1991) explained that soybean initially responds more to applied P than lime and that lime treatments improve crop performance with time. Follet *et al*. (1981) reported that lime action is slow acting, of long duration and not conspicuous. For TGx1844-18E, OF, OF+CRYS and L+OF treated plants gave increases in root weight approximately twice that of control. In the first cropping, shoot: root ratio of TGx1485-1D was significantly higher in CRYS treated plants than control (Table 2) indicating that CRYS enhanced root absorption of plant nutrients hence, shoot growth was promoted. However, there was no significant difference in the late variety.

In the second cropping, TGx1485-1D responded more to lime treatments than the TGx1844-18E in dry matter produced. Also, pod weight, seed weight and seed number of TGx1485-1D were significantly affected by L+OF combination while the TGx1844-18E was affected by OF and most lime combinations (Table 3).

Nutrient uptake: Ca, Mg, Zn, Fe, Mn and P content and

Table 2: Dry matter yield of shoot and root as affected by lime and P treatments

Treatment	Early maturing soybean variety (Tgx1485-1D)					Late maturing soybean variety (Tgx1844-18E)				
	Shoot yield		Root yield		shoot: root ratio	shoot yield		Root yield		Shoot: ratio root
	1st cropping	2nd cropping	1st cropping	2nd cropping	1st cropping	1st cropping	2nd cropping	1st cropping	2nd cropping	1st cropping
CTRL	2.86^{bc}	2.36^{bc}	0.70^{b}	0.56^{c}	4.24^{b}	2.73^{bc}	5.30^{abc}	0.56^{c}	1.36^{bc}	4.91^{a}
Lime (L)	1.90^{c}	5.86^{a}	0.40^{b}	1.73^{ab}	4.97^{ab}	2.10^{c}	3.36^{dc}	0.53^{c}	1.06^{c}	4.30^{a}
CRYS	3.53^{bc}	2.90^{bc}	0.63^{b}	1.03^{bc}	5.62^{a}	3.73^{b}	3.00^{d}	0.76^{bc}	1.43^{bc}	4.88^{a}
O.F	5.63^{a}	3.33^{bc}	2.20^{a}	0.83^{c}	4.87^{ab}	5.63^{a}	6.03^{ab}	1.13^{a}	1.93^{ab}	5.12^{a}
L+ CRYS	3.53^{bc}	4.56^{abc}	0.83^{ab}	1.06^{bc}	4.21^{b}	2.36^{c}	6.20^{a}	0.60^{c}	2.46^{a}	4.00^{a}
L+O.F	4.26^{ab}	4.80^{ab}	0.96^{ab}	2.20^{a}	4.41^{ab}	4.80^{a}	5.20^{abc}	1.13^{a}	1.73^{b}	4.25^{a}
O.F+ CRYS	5.66^{a}	4.80^{ab}	1.20^{ab}	1.86^{ab}	4.85^{ab}	4.90^{a}	3.86^{bcd}	1.00^{ab}	1.66^{bc}	5.00^{a}
L+CRYS+O.F	3.80^{b}	3.96^{abc}	0.83^{ab}	1.76^{ab}	4.53^{ab}	3.60^{b}	5.7^{ab}	0.76^{bc}	1.86^{ab}	4.72^{a}

Table 3: Influence of lime and phosphorus treatment on number of pod, pod weight, seed weight and number of seeds of early and late maturing soybean varieties after second cropping

Treatment	Number of pods	Pod weight (g pot^{-1})	Seed weight g pot^{-1})	Number of seeds	Treatment	Number of pods	Pod weight (g pot^{-1})	Seed weight (g pot^{-1})	Number of seeds
	Early maturing soybean variety (Tgx1485-1D)					Late maturing soybean variety (Tgx1844-18E)			
Control	8.00^{c}	0.83^{d}	0.26^{d}	7.66^{c}	Control	13.33^{a}	0.90^{abc}	0.20^{ab}	12.00^{a}
Lime	14.00^{bc}	1.50d^{c}	0.40^{d}	1.66^{bc}	Lime	16.66^{a}	0^{c}	0^{b}	0^{b}
CRYS	10.00^{bc}	1.30d^{c}	0.46^{d}	13.00^{c}	RP	12.66^{a}	1.10^{ab}	0.16^{ab}	10.66^{a}
O.F	16.33^{b}	2.10b^{cd}	1.76^{b}	17.00^{bc}	OF	18.66^{a}	1.50^{a}	0.50^{a}	17.33^{a}
L+CRYS	15.66^{bc}	1.86b^{cd}	0.66^{d}	12.00^{c}	L+RP	17.66^{a}	1.63^{a}	0.33^{ab}	20.00^{a}
L+O.F	26.00^{a}	5.26^{a}	2.66^{a}	39.33^{a}	L+OF	11.66^{a}	0.53^{bc}	0^{b}	0^{b}
O.F+CRYS	12.66^{bc}	2.30^{bc}	0.96^{dc}	19.00^{bc}	OF+RP	14.00^{a}	0.70^{abc}	0.40^{a}	1.33^{a}
L+O.F+CRYS	15.66^{b}	2.93^{b}	1.63^{bc}	27.33^{ab}	L+OF+RP	1.66^{a}	1.13^{ab}	0.33^{ab}	15.33^{a}

Table 4: Influence of lime and phosphorus on nutrient uptake in the early variety

Soil treatments	Plant uptake (mg pot^{-1})						
	Ca	Mg	Fe	Mn	Zn	P (1st cropping)	P (2nd cropping)
Control	5.72	6.00	0.12	0.13	0.27	3.14	2.12
Lime	3.52	3.99	0.10	0.10	0.13	1.90	3.51
CRYS	6.00	5.71	0.14	0.17	0.35	4.94	2.90
O.F	11.82	11.26	0.22	0.24	0.43	9.57	3.66
L+ CRYS	7.41	7.76	0.20	0.18	0.22	3.88	1.82
L+O.F	9.37	7.66	0.14	0.20	0.23	6.39	2.40
O.F+ CRYS	14.15	13.01	0.23	0.29	0.44	9.62	5.28
L+O.F+CRYS	9.50	9.50	0.11	0.13	0.25	6.46	1.98
±S.E	1.229	1.064	0.018	0.022	0.038	0.992	0.400

uptake of TGx1485-1D were high in OF and OF + CRYS treated soybean plants compared to control and sole lime treated ones (Table 4 and 9). It was quite different for TGx1844-18E (Table 5) as OF and L+OF treated plants had the highest nutrient uptake with control and sole lime still having lower uptake. This increase in nutrient uptake is probably responsible for the improved growth parameters observed in these varieties. In the second cropping, P uptake still increased in OF and OF+ CRYS treated TGx1485-1D while L+OF+ CRYS treated plant had the highest P uptake for the late variety.

Soil chemical properties: Soil pH, available P and extractable Ca, Mg, Zn, Fe and Mn values obtained after first cropping are provided in Table 6 and 7. Soil pH increased from 5.48 to a range of 7.27-7.77 for sole and combined lime treatments while, sole P fertilizer and its combination had a range of 5.88-6.01. TGx1844-18E did not differ much from this trend with control having significantly lower values. This is in line with Eghball (1999) that organic manure/fertilizer can increase soil pH. Significantly high amount of available P was influenced greatly by P fertilizer whether sole or combined however; there was no significant difference in TGx1844-18E. For the second cropping, sole lime and lime combinations significantly improved soil pH from 5.12 to a range of 7.19 - 7.41 while P fertilizer increased soil pH value in the range of 5.61 - 5.97 with control

Table 5: Influence of lime and phosphorus on nutrient uptake in the late maturing soybean variety

Soil treatments	Plant uptake (mg pot^{-1})						
	Ca	Mg	Fe	Mn	Zn	P (1stcropping)	P (2nd cropping)
Control	5.86	5.73	0.02	0.01	0.19	1.64	3.18
Lime	4.41	3.99	0.01	0.01	0.13	1.68	4.36
CRYS	7.08	7.08	0.01	0.02	0.35	3.35	3.60
OF	13.51	12.49	0.02	0.02	0.35	7.88	5.42
L+ CRYS	6.60	5.42	0.01	0.01	0.15	1.41	4.96
L+OF	10.08	12.00	0.02	0.02	0.34	7.68	5.20
OF+ CRYS	8.33	8.82	0.02	0.02	0.39	4.90	5.79
L+OF+CRYS	6.48	7.20	0.01	0.01	0.25	3.96	20.05
± S.E	1.009	1.086	0.002	0.002	0.036	0.921	1.952

Table 6: Influence of lime and Phosphorus on soil pH and available P, 5 weeks after growing early and late maturing soybean varieties

Treatments	Original Soil		Soybean varieties planted							
	Soil pH	Available P (mgkg^{-1})	Early (Tgx1485-1D)				Late (Tgx1844-18E)			
			Soil pH		Available P (mgkg^{-1})		Soil pH		AvailableP(mgkg^{-1})	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control	4.70	2.91	5.48^{d}	5.12^{c}	20.71^{bc}	9.23^{b}	5.41^{c}	4.94^{c}	20.70^{a}	4.63^{d}
Lime (L)	4.70	2.91	7.77^{a}	7.41^{a}	15.89^{c}	10.44^{ab}	7.34^{a}	7.38^{a}	19.28^{a}	7.17^{d}
Organic fertilizer (OF)	4.70	2.91	6.00^{c}	5.61^{b}	27.52^{ab}	4.22^{c}	6.24^{b}	6.12^{b}	33.15^{a}	3.46^{d}
Crystallizer (CRYS)	4.70	2.91	5.88^{cd}	5.97^{b}	14.45^{c}	13.65^{a}	6.19^{b}	5.60^{b}	21.64^{a}	13.44^{c}
L+RP	4.70	2.91	7.36^{ab}	7.36^{a}	21.47^{abc}	9.72^{b}	7.45^{a}	7.37^{a}	38.91^{a}	12.25^{c}
L+OF	4.70	2.91	7.27^{b}	7.50^{a}	26.59^{ab}	10.99^{ab}	7.61^{a}	7.41^{a}	30.55^{a}	18.97^{a}
OF+ CRYS	4.70	2.91	6.01^{c}	5.72^{b}	28.55^{a}	8.03^{bc}	6.00^{bc}	5.62^{b}	39.43^{a}	18.02^{ab}
L+OF+CRYS	4.70	2.91	7.27^{b}	7.19^{a}	24.21^{ab}	10.20^{ab}	7.05^{a}	7.39^{a}	19.37^{a}	14.20^{bc}

Table 7: Influence of lime and phosphorus on soil extractable nutrients

Soil Treatment	Soil extractable nutrients after first cropping					
	Ca (cmol/kg)		Mg (cmol/kg)		Feppm	
	Tgx1485-1D	TGx1844-18E	TGx1485-1D	TGx1844-18E	Tgx1485-1D	Tgx1844-18E
Control	0.512	0.431	3.493	1.543	39.000	39.000
Lime	0.937	1.186	3.704	1.687	33.000	45.000
CRYS	0.587	0.581	3.086	1.049	34.000	40.000
O.F	0.624	0.493	3.909	1.502	43.000	45.000
L+CRYS	0.518	0.443	2.016	1.564	54.000	56.000
L+O.F	0.749	0.624	1.955	2.016	43.000	32.000
O.F+CRYS	0.574	0.512	2.469	1.728	32.000	0.025
L+O.F+CRYS	1.124	0.999	1.5502	1.687	35.000	39.000
± S.E	0.084	0.107	0.349	0.11	2.92	2.775
Soil Treatment	Soil extractable nutrients after first cropping					
	Mnppm		Zn (ppm)		Al (mgKg^{-1})	
	Tgx1485-1D	TGx1844-18E	TGx1485-1D	TGx1844-18E	Tgx1485-1D	Tgx1844-18E
Control	68.000	50.000	79.000	86.000	0.033	0.032
Lime	64.000	59.000	77.000	98.000	0.035	0.028
CRYS	52.000	42.000	89.000	88.000	0.033	0.035
O.F	58.000	44.000	85.000	91.000	0.036	0.026
L+CRYS	41.000	58.000	72.000	71.000	0.040	0.028
L+O.F	55.000	54.000	74.000	80.000	0.040	0.03
O.F+CRYS	54.000	39.000	67.000	75.000	0.033	0.025
L+O.F+CRYS	49.000	45.000	85.000	68.000	0.030	0.036
± S.E	2.78	3.068	2.76	4.202	0.0014	0.0016

Table 8: Soil pH of early and late maturing soybean varieties in the first cropping treated to lime and phosphorus and the RAE of the soil amendments

Treatment	Soil pH (Tgx1485-1D)	RAE (%)	Soil pH (TGx1844-18E)	RAE (%)
Control	5.48	0	5.41	0
Lime (L)	7.77	100	7.34	100
Crystallizer (CRYS)	5.88	17.46	6.19	40. 41
Organic Fertilizer (O.F)	6.00	22.70	6.24	43.00
L+ CRYS	7.36	82.09	7.45	105.69
L+O.F	7.27	90.39	7.61	113.98
O.F+ CRYS	6.01	23.14	5.94	27.46
L+O.F+ CRYS	7.27	90.39	7.05	84.97

Table 9: Influence of lime and P fertilizer on Calcium (Ca), Magnesium (Mg), Iron (Fe), Maganese (Mn), Zinc (Zn) and Phosphorus (P) content of early and late soybeanvarieties in the first cropping

Soil treatments	Plant nutrients content (%)		[Tgx1485-1D]			Total P	
	Ca	Mg	Fe	Mn	Zn	1s cropping	2nd cropping
Control	0.2000	0.2075	0.0043	0.0046	0.0093	0.11	0.09
Lime(L)	0.1850	0.2050	0.0054	0.0052	0.0068	0.10	0.06
Crystalizer (CRYS)	0.1675	0.162	0.0039	0.0047	0.0100	0.14	0.10
Organic Fertilizer (O.F)	0.2125	0.2000	0.004	0.0043	0.0076	0.17	0.11
L+CRYS	0.2050	0.2175	0.0056	0.0051	0.0062	0.11	0.04
L+OF	0.2175	0.1825	0.0032	0.0046	0.0055	0.15	0.05
OF+CRYS	0.2500	0.2275	0.004	0.0052	0.0078	0.17	0.11
L+OF+CRYS	0.25	0.2500	0.0029	0.0035	0.0066	0.17	0.05
± S.E	0.0116	0.0109	0.004	0.0002	0.0006	0.011	0.01
Soil treatments	Plant nutrients content (%)		[Tgx1844-18E]			Total P	
	Ca	Mg	Fe	Mn	Zn	1s cropping	2nd cropping
Control	0.2150	0.2125	0.0059	0.0040	0.0070	0.06	0.06
Lime(L)	0.2050	0.1900	0.0047	0.0034	0.0061	0.08	0.13
Crystalizer (CRYS)	0.1900	0.1850	0.0037	0.0041	0.0093	0.09	0.12
Organic Fertilizer (O.F)	0.2400	0.2225	0.0035	0.0037	0.0063	0.14	0.09
L+CRYS	0.2750	0.2300	0.0048	0.0048	0.0062	0.06	0.08
L+OF	0.2100	0.2500	0.0041	0.0038	0.0071	0.16	0.10
OF+CRYS	0.1675	0.1750	0.0032	0.0036	0.0080	0.10	0.15
L+OF+CRYS	0.1825	0.2025	0.0029	0.0040	0.0070	0.11	0.35
± S.E	0.0116	0.0103	0.0003	0.0002	0.0004	00.013	0.033

having the least. The same trend was observed for TGx1844-18E. Cumming (1991) reported long term effect of lime in improving soil pH. Improvement in available P content was linked to the release of P from sorption sites by lime reaction, as lime combinations in addition to OF and OF+CRYS treated soils gave significantly higher available P however, CRYS only gave low available P. This may suggest that for better rock phosphate use efficiency, application should be 3-5 times above the conventional P rate (Tisdale *et al*., 1996). A general decrease in available P from first to second cropping indicated plant uptake during the growing period. Soil amendments enhanced soil extractable Ca, Mg, Fe, Mn and Zn for both varieties after first cropping.

Relative agronomic efficiency (RAE) or Lime effectiveness (LE) of the soil amendments with respect to cropped soil: Data in Table 7 shows the high RAE / LE associated with lime and its combinations. The high RAE of the P fertilizer materials plus conventional lime confirms the additional liming benefit of the P sources (Eghball, 1999; Fageria *et al*., 1991). Evidently, it may be beneficial, long lasting and cost effective to lime acid soils. Alternatively, however, the use of organic fertilizer, rock phosphate and their combination may also be very efficient and sustainable. This is more so considering the fact that, RP supplies Ca while P – availability was ensured by the release of organic acids (during mineralization of organic fertilizer) which frees Al and Fe bound phosphates from sorption sites

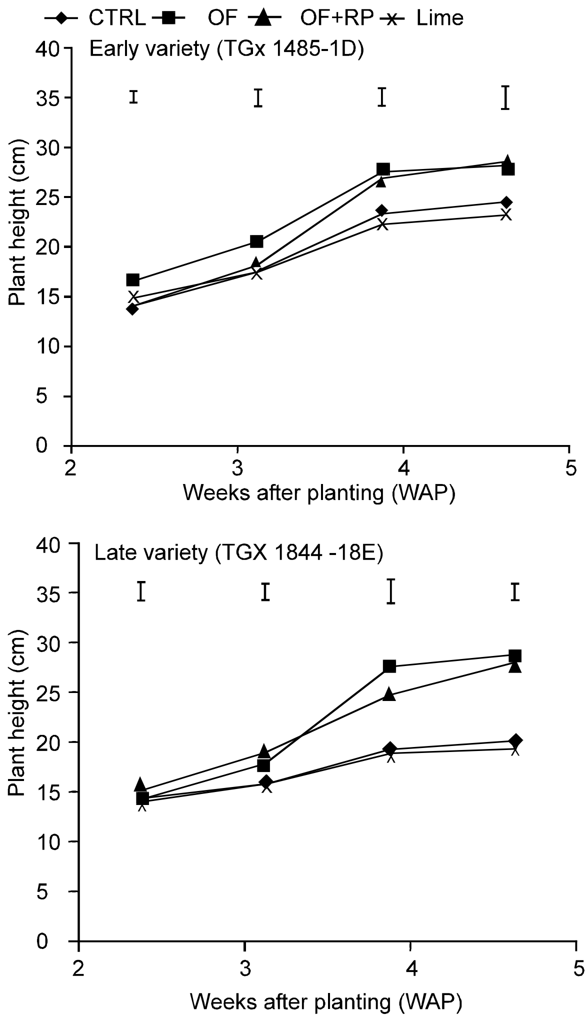

Fig. 1: Influence of lime, organic fertilizer (OF), rock phosphate (RP) and OF+RP on height of early and late maturing varieties of soybean after 5 weeks of growth

(Agegnehu and Taye, 2004). Not forgetting that, for better RP use efficiency, application should be 3-5 times above the conventional P rate (Tisdale *et al*., 1996).

Conclusion: Results obtained shows that P deficiency in soil is an important growth-limiting factor in acidic alfisol of Western, Nigeria. The P fertilizer sources and their combinations also gave appreciable increases in soil pH, indicating their liming effectiveness. Since P release was sustained for sole CRYS and OF treated soil, P availability during residual cropping is likely unlike SSP, which suffered fixation. P fertilizer addition was more prominent in the first cropping while lime and P application enhanced soybean growth and yield in the second cropping. From the results, it is clear that organic fertilizer (sole or combined with crystallizer) may sustain soybean growth and yield in the first and second cropping under acid conditions. Lime and its combination improved soil pH and available P from 5.4 to 7.2-7.7 and from 20.70 mg kg^{-1} to 15.89 – 26.59 mg kg^{-1} respectively while, sole and combined P sources gave soil pH and available P of 5.8-6.0 and 14.45- 28.55 mg kg^{-1} respectively with control soils remaining acidic for both varieties and in both cropping. Lime application may not be feasible for poor resourced farmers. However, the complementary benefits (liming and nutrient supply) of organic fertilizers and rock phosphates could sufficiently ameliorate acid soil conditions and greatly reduce P fertilizer cost for effective and sustainable soil fertility management. Also, the superior performance of OF and OF+CRYS on soybean growth over control clearly indicates its efficacy as a viable alternative for correcting soil pH, releasing P for direct and residual use. More work would be required to determine the amount of organic fertilizer, rock phosphate and its combination that would be required to amend this soil, especially under field conditions.

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