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Use of Organic-Based Amendments to Ameliorate Aluminium Toxicity in Legume Production on a Typic Paleudalf of South-Western Nigeria

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Abstract: Aluminum (Al) toxicity is a major limitation to leguminous crop production in acidic soils and fertilizer treatment could ameliorate the condition. In this study, direct and residual effects of fertilizers on the growth and yield of cowpea and soybean grown with or without Al treatment were evaluated on an alfisol. The investigation involved a greenhouse (2 kg soil/pot) experiment with two factors: Fertilizer types- (Control, Organic, Inorganic and Organomineral) and Al rates (0, 50, 100 µM $AlCl_3$) at the Agronomy Department, University of Ibadan, Nigeria. Treatment combinations were replicated three times in completely randomized design, giving 36 experimental units for each crop. Growth parameters (plant height and number of leaves) and biomass yield were determined and data Analyzed using ANOVA while treatment means were separated by Duncan's Multiple Range Test. High Al rate (100 µM) reduced growth and yield of the crops while moderate application (50 µM) enhanced their performance. Organomineral fertilizer promoted crops' performance better than the other fertilizer materials while the application of inorganic or organic fertilizers with 50 µM $AlCl_3$ proved most effective. Organic fertilizer had the highest residual effects equivalent to that of organomineral fertilizer applied with 50 µM $AlCl_3$, confirming that organic based fertilizers could be used to minimize the deleterious influence of Al toxicity on the production of these legumes in acid soils.

Key words: Cowpea, soybean, fertilizer treatments, aluminum treatments, alfisol

INTRODUCTION

Aluminium is the most abundant metal in the earth's crust constituting approximately 7% of its mass, occurring in a number of forms in soils (R'bia *et al*., 2011). It is generally accepted that Al toxicity is a primary factor limiting plant growth on acid soils (Kochian, 1995). Toxic effects of Al on plant growth have been attributed to several physiological pathways, although the precise mechanism has not yet been understood (Kochian *et al*., 2004). Proposed mechanism of Al toxicity include Al interactions with the root cell wall, Al disruption of plasma membrane and membrane transport processes and Al inhibition of mineral uptake and metabolism, especially that of Ca and P (Rout *et al*., 2001; Akinrinde, 2006).

Besides salinity, Al toxicity is among the widespread problems of ion toxicity stress in plants. Deficiency of phosphorus, calcium and magnesium coupled with presence of phytotoxicity substances (soluble Al and manganese) are responsible for the fertility limitation of acid soils as aggravated by industrial pollution and nitrification. Poor growth in acid soils could be related directly to Al saturation (Akinrinde *et al*., 2004). In acid soils, Al toxicity limits plants' growth due to series of chemical factors and interactions including toxicities of hydrogen, Al and manganese. Oluwatoyinbo *et al*. (2005) showed that acid soils cover about 17 million hectares of land (representing about 18% of total land area) in Nigeria.

Soil acidity is normally corrected by application of calcitic and dolomitic lime. Liming has a beneficial effect on plant growth under Al stress and alleviates Al toxicity of plants (Bessho and Bell, 1992). However, in many developing countries where subsistence agriculture prevails, economic and logistic reasons make it difficult for the resource poor farmers to apply high rates of fertilizer P and/or lime (Akinrinde *et al*., 2004; Anetor and Akinrinde, 2006). It has been discovered that over liming may also cause negative effects on plant growth and soil properties (Ahmad and Tan, 1986). Deficiencies, for example, of some nutrients such as P, Zn, B and Mn can be induced by lime application (Nikolic *et al*., 2000; Shaaban *et al*., 2007). However, a

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number of workers have shown that the addition of green manures and animal waste to acid soils can reduce Al toxicity and increase crop yields (Berek *et al*., 1995; Hue *et al*., 1994; Hue, 1992; Duruigbo *et al*., 2007). The application of organic residue to acid soils in order to minimize the need for lime and fertilizer P application would be beneficial to resource poor semi-subsistence farmers (Haynes and Mokolobate, 2001).

The present study sought to investigate the short-term and long-term (residual) effects of different types of fertilizer (organic, inorganic and organomineral), Al treatments and the interaction of the two on the growth and yield of legumes (cowpea and soybean) on an alfisol.

MATERIALS AND METHODS

The study was carried out in the greenhouse at the Department of Agronomy, University of Ibadan, Nigeria from July to December, 2007. The experimental soil was an alfisol collected from Ajibode village near the University of Ibadan and cropped thrice with cowpea (*Vigna unguiculata*) before the study reported here. The pre-cropping physico-chemical properties of the soil were determined (Table 1).

The experimental design used was Completely Randomized Design (CRD) with two crops, cowpea (IT93K-452-1) and soybean (TGX1485-1) replicated three times. It was a factorial experiment with two factors; Al at three levels (0, 50 and 100 μM) and four fertilizer treatments (control, organic, inorganic and organo-mineral).The total treatment combinations was 12 for each of (soybean and cowpea). The fertilizers used for the study include: Organo-mineral fertilizer (Sunshine organic fertilizer and NPK in ratio 2:1), NPK 15-15-15 and Sunshine organic fertilizer. The experimental treatment also involved the application of three levels of Al (0, 50 and 100 μm) using $AlCl_3.6H_2O$. The fertilizer materials were applied at the rate of 200 kg P_2O_5 ha^{-1} before planting while Al was apply at fourth week of growth. Watering and weeding of pots were also carried out. The treatment combinations were: control, Organic Fertilizer (OF), Inorganic Fertilizer (IF), Organomineral Fertilizer (OMF), Al_{50}, Al_{50} and OF, Al_{50} and IF, Al_{50} and OMF, Al_{100}, Al_{100} and OF, Al_{100} and IF, Al_{100} and OMF.

The parameters measured during the growth period include plant height and number of leaves per plant. The experiment was carried out twice. Aluminium and fertilizer treatments were used only in the first experiment while the second experiment evaluated the residual effects of the treatments on cowpea. The first experiment was terminated after eight weeks while the second experiment was terminated after six weeks. The plants were oven-dried at 70°C to a constant weight. Dry weights of samples were recorded.

Table 1: Pre-cropping soil physical and chemical properties

Parameters	Values
pH (H_2O)	6.50
Org C (g kg^{-1})	14.63
Org M (g kg^{-1})	25.22
Total N (g kg^{-1})	0.84
Bray-1-P (mg kg^{-1})	8.62
Exchangeable bases (cmol kg^{-1})	
K	1.07
Ca	8.59
Mg	4.42
Na	10.48
Exchangeable acidity (cmol kg^{-1})	0.15
Effective CEC (ECEC)	24.00
Extractable micronutrients (mg kg^{-1})	
Mn	178.40
Fe	230.60
Zn	97.70
Cu	35.00
Al	0.0046
Mechanical analysis (g kg^{-1})	
Sand	844.00
Silt	76.00
Clay	80.00
Textural class	Loamy sand

Statistical analysis: Data were analyzed using the Statistical Analytical System (SAS 2003 to carry out Analysis of Variance (ANOVA) and in separating the means multiple comparisons were performed across treatments using Duncan's Multiple Range Tests (DMRT).

RESULTS AND DISCUSSION

Pre-cropping soil fertility status: The physical and chemical properties of the soil used are given in Table 1. The particle size distribution of the soil indicated that the textural class was loamy sand. It was slightly acidic (pH 6.5) and the organic matter content (25.22 g kg^{-1}) was below the critical level of 26 g kg^{-1} given by Adeoye and Agboola (1985) Cation exchange capacity and exchangeable Ca and Mg (8.59 and 4.42 cmol kg^{-1}, respectively) in the soil were high compared with 2.6 and 0.26 cmol kg^{-1} proposed as critical values by Agboola and Corey (1973). The aluminium content of the soil was 0.0046 mg kg^{-1} while Total N (0.84 g kg^{-1}) content and available P (8.62 mg kg^{-1}) were marginal in the soil.

First cropping: The immediate or short-term effect of fertilizer treatment revealed that the test crops (cowpea and soybean) performed better (Table 2, 3) under organomineral fertilizer treatment especially with respect to number of leaves. There was a general increase from 4 to 7 week after planting with the highest number of

Table 2: Effects of the interaction between fertilizer and aluminium treatments on No. of leaves of cowpea at successive weeks after planting

Treatment: µM $AlCl_3$ Treatment	Fertilizer treatment	Weeks after planting: 4	5	6	7	8
0	Control	8.00[bc]	12.33	15.67	20.33	17.00
	Organic	9.00[abc]	15.00	18.00	20.00	13.00
	Inorganic	9.00[abc]	11.67	13.00	12.00	4.33
	Organo mineral	10.33[ab]	15.67	18.33	27.33	16.67
50	Control	7.33[c]	11.67	14.00	20.00	15.00
	Organic	7.67[c]	13.33	16.33	19.67	14.00
	Inorganic	11.00[a]	13.33	17.33	18.00	14.00
	Organo mineral	8.00b[c]	12.00	14.67	15.00	9.67
100	Control	7.67[c]	13.67	16.00	16.33	9.33
	Organic	7.67[c]	10.33	13.67	16.67	10.33
	Inorganic	9.00[abc]	12.00	17.00	9.33	15.67
	Organo mineral	9.00[abc]	13.00	20.67	20.67	8.00
			ns	ns	ns	ns

Means with the same letter (s) in the same columns are not significantly different from each other p = 0.05 (DMRT). ns: Not significant

Table 3: Effects of the interaction between fertilizer and aluminium treatments on number of leaves of soybean at successive weeks after planting

Treatment: µM $AlCl_3$ treatment	Fertilizer treatment	Weeks after planting: 4	5	6	7	8
0	Control	12.33	23.00	28.67	34.67	34.67
	Organic	11.33	18.33	24.67	29.33	27.00
	Inorganic	12.00	19.67	23.67	31.67	36.00
	Organo mineral	13.67	22.67	28.00	33.67	31.33
50	Control	14.33	26.00	29.33	35.67	36.33
	Organic	13.00	24.00	31.67	40.00	37.33
	Inorganic	12.67	23.33	26.67	32.67	33.33
	Organo mineral	11.00	22.00	28.00	36.67	34.67
100	Control	14.33	21.33	28.67	31.33	37.33
	Organic	13.00	19.67	24.33	28.67	33.67
	Inorganic	12.67	19.33	25.00	35.00	32.67
	Organo mineral	11.67	22.33	26.67	31.00	31.00
		ns	ns	ns	ns	ns

ns: Not significant

cowpea leaves (27.3) obtained from plant treated with organomineral and this could be adduced to the fact that organomineral combined the benefits of organic manure such as nutrient supply, soil structure improvement and inorganic fertilizer (high and fast nutrient release) that enhanced vegetable production (Olaniyan *et al*., 2006). Also there was no significant difference in terms of number of leaves (Table 3) of soybean irrespective of fertilizer treatment. However, the data summarizing the effect of Al treatment, interaction between fertilizers and Al treatments on number of leaves of cowpea and soybean (Table 2, 3, respectively) indicate no significant difference among the various treatments throughout the period of experiment between the treated and untreated plants. This suggests that Al rates applied had no significant effect on the leaf production of the test crops. Sole fertilizer effects (Table 4, 5) were significant for both crops throughout the duration of the experiment. The tallest plants (20.9 and 30.5 cm) cowpea and soybean, respectively were obtained at 8 week after planting with sole application of inorganic fertilizer.

This could be adduced to the fast release of nutrients by inorganic fertilizer. This is in consonance with the study of Mokwunye and Vlek (1986) which revealed that the judicious use of N and P fertilizer can bring out substantial yield increase in West Africa. With respect to the effects of interaction between fertilizer and Al treatments on cowpea height (Table 4) indicate that there were significant differences ($p<0.05$) among the treatment means for cowpea. The highest cowpea height (23.3 cm) was obtained when 50 µM was applied with Inorganic Fertilizer (IF). Plant height was improved with the application of inorganic fertilizer by 5.19 and 15.57% compared with organomineral and Organic Fertilizer (OF), respectively. This trend was maintained throughout the experiment with IF proved to be most effective fertilizer for cowpea height. On the other hand, the interaction between fertilizer and Al on soybean plant (Table 5) indicates that treatment combination of 50 µM level of Al and OF was observed to favour the attainment of the highest soybean plant (34.8 cm) while the lowest (24.4 cm) was obtained at 8 WAP from sole application of 50 µM Al. This observation shows that organic fertilizer application had a beneficial effect on Al detoxification as it had been established by many researchers (Ahmad and Tan, 1986; Hue and Amien, 1989; Ostatek-Boczynski *et al*., 1995).

Organomineral fertilizer increased cowpea biomass production by 16.8 and 5.8% compared with inorganic and organic fertilizers, respectively this is in consonance with the findings of Singh *et al.* (2011) which stated that combined application of organic manures and inorganic fertilizers increased the dry matter accumulation. It was also observed that Al application reduced the performance of the crops, when applied at the highest rate (100 µM). The results of the sole application of Al (100 µM) for both crops (Table 6) show that the least biomass production (9.3 and 12.9 g pot^{-1}) were obtained from cowpea and soybean, respectively, Petra and Proctor (2000) observed similar trends. Dry matter (Table 7) indicates that cowpea was reduced by 14.79% with 100 µM compared with 50 µM application level. This confirms that Al limits plants growth at high concentration; it is also in line with the submissions of Kochian (1995) which reported that Al toxicity is a primary factor limiting plant growth on acid soils.

There were significant interactions between Al and fertilizer treatment on cowpea (Table 7) dry matter yield. The highest cowpea dry matter (3.1 g pot^{-1}) was obtained with the application of 50 µM Al and inorganic fertilizer

Table 4: Effects of the interaction between fertilizer and aluminium treatments on cowpea height (cm)

Treatments		Cowpea height (cm) at successive weeks after planting				
μM $AlCl_3$ treatment	Fertilizer treatment	4	5	6	7	8
0	Control	14.0^{bc}	14.9^{cd}	15.6^{abc}	15.9^{bcd}	18.2^{bc}
	Organic	13.7^{bc}	14.1^{d}	14.5^{c}	14.8^{d}	16.4^{c}
	Inorganic	16.8^{a}	17.9^{a}	18.9^{a}	19.1^{ab}	20.9^{ab}
	Organo mineral	14.7^{abc}	15.9^{bcd}	16.6^{abc}	17.3^{bcd}	18.8^{bc}
50	Control	13.7^{bc}	14.6^{cd}	15.1^{bc}	16.5^{bcd}	17.5^{bc}
	Organic	15.5^{ab}	16.8^{ab}	17.9^{ab}	18.5^{abc}	19.7^{abc}
	Inorganic	16.9^{a}	17.9^{a}	18.7^{a}	20.9^{a}	23.3^{a}
	Organo mineral	16.1^{ab}	17.8^{a}	18.6^{ab}	19.1^{ab}	20.7^{ab}
100	Control	15.8^{ab}	16.4^{abc}	16.9^{abc}	16.9^{bcd}	18.8^{bc}
	Organic	12.3^{c}	14.0^{d}	15.5^{abc}	15.1^{cd}	17.5^{bc}
	Inorganic	15.5^{ab}	16.4^{abc}	17.1^{abc}	17.9^{abcd}	19.3^{bc}
	Organo mineral	16.6^{a}	17.7^{ab}	18.6^{ab}	18.8^{ab}	20.9^{ab}

Means with the same letter (s) in the same columns are not significantly different from each other p = 0.05 (DMRT)

Table 5: Effects of the interaction between fertilizer and aluminium treatments on soybean height (cm)

Treatments		Weeks after planting				
μM $AlCl_3$ treatment	Fertilizer treatment	4	5	6	7	8
0	Control	14.1^{c}	18.8^{b}	22.5^{d}	23.1^{b}	25.7^{cd}
	Organic	14.9^{bc}	21.9^{a}	27.4^{ab}	28.5^{ab}	28.9^{bcd}
	Inorganic	16.5^{ab}	22.7^{a}	27.2^{ab}	29.6^{a}	30.5^{abc}
	Organo mineral	15.3^{abc}	21.6^{a}	26.5^{ab}	27.1^{ab}	28.2^{bcd}
50	Control	14.3^{c}	19.6^{b}	22.9^{cd}	23.3^{b}	24.4^{d}
	Organic	15.5^{abc}	23.3^{a}	29.1^{a}	31.9^{a}	34.8^{a}
	Inorganic	15.9^{abc}	22.6^{a}	28.3^{ab}	29.9^{a}	31.3^{abc}
	Organo mineral	17.1^{a}	21.9^{a}	27.5^{ab}	28.5^{ab}	29.2^{abcd}
100	Control	15.9^{abc}	22.1^{a}	27.5^{ab}	29.9^{a}	31.6^{ab}
	Organic	16.3^{ab}	21.6^{a}	25.3^{bc}	26.7^{ab}	27.1^{bcd}
	Inorganic	16.4^{ab}	23.1^{a}	28.9^{a}	29.6^{a}	31.3^{abc}
	Organo mineral	15.6^{abc}	22.3^{a}	26.9^{ab}	27.3^{ab}	29.0^{bcd}

Means with the same letter (s) in the same columns are not significantly different from each other p = 0.05 (DMRT)

Table 6: Effects of the interaction between fertilizer and aluminium treatments on cowpea and soybean biomass weight (g pot^{-1})

Treatment		Biomass weight (g pot^{-1})	
μM $AlCl_3$ treatment	Fertilizer treatment	Cowpea	Soybean
0	Control	12.40^{abc}	14.27
	Organic	11.10^{bc}	15.90
	Inorganic	9.67^{bc}	15.27
	Organomineral	15.97^{ab}	15.33
50	Control	9.43^{c}	13.10
	Organic	18.50^{a}	14.90
	Inorganic	14.73^{abc}	15.43
	Organomineral	13.23^{abc}	15.77
100	Control	9.30^{c}	12.87
	Organic	11.53^{bc}	14.67
	Inorganic	13.27^{abc}	14.80
	Organomineral	13.73^{abc}	14.17
			ns

Means with the same letter (s) in the same columns are not significantly different from each other p = 0.05 (DMRT). ns: Not significant

while the least dry matter weight (1.5 g pot^{-1}) was obtained from 100 μM Al. This could be attributed to the fact that inorganic fertilizer increases the crop yield. Peter *et al.* (2000) reported that targeted sufficient and balanced quantity of inorganic fertilizer will be necessary to make nutrients available for high yield without polluting the environment.

Table 7: Effects of the interaction between fertilizer and aluminium treatments on cowpea and soybean shoot dry weight (g pot^{-1})

Treatments		Dry shoot weight (g pot^{-1})	
μM$AlCl_3$ treatment	Fertilizer treatment	Cowpea	Soybean
0	Control	2.03^{cde}	3.83^{de}
	Organic	1.60^{e}	3.93^{de}
	Inorganic	1.57^{e}	4.83^{a}
	Organo mineral	3.03^{ab}	4.37^{abcd}
50	Control	2.03^{cde}	3.73e
	Organic	2.97^{abc}	4.03^{cde}
	Inorganic	3.13^{a}	4.70^{ab}
	Organo mineral	2.10^{bcde}	4.43^{abcd}
100	Control	1.50^{e}	4.20^{bcde}
	Organic	1.77^{de}	4.43^{abcd}
	Inorganic	2.70^{abcd}	4.57^{abc}
	Organo mineral	2.90^{abc}	4.10^{bcde}

Means with the same letter (s) in the same columns are not significantly different from each other p = 0.05 (DMRT)

Second cropping: Evaluation of the residual effects of the fertilizer treatments (Table 8) showed that production of leaves in cowpea followed the same trend with control plants having the lowest number of leaves (9.7) at 6 weekafter planting. The leaves however increased in number with inorganic fertilizer application and there was no significant difference among the fertilizer types. Organic fertilizer addition increased dry matter production

Table 8: Residual effects of the interaction between fertilizer and aluminium treatments on number of leaves of cowpea

Treatments		Weeks after planting		
μM $AlCl_3$ treatment	Fertilizer treatment	4	5	6
0	Control	4.67^{c}	8.17^{bcd}	9.67^{bc}
	Organic	6.33^{abc}	8.83^{abcd}	12.00^{abc}
	Inorganic	8.33^{a}	11.83^{a}	12.17^{abc}
	Organomineral	6.67^{abc}	10.00^{abc}	12.00^{abc}
50	Control	5.83^{abc}	6.33^{d}	9.33^{c}
	Organic	5.67^{abc}	10.33^{abc}	12.50^{ab}
	Inorganic	5.33^{bc}	7.17^{cd}	11.83^{abc}
	Organomineral	7.83^{ab}	9.83^{abc}	13.17^{a}
100	Control	4.67^{c}	7.83^{bcd}	9.17^{c}
	Organic	7.33^{abc}	10.83^{ab}	12.67^{ab}
	Inorganic	7.17^{abc}	9.00^{abcd}	11.33^{abc}
	Organomineral	7.83^{ab}	10.67^{ab}	12.50^{ab}

Means with the same letter (s) in the same columns are not significantly different from each other p = 0.05 (DMRT)

Table 9: Residual effects of the interaction between fertilizer and aluminium treatments on cowpea shoot dry weight (g pot^{-1})

Treatments		
μM $AlCl_3$ treatment	Fertilizer treatment	Cowpea dry shoot weight (g pot^{-1})
0	Control	0.73^{c}
	Organic	1.5^{abc}
	Inorganic	0.77^{c}
	Organo mineral	1.13^{bc}
50	Control	1.80^{ab}
	Organic	1.47^{abc}
	Inorganic	1.27^{bc}
	Organo mineral	2.43^{a}
100	Control	1.30^{bc}
	Organic	1.50^{abc}
	Inorganic	1.37^{bc}
	Organo mineral	1.73^{abc}

Means with the same letter(s) in the same column are not significantly different from each other p = 0.05 (DMRT)

by 24.67 and 48.67% compared with organomineral and inorganic fertilizer, respectively. This could be adduced to the fact that organic improve moisture availability and nutrients supply. Organic additions also supply N to the legume crops which could be limiting factor for the grain legumes if biological activity is low. Carsky (2003) observed that organic additions substantially increased cowpea grain yield.

The 50 μM Al applications favoured the growth and yield of cowpea unlike the case with 100 μM Al application level. Combined Al at 50 μM and organomineral treated plants (Table 8, 9) produced more leaves (13.7) and dry matter (2.43 g pot^{-1}) than the other treatment combinations.

CONCLUSION

It is evident from this study that high Al concentrations in soils would reduce the growth and yield of cowpea and soybean while moderate Al amounts (e.g., 50 μM) would enhance the performance. Organomineral fertilizer application also promoted the growth and yield of the two crops more than the other fertilizer types. However, combined applications of 50 μM Al and IF or OF proved to be the most effective in enhancing crop growth. Expectedly, organic fertilizer had the highest residual effect while OMF was the best in ameliorating acid soils with moderate Al concentration.

REFERENCES

Adeoye, G.O. and A.A. Agboola, 1985. Critical levels for soil pH, available P,K, Zn and Mg and ear leaf content of P, Cu and Mn in sedimentary soil of South Western Nigeria. Nutr. Cycl. Agroecosys., 6: 65-71.

Agboola, A.A. and R.B. Corey, 1973. The relationship between soil pH, organic matter, available P, exchangeable K, Ca, Mg and 9 elements in the maize tissue. Soil Sci., 115: 367-375.

Ahmad, F. and K.H. Tan, 1986. Effects lime and organic matter on soybean seedling grown in aluminium toxic soil. Soil Sci. Soc. Am. J., 50: 656-661.

Akinrinde, E.L., L. Iroh, G. Obigbesan, T. Hilger, V. Romheld and G. Neuman, 2004. Tolerance to soil acidity in cowpea genotypes is differentially affected by phosphorous nutritional status. Proceedings of the Paper Presented at Annual Conference of Deutshe Gesellschaft fuer Pflanzenernahrung, Goettigen, Sept. 1-3, Munich, Germany, pp: 12-17.

Akinrinde, E.A., 2006. Strategies for improving crops use-efficiencies of fertilizer nutrients in sustainable agricultural systems. Pak. J. Nutr., 5: 185-193.

Anetor, M.O. and E.A. Akinrinde, 2006. Response of soybean [*Glycine max* (L.) merrill] to lime and phosphorus fertilizer treatments on an acidic Alfisol of Nigeria. Pak. J. Nutr., 5: 286-293.

Berek, A.K., B. Radjaguk and Maas, 1995. The Effect of Different Organic Materials on the Alleviation of Al Toxicity in Soybean on a Red- Yellow Podzoic Soil. In: Plant Soil Interactions at Low pH: Principles and Management, Date R.A., N.J. Grundon, G.E. Rayment and M.E. Probert (Eds.). Klumer Academic Publisher, Dordrect, The Netherlands, pp: 579-584.

Bessho, T. and L.C. Bell, 1992. Soil solid and solution phase changes and mung beam responsible during amelioration of aluminium toxicity with organic matter. Plant, 140: 183-186.

Carsky, R.J., 2003. Response of cowpea and soybean to P and K on terre de Barre soils in southern Benin. Agric. Ecosysyt. Environ., 100: 241-249.

Duruigbo, C.I., J.C. Obiefuna and E.U. Onweremadu, 2007. Effect of poultry manure rates on soil acidity in an ultisol. Int. J. Soil Sci., 2: 154-158.

Haynes, R.J. and M.S. Mokolobate, 2001. Amelioration of aluminium toxicity and P deficiency in acid soils by addition of organic residue: A critical review of the phenomenon and the mechanism involved. Nutrient Cycling Agroecosyst., 59: 47-63.

Hue, N.V. and I. Amien, 1989. Aluminium detoxification with green manure. Comm. Soil Sci. Plant Anal., 20: 1499-1511.

Hue, N.V., 1992. Correcting soil acidity if lightly weathered ultisol with chicken manure and sewage sludge. Commun. Soil Sci. Plant Anal., 23: 241-264.

Hue, N.V., H. Ikawa and J.A. Silva, 1994. Increasing plant available phosphorous in an ultisol with a yard-waste compost. Commun. Soil Sci. Plant Anal., 25: 3291-3303.

Kochian, L.V., 1995. Cellular mechanism of aluminium toxicity and resistance on plant. Ann. Rev. Plant Physiol Plant Mol. Biol., 46: 237-260.

Kochian, L.V., O.A. Hoekenga and M.A. Pineros, 2004. How do crop plants tolerate acid soils? Mechanism of aluminum tolerance and phosphorus efficiency. Annu. Rev. Plant Biol., 55: 459-493.

Mokwunye, A.U. and P.L.G. Vlek, 1986. Management of Nitrogen and Phosphorus Fertilizers in Sub-Saharan African Soils. Martinus Nijhoff Publishers, The Hague, The Netherlands, pp: 117-172.

Nikolic, M., V. Roemheld and N. Merkt, 2000. Effect of bicarbonate on uptake and translocation of Fe in two grapevine rootstocks differing in their resistance to Fe deficiency chlorosis. Vitis, 39: 145-149.

Olaniyan, A.B., A.H. Akintoye and O. Bunmi, 2006. Effect of different sources of nitrogen on growth and yield of solanum macrocarpon in derived savanna of Nigeria. J. Agron., 5: 182-185.

Oluwatoyinbo, F.I., M.O. Akande and J.A. Adediran, 2005. Response of okra (*Abelmoschus esculentus*) to lime and phosphorus fertilization in acid soil. World J. Agric. Sci., 1: 178-183.

Ostatek-Boczynski, Z., G.L. Kerven and F.P.C. Blamey, 1995. Aluminium reactions with polygalacturonate and related organic ligands. Plants Soils, 171: 41-45.

Peter, G., G. Francesco and Y. Montaque, 2000. Integrated Nutrient Management; Soil Fertility and Sustainable Agriculture: Current Issues and Future Challenges. International Food Policy Research Institute, Washington, DC.

Petra, S.K. and J. Proctor, 2000. Effects of aluminium on the growth and mineral composition of *Betula pendula* Roth. J. Exp. Bot., 51: 1057-1066.

R'bia, O., F. Horchani, I. Smida, M. Mejri and S. Aschi-Smiti, 2011. Aluminium phytotoxicity and plant acclimation to acidic soils. Int. J. Agric. Res., 6: 194-208.

Rout, G.R., S. Samantaray and P. Das, 2001. Aluminium toxicity in plants: A review. Agronomie, 21: 3-21.

SAS, 2003. Software/Release. Version 9, SAS Institute Inc., Cary, NC, USA.

Shaaban, M.M., O. Loehnertz and M.M. El-Fouly, 2007. Grapevine genotypic tolerance to lime and possibility of chlorosis recovery through micronutrients foliar application. Int. J. Botany, 3: 179-187.

Singh, C.M., P.K. Sharma, P. Kishor, P.K. Mishra, A.P. Singh, R. Verma and P. Raha, 2011. Impact of integrated nutrient management on growth, yield and nutrient uptake by wheat (*Triticum aestivum* L.). Asian J. Agric. Res., 5: 76-82.