GLOBAL JOURNAL OF ENVIRONMENTAL SCIENCES VOL. 6, NO. 1, 2007: 15 - 19
COPYRIGHT (C) BACHUDO SCIENCES CO. LTD. PRINTED IN NIGERIA. 1SSN 1596 - 6194

TOXICITY OF ALUMINUM TO PINEAPPLE (*ANANAS COMOSUS*) GROWN ON ACID SANDS OF CROSS RIVER STATE, NIGERIA

W. UBI AND V. E. OSODEKE

(Received 6 April 2006; Revision Accepted 20 December, 2006)

ABSTRACT

A solution culture experiment was carried out in April, 2003 at Calabar using two cultivars of pineapple suckers (*Ananas Comosus*) smooth Cayenne, and Queen to assess the Al toxicity to pineapple solution culture, consider the Al up-take, and attendant Al symptoms, together with shoot and roots growth.

The treatment consisted of three levels of Al concentrations 0, 0, 0.35 and 0.070mmol dm^{-3}, combined with four levels of ionic strength produced by diluting a complete nutrient solution to relative concentration of 1.0, 0.5, 0.25 and 0.12. The phosphorus (P) ion concentration of each solution was adjusted to 0.1mmol dm^{-1} The pH of the solution was maintained at 4.5 ± 0.3. The results showed that shoot and root growth decreased significantly under the Al treatments. The observed lateral roots of Al stressed plant of the two varieties was significant ($P<0.05$).

The roots were thicker, shorter and fewer in number. Smooth Cayenne responded more to Al-stress than Queen Cultivar and the effect was significant given equal experimental treatments. The younger leaves of Al-stressed plants were small curled along the margin and frequently Chlorotic.

The effect was less pronounced in Queen than in smooth Cayenne. Leaf analysis of Pineapple suckers showed reduction in Ca and P and increased Al value for plants exposed to excess of soluble Al. When the Al-concentration solution was made constant, the growth of suckers in both varieties was significantly reduced with dilution of the nutrient solution. All roots of Al-stressed pineapple suckers changed from a milky to a brown colour within a few weeks due to excessive concentration of solution Al.

KEYWORDS: Toxicity, Aluminum, Pineapple suckers

INTRODUCTION

The pineapple growing areas of Cross River State of Nigeria stretch from the Southern Senatorial District to the Northern Senatorial District. The south is made up of coastal plain soil terminating with basement complex soil some parts of the North. These acid sand soils contain sufficient exchangeable aluminum (Al) in amount high enough to restrict root growth of some economic crop-species (Dematte, 1981). The danger posed by available Al on root growth in this acid sands has been reported by several Scientists (Adams and Lund 1966, Clarkson 1969. Foy et al (1978), Helyar 1978 and Pearson 1975). However, critical levels of toxic aluminum seems to be different for each plant species and soil type. In working with cotton (*Gossypium Hirstuim L*) Adams and Lund (1966) reported that the exchangeable Al percent, Al saturation and toxicity threshold values for Al in the soil solution, varied depending upon the soil. The researchers also found essentially the same threshold activity value for all when expressing the soil solution Al on an activity basis. When calculating Al^{3t} activity, they reported that the total soluble Al was present in solution as the Al^{3t} species. In another study, Brenes and Pearson (1973) similarly demonstrated that Al^{3t} activity was a good index of Al toxicity for corn (*zea-mays*) and sorghum (Sorghum Vulgare). Information concerning the effect of Al on Pineapple plants based on research findings had not been sufficient. The objectives of this trial were to assess the Al toxicity to Pineapple in nutrient solution culture. The study was designed to show the effect of Al species on the availability of Al, taking into consideration the Al uptake of Pineapple (*Ananas Comosus*) suckers, attendant Al toxicity symptoms, shoot and root growth.

MATERIALS AND METHODS

Suckers of two varieties of pineapple: Smooth Cayene characterized by smooth and spineless leaf blade and Queen-characterized by spine leaf blade, were planted in a flat top round bottomed 1 litre plastic container, of 10cm diameter with a hole perforated on top of the that flat cover. The size of the hole was 5cm, sizable to accommodate the trunk of the progagules. Each plastic container was treated with complete nutrient solution, (Parker and Goddard 1950). The suckers used for the study were harvested at 8 leaf stage from a large population in an experimental farm. The bracks at the based of suckers were removed and the base neatly prepared to fit into the holes. The trial was laid out in a 2 x 3 split plot, in a completely randomized Blocks Design replicated three times The main plot was the cultivars; the sub-plot was the Al treatment: 1.00, 0.035, 0.070mmol dm^{-3} with four levels of ionic strength prepared by diluting the complete Hoagland solution to relative concentrations of 1.0, 0.5, 0.25 and 0.12. Aluminum was added as $Al_2 (SO_4)_3$ $18H_2O$. Plot size was 3m x 10m, sub-plot size was 3 x 5m, laid out in a farm house with natural air and protected against insects with wire gauze. Equally, the nutrient solution was modified as follows;

1. (1) P, was adjusted to 0.1mmol dm^{-3} in treatments to minimize Al phosphate precipitation reactions (Foy and Brown, 1963).
2. (2) The pH of nutrient solution was adjusted daily to 4.9 ± 0.2 with dilute HNO_3. Nitric acid was used in this study to minimize ion pairing of Al.

The Composition of the nutrient solution is shown in Table 1 Suckers were grown for 10 months during which the solutions were checked daily and adjusted as required to meet the desired Al levels, and reversed twice weekly to avoid contamination. About 200ml aliquot of each solution was collected. The aliquot was filtered and analyzed for Al, Ca, Mg, Mn, K, Fe, Cu and Zn by atomic absorption spectrometry (Webber, 1974). In addition, Al was determined by the Erio Chrome Cyanine-R method (Jones and Thurman, 1967) and by Alizarin Red method (Parker and Goddard, 1968). Nitrate in nutrient solution was determined by phenolledisulfonic acid (Bremnar, 1965): sulfate by an indirect AAS, method and Chloride by the standard silver nitrate titration procedure.

W. Ubi, Director/Head of Department, Ministry of Agriculture, 3 Barracks Road, Calabar
V. E. Osodeke, Department of Soil Science, Michael Okpara University of Agriculture, Nigeria.

Phosphorus was determined colorimetrically by the Molybdenum blue method using ascorbic acid as the reducing agent (Jackson 1958).

The result of the chemical analysis of the nutrient solutions were averaged and used as impact data for GEOCHEM computer programme (Sposito and Mattigod, 1980), to calculate the ionic strength (I) of the nutrient solutions and to estimate the speciation of Al in solution.

Five suckers were selected and marked per plot for shoot and root weight determination. Five leaves were randomly selected from each plot for determination of leaf composition. Leaves were washed in a detergent solution, rinsed with deionized water, dried, weighed and ground in wiley mill. The samples of the ground materials were digested in concentrated nitic acid and perchloric acid (Ganje and Page, 1974), using digestion blocks. The acid digest were analyzed for Al, Ca, Mg, Zn, and Mn, by AAS and for P by the Molybdenum blue method. Samples of the ground leaf material were made to pass through 0.5mm seive and 2g of each was measured out for the determination of total nitrogen by the micro-kjeldahl method.

Plant tops and roots were separated, washed with deionized water, dried and weighed. The weight of the shoot and roots were determined.

STATISTICAL ANALYSIS

Crop data was analyzed by the use of Duncan's Multiple Range Test at 5% level, deploying the methods of Wahau (1999).

RESULTS

Al species in nutrient solution

The dominant Al species in solution Al^{3t} representing 77 – 87% of added soluble Al (Al$_t$), the amount of Al ion pairing with S0$_4$ as AlS0$_4^+$ species accounted for 6-12% of Al^t. Almost all the entire Al complexed with OH$^-$ was as the Al0H^{2+} species which amounted to about 5.8% of Al^t One exciting observation was that there was a decrease in the concentration of the Al^{3+} species as the ionic strength increased at a given Al treatment. For instance, Al^{3+} concentration decreased from 0.0356mmol dm^{-3} to 0.026mmol dm^{-3} for Al = 0.035mmol dm^{-3} (see Table 3).

Table 1: Composition of nutrient solution maintained at pH 4.2 Macro Nutrient Composition

TREATMENTS	MACRONUTRIENT COMPOSITION						
Relative strength of nutrient solution	Al	Ca	Mg	K	So$_4$	H$_2$PO$^+$	N0$_3^-$
1.0	0.000	4.35	1.80	4.50	3.00	0 075	18.00
	0.035	4.35	1.80	4 50	3.00	0.075	18.00
	0.070	0.35	1.80	4.50	3.00	0.03	18.00
0.5	0.000	3.10	1.20	2.50	1.50	0.085	8.20
	0.035	3.10	1.20	2.50	1.50	0.084	8.20
	3.10	1.20	2.50	1.50	0.83	0.083	8 20
0.25	0.000	2.20	0.60	1.40	0.35	0.086	4.50
	0.035	2.20	0 60	1.40	0.75	0.087	4.50
	0.020	2.20	0.60	1.40	0.75	0 088	4.50
0.10	0.000	0.75	0.30	0.40	0.35	0.095	2.25
	0.035	0.75	0.30	0.40	0.35	0.094	2.25
	0.070	0.25	0.30	0.40	0.35	0.096	2.25

Table 2: Dominant Al species in nutrient solutions at pH 4.5 as related to ionic strength and conc. of Al$_t$ in the nutrient solution.

Relative strength of nutrient solution	**Al**	**Al$_t$**	**Al^{3+}** (% of Al)	**AlSO$_4^+$$_t$**	**AlOH^{3+}**	**Other species**
1.0	25.2	0.035	75.0	12.6	6.5	3.8
	27.3	0.070	73.0	15.0	6.4	3 8
0.5	15.1	0.035	81.0	10.2	6.2	3.6
	15.4	0.070	80.0	11.4	6.4	3.7
0.25	7.6	0.350	83.0	8.2	6.1	2.5
	7.8	0.070	81.0	9.3	6.2	2.8
0.10	3.5	0.035	86.0	6.5	6.0	2 4
	3 3	0.070	82.0	8.4	6.1	2.6

Table 3: Shoot and root weighs and symptoms intensity of smooth canynne and queen at 10 month after initiating Al$_t$ treatment.

Relative strength of nutrient solution	Al$_t$ (%	Al^{3t}	Al^{3t} (Al$_t$)	Shoot weight g/plant	Root weight	Injury symptom	
						Shoot	Root
Smooth Canyenne Cultivar							
1.0	0.000	0.000	00.0	16.2a	4.5a	None	None
	0.025	0.026	0.64	15.6b	3.4b	Slight	Medium
	0.070	0.058	0.51	12.5b	3.2b	Medium	Slight

0.5	0 000	0.00	00.0	15.5a	3.3b	None	None
	0.035	0 027	0.91	14.5ab	2.4c	Slight	Slight
	0.070	0.056	2.85	10.6c	4.2c	Severe	Medium
0.25	0.000	0.000	0.00	15.3a	4.2a	None	None
	0.035	0.029	2.10	13.4b	3.1b	Slight	Slight
	0.070	0.067	3.85	8.6d	2.3c	Very severe	Medium
0.10	0.000	0.000	0.00	14.6ab	4.1a	None	None
	0 035	0.036	1 65	10.1c	3.4b	Slight	Slight
	0.070	0.560	5.34	8.3d	2.0e	Very severe	Medium
Queen Cultivar							
1.0	0.000	0 000	00.0	24.6b	6.8a	None	None
	0.050	0.024	0.52	21.0b	4.2c	Slight	Slight
	0.070	0.046	0.04	15.2e	3.6d	Slight	Medium
0.5	0.000	0.000	00 0	25.4a	5.7b	None	None
	0.035	0.025	0.72	20.6b	5.2b	Slight	Slight
	0.070	0.042	1 39	18.2c	4 1c	Slight	Slight
0.25	0.000	0.000	0 00	21.8b	4.6c	None	None
	0.035	0 030	2.02	20[illegible]b	3.9d	Slight	Slight
	0.070	0.042	2 16	17.6a	2.8e	Medium	Medium
0.10	0.000	0.000	0.00	20.2b	4 3c	None	None
	0.035	0.034	2.75	18 6c	3 5b	Slight	Slight
	0.070	0.056	2.12	17 1d	2.1e	Medium	Medium

Mean differences between Columns by Duncan's Multiple Range Test at 5% level.

The decrease in Al^{3t} concentration may be due to greater complication of Al caused by the increased concentration of ligands. It was also noticed that increasing the ionic strength produced a large decrease in the Al^{3t} activity. For instance, 1 65 x 10^{-5} to 0.64 x 10^{-5} for Alt = 0.035mmol dm^{-3} This is because the activity coefficient varies as the square of the valance time V_t raised to a power of 10, and 2.25 x 10^{-5} to 0.52 x 10^{-5} for Al_t = 0.035mmol dm^{3} for smooth Cayanne and Queen respectively.

SHOOT AND ROOT GROWTH

The effect of Al treatment on shoot and root growth is presented in Table 3. The result shows that diluting the strength of nutrient solution without Al from a relative concentration of 1.0 (Complete solution) to 0.01 did not show any significant effect on root and shoot growth of Pineapple suckers. In addition, at a given Al_t level, growth was depressed by decreasing the ionic strength of nutrient solution. In other words, the toxicity effects of 0.035 and 0 070mmol dm^{-3} Al treatment were influenced by decreasing the ionic strength of nutrient solution from 27.3 to 3.3mmol dm^{-3} (Table 2).

LEAF COMPOSITION

The combined effect of Al and ionic strength treatments on the composition of Pineapple leaves of smooth Cayenne and Queen Cultivars is shown in Table 4.

Table 4: Leaf composition sampled ten months after initiating Al treatments

Relative strength nutrient solution	Al_t Mmo dm^{-3}	Ca. (Mg/ha)	Mg. (Mg/ha)	K. (Mg/ha)	P. (g/ha)	N. (g/ha)	Mn. µg	Mn. µg	Al µg
Smooth Canyenne Cultivar									
1.0	0.000	1.5a	0.31a	2.5c	0.23c	3.6a	1,58a	2.3a	2.9hi
	0 035	1 4a	0.29a	2.3c	0.21c	3.7a	1.41c	2.1ab	4.1fg
	0 070	1.0c	0.30a	2.6b	0.1fe	3.7a	1.27e	1.8c	8.5c
0.5	0 000	1 4a	0.32a	2.8a	0.26ab	3.5ab	1.58a	2.1ab	2.9hi
	0.035	1 3b	0.31a	2.7ab	0 20c	3 4b	1.22ef	1 8c	4 9f
	0.070	1 2bc	0.31a	2 8a	0.14f	3.4b	0 70g	1.5de	9.2bc
0.25	0.000	1 3b	0.32a	2.8a	0.28a	3.6a	1.33d	2.2a	3.1h
	0.035	1 2bc	0.30a	2 7ab	0.24b	3.4b	0.60h	1.8c	8.0cd
	0 070	1.0c	0 28c	2.9a	0.14f	3.3bc	0.50j	1.6d	9.2bc
0 10	0.000	1.2bc	0.32a	2.8a	0.27a	3.4b	1.32d	1.7c	1.05b
	0.035	1.0c	0.29a	2.8a	0.26a	3.2cd	0.10hi	1.6d	9.8bc
	0.070	0.8d	0.25d	2.9a	0.21e	3.2cd	0.20k	1.5d	12.6a

Queen cultivar

1.0	0.000	1.5a	0.32a	2.4c	0.24c	3.5a	1.54ab	0.24a	0.03i
	0.035	1.3b	0.28b	2.4c	0.22d	3.6a	1.42b	0.22ab	0.39h
	0.070	1.0c	0.29b	2.3c	0.19e	3.6a	1.31c	0.17d	0.82b
0.5	0.000	1.4a	0.31a	2.8a	0.25b	3.5a	1.61a	0.23a	0.31i
	0.035	1.3b	0.30a	2.6b	0.21d	3.5a	1.32c	0.21b	0.43g
	0.070	1.2bc	0.30a	2.8a	0.17f	3.4a	0.81g	0.18cd	0.86b
0.25	0.000	1.4a	0.32a	2.8a	0.28a	3.6a	1.36bc	0.23a	0.31i
	0.035	1.3b	0.30a	2.7ab	0.20d	3.5a	1.02ef	0.19c	0.81b
	0.070	1.0c	0.29b	2.8a	0.19e	3.5a	0.80g	0.18cd	0.90ab
0.10	0.000	1.3b	0.31a	2.9a	0.26b	3.4ab	1.29cd	0.21b	0.10b
	0.035	1.1c	0.29b	2.8a	0.24c	3.2b	1.06e	0.18cd	0.82b
	0.070	0.8d	0.26d	2.8a	0.20d	3.1b	0.87i	0.16e	1.24a

Mean different between the same letters are not significantly different according to Duncan's multiple range test at 5% probability level

MINERAL CONTENT OF LEAF

The investigation showed that decreasing the ionic strength of the solution in the two cultivars tended to produce significant ($P < 0.05$) decreased in leaf Ca, N, Mg, and Zn, values, but increased leaf P given the same treatment Equally, the addition of Al to nutrient solutions (0.035 and 0.070mmol dm^{-3}) resulted to a significant change in the concentration of mineral constituents in the leaves of pineapple cultivars decreasing as the Al in nutrient solution increased The effect of A^{3t} activity as it decreases growth of pineapple at different levels of concentration was not significantly different between the two pineapple cultivars However, toxicity symptoms were more claring in smooth Cayenne than in the queen cultivar In both cultivars however root and leaf toxicity symptoms were related primarily to the activity of Al^{3t} in nutrient solution rather than to the concentration of Al or Al^{3t}

Increasing Al activity significantly increased injury symptoms in both cultivars during the study period The change in colour of the roots of queen cultivar from milky to brown was faster and well identified than in the Smooth Cayenne Cultivar throughout the study period In general smooth canyenne Cultivar appeared to be more tolerant to different levels of Al, concentration than queen cultivar as evidenced in the injury symptoms observed during the study period (Table 3)

DISCUSSION

The toxicity of soluble Al assessed in this study as being mitigated in part, by increase in the soluble Ca concentration was earlier reported (Jackson, 1967, Kamprath and Foy, 1971, Foy *et al* 1978 and Helyar 1978).

However, Helyar (1978) reported that the ameliorating effect of Ca on Al toxicity was a major effect and that it occurs at moderately low concentrations of soluble Al not at a phytoxic level. In addition Paran (1981) in a separate solution culture experiment with Coffee seedlings did not find a change in the toxicity of soluble Al at added levels of 0.148, and 0.74mmol dm^{-3} upon increasing the soluble Ca level from 0.5 to 1.25mmol dm^{-3} By implication, the reported increased toxicity of Al brought about by diluting the nutrient solution in this study may be associated with the effect of ionic strength upon the activity of Al^{3t} instead of the concentration of Ca The values of the threshold, associated with a growth reduction reported in Table 4 compared favourably with that observed for roots on Coffee seedlings grown in acid soils, (Paran *et al* 1981) root of cotton seedlings, (Adams and Lund 1966) and roots of cotton and Sorghum (Brenes and Pearson 1973).

The change in colour of the entire Al stressed Pineapple suckers from milky to brown observed in this experiment was similar to the root symptoms described for a wide variety of crops (Jackson 1967, Pearson 1975, Foy et al 1978)

The observed reduction in the plants P concentration showed that Al reduced P movement to plant shoot, may be by precipitation of P on the root surface or it could be right in the root tissues. The suggested action of immobilization of P in the root cells is capable of inducing P deficiency as a whole

The severity of injury symptoms associated with the activity of Al^{3t} rather than with the concentration of soluble Al species was clearly marked in queen than in smooth Canyenne probably due to the genetic composition of this cultivar The decreased in Ca, N, Mg and Zn contents of the leaf due to decreased in ionic strength of the solution in the two cultivars found in this study was as earlier reported (Paran, 1981, Hussan and Leitch, 2000)

CONCLUSION

Report from this study showed that leaf analysis of Pineapple suckers planted on acid sands of Cross River State, Nigeria reflected reduction in Ca, and P and increased Al values for suckers exposed to excesses soluble Al The import figure for fruit juices in Nigeria in recent times stood at Six Billion Naira (N6 billion) annually prior to the ban on the importation. The recent ban has created an opportunity for farmers to embark on large scale fruit farming in Nigeria

Smooth Canyenne Cultivar in this experiment has proved to survive in acid sands at different levels of Al toxicity, with minimal injury symptoms than the Queen Cultivar It is therefore recommended for large scale production for greater economic benefits to the farmer in the acid sands of Cross River State, Nigeria

REFERENCES

Adams, F and Lund, Z. F , 1966 Effect of chemical activity of soil soluble aluminum on Cotton root penetration of acid sub-soil Soil Science Journal ,101 193 – 198.

Brenes, E and Pearson, R W 1973 Root responses of three gramineae species to soil acidity in an Oxisol and an Utisol Soil Sc Journal 116· 295 – 302

Dematte, J L J 1981 Characteristics of Brazillian soils related to root growth p. 21 – 42 in R S. Russell *et al* (ed) The soil/root system in relation to Brazilian agriculture IAPA, Londrina, Brazil.

Clarkson. D T 1969 Metabolic aspects of aluminum toxicity and some possible mechanisms for resistance p. 381 – 397 In I H Robison (ed) *Ecological aspects of the* minerals nutrition in plants. Blackwell. Oxford. *England*

Foy. C. D and Brown. J. C , 1963 Toxic factors in acid soils Characterization of Al toxicity in Cotton Soil science society of American proceedings 27· 403 – 407

Ganje, T J. and Page, A. L., 1974. Rapid acid dissolution of plant tissues for cadmium determination by atomic absorption spectrophotometry 13: 131 – 134

Helyar, K. R , 1978 Effect of aluminum and managenes toxicity on Legume growth Pg 207 – 231 In C. S Andrew and E. J. Kamprath (ed) Mineral nutrition of legumes in tropical and subtropical soils. CSIRO, Melbourne. Australia.

Hussan, F U and Leitch. M. H 2000 Influence of seedlings density on contents and update of N P K in linseed *Vinum Usitatissimum L*) Journal of Agronomy and crop science 185.

Jackson, M. L., 1958 Soil chemical analysis Prentice Hall Inc England Cliffs. N J

Jackson. W A 1967 Physiological effect of soil acidity pg. 43 – 124 in R W Pearson and F Adam (ed) Soil acidity and Liming "American Society of Agronomy. Madison, Wis

Kamprath, E. J and Foy. C D . 1971 Line-Fertilizer-Plant interaction in acid soils Pg 105 In R A Olsen (ed) Fertilizer Technology and Use (2nd ed) Soil Science Society of American. Madison. Wis

Parker C A. and Goddard, A P . 1968 The reaction of aluminum ions with a alizarin -3-solphonate with reference in the effect of Calcium ions. Ana Chim. Act 4· 517 – 535.

Paran, M A.. Brigham, F T and Pratt. P F . 1982 Toxicity of Aluminum to (*Coffee Arabica L*) in Utisols and Otisols amended with $CoCa_3$ and $CaSO_42H_20$ Soils Science Society of America Journal 4 · 160 – 169

Paran. M A ,1981 Toxicity of Al (III) to Coffee (*Coffee Arabica. L*) In nutrition solution culture and in Oxisol and Utisol as amended with $CaC0_3$ Mg. $C0_3$ and $CaSO_42H_20$ Soil Science Society, American Journal 5 512 – 518

Pearson. R H 1975 Soil acidity and liming in the humid tropics *International* Agric Bull No 30 Cornell University

Sposito. O G. and Mattigod. S V., 1980 GEOCHEM' A computer programme for the calculation of chemical equilibria in soil soluble and other natural water system. Kiearney foundation of Soil Science, University of California. Riverside

Wahau. T A. T , 1999. Applied Statistics for Scientific Studies Africa-link Books, Ibadan, Nigeria 162 – 214