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Heavy Metals Nutrition Of Pineapple in Soils of Southeastern Nigeria

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Abstract: ***In 2015, three experiments were carried out to evaluate the application of heavy metals (Cu, Zn, Bo, Mo and Mn) on the growth and development of pineapple culivar smooth cayenne, (Ananas comosus Merril L.) in the basement complex soils of Iwuru in Biase Local Government Area of Southern Nigeria. In experiment I, application of micro-nutrients were made to the soil while in experiment 2, the treatments were applied in a low volume foliar spray solution. Experiments 1 and 2 were laid out in a 2^5 factorial with 4 blocks of 8 boxes. In experiment 3, the trial was laid out in 2^6 confounded factorial designs with 8 blocks and 8 boxes. Treatments were randomly assigned to all boxes in each block, maintaining uniform experimental condition. The results showed that Copper had a beneficial effect on dry weight of leaf material produced (significant, $p<0.05$), but the effect of molybdenum was negative ($p<0.001$). The interaction between molybdenum and manganese was positive ($p<0.01$), while that between molybdenum and Copper was negative ($p<0.001$). The interaction between iron and molybdenum was positive ($p<0.05$) and that of iron and boron, were negative ($p<0.001$) and ($p<0.05$). Copper was reported to have stimulated leaf length production while iron and molybdenum depressed it. The depressive effect of iron on leaf production per sucker was also noted, at that time the interaction of molybdenum and boron was positive ($p<0.05$). On the whole, boron when interacting with zinc, iron and copper had produced depressive effect on growth. These results are discussed in light of heavy metals nutrition in smooth cayenne pineapple in southeastern Nigeria.***

Keywords: Plants nutrition, trace elements, pineapple, soils

I. INTRODUCTION

The role of the major elements in the nutrition of pineapple has been studied extensively for soils of southeastern Nigeria, (Hassan and Leitch, 2000; Ubi and Omaliko, 2005). However, studies on the trace element nutrition of pineapple have not been as extensive. In Central Congo (Kinshasa), boron, manganese, zinc and copper were shown to increase yields of crops by 42% to 64% over the control during three year period, (Ferrend, 1995). The effect of zinc and molybdenum in conjunction with a complete mixed fertilizer on the yield of field crops have been investigated in trails carried out in Malaya (Chemara, 1962). While a times it appeared that the applications of zinc and molybdenum were beneficial, the main effects of these micro-nutrients on crop yield never attained any significance. In a more recent series of trace element experiments on peat and organic clay soils in the tropics, response to the application of manganese, boron, copper and zinc plus molybdenum have been variable, (Udo, 2007). In one case, manganese, boron and zinc plus molybdenum produced significant increases in yield, while in another, manganese reduced yield. In a trace element experiment at NIFOR main station near Benin City, mid-western Nigeria, the yields showed a 6.5% increase result from the application of 6g of sodium borate per plant. However, the application of 1kg of manganese sulphate per plant resulted in a 13% decrease in the yield of the fruits. The responses to copper and zinc were not straight forward; although the higher rates of application tended to increase yields. In a similar trial in 1996 at Abak in southeastern Nigeria, the results followed a similar pattern as those from the experiment at Benin but none of the differences was statistically different, (NIFOR, 1965; Mulder, 1994).

However, the application of boron as "solubor" (66%B_2O_3) in 1965 as split-plot treatment in another fertilizer experiment on a very much poorer soil at Umuabi, southeastern Nigeria, did not affect yields, (NIFOR, 1967). With exception of boron, no micro-nutrient deficiency symptoms have been reported in the mature crop. Fermeda (1994) in presenting data to show the relationship between the incidence of little leaf disease and fertilizer application using all-minus-one technique, concluded that little leaf disease was directly related to boron deficiency. It must however be noted that, while the plot receiving complete fertilizer without boron did have a high number of affected plants, the control (no fertilizer) did not. It would then seem that if boron was related to little leaf disease, the appearance of the symptoms became manifest only when a state approaching complete fertility was achieved.

In the absence of iron, the leaves exhibited a chlorosis which finally led to necrosis and an arrest of growth of the crop. Manganese deficiency was characterized by the plant appearing flaccid with the leaves becoming affected by chlorosis. In the absence of any well defined responses of mature crop to trace elements the objective of this study was to investigate the heavy metals nutrition on the growth and development of smooth cayenne pineapple (*Ananas comosus Merrill L.*) to see whether the results would give an indication as to the heavy metals nutrition that may prove important to the pineapple, planted in southeastern Nigeria.

II. MATERIALS AND METHODS

Three experiment which were similar is design where carried out at Iwuru, in Biase Local Government Area almost at the centre of Cross River State, bounded by 8^{o}03' to 8^{o}17E and latitude 38^o to 5^{o}59^{o}N respectively. The mean annual rainfall in most parts of this area of Cross River State is 2560mm (range 2250 to 1700mm), while its distribution is bimodal with a dry season of 4 months between November and March. Mean daily minimum and maximum temperature varies from 21^{o}C to 24^{o}C and 27^{o}C to 32^{o}C respectively, while relative humidity varies from 82 to 97%, (Eshett, 1987). In one case (Experiment 1), applications of micro-nutrients were made to the soil, while in the other (Experiment 2) the treatments were applied in a low volume foliar spray solution. A trial (Experiment 3) was also carried out where the treatments were applied in the form of a foliar spray. The area was previously cropped with cassava followed by a five year fallow, in which Guinea grass (*Panicum maximum* S112) was the dominant fallow species.

EXPERIMENTAL DETAILS (EXPERIMENTS 1 AND 2)

A bulk soil sample was obtained from the nil plot of a fertilizer trial. Boxes containing 15kg of soil were used and treated with a basal dressing of major elements (N:P:K: Mg 15:15:15:2). The planting material consisted of suckers of smooth cayenne variety of pineapple (*Ananas comosus Merrill L.*) which were planted six to a box. Each box was 100 x 50 x 50cm, laid out in a 2^5 factorial trial with 4 blocks of 8 boxes per block measuring 10 x 10m. An area of 2^2m was marked out from each box for measurement of yield and yield attributes of the crop. The plants were planted in the field which was completely enclosed by a Tygon mesh screen to prevent the intrusion of insects or animals. Ten leaves were randomly harvested per box after 35 weeks and were dried in Gallen Kamp Air Laboratory Ovun, at 75^{o}C for 48 hours. Dried materials were weighed for dry weight and 500g samples were milled and analyzed for mineral content. Mineral assays were performed on acid-digested samples of ground and sieved materials at the University of Calabar Soil and Plant Science Laboratory, Calabar. The leaf laminae were cut from the suckers and separate dry weights were recorded for the leaves and the residual tissues (i.e. roots, stem and number of leaves produced in "October" per sucker). Chemical analysis for major and minor elements were carried out on the ground materials. Leaf length was measured from the marked plots from 10 randomly selected leaves. Measurement was from the petiole to the mid-rib using a graduated metre ruler. All leaves produced irrespective of being dead or alive at the end of the month of October represented the total number leaf blades per sucker (Ubi *et al.*, 2006).

Element	Form added	The soil (kgha^{-1})
Boron	Boric acid	1.0
Zinc	Zinc sulphate	1.0
Molybdenum	Amonum molyphate	1.0
Manganese	Manganese sulphate	2.0
Copper	Copper sulphate	2.0

Table 1: Heavy Metals Used and their Quantities Applied in Experiment1

In experiment 2, the design and treatments were the same except that manganese was replaced by iron supplied as Fe-EDTA. The trace elements were applied in a low-volume spray solution at fortnightly intervals at the following rates:

Elements	9-22 Weeks (µg per box)	24-30 Weeks (µg per box)
B, Fe, Mo, Zn	nil; 100	nil; 100
Cu	nil; 200	nil; 200

EXPERIMENTAL DETAILS – EXPERIMENT 3

Experiment 3 was laid out on 2^6 confounded factorial designs with 8 blocks of 8-plots. Each box had 30 suckers. The original content of micro-elements in the soil formed the first treatment level and the second was obtained by applying foliar sprays of the following elements at monthly internals from April to November of the planting year.

Element	Form	Rate per sucker of 200ml
B	Sodium Tetraborate	0.300
Zn	Zinc sulphate	0.300
Mo	Sodium molyphate	0.300
Mn	Manganese sulphate	0.300
Fe	Iron sulphate	0.300
Cu	Copper sulphate	0.150

Table 2

The application of 0.300 of copper as copper sulphate produced symptoms of scorch and so that amount was reduced to 0.150.

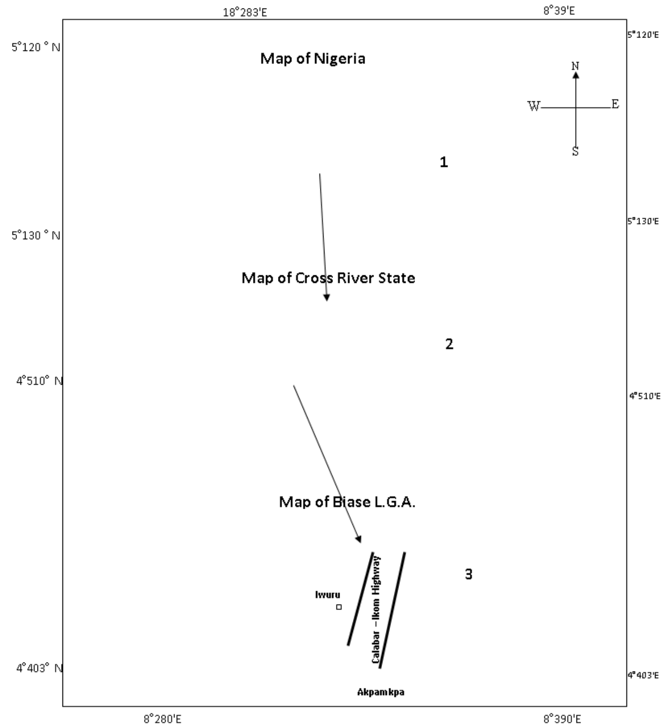

Figure 1: Maps showing experimental site

STATISTICAL ANALYSIS

Data was subjected to analysis of variance (ANOVA) and means compared using Fisher's Least Significant Difference (F-LSD) at 5% probability level.

III. RESULTS

EXPERIMENTS: In both experiments, uniform establishment of the suckers was achieved. No visual trace element deficiency symptoms were noted neither was there any apparent increase in length of the suckers due to treatment effect. The data from the oven dried weight of leaf and residual material were analyzed statistically.

EXPERIMENT 1

The results from the weight of residual tissue showed no significant effect (Table 1a and b), copper had a beneficially significant ($p<0.05$) effect on dry weight of leaf materials produced but the effect of molybdenum was not significant ($p<0.05$).

Treatment	Mean leaf dry weight (per sucker (g))
With Boron	4.01
Without Boron	4.12
With Manganese	4.15
Without Manganese	4.04
With Copper	4.21
Without Copper	3.90
With molybdenum	3.81
Without molybdenum	5.32
With zinc	4.02
Without zinc	4.08
LSD p<0.05	0.20
LSD p<0.01	0.32

Table 1a: Treatment effect on weight of leaf material

The interaction between molybdenum and manganese in terms of leaf dry weight was significant at $p<0.01$, while that between molybdenum and copper was not significantly different. Two-way tables showing these relationships are presented in Table 1b.

Two-way table showing interaction of molybdemum – boron and molybdenum copper on dry weight of leaves of smooth cayenne pineapple

Mno		Mn	Cuo	Cu	Means
MoO	4.35	4.15	3.87	4.56	4.28
Mo	3.36	4.04	3.78	3.65	3.76
Mean	4.05	4.10	3.86	4.15	-

Table 1b: Dry weight of leave per sucker

$P<0.05$ $p<0.01$

LSD between 2 means within the table = 0.32, 0.43

LSD between 2 means on the same border = 0.23, 0.33

EXPERIMENT 2

Following the harvesting of Suckers the weight of the dried leaves and residual tissues were recorded and data analyzed statistically. There were no significant effects due to the treatments on the residual tissues. However, the results obtained with the leaf material is presented in Table 2.

The main effects of molybdenum and copper were not significantly different at $p<0.05$ and $p<0.01$. The interaction between iron and molybdenum was significant ($p<0.05$) while those between boron and zinc, and between boron and iron were not significantly different ($p<0.05$). Data on leaf analysis showed that none of the micro-element treatments affected the leaf composition in so far as this applied to the leaf content of potassium, magnesium, nitrogen and manganese. The Calcium content in the leaves decreased with the application of boron while phosphorus was increased by applications of boron, molybdenum and iron. Trace element analyses were carried out on the leaves for iron and copper, and as might be expected, these elements were significantly ($p<0.05$) high in the leaf in all treatments.

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EXPERIMENT 3

Two way tables showing interaction of various micro-elements on leaves

	MoO g	Mo g	Mean g		Feo g	Fe g	Mean g		Zno g	Zn g	Mean g	Cao g	Ca g
Feo	5.21	4.71	5.12	Bo 5.025	5.12	5.15	5.01	Bo 4.56	-	5.25	5.18	5.21	4.88
Fe	5.10	5.01	5.10	B1 5.215	5.24	4.76	5.06	B1 5.18	-	5.04	5.10		
Mean	5.16	4.76	-	Mean -	5.13	5.45	5.01	Mean -	4.97	5.18			

Table 2: Dry weight of leaf per sucker

LSD between 2 means within table =

$p<0.05$ $p<0.01$

LSD between 2 means on the same border =

0.25 0.35

0.18 0.24

TREATMENTS

Leaf factor	**B**	**Zn**	**Mo**	**Fe**
Ca	**(-)	nil	nil	nil
P	**	*(-)	*	
Fe	nil	nil	nil	
Cu	nil	nil	nil	

Measurement of the length of the youngest fully developed leaf in July, September and November of the planting year showed a progressive trend. A summary of the data is presented below; which shows a very uniform growth of the suckers within the experiment and no treatment differences.

Treatment	July (cm)	Sept (cm)	Nov (cm)
With Manganese	25.4	31.0	38.6
Without Manganese	25.4	31.0	38.2
With Boron	25.3	31.1	38.4
Without Boron	25.2	31.0	38.3
With Copper	25.2	31.0	38.2
Without Copper	25.2	31.0	38.1
With iron	25.1	31.0	38.0
Without iron	25.1	31.0	38.1
With zinc	25.0	31.1	38.0
Without zinc	25.1	31.0	38.1
With molybdenum	25.1	31.0	38.0
Without molybdenum	25.0	31.0	38.0

Table 3: Mean leaf length per sucker

EXPERIMENT 3: Beginning in 8 months after planting, measurements of the height of the youngest fully developed leaf and number of leaves produced were made in October. The information from this experiment has been highly variable. The result from the data collected in October revealed that copper had stimulated leaf production in pineapple while iron and molybdenum had depressed it. From the results in Table 4, the application of copper resulted in a mean number of leaves per sucker of 18. 52 while 11.05 was the mean value obtained from plots without copper. On the other hand, the application of iron and molybdenum resulted in a significant ($p<0.05$) unit drop in number of leaves in October of 78.04% $\frac{(21.65-12.16)}{12.16}\times\frac{100}{1}$ and 75.11% $\frac{(16.18-9.24)}{9.24}\times\frac{100}{1}$ for iron and molybdenum respectively. These results are shown below.

Treatment	Mean number of leaves produce Per sucker in October 2015
With Copper	18.52
Without Copper	11.05
With Iron	12.16
Without Iron	21.65
With Molybdenum	9.24
Without molybdenum	16.18

Table 4

LSD (0.05) between means

p = 0.05 0.20

P = 0.01 0.32

P = 0.001 0.45

Statistical analysis of the data showed that by October, while the effect due to copper was no longer significant, iron which had previously reduced leaf production significantly ($p<0.05$) depressed growth. The depressive effect of iron on leaf production was therefore clearing later in the season.

IV. DISCUSSION

The trend of results in this study suggests that in the absence of any knowledge about critical levels or well defined deficiency symptoms for trace elements in the smooth cayenne pineapple, it is not possible to state whether or not a soil is deficient in a particular trace element. In similar experiments, Privet (1959), Forde *et al.* (1965), Jenkins & Ali (2000) reported that the influence of a particular trace element on leaf production may be considerable, depending on the location. Some work had been undertaken to evaluate the trace element status of some Nigerian and temperate soils (NIFOR 1966, Omoti and Ataga, 1983; Hassan and Leitch 2000) and results showed that the content of trace elements in the soils used in these experiments was within the range usually found in sandy soils elsewhere, Wahahab and Bhatti (1958) Jenkins and Ali (1999). Although the original levels of the trace elements present in the soil used for the box experiments was increased by 0.3%, treatment effects were however noted. This showed that smooth cayenne pineapple suckers respond to small changes in the concentration of trace elements applied either to the soil or to the foliage. The results presented here showed that when copper was applied to the soil, it had a beneficial effect, but when applied to the leaf, there was a decrease in dry matter production. The concentration at which copper can be applied in spray solution to the leaves of smooth cayenne is critical, for the application of 0.300 of copper as copper Sulphate in 200ml of solution produced leaf scorch early in the season. The most consistent observation has been that molybdenum has a definite adverse effect on the growth of smooth cayenne pineapple suckers. The interaction between molybdenum, manganese and iron were positive in the work reported here. Again, the interaction between manganese and boron had a positive effect in stimulating leaf production. On the other hand, boron when interacting with zinc, iron, and copper has produced depressive effect on growth. On number

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of leaves produced per sucker in the month of peak production of leaves in smooth caryane pineapple, (Ubi *et al.*, 2006) the application of copper increased leaves production per sucker while iron and molybdenum depressed it. These results were earlier reported by Fermeda (1994) and Leitch (2000).

V. CONCLUSION

The trend of the results in this experiment suggests that the role of trace elements in the nutrition of smooth cayenne pineapple showed statistically significant responses to the application of micro-nutrients with high variability. The trend observed did not produce a consistent response pattern to trace elements when applied to the soil or as foliar spray. The most interesting observation has been that molybdenum tended to depress dry-matter production and number of leaves per sucker in October. It is suggested that the interactions involving manganese may be beneficial to smooth cayene Pineapple while those with boron may be harmful. It seemed that the applications of zinc and molybdenum were beneficial but the main effects of these micro-nutrients on yield never attained significance in the southeastern, Nigeria.

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