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Impact of Missing Elements on Nutrient Use Efficiency of Sweet Corn (*Zea mays* L. Saccharum) on Five Tropical Soils

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Abstract: The influence of single element (N, P, K, Ca and Mg) inorganic fertilizers on nutrient use efficiency of sweet corn (*Zea mays* L. Saccharum) was investigated on some tropical alfisols, ultisols and oxisols of Nigeria. Experimentation involved soils from 5 locations (Enugu, Rockefellar, Alabata, Barthroad and NIFOR) and 7 fertilizer treatments (Control, Complete/adequate nutrient supply, minus (-) N, -P, -K, -Ca and -Mg), replicated three times in a Completely Randomized Design (CRD). Expectedly, the soils supported crop performance to various extents associated with their fertility levels. Complete nutrient supply and-Ca treatment resulted in the highest biomass production (13.9 and 13.8 g pot^{-1}, respectively) while the control had the least (4.9 g pot^{-1}) followed by-N (5.3 g pot^{-1}) and-P (10.7 g pot^{-1}), indicative of their importance in the nutrition of the crop. The effects on crop nutrient uptake followed the same trend. Nitrogen was the least while K was the most efficiently used nutrient by the crop. Across fertiliser treatments, N use efficiency ranged between 2.4 g g^{-1} (NIFOR location soil) and 7.0 g g^{-1} (Bart road location soil). Across soil types, the range was between 2.4 g g^{-1}(-N treatment) to 6.8 g g^{-1} (with complete nutrient application). Nutrient use efficiencies were highest when the elements considered are omitted in the fertiliser application schedule and/or when its initial content in the soil was low. A categorisation of efficiencies of nutrient use values (into low, medium and high levels) for the soil types was provided on the basis of the experimental data.

Key words: Alfisols, nutrient use efficiency, oxisol, single element fertilizers, soil locations, sweet-corn, ultisols

INTRODUCTION

Sustainable farming is often limited on tropical soils by inherently low fertility. The situation is further worsened by continuous cropping, coupled with poor soil management practices (Agboola and Unamma, 1991). In most developing countries, including Nigeria, food production has had serious setbacks due to general shortage and unaffordable cost of chemical fertilizers. Most farmers do not adopt fertilizer recommendations. Instead, they indulge in its abuse (Chude, 1999). The unsatisfactory use efficiencies of essential nutrient elements by crops have also resulted in increased environmental problems. The ability to improve the effectiveness of applied nutrients (and hence reduce pollution) depends on matching supply of the nutrients with plant demand and maintaining nutrient availability (Shaviv *et al*., 1985). Yet, the response of crops to fertilizers is often site specific (Balasubramanian *et al*., 1978; Mustapha *et al*., 1997), varying as soils' native fertility statuses vary.

Sweet corn (*Zea mays* L. Saccharum) has become a popular and an economically important vegetable in the world. Reversing soil fertility depletion for sustainable production of the crop in sub-Saharan Africa demands improved nutrient use efficiency (NUE) in the face of fertilizer procurement difficulties (price, accessibility and availability) in the region (Lafitte, 1998). In the determination of NUE, native soil nutrient is as important as the applied one. Akinrinde *et al*. (2000) observed marked differences between the use efficiency of P by cowpea plants fertilized with organic and inorganic fertilizers. Akintoye *et al*. (1999) also noted that NUE of single, double and synthetic maize lines grown in three ecological zones of West Africa decreased significantly with increasing N level.

This study investigated the efficiencies of use of inorganic N, P, K, Ca and Mg fertilizers by sweet corn (variety Shrunken-2) in five soils located within Nigeria. This was with a view to ensure optimal utilization of fertilizers, thereby saving crop production costs and reducing environmental pollution.

MATERIALS AND METHODS

The reserach involved a soil culture study conducted (between April and May 2003) in the greenhouse of the Department of Agronomy, University of Ibadan, Nigeria.

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Table 1: Locations, ecological zones, parent materials, classification and (B) physico-chemical properties of the soils used

(A)

Location	Ecological zone	Parent material	Soil taxonomy USDA	Soil taxonomy FAO
Enugu	Rainforest	Imo shale	Ultisol	Luvisol
Rockefellar	Rainforest	Basement complex	Alfisol	Luvisol
Alabata	Rainforest	Basement complex	Alfisol	Luvisol
Barthroad	Rainforest	Basement complex	Alfisol	Luvisol
NIFOR/Agbaro	Coastal Rainforest	Basement complex	Oxisol	Nitosol

(B)

Soil properties	Experimental soil location: Enugu	Rockefellar	Alabata	Barthroad	NIFOR/Agbaro
Org. M (g kg^{-1})	19.7	20.9	21.3	11.4	48.5
N (g kg^{-1})	0.70	1.1	1.1	0.7	2.2
Bray1 P (mg kg^{-1})	37.9	43.8	5.6	4.1	66.9
K (cmol kg^{-1})	0.31	0.31	0.15	0.10	0.09
Ca (cmol kg^{-1})	1.06	1.86	4.0	0.24	2.14
Mg (cmol kg^{-1})	0.36	0.45	0.75	0.30	0.33
Na (cmol kg^{-1})	2.58	1.91	0.02	0.06	2.05
Mn (cmol kg^{-1})	0.03	0.12	0.03	0.08	0.03
Al+H (cmol kg^{-1})	0.11	0.00	0.00	0.25	0.06
Effective CEC	4.5	4.7	5.0	1.1	5.3
pH (H_2O)	5.8	6.0	6.1	5.8	4.9
pH (Kcl)	5.0	5.5	5.6	4.2	3.9
pH (CaCl2)	5.5	5.8	5.9	4.6	4.3
Sand (g kg^{-1})	828	948	894	800	918
Clay (g kg^{-1})	92	32	56	85	420
Silt (g kg^{-1})	80	20	50	115	40

A set of 21 plastic pots (17 cm diameter, 29 cm height) were filled with 4.0 kg surface soil samples collected from each of five locations-Enugu, Rockefellar, Alabata, Barthroad and NIFOR (Benin-city), giving a total of 105 pots for all the soils. The pots were perforated at the bottom to facilitate drainage. They were arranged on a raised platform but in a Completely Randomised Design (CRD) in the greenhouse. Ten sweet corn (Var. shrunken-2) seeds were sown in each pot and later thinned to 4 plants one Week after Sowing (WAS).

The experimental treatment involved seven N, P, K, Ca and Mg fertilizer treatment combinations (control, Complete/adequate nutrient supply, minus N, -P, -K, -Ca and -Mg) repeated three times in each of the five location soils, giving a total of 7×5×3 (= 105) experimental units. Application rates were 120 kg N (Urea, 45%N), 45 kg P (single super phosphate, SSP), 60 kg K_2O (muriate of potash, KCl, 60% K_2O), 20 kg Ca (Calcium carbonate, $CaCO_3$, 40% Ca) and 20 kg Mg (Magnesium sulphate, $MgSO_4$, 20% Mg). The fertilizer materials were mixed with the soils according to treatment before sowing and watering was maintained at 60% Field Capacity (FC). Heights of plants were measured at weekly intervals for six weeks. Fresh and dry forage (roots and shoot) yields, macronutrient (N, P, K, Ca and Mg) as well as micronutrient (Mn, Zn and Fe) contents and uptake values were also determined after 6 weeks of growth.

The pre-cropping soil samples (taken 0-15 cm depth) were analysed for the parameters given in Table 1 by the standard procedures described by Page *et al*. (1982). Nutrient Use Ffficiency (NUE) was estimated as yield produced (Y_g) per unit of Nutrient supplied N_f) and expressed as Y_g/N_f (Moll *et al*., 1982).

All statistical analyses were performed using the Statistical Analysis System (SAS, 1985).

RESULTS AND DISCUSSION

Experimental soils: Details of the locations, ecological zones, parent materials, physico-chemical properties and classification of the surface soils used are presented in Table 1. The quality and magnitude of the various parameters varied widely among the soils although they are all located in the rainforest ecological zone. Soils from three of the locations (Rockefellar, Alabata and Barthroad) are Alfisols derived from basement complex rocks while the Enugu and NIFOR location soils are Ultisols and Oxisols formed on Imo shale and Coastal plain sands, respectively.

Soils from Enugu and Barthroad were the poorest in fertility. They had very low Organic Matter (OM) contents, total N and available-P. Only the NIFOR (Agbaro) location soil had 48.5 g OM kg^{-1} soil that is higher than the 30 g kg^{-1} which Agboola (1973) had suggested as the level at which response to N fertilization is not expected. The soil also had 2.20 g N kg^{-1}, which is higher than 1.5 g kg^{-1} believed to be optimal for maize production (Singh and Uriyo, 1980). On the other hand,

Table 2: Influence of fertilizer treatment and soil type on height and biomass yield of maize

	Plant height (cm)						Biomass yield (g pot^{-1})			
	Weeks after planting								Root/shoot	
Treatment	1	2	3	4	5	6	Root	Shoot	ratio	Relative yield (%)
Fertilizer										
Control	16.1	25.6	29.7	32.1	34.5	36.2	2.4	2.5	0.96	35.3
Complete	17.0	34.8	42.5	47.9	51.8	54.0	6.9	7.0	0.99	100.0
Minus N	16.9	26.3	31.2	34.6	37.6	39.7	2.8	2.5	1.12	38.1
Minus P	17.0	32.0	38.8	44.5	49.3	52.6	5.1	5.6	0.91	76.9
Minus K	17.8	35.2	42.6	49.2	53.7	55.0	6.5	6.7	0.97	94.9
Minus Ca	17.7	36.2	44.9	51.2	56.8	60.1	6.5	7.3	0.89	99.3
Minus Mg	16.9	35.2	43.5	9.1	53.6	56.5	5.6	6.7	0.84	88.5
LSD (0.05)	0.5	4.0	5.5	2.7	7.9	8.3	1.7	1.9	0.89	26.7
Soil										
Location Type										
Enugu (Ultisol)	22.2	33.2	38.2	42.9	47.1	50.0	3.7	5.4	0.17	77.8
Rockefellar (Alfisol)	15.4	31.0	37.8	43.2	47.7	50.5	5.8	5.5	1.05	96.6
Alabata (Alfisol)	15.9	29.4	35.5	40.9	45.1	48.0	6.5	4.5	1.44	94.0
Barthroad (Alfisol)	16.7	31.9	38.7	43.2	47.4	50.0	4.9	5.3	0.92	87.2
NIFOR (Oxisol)	15.0	15.4	44.7	50.3	53.5	55.1	5.1	6.6	0.77	100.0
LSD (0.05)	2.6	2.0	3.1	4.4	3.9	3.3	1.3	0.9	1.44	9.8

only Alabata and Barthroad location soils had available P values (5.6 and 4.1 mg kg^{-1} soil, respectively) that are lower than the critical level of 10 mg kg^{-1} (Adeoye and Agboola, 1985). Considering the 0.16-0.20 cmol kg^{-1} critical range for K (Ayodele, 1984), Enugu and Rockefellar location soils were sufficient in the element while Alabata, Barthroad and NIFOR location soils were marginal. Based on 2.0 cmol kg^{-1} critical Ca level (Akinrinde and Obigbesan, 2000), only Alabata location soil should respond to Ca fertilizer application. As regards Mg, Barthroad, Agbaro and Enugu had less than 0.40 cmol Mg kg^{-1} soil given as the critical level (Lombin, 1974). It could be expected from these analyses that plants growing on these soils would perform and respond to fertilizer application differently. The magnitude of crop response to fertilizer input is abundantly dependent on soil native (inherent) fertility level (Singh and Uriyo, 1980; Akinrinde and Obigbesan, 2000). As such, for optimum crop utilization of soil and fertilizer nutrients on the soils, recommendation of fertilizer use should be specific to each soil type and location.

Height growth and yield of sweet corn: A summary of height growth and yield of sweet corn both across the various soil types and fertiliser treatments is given in Table 2. At the end of first week, Enugu location soil supported crop growth to an average height of 22.2 cm. This was significantly ($p<0.05$) higher than the means of 19.9 and 16.7 cm obtained in respect of Alabata and Barthroad location soils. During this initial growth period, plants grown in Rockefellar or NIFOR location soils had least heights (15.4 and 15.0 cm, respectively). Between the 2nd and the 6th weeks, however, the NIFOR location soil consistently produced the tallest plants (35.4-55.1 cm) compared with those produced on Barthroad (31.9-50.0 cm), Rockefellar (31.0-50.5 cm) and Enugu (33.3-50.0 cm) location soils. Alabata location soil gave the shortest plants (29.4-48.0 cm) at the successive growth periods. The summarised fresh and dry yield data in respect of roots; shoots and total biomass (Table 2) also confirm this order of performance among the soils. Thus, at the end of 6 weeks, NIFOR location soil (an Oxisol) gave the highest yield of 41.0 g pot^{-1} of fresh roots (5.1 g dry matter, DM) and 25.9 g pot^{-1} of fresh shoot (6.6 g DM) compared with the least (4.5 g dry shoot pot^{-1}) on Alabata location alfisol. It is worthy to note that variations in growth and yield of the crop are closely associated with differences in fertility status of soil types and locations as given in Table 1.

Table 2 also shows that sweet corn plants significantly responded to the missing fertiliser nutrient application schedule (across the soils), particularly after 2 weeks of growth when native fertility started to be insufficient for crop growth. The untreated (control) plants were consistently the shortest (16.1-36.2 cm), indicating that the growth medium (soil) is deficient in one or more nutrient elements and the plants are in dire need of such nutrients for their growth. Minus Ca treated plants were the most vigorous in growth (17.7-60.1 cm tall), implying the irrelevance of including the element in crop fertilization schedule on majority of the soils. Continuous application of nutrient elements that occur in sufficient amounts in soil might lead to nutrient imbalance after some time (Adeoye and Agboola, 1985)

Table 3: Influence of fertilizer treatment and soil type on content and uptake of nutrients by maize

Treatment	Nutrient content in maize tissue								Nutrient uptake by maize							
	N	P	K	Ca	Mg	Mn	Fe	Zn	N	P	K	Ca	Mg	Mn	Fe	Zn
	%					mg kg^{-1}			mg pot^{-1}							
Fertilizer																
Control	0.64	0.24	2.07	1.02	0.48	329.0	361.0	45.7	15.00	3.50	45.90	23.90	11.70	0.86	0.86	0.12
Complete	0.61	0.20	1.61	0.80	0.40	262.0	317.0	39.4	42.90	13.90	111.70	54.80	27.40	1.88	2.23	0.28
Minus N	0.65	0.27	2.74	0.93	0.41	255.0	328.5	46.4	16.10	6.70	66.80	22.70	10.20	0.67	0.78	0.12
Minus P	0.70	0.10	1.99	0.87	0.42	246.0	322.3	45.3	36.50	6.30	104.40	47.40	23.00	1.48	1.82	0.24
Minus K	0.65	0.22	1.16	0.84	0.48	284.0	313.3	42.5	43.50	15.10	74.80	55.60	31.60	1.99	2.02	0.29
Minus Ca	0.63	0.22	1.74	0.84	0.43	229.0	365.0	40.5	44.70	16.10	119.70	61.80	31.00	1.77	2.58	0.29
Minus Mg	0.61	0.22	1.74	0.78	0.38	220.0	349.0	53.1	40.00	14.60	112.60	51.40	25.10	1.51	2.30	0.35
LSD (0.05)	0.03	0.05	0.44	0.08	0.04	34.0	19.8	4.2	11.98	4.78	26.10	14.52	8.03	0.47	0.66	0.08
Soil																
Location/Type																
Enugu/ Ultisol	0.65	0.16	2.17	0.54	0.36	173.6	382.9	52.53	4.09	8.66	104.30	29.00	19.4	40.9	51.93	0.28
Rockefellar/ Alfisol	0.70	0.25	2.31	0.72	0.37	202.1	365.4	33.6	36.71	12.89	114.20	35.19	19.46	1.01	1.97	0.17
Alabata/ Alfisol	0.61	0.23	1.76	1.08	0.46	110.7	340.7	36.5	27.68	7.10	74.00	47.21	20.21	0.47	1.60	0.17
Barthroad/ Alfisol	0.66	0.18	1.79	0.99	0.52	280.7	300.0	51.6	33.05	9.64	84.00	51.08	27.45	1.51	1.62	0.27
NIFOR/ Oxisol	0.50	0.25	1.29	1.00	0.44	534.3	286.3	49.33	8.93	16.18	77.30	84.40	27.77	3.32	1.87	0.31
LSD (0.05)	0.09	0.05	0.05	0.03	0.08	204.7	51.4	11.1	5.28	4.51	21.86	26.70	1.24	1.23	0.19	0.07

and antagonises the absorption of other essential nutrients by the crop (Mengel and Kirkby, 1987). Minus N treated plants performed less (39.7 cm in height) than minus P treated ones (52.6 cm), suggesting that N is the "key" nutrient element for sweet corn production in the experimental soils. This is in consonance with the general reports on tropical soils (Sanchez, 1976; Sanchez and Uehara, 1980; Singh and Uriyo, 1980). Minus Mg and K^- treated plants were as tall or even taller (56.5 cm and 55.0 cm, respectively) than those that had complete nutrient fertilisation (54.0 cm). However, in most cases, complete nutrient supply and -Ca treatment gave the highest total biomass (13.9 and 13.8 g pot^{-1}, respectively) while the control again produced the least (4.9 g g^{-1}) followed by -N (5.3 g g^{-1}) and -P (10.7 g g^{-1}). These results further confirm that the differences in crop performance are in consonance with the initial variation in the fertility levels of the experimental soils.

Nutrient content and uptake by sweet-corn: Nutrient concentration in sweet-corn plant tissue also varied exceedingly under the influence of the various soils and the fertiliser treatments (Table 3). The alfisol from Rockefellar location enhanced the greatest accumulation of P, K, Fe, N and hence crude protein while the alfisol from Alabata enhanced the accumulation of P, Ca and Mn and the oxisol from NIFOR permitted plants' accumulation of P and Mn. Removal of N from the fertilisation schedule caused plants to accumulate the greatest amounts of P, (0.27%) and K (2.74%) while the non application of P enabled plants to accumulate the greatest amounts of N (0.70%). The control plants had the highest concentrations of Ca (1.02%), Mg (0.48%) and Mn (329 mg kg^{-1}). It is worthy to note that complete (balanced) nutrient supply did not permit exceptional accumulation of any of the nutrients. According to Janssen (1998) balanced nutrition is the best guarantee for the simultaneous optimum use of all nutrients.

The influence of soil type and fertiliser treatment on nutrient uptake by sweet corn plants were of quite similar trends to those obtained in respect of the forage yield and almost like the exact opposite of the response of the crop in terms of the nutrient content. Thus, the NIFOR location soil produced plants with highest uptake of N, P, Ca, Mg, Mn and Zn while Alabata location soil produced the least. Table 3 also shows clearly that -Ca fertiliser treatment favoured the uptake of N, P, K, Ca, Mg and Fe while the control led to the least uptake values.

Nutrient use efficiency by sweet corn: The effects of soil type and fertiliser treatments on N-, P-, K-, Ca-and Mg-use efficiency by sweet-corn are indicated in Tables 4 and 5. It is evident from these data that N is the least efficiently used nutrient by the crop. The ranges are 2.43 (in NIFOR soil) to 7.0 g g^{-1} (in Barthroad location soil) across fertiliser treatments and 2.4 g g^{-1} (with -N) to 6.8 g g^{-1} (with complete nutrient application) across soil types. These values are low compared with a mean of about

Table 4: Influence of fertilizer treatment and soil type on nutrient use efficiency by maize

	Nutrient use efficiency (g g^{-1})				
Treatment	N	P	K	Ca	Mg
Control	26.0	239.2	174.4	16.0	52.0
Complete	68.0	100.2	230.0	37.4	117.6
Minus N	24.0	38.4	90.0	15.4	46.0
Minus P	48.0	481.4	178.0	25.8	90.4
Minus K	64.0	93.4	458.2	39.0	114.8
Minus Ca	64.0	100.2	228.0	42.0	123.6
Minus Mg	56.0	88.2	206.0	32.2	127.6
LSD (0.05)	16.9	141.8	105.3	10.1	31.7
Soil					
Location/type					
Enugu (Ultisol)	61.4	69.3	411.9	208.6	95.86
Rockefellar (Alfisol)	48.6	75.6	433.71	148.6	89.71
Alabata (Alfisol)	45.7	289.7	718.41	65.7	54.29
Barthroad (Alfisol)	70.0	319.9	1419.57	928.6	116.71
NIFOR (Oxisol)	24.3	60.6	478.77	132.9	123.43
LSD (0.05)	21.6	161.4	526.94	42.9	33.8

30.0 g g^{-1} obtained for single, double and synthetic lines by Akintoye *et al.* (1999). The disparity is, however, most probably due to differences in soil nutrient status and the restriction of root growth in plastic pots used in this work unlike the situation on the field.

An intensive study of the data summarised in Tables 4 and 5, however, made the categorisation of the various nutrients' use efficiency values (into low, medium and high levels) possible. The corresponding soil location and fertiliser treatment were also considered and indicated in Table 6. It is evident from these evaluations that values of less than 2.6, 2.6-6.8 and above 6.8 g g^{-1} are indicative of the capacity (low, medium and high) to efficiently use N, respectively. The respective P, K, Ca and Mg levels are also given in Table 6. The use efficiency of each of the nutrients was highest when that nutrient was omitted in the fertiliser application schedule and/or when its initial content in the soil was low.

Table 6 also highlights the facts that the use efficiency of a particular nutrient can best be achieved by improving the supply of the other nutrients. This is not unexpected since nutrient use efficiency is the yield per nutrient applied. The more the fertiliser nutrient quantity applied, the less the nutrient use efficiency value (Akinrinde *et al.*, 2000). When other nutrient(s) is/are applied the increase in use efficiency of the original nutrient by the crop is at the expense of the new one (s). This is in line with the report by Janssen (1998) that efficient use of nutrients is an art of balancing, which enhances nutrient synergism (Mengel and Kirkby, 1987).

The soil as a medium for plant growth, also determines the capacity of crops to efficiently use nutrients in as much as they contain native nutrients. As in the case of fertilizer nutrient additions, use-efficiency of native nutrient elements by the crop decreases with increase in the available quantities in soil. Environmental contamination (particularly via seepage of excess fertilizer nutrients into underground water) is more certain with low nutrient use efficiency level than with medium and high levels.

Nitrogen (followed by P) is the "key" nutrient element for sweet corn production in the soils. Yet, N was the least efficiently used nutrient element, suggesting that soil N removal (or losses) other than by crop uptake is more than for any of the other elements. Sound soil management practices (including complete nutrient application) that

Table 5: Influence of the interaction between fertilizer treatment and soil type on nutrient use efficiency by maize

	Nutrient use efficiency (g g^{-1})				
	Soil location/soil type				
	Enugu (Ultisol)	Rockefellar (Alfisol)	Alabata (Alfisol)	Barthroad (Alfisol)	NIFOR (Oxisol)
Nitrogen					
Control	4	2	2	4	1
Complete	9	7	6	9	3
Minus N	3	2	2	4	1
Minus P	5	5	5	6	3
Minus K	8	7	4	10	3
Minus Ca	7	6	7	9	3
Minus Mg	7	5	6	7	3
LSD (0.05)	2.0	2.0	1.8	2.3	0.9
Phosphorus					
Control	77	37	429	610	43
Complete	78	96	138	133	56
Minus N	28	29	51	59	25
Minus P	102	137	1027	1037	104
Minus K	70	84	99	150	64
Minus Ca	62	79	155	136	69
Minus Mg	68	67	129	114	63
LSD (0.05)	20.6	33.8	321.1	339.1	22.6
Potassium					
Control	935	516	1600	2500	3170
Complete	210	280	230	220	210
Minus N	80	90	90	100	90
Minus P	130	200	190	140	230
Minus K	1870	2420	3330	7350	7940
Minus Ca	170	230	260	220	260
Minus Mg	190	200	220	190	230
LSD (0.05)	616.7	767.2	1123.6	2505.1	2730.6
Calcium					
Control	14	4	3	52	7
Complete	29	22	9	113	14
Minus N	11	7	3	50	6
Minus P	17	16	7	73	16
Minus K	26	20	6	127	16
Minus Ca	24	19	10	139	18
Minus Mg	25	16	8	96	16
LSD (0.05)	6.3	6.3	2.6	32.9	4.4
Magnesium					
Control	66	29	26	68	71
Complete	120	132	69	141	126
Minus N	4	40	29	62	55
Minus P	72	93	57	91	139
Minus K	108	116	49	158	143
Minus Ca	133	109	78	144	154
Minus Mg	128	109	72	153	176
LSD (0.05)	32.2	36.6	19.1	18.5	40.9

Table 6: Calibration of sweet-corn nutrient (N, P, K, Ca and Mg) use efficiency values

Plant nutrient element	Use efficiency data rating	Use efficiency values (g g^{-1})	Facilitating treatment: Soil location	Fertiliser treatment
N	Low	<2.6	NIFOR (oxisol)	Control,-N
	Medium	2.6-6.8	Enugu, Rokefellar and Alabata	-P,-K,-Ca and -Mg
	High	>6.8	Barthroad,(Alisol)	Complete
P	Low	<60.57	NIFOR	-N
	Medium	61.00-319.00	Enugu, Rokefellar and Alabata	-P,-K,-Ca and -Mg
	High	>320.00	Barthroad	-P
K	Low	<229	---	-N,-P,-Ca,-Mg
	Medium	230-4000	---	Complete
	High	>4000	All the soil types	Control,-K
Ca	Low	<16.00	NIFOR, Alabata & Rockefellar	-N
	Medium	17-39	Enugu	Control, Complete, -P, K and -Mg
	High	>40	Barthroad	-Ca
Mg	Low	<59	Alabata	Control,-N
	Medium	60-90	Rockefallar	-P
	High	>90	Enugu,Barthroad, NIFOR	Complete, -K, -Ca,-Mg

guarantee gradual release of fertilizer nutrients should be adopted. To ensure that the crop efficiently uses a nutrient, fertilizer application should not be based on "blanket recommendation".

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