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Optimum NPK Fertilizers Rates Based on Soil Data for Grain Maize (*Zea mays* L) Production in Some Soils of Southeastern Nigeria

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Abstract: Grain yield of hybrid maize (Oba-2 super) and a popular open-pollinated (O.P) local variety were studied over 3 years (1996-1998) in three selectd locations-Nsukka, Awgu and Abakaliki, all of which belong to derived savanna agro ecological zone of Nigeria. Under a factorial arrangement fitted into a RCB and with four replicates, the cultivars were treated to 5 levels of fertilizer NPK derived from soil analytical data. The levels were F_0, F_1, F_2, F_3 and F_4 caluclated and applied according to crop need in each location. An optimum rate (F_3) of 493, 566 and 540 kg ha^{-1} mixed NPK fertilizers was established at Nsukka, Awgu and Abakaliki, respectively, for maize cultivation. Each of the rates was location specific. They are, however, 1.5 times the agronomically recommended rate of 300 kg ha^{-1} in the general area. The results showed that average grain yields of 311.5, 3371.5 and 338.2 kg ha^{-1} were, respectively, obtained at Nsukka during 1996, 1997 and 1998 cropping seasons. At Awgu, the average yields obtained at the same periods included 4033.1, 4576.4, 4123.1 kg ha^{-1}, while Abakaliki had 4309.8, 3766.5, 3834.8 kg ha^{-1}. Grain yield response to the mixed NPK fertilizer was higher at F_3 rate while higher grain yields were obtained by the cultivation of hybrid in preference to O.P. From the study, it was concluded that for rainfed maize cultivation such as is the case in the study, adequate dosage of fertilizers based on soil and analytical data is attainable and thus, one doze application of F_3 rate is recommended for optimum performance of maize.

Key words: Soil data, NPK fertilizers, maize cultivars and yield performance

INTRODUCTION

Sufficient and balanced amounts of soil nutrients particularly NPK elements are important in maize production. The crop takes up the elements in large quantities, the yield magnitude being closely associated with N fertilization (Akintoye *et al.*, 1997). The introduction of improved maize varieties, the spread of maize cultivation to the savanna ecological zones and the gradual shift of maize cultivation from subsistence to commercial level have made the use of chemical fertilizers to be on the increase for more than 2 decades (Akintunde *et al.*, 2000).

Agronomically, the optimum fertilizer levels of 300-400 kg ha^{-1} NPK were recommended for maize production in southeastern Nigeria (Enwczor *et al.*, 1989; Uguru and Obi, 1991). This shows that most recommended rates of NPK fertilizers for maize production in the derived savanna zone of Nigeria have been based on maize yield from a few experimental locations. In other words, these often used NPK ratios are based on agronomic recommendation. These rates and ratios may not always be suitable for optimum yield of maize because reference to soil information is not made, even though such information are crop and site specific (Ezeaku, 1999). Earlier, Pal (1991) has similarly observed that the optimum rate of NPK fertilizer depends among other factors: upon the crop, soil type and rainfall. Unfavorable soil factors and poor climatic conditions have been observed to lead to sub-optimal or decline in yields of maize (Ezeaku, 2001). Furthermore, the soil factors critical in terms of yield are low organic matter contents and CEC. Fertilizer application based on soil requirement envisages reduction in cost of production in terms of reducing luxury input for plant use, soil acidification and plant eutrification.

In Nigeria, the average maize grain yield (1.5 t ha^{-1}) is quite low compared with 7.4 and 7.0 t ha^{-1} in the USA and Canada, respectively (De Jerphanion, 1988) where 240 and 300 kg ha^{-1} fertilizer are applied. This might be due to faulty or inadequate fertilizer recommendations based on proper agronomic assessment of the crop. Coupled with this problem, the sky-rocketing price of fertilizers has

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made it difficult for farmers to profitably cultivate the improved maize varieties introduced by researchers due to their high nutrient demands. Cost of production could be reduced by applying fertilizers according to crops needs, correcting the deficiency levels of the nutrients in the soil and prevent luxury input and soil acidification and making fertilizer recommendations that are based on soil analytical information. Deriving fertilizer recommendations purely from soil analytical data in the derived savanna zone of Nigeria has not been attempted and scientifically experimented on. This suggests that the use of fertilizer determined from soil data has not received the desired research attention in southeast Nigeria. This investigation, therefore, sought to determine rates of NPK fertilizers from soil data; and to evaluate grain yield response of two cultivars of maize to these different NPK rates. It is hoped that the optimum fertilizer NPK requirements for maize production in the selected sites will thus be established.

MATERIALS AND METHODS

Field experiments were established during 1996, 1997 and 1998 cropping seasons in the soils of three locations (Nsukka, Awgu and Abakaliki) in southeastern Nigeria. Nsukka (06°25'N, 07°24'E; 419 masl) is the University of Nigeria Teaching and Research Farm. The site is a plain surrounded by conical hills. The vegetation is derived savanna with small patches of woody shrubs, while the parent material is colluvium on false bedded sandstone (Ofomata, 1975).

The Awgu location (06°18'N, 7°34'E; 137 masl) has gentle, undulating topography. The experiment was sited in a farmer's field. The parent material is Asata Nkporo shale residiuum (Ofomtata, 1975). The research at Abakaliki location (6°25'N, 8°05' E, 400 masl) was conducted in the Teaching and Research Farm of Ebonyi State University, Abakaliki. The site is surrounded by gently sloping hills with a savanna dominated vegetation type. The parent material is weathered shales (shale residiuum and schists of the Asu River group (Ofomata, 1975).

The general climate is tropical, having distinct rainy and dry season. The annual rainfalls at Nsukka, Awgu and Abakaliki are 1665, 1800 and 2000 mm, respectively while the mean annual temperature for the three locations is 32°C. The mean sunshine hours are 5.0, 4.9 and 4.8, respectively (Ezeaku, 2000).

Field layout: Split-split plot design was used with 3 locations (Nsukka, Agwu and Abakaliki) as the main plots, 2 maize cultivars (Oba-2 super and local maize) as the sub-plots; and 5 fertilizer levels: F_0, F_1, F_2, F_3 and F_4 as the sub-sub-plot treatments. The trials were replicated four times in a RCB for 3 cropping seasons in each location. The experimental units consisted of ten plots, each 6 meters long and 5 meters wide (30m^2) and there were 8 rows plot^{-1}. Two maize seeds per hole were sown at 2-4 cm depths and thinned to one plant per stand. In most cases throughout the three years of cultivation, maize grains were sown in the second week of April at a spacing of 0.25 m by 0.75 m (53,333 plants per hectare).

Table 1: Applied fertilizer rates/ratios in the selected sites

Fertilizer frequent levels	Initial (Pre-plant) Chemical characteristic N (%)	P (ppm)	K meq 100 g^{-1} soil	kg ha^{-1} (ratios) N	P_2O5	K_2O	Mean (x) N, P_2O_5, K_2O kg ha^{-1}	Equivalent N, P_2O_5, K_2O in Urea, SSP, MOP (kg ha^{-1}) Urea	SSP	MOP	Mixed NPK fertilizers applied
Nsukka											
F_0	0.042	43.82	0.004	8.4	2.0	37.5	16.0	0.0	0	0	0
F_1				23.4	17.0	52.5	31.0	52.0	85.0	89.3	226.3
F_2				38.4	32.0	67.5	46.0	85.0	160.0	115.0	360.0
F_3				53.3	47.0	82.5	61.0	118.0	235.0	140.3	493.3
F_4				68.4	62.0	97.5	76.0	151.0	310.0	166.0	627.0
Awgu											
F_0	0.07	31.25	0.008	14	14.2	75.1	30.2	0	0	0	0
F_1				29	16.4	90.1	45.2	64	82.1	153.2	299.3
F_2				44	31.4	105.1	50.2	97	157.1	179	433.1
F_3				59	46.3	120.1	75.2	130	232.1	204.2	566.3
F_4				74	61.4	135.1	90.1	163	307.1	230	700.1
Abakaliki											
F_0	0.084	30.24	0.006	16.8	1.4	56.3	24.8	0	0	0	0
F_1				31.8	16.4	71.3	39.8	70	82	121.2	273.2
F_2				46.8	31.4	86.3	54.8	103	157	147	40.7
F_3				61.8	46.4	101.3	69.8	136	232	172.2	540.2
F_4				76.8	61.4	116.3	84.8	169	307	198	674

NB: N=nitrogen; P= Phosphorus; K= Potassium; F_0 = no fertilizer; F_1-F_4= fertilizer treatment levels; SSP = single super phosphate; M.O.P = muriate of potash; P_2O_5 = Phosphorus penthoxied; K_2O= Potassium oxide

Fertilizer treatment (rates and ratios) application: After the field layout, bulked soil samples taken 2 weeks before cultivation at 0-15 and 15-30 cm soil depths were air dried, passed through 2 mm mesh and the physico-chemical properties determined using standard laboratory procedures. Analyzed %N, ppm P and meq 100 g^{-1} soil K values were averaged. At Nsukka, the average initial soil values for NPK were 0.042%, 43.8 ppm and 0.004 meq 100 g^{-1} soils, respectively. At Awgu, the average initial NPK soil data were 0.70%, 31.25 ppm and 0.008 meq 100 g^{-1} soil, while the corresponding average initial values of NPK at Abakaliki were 0.084%, 30.25 ppm and 0.006 meq 100 g^{-1} soil (Table 1).

The levels of NPK fertilizers used were calculated based on these initial values in the soil (F_0-level). The values of the initial levels (F_0) were converted from %N, ppm P and meq 100 g^{-1} soil K to Kg N, P and K; and subsequently to kg ha^{-1} N, P_2O_5 and K_2O where each value of P and K was multiplied by conversion factor of 2.29 and 1.20 according to Kang (1995).

For each site, five nutrient levels were chosen as F_0, F_1, F_2, F_3 and F_4 where F_0 was the control, while F_1 to F_4 were treatment levels which were increased by 15kg ha^{-1} of each nutrient element (N, P_2O_5 and K_2O) stepwise. In other words, F_1, F_2, F_3 and F_4 levels increased by 0.5, 1.0, 1.5 and 2.0 times to the initial soil data. The 5 levels of NPK ratios from soil data are as shown in Table 1.

The values of NPK ratios used to calculate equivalent amounts of N, P_2O_5 and K_2O in Urea, Single Super Phosphate (SSP) and Muriate of Potash (M.O.P) were also shown in Table 1. Each kg ha^{-1} N, P_2O_5 and K_2O value was multiplied by a factor of 2.2, 5.0 and 1.7 according to Kang (1995). The values of Urea, SSP and M.O.P obtained were summed up to get average value for fertilizer mixture. The five rates of mixed NPK fertilizer applied to the soils of Nsukka were 0.266.3, 360, 493.3 and 627 kg ha^{-1}; at Awgu, the fertilizer rates applied were 0, 299.3, 430.1, 566.3 and 700.1kg ha^{-1}, while at Abakaliki the fertilizer rates applied were 0, 273.2 407, 540.2 and 674.0 kg ha^{-1} NPK corresponding to F_0, F_1, F_2, F_3 and F_4 fertilizer treatment levels.

The mixed fertilizer rates were applied to the maize stands by side banding at 3 weeks after planting (3WAP). Maize was harvested at 16 WAP, shelled and weighed. The weight was, thereafter, adjusted to 14% moisture content. Data collected were subjected to Analysis of Variance (ANOVA) according to Steel and Torrie (1980), while means were separated using Duncan's New Multiple Range Test at 5% level of probability.

Soil physical and chemical properties were determined using the methods described below. Particle size separates by hydrometer method (Gee and Bauder, 1986) using sodium hexametaphosphate as dispersant; soil pH in both distilled water (H_2O) and 0.1 N solutions using a soil: liquid ratio of 1:2.5 and read on a Beckman Zeromatic pH meter after equilibrating for 30 min according to McLean (1982) method. Total N determined by Macro-Kjeldahl method of Bremmer and Mulvaney (1982). Organic carbon was obtained by dichromate (wet) oxidation method (Nelson and Sommers, 1982), available P by the Bray-II extractant method (Olsen and Sommers, 1982), Ca and Mg by complexometric titration method, while Na and K was determined using flame photometer.

RESULTS AND DISCUSSION

The Analysis of Variance (ANOVA) showed that the fertilizer treatment levels (F_1, F_2, F_3 and F_4) generally have significant ($p<0.05$ or 0.01) effects on the mean maize yields compared to F_0 treatment (Table 2) over the years (1996-1998). Maize grain yield increased with increase in the fertilizer rates.

At Nsukka in 1996, maize yield from the plots that received F_4 treatment level was significantly (p=0.01) higher than mean yields from F_0, F_1 and F_2, treatments by 52.3, 44.4 and 36.5%, respectively. Mean yield from F_3 level was statistically and significantly higher than those of F_0, F_1, (p=0.01) and F_2 (p=0.05) by 59.4, 52.7 and 45.9%, respectively while, mean yield from F_1 was higher than that of F_0 by 14.3% but not significant. In 1997, mean yield from F_3 treatment was significantly higher than F_2 and F_1 (p=0.01) as well as F_2 (p=0.05) by 67.2, 54.7 and 27.3%, respectively. F_2 mean yield was significantly (p=0.05) higher than F_0 and F_1, mean yields by 54.8 and 24.8%, respectively while F_1 was statistically higher than F_0 mean yield by 40.5% at 0.05 significant level. Mean yield difference between F_3 and F_4 plots was significantly higher than F_0, F_1, (p=0.01) and F_2, (p=0.05) by 61.3, 56.3 and 35.7%, respectively in 1998. Also, mean yield from F_3 was significantly higher than those of F_0, F_1, (p=0.01) and F_2 (p=0.05) by 62.8, 58.1 and 38.4%, respectively while percentage mean yield difference between F_2 and F_1 (12.0%) as well as F_1 and F_0 (11.4%) did not show significant difference and that between F_2 and F_0 (39.7%) significant (p = 0.05).

In 1996 at Awgu, the value of mean yield obtained from F_3 plots was significantly higher than F_0 (p=0.01), F_1 and F_2 (p=0.05) by 59.0, 40.3 and 30.6%, respectively. Mean yield difference between F_3 and F_4 (9.4%) as well as F_2 and F_1 (12.5%) did not show significant difference, while that between F_1 and F_0 (28.5%) was significant (p=0.05) (Table 2).

Table 2: Mean yield of maize (kg ha^{-1}) from the fertilizer treatments

		1996		1997		1998		Mean (x)	
Location	Treatment	HM	LM	HM	LM	HM	LM	HM	LM
Nsukka									
	F_0	2032.1^c	1691.5^a	2083.3^a	1899.9^a	2291.5^a	1791.6^a	21355.6	1794.3
	F_1	2499.9^c	2099.1^a	2516.5^c	2083.2^b	2583.2^c	2208.3^a	2533.2	2130.5
	F_2	2666.6^{bc}	2466.5^b	3641.5^{bc}	3083.2^b	3291.5^{bc}	2791.6^{bc}	3199.8	2780.4
	F_3	3999.8^b	3416.4^{ab}	4016.8^{abc}	4105.1^b	4499.8^{ab}	3249.8^a	4172.1	3590.4
	F_4	4333.2^{ab}	4208.1^a	4599.8^a	4399.8^{ab}	4249.8^{ab}	3074.8^{ab}	4394.3	3894.2
	Mean (x)	3116.5	30165	33711.5	3134.9	3383.2	3083.3	-	-
	LSD (0.05)	0.2294	1.1734	1.1733	0.8982	0.9498	0.8711	-	-
Awgu									
	F_0	2499.9^c	1416.5^a	2058.2^c	2016.5^a	2274.9^c	2058.2^a	2277.6	1997.1
	F_1	2916.5^{bc}	1920.3^a	2458.1^c	2833.2^{bc}	2566.5^c	2474.9^{bc}	2447	2409.4
	F_2	3833.2^b	2499.9^{bc}	4558.1^b	3083.2^{bc}	3774.8^b	3249.8^a	4055.3	2944.3
	F_3	6166.4^a	3416.5^{ab}	6291.4^a	4166.5^b	6124.7^a	3641.5^a	6194.2	3741.5
	F_4	5249.7^a	3833.1^a	6516.4^a	4416.4^a	5874.7^a	3499.8^a	5880.3	3914.4
	Mean (x)	4033.1	2126.5	4576.4	3383.2	4123.1	2984.8	-	-
	LSD (0.05)	1.2759	1.0757	1.1914	1.3518	2.1551	0.706	-	-
Abakaliki									
	F_0	2891.5^{bc}	1874.9^a	2499.1^c	2458.2^{bc}	2624.8^c	2108.2^a	2672.1	2147.1
	F_1	3458.1^b	2499.9^{bc}	3499.8^b	2666.5^{bc}	3208.2^c	2358.2^a	3388.7	2508.2
	F_2	4016.5^{ab}	2683.2^{bc}	3999.8^b	3266.5^b	3774.8^b	2733.2^{bc}	3930.4	2898.3
	F_3	5391.4^a	3024.8^{ab}	4416.4^{ab}	4208.1^{ab}	4999.8^{ab}	3833.1^a	4935.8	3688.6
	F_4	5791.4^a	3624.8^{ab}	4576.4^{ab}	4016.5^{abc}	4566.4^{ab}	3941.5^a	4978.1	3860.9
	Mean (x)	4309.8	3021.5	3766.5	3323.2	3834.8	2994.8	-	-
	LSD (0.05)	1.3291	0.8716	1.0335	0.7059	0.3475	0.6537	-	-

NB: HM=hybrid maize; LM = local maize; F_0-F_4= five levels of NPK fertilizers; LSD 0.05=least Significant difference at 0.05 level of probability; a, b and c letters indicate treatment means that are statistically the same or different according to Duncan's New Multiple Range Test (DNMRT) procure.

Table 3: Summary of fertilizer x cultivar interaction effects on maize yield (kg ha^{-1})

	1996		1997		1998		Mean (x)	
Source variation	HM	LM	HM	LM	HM	LM	HM	LM
Fertilizer								
F_0	2520.7^c	1995.8^c	2124.9^c	2270.7^c	2270.80^c	2062.4^c	2315.5	2109.6
F_1	2689.5^{bc}	2479.1^{bc}	3458.2^b	3062.4^{bc}	3187.4^c	2270.8^b	3111.7	2604.1
F_2	4020.7^{abc}	2499.9^{bc}	4562.4^b	3083.2^{bc}	4395.7^b	3249.9^a	4326.3	2944.33
F_3	4778.9^{ab}	4081.5^a	6005.0^a	4458.0^a	6249.7^a	3645.7^a	5677.9	3061.7
F_4	5208.2^a	3425.5^{ab}	6478.9^a	3406.0^{ab}	5874.8^a	3499.9^a	5854	3443.9
Mean (x)	3843.6	2896.3	4525.8	3256.1	4395.7	2945.7	-	-
CV (%)	38.2	22.6	16.4	21.2	15.7	17.7	-	-
SE±	734.8	327	371.4	345.4	344.8	260.9	-	-
LSD (0.05)	2215	985.8	1119.5	1041.3	1039.3	786.5	-	-

NB: HM=hybrid maize; LM= local maize; CV (%) = coefficient of variation percentage; SE± = standard error' LSD 0.05= least significant difference at 0.05 probability level; a, b and c letters indicate treatment means that are statistically the same or different (DNMRT procedure).

The 1997 results showed that mean yield values from F_4 levels were significantly higher than those of F_0 and F_1 (p=0.05) by 43.3 and 20.7%, respectively. Mean yield differences between F_2 and F_0 (37.5%) as well as F_1 and F_0 (28.5%) were significant, while that between F_3 and F_4 as well as F_1 and F_2 and were not significant. In 1998, mean yield from F_3 level was significantly (p=0.05) higher than mean yields from F_0, F_1 and F_2 treatments by 47.5, 35.3 and 34.8%, respectively. Similarly, mean yield from F_4 treatment was higher than F_0, F_1 and F_2 mean yields by 42.5, 29.7 and 17.3%, respectively, at 0.05 probability level. Mean yield difference between F_2 and F_0 was significant (p=0.05) by 30.5% and that between F_1 and F_2 (18.2%) non-significant.

At Abakaliki in 1996, the result showed that mean yield from F_4 level was significantly higher than mean yield from F_0 (p = 0.01), F_1 and F_2 (p=0.05) by 54.7, 45.3 and 38.5%, respectively. Also, mean yields from F_3 was significantly higher than F_0, F_1 (p=0.01) and F_2 (p=0.05) by 50.0, 40.2 and 30.6%, respectively. Mean yield differences between F_2 and F_0 (21.8%) as well as F_1 and F_0 (16.6%) were significant (p=0.05), while mean yield difference between F_2 and F_1 (6.3%) did not show significant difference. In 1997, mean yield difference from F_4 treatment was significantly (p=0.05) higher than F_0 (45.4%) and F_1 (37.3%). F_3 mean yield was statistically significant and higher than mean yields from F_0 and F_4 (10.6%), F_4 and F_2 (9.3%), F_3 and F_2 (11.8%) as well as F_1 and F_0 (8.2%) did not establish significant difference. The 1998 result showed that mean yield from F_4 levels was significantly higher than mean yields from F_0, F_1 and F_2 (p=0.05) levels by 46.1, 39.2 and 22.5%, respectively. Grain yield from F_3

was also significantly higher than mean yields from F_0 (p=0.01), F_1 and F_2 (p=0.05) by 49.1, 42.6 and 24.5%, respectively. Grain yield difference between F_2 and F_0 (30.4%) as well as F_1 and F_2 (21.5%) were significant (p=0.05), while mean yield difference between F_3 and F_4 (9.4%), F_0 and F_1 (11.3%) levels did not establish significant difference.

It can be observed from the result (Table 2) that relatively higher grain yields were obtained at Awgu and Abakaliki than at Nsukka. This might be attributed to significant interaction between Awgu and Abakaliki locations and the applied NPK fertilizers. Also, the increase in yield from Awgu to Abakaliki and Nsukka did not agree with the observation by kassam *et al.* (1975) that dry matter production of maize was greater in the northern drier areas than in the southern humid zones. They associated their reason to high incidence of pest and diseases, lower solar radiation and temperature levels. Furthermore, Kassam *et al.* (1975) reported that incoming solar radiation increases with latitude from southern to northern Nigeria. Hence, the net photosynthesis increased with solar radiation and latitude. But, Ezeaku (1999) reported that except for edaphic factors such as soils; climatic elements such as rainfall, solar radiation and temperature levels do not constitute major limitations to crop production in southeastern Nigeria especially in the locations of study. Boguslawski (1964) rather, concluded that yield is the result of complex interaction between fertilizer and climatic conditions in the respective years and locations. Ayuk-Takem (1981) indicated that as a general rule with increasing altitude, yield and days to tassel increase.

The results as shown in Table 3 were the summary of fertilizer X cultivars interaction effects on the grain yield with all locations considered. The result showed that yield increased with increase in the fertilizer levels. The mean grain yield obtained from F_3 and F_4 levels did not establish significant difference, while the mean yield differences between F_3 and F_4 showed significant differences either at p=0.05) or 0.01 with the rest levels (F_0, F_1 and F_2) (Table 3).

For instance in 1996, mean yield obtained from F_3 treatment plot was statistically and significantly (p=0.05) greater than mean yield obtained from F_1 treatment plot by 39.3%, while the percentage (51.1%) mean yield difference between F_3 and F_0 treatments was highly significantly (p=0.01). In 1997, mean grain yield from F_3 plot was statistically higher than mean yields of F_1 and F_2 plots by 42.4% (p=0.01) and 24.0% (p=0.05), respectively. In 1998, mean grain yield difference between F_3 and F_2 was 29.6% (p-0.05), F_2 and F_1 (20.6%; P=0.05), while F_3 and F_1 (63.6%) was highly significant (p=0.01). All these analyses show that doubling the fertilizers after F_3 treatment level might not lead to significant increases in yield and could be very uneconomical to the farmer. The average maize yield obtained at F_3 level for hybrid maize (5677.9kg ha^{-1}) and for the local variety (3061.7kgha-^{1}) might be regarded as the optimum for the locations of study (Table 3). The average value of hybrid maize yield obtained in this study compares well with the mean yields reported for U.S.A and Canada by De Jerphanion (1988).

The result (Table 3) showed that maize hybrid performed better than the local maize when exposed to both low and high supply of fertilizer NPK. The hybrid yields obtained in 1996, 1997 and 1998 cropping seasons were 3843.6, 4525.8 and 4395.7 kg ha^{-1}, respectively, while the yields established for the same years for local variety included 2896.3, 3256.1 and 2945 kg ha^{-1} (Table 3). Furthermore, the higher grain yield obtained in 1997 and 1998 than in 1996 for each of the maize cultivars was due to higher rainfall distribution. Lower number of rain days was recorded in 1996. Despite this, appreciable differences in mean daily temperature and relative humidity have been observed not to be common (Ezeaku, 1999). In general, good performance of the maize varieties might be related to better responsiveness to fertilizations; to the expression of the genetic composition of the cultivars; and to heterosis. Genetic effect according to Webster and Wilson (1980) is expressed mainly in terms of maximum rate of leaf area development, especially the leaf area index at the juvenile phase and which increase dry matter and harvestable yields of annual crops. Tisdale and Nelson (1975) observed that fertilizer is often the management factor that produces the highest increases in reference crop yield.

The increase in yield of maize with crop years also reflected on the yield variation (Table 3). Hybrid maize yields varied more in 1996 (CV. of 38.3%) followed by 1997 (CV. of 16.4%) and the least variation obtained in 1998 (CV. of 15.7%). For local maize, the highest CV (22.6%) was obtained in 1996, the least CV (17.7%) in 1998 and intermediate variation (CV. of 21.2%) obtained in 1997. Thus, the CV (%) decreased with the cropping seasons. The improvement of the yield variability (CV. %) of both cultivars with years might be attributed to better management in terms of timely tillage, using recommended seeding rate for maize variety, lack of pest and disease incidence and reduced experimental and human error in fertilizer application.

CONCLUSION

In the southeast agro ecological zone of Nigeria, increased maize yields could result from increase NPK fertilizer application, the magnitude of response for specific growing season being dependent on soil and rainfall distribution. The results revealed that the response magnitude was higher at Awgu and Abakaliki than at Nsukka. Even-though, the hybrid maize had better yields than the local variety, both appeared to have performed well. This might be attributed to heterosis and greater responsiveness to fertilization due to their physiologic potentials.

Optimum hybrid maize production was obtained over the locations with fertilizer rate at F_3 level. The fertilizer NPK rate considered optimum in this study for Nsukka was 493.3kg ha^{-1}, Awgu (566.3 kg ha^{-1}) and Abakaliki (540.2kg ha^{-1}), all of which are 1.5 times higher than the 300 kg ha^{-1}NPK agronomically recommended for optimum in hybrid maize production for southeastern Nigeria. Doubling the fertilizer rate after F_3 may be scientifically uneconomical to the farmer in terms of increased cost of production, served as luxury input for plant use and increase in level of soil acidity. Therefore, F_3 fertilizer rate is recommended in this study as the optimum for maximizing maize cultivation in the soils of study. The recommendation might be attributed to appreciable reduction of organic matter and available N in these soils over one or two decades due to cultivations; minimized unfavorable soil reaction and nutrient losses.

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