EFFICIENCY OF SOME MAIZE (Zea mays L.) CULTIVARS TREATED WITH CHICKEN MANURE AND INORGANIC FERTILIZERS IN SOILS DERIVED FROM COASTAL PLAIN SANDS OF AKPABUYO, NIGERIA

Ubi[1], M. W., A. Akpan-Idiok[2] and A. E. Eneji[3]
Department of Soil Science, University of Calabar, Calabar Nigeria.
Correspondence: Martina Ubi, Soil Science Department, University of Calabar, Calabar. martinaubi@yahoo.com

ABSTRACT

The study evaluated the combined effects of chicken manure (CM) and inorganic (NK) fertilizer on yield and yield attributes of three hybrid maize varieties. Field experiments were carried out during the 2010 and 2011 planting seasons on soils derived from coastal plain sands in Akpabuyo, Nigeria. Five fertilizer treatments (0, Nitrogen (Urea 46%) +Muriate of Potash (60%), 5t chicken manure+urea and muriate of potash designated (5 tonnes CM+NK), 10 tonnes CM+NK and 20 tonnes CM alone and three maize varieties Suwan-1-SR, Obatanpa, NDD20 and Calabar White) were studied. The sustainability index (SI) was also determined. Application of chicken manure significantly ($P<0.05$) increased plant growth parameters, with a peak at 8weeks after sowing (WAS). The Calabar White variety treated with 10 tonnes CM+NK had the tallest plants (166.10 cm), highest number of leaves (13.70) and largest leaf area (595.4 cm2) at 8WAS while ND4420 had the shortest plants. Averaged across fertilizer treatment, Suwan-1-SR had the highest yield (2904.46 kg ha-1) with 10 tonnes CM+NK treatment while ND4420 had the lowest (923.86 kg ha-1) with 0 CM. Agronomic efficiency was highest with NK treatment (316 kg ha-1) followed by (195.42 kg ha-1) under 10 tonnes CM+NK while 20 tonnes CM had the lowest (8.6 kg ha-1). The Partial factor productivity (Pfp) followed the same trend with the highest value (658 kg) obtained from NK and the lowest (8.6 kg) from 20 tonnes CM. However, sustainability index (SI) followed a descending trend in the order 10 tonnes CM+NK, 20 tonnes CM, 5 tonnes CM+NK and NK. Thus, the 10 tonnes CM+NK with 72.5% SI was more productive and environmentally safer than NK with the highest agronomic efficiency and partial factor productivity.

Keywords: Chicken manure, inorganic fertilizers, yield, agronomic efficiency and sustainability index.

I. INTRODUCTION

Sustainable maize production is not only a question of increased yield but also of environmental protection, farmers' livelihoods, social welfare and food security [1]. Combining organic and inorganic fertilizer has been proved to be an effective and sustainable soil management strategy in many countries of the world [2] for increased yield and safe environment. The best growth parameters such as plant height, leaf area and yields of maize were obtained by appropriate combination of organic and inorganic fertilizers (2.5 tonnes poultry manure + 150 kg NPK ha^{-1} [3]. The growth of maize was better when soil was enriched with organic manure than with sole inorganic fertilizer and the dry matter yield was also greater [4], [5]. High and sustained crop yield could be obtained with judicious and balanced NPK application combined with organic matter amendment [6]. The study of [7], found that combination of animal manure and inorganic fertilizer increased crop relative to sole use of inorganic fertilizer. Current interest in increasing maize yield also emphasizes sustainability. Sustainable maize production is not only a question of increased yield but also of environmental protection, farmers' livelihoods, social welfare and food security [1]. Application of inorganic fertilizer NPK readily provides nutrients for profitable maize yield but environmental pollution is often associated with improper use of nitrogenous fertilizers. Studies focusing on effects of combined application of chicken manure and NPK fertilizers have rarely considered the sustainability of such a practice to the field scale.

The objective was to determine the effects and sustainability of combined use of chicken manure and NK on the growth and yield of some hybrid maize grown in soils derived from coastal plain sands.

II. MATERIALS AND METHOD

Study area

The study site was at the Ministry of Agriculture Land in Ikot Efio Enang, Akpabuyo Local Government Area, (5°32' - 04° 57′N; 07°15′ - 09° 28'E) Nigeria. Three high yielding and disease resistant hybrid maize varieties [SUWAN-SR-1 (V_1) Obantanpa 98 (V_2)] and hybrid ND4420 and one local variety-Calabar White (V_3) were studied. Five rates of fertilizer were used 0, NK, 5, 10, 20 tonnes ha^{-1} chicken manure. The 5 and 10 tones chicken manure were combined with inorganic N (Urea) and K (Muriate of Potash) to achieve the recommended rates of 180 kg N ha^{-1}, 90 kg P ha^{-1} and 90 kg K ha^{-1} (RMRDC, 2004) for hybrid maize. The equivalent rates based on soil test were calculated and applied on a presumption that 40% of N in organic manure is available during the first cropping season [9]. The chicken manure contained 2.6% N, 1.2% P and 0.08% K. Phosphorus was not applied because the soil test value was high enough for maize. The experimental design was a 4 x 5 split plot in randomized complete block replicated three times. The main plots were assigned the four maize varieties and sub-plots were the five fertilizer combinations. Main plots were separated by 2m and sub-plot by 0.75 m alley-ways. Main plot size was 6 x 15 m = 90 m^2 while the sub-plot was 3 x 6m = 18m^2. Net sampling area was 1.5 x 3m within the two inner rows with 24 plants/row x 2=48plants. Land was manually cleared and prepared with machetes, spade and hoe to minimize nutrient loss. Seeding was done on 25th March of each planting season (2010 and 2011). Two seeds were sown at a spacing of 25cm x 75cm and thinned to one plant per stand 14days after germination, to give a population of 53, 300 plants per hectare. The chicken manure was applied and incorporated into the soil with a spade one week before seeding. At seeding, a basal application of potassium was given to all plots using the calculated rate as stated earlier. The first half of muriate of potash (60% K_2O) was applied at planting and urea (46% N) 2 weeks after seeding (WAS). The second half of Urea and Muriate of Potash was top-dressed at 6 WAS. Four litres of Primextra (ai 250g prometryn + 162.5 S-metolachlor per litre) a pre-emergence herbicide was applied at 4L ha^{-1} before seeding. Subsequently, hoe weeding was done 3 and 6 weeks after seeding during which time earthening up was done to prevent lodging.

Five plants of each cultivar were selected per plot and tagged for height measurement, number of leaves/plant and leaf area at 2, 4, 6, and 8 weeks after seeding (WAS) and at maturity. The number of cobs/plot and number of kernels/cob were determined by selecting and counting kernels of cobs from five plants per subplot. The yield of fresh cobs was determined at harvest when 95% of the silk turned brown. The average dry weight of cobs from five plants was taken. Harvesting was carried out when the silk and husk turned brown using a sharp knife to cut the stalk and removing the dry cob. Mean grain yield was obtained from the total dry weight of grain of five cobs from each net plot and converted to yield per hectare. The above ground dry matter was determined from five randomly selected plants per plot at 4 and 6 weeks after seeding. The weight of the plants was taken before and after oven drying at 60ºC for 72 hours to obtain fresh and dry weight of the plants.

Agronomic Efficiency (AE).

The yield increase per unit of nutrient applied was calculated to determine how much productivity improvement was gained for each fertilizer rate [10]:

$$AE = \frac{\text{Yield in fertilized plots (kg ha}^{-1}\text{)} - \text{Yield in control plots (kg ha}^{-1}\text{)}}{\text{Quantity of fertilizer nutrient applied (kg ha}^{-1}\text{)}}$$

Partial Factor Productivity (Pfp) and Nutrient Budget

The ratio of yield to applied nutrients was calculated as:

Pfp = Y/Nr, where Y = Yield of dry grain, Nr is the amount of fertilizer nutrient.

The nutrient in harvested crop per unit of nutrient applied was determined to know how much nutrient was taken out of the system in relation to amount put in (Nutrient budget), [10].

Sustainability Index (SI)

The effect of different fertilizer combinations on sustainable maize productivity (yield) and the impact on the soil environment was evaluated at the end of the experiment using sustainability index (SI) as developed by Rothamsted Experimental Station [11] as follows.

$SI=\bar{Y}-S/Y_{max.}$ $\bar{Y}$ = average yield of a treatment. S = standard deviation (SD) of yields over the years. Y_{max} = maximum yield of treatment in any year, The SI value increases with increasing sustainability is high.

Statistical Analysis

Data collected were subjected to analysis of variance using the STATVIEW Software [12]. Means were separated using Least Significant Difference (LSD) test. Correlation matrix was used to explore the relationship between crop growth and grain yield.

III. RESULTS AND DISCUSION

Plant growth

A summary of analysis of variance for plant growth is presented in Table I. There was a significant varietal difference in plant height and leaf area due to fertilizer application but not in the number of leaves per plant. The fertilizer and variety interaction effect on leaf area was the highest followed by plant height.

TABLE I. Summary of analysis of variance for plant growth parameters.

		Means Squares		
Source of Variation	**Df**	**Plant height**	**Number of leaves/plant**	**Leaf area**
Fertilizer	4	21506.8**	52.5NS	418864.3**
Variety	3	1296.9**	8.5NS	436334.7**
Fertilizer*Variety	12	219.2**	0.44NS	15860.5**
Residual	40	9.5	0.26	60.3

***Significant at (P<0.05). **Significant at (P<0.01). NS, not significant**

There was significant effect of chicken manure and inorganic fertilizer on the height of four maize varieties as presented in Figure 1. The tallest plants (133.40 cm) were observed under 10 tonnes CM+NK treatment at 8WAS and the tallest variety (198.4cm) was Calabar White while the shortest (54.34 cm) was ND4420. Plant height increased progressively from 2WAS to a peak at 8WAS. The effects of 10 tonnes CM+NK and 20 tonnes CM were similar as were those of NK and control. The response to varietal effect was more than fertilizer effect.

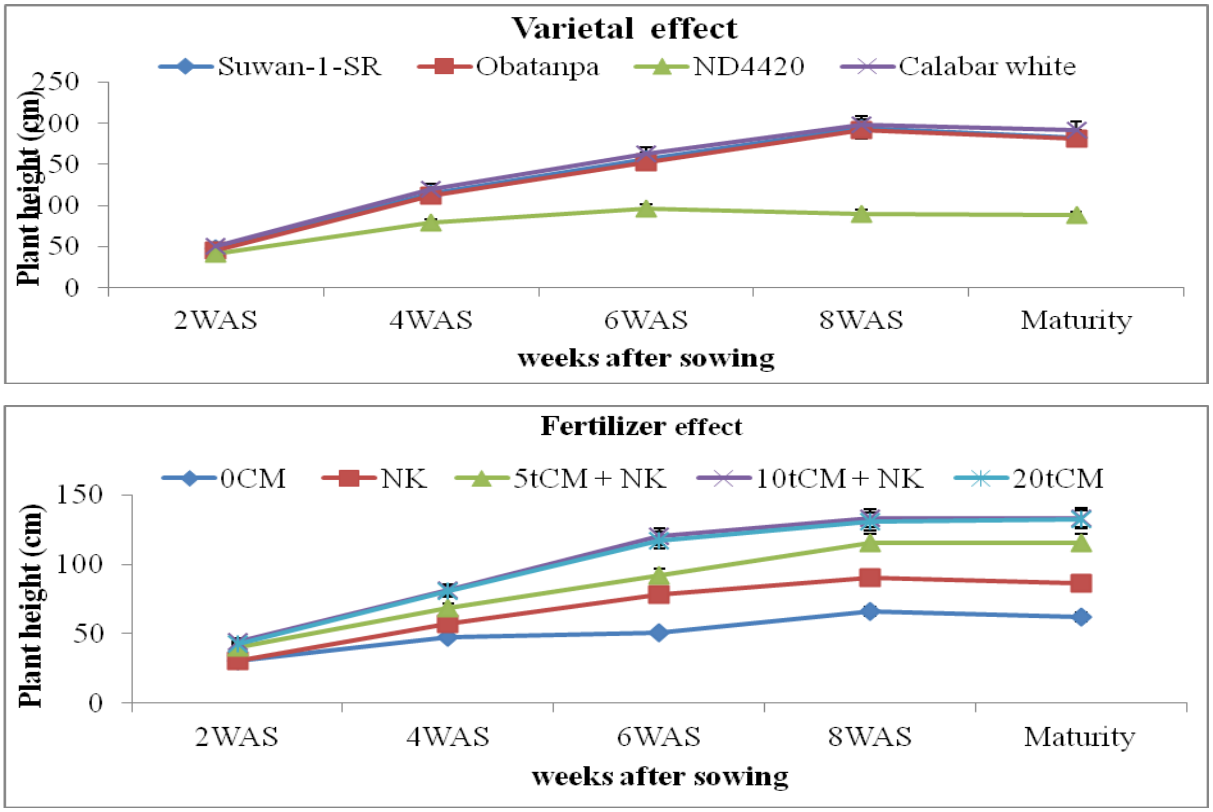

Fig. 1. Effect of fertilizer and variety on plant height at successive weeks after sowing

Number of leaves

The highest number of leaves per plant (15.70) was obtained from Calabar White at 8WAS and the number increased by 219% with 10 tonnes CM+NK at 8WAS (Figure 2).

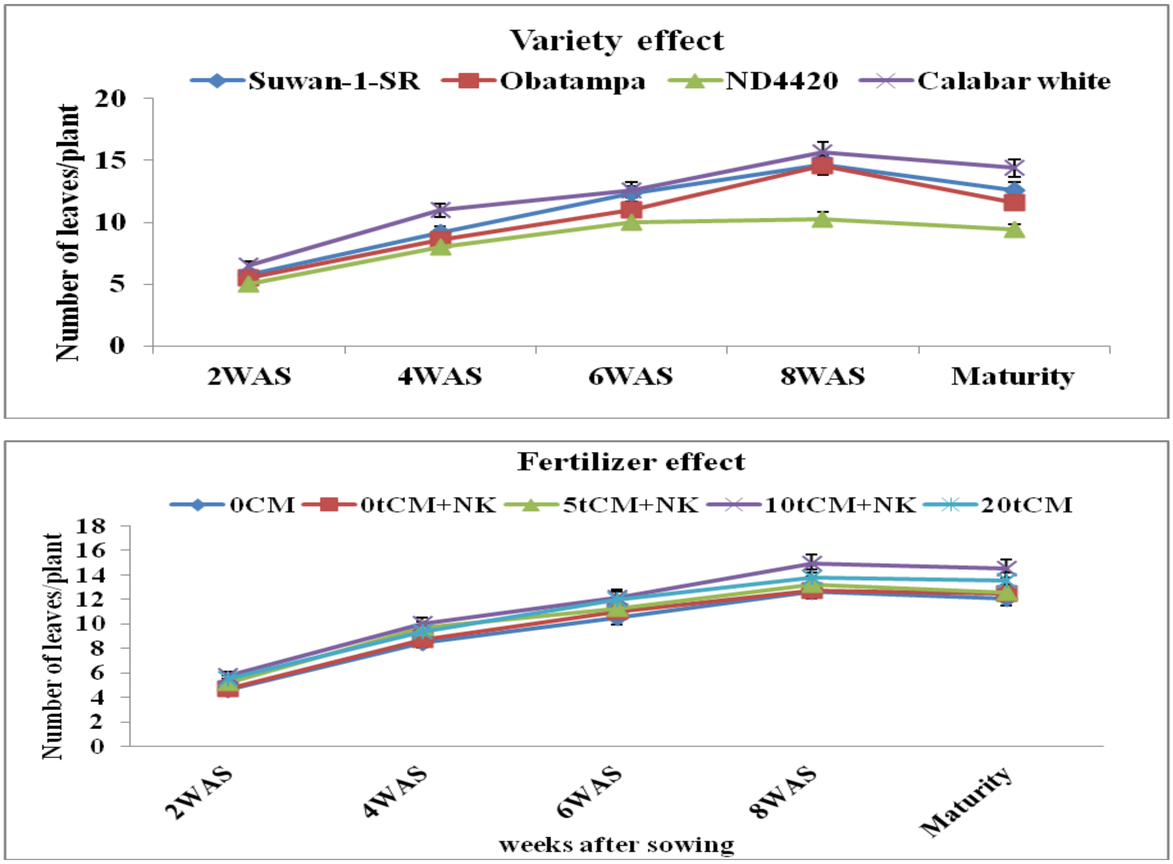

Fig. 2. Effect of fertilizer and variety on number of leaves at successive weeks after sowing

Leaf area

The highest leaf area (696 cm^2) was obtained from Calabar White at 8WAS (Figure 3) and the fertilizer treatment with the largest leaf area was 10 tonnes CM+NK while the lowest leaf area (112.54 cm^2) was from ND4420.

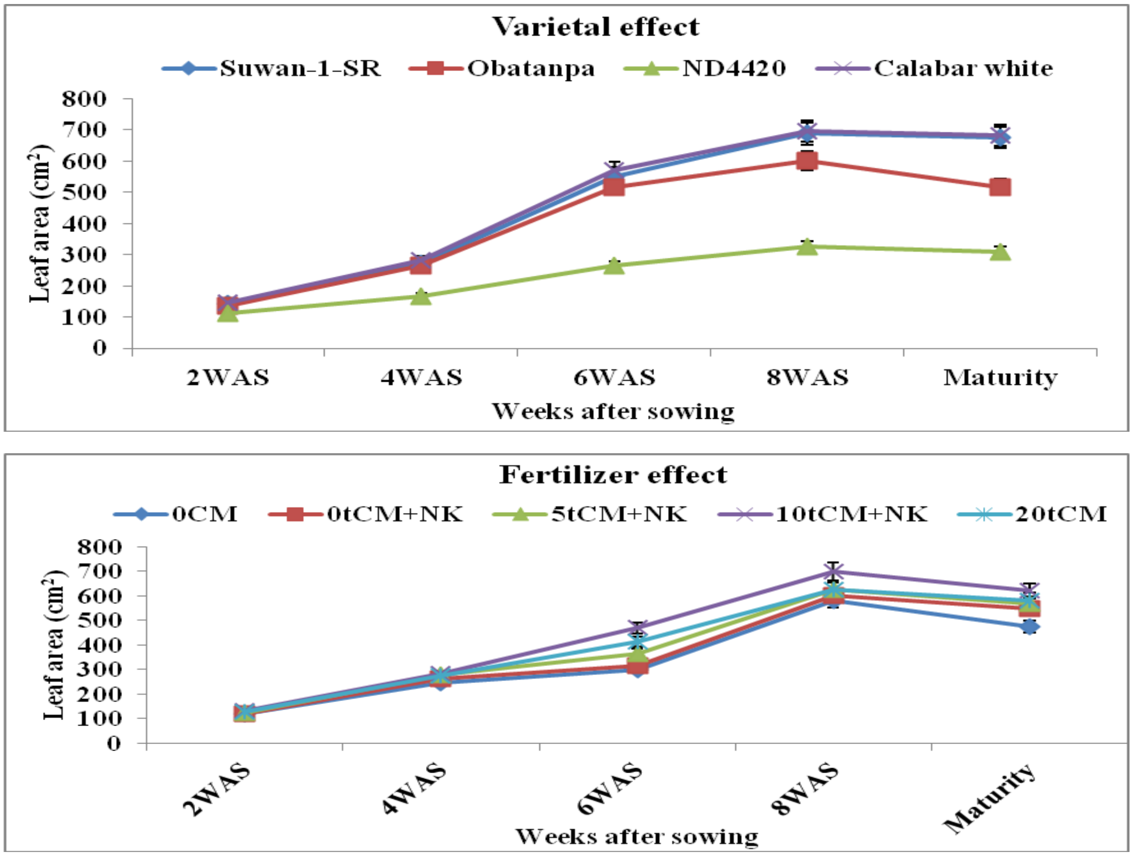

Fig. 3. Effect of fertilizer and variety on leaf area at successive weeks after sowing**.**

Analysis of Variance

A summary of the analysis of variance of the influence of chicken manure and NK on cob fresh weight (CFWT), cob dry weight (CDWT), number of kernels/cob (NKC), seed weight/plant (SWTP), 500 seed weight and grain yield of maize is shown in Table II. Fertilizer effects were more pronounced on yield and yield attributes than the varietal effect except for CDWT, SWTP and 500 SWT. The fertilizer x variety interaction significantly influenced CDWT, NKC, SWTP and 500 SWT while the effects on grain yield with CFWT were highly significant.

TABLE II. Summary of analysis of variance for yield and yield attributes.

		Means Squares					
Source of Variation	Df	CFWT	CDWT	NKC	SWTP	500SWT	YIELD
Fertilizer	4	18303057.2**	22290.3**	231978**	10695.5*	5477.9**	14577014**
Variety	3	2500712.6**	43621.5*	26026.5**	14637.7*	23191**	2203672.9**
Fert x var.	12	24084.1**	7425.6*	527.9*	962.8*	273.1*	1358480.7**
Residual	40	1166.2	473.8	107.6	1.4	5.1	353.2

***Significant at (P<0.05). **Significant at (P<0.01). CFWT= Cob fresh weight. CDWT= Cob dry weight. NKC=Number of kernels/cob. SWTP=Seed weight/plant.**

Effects of Fertilizer on Grain Yields of Maize

The application of chicken manure or NK significantly increased grain yields, especially in combination. The Suwan-1-SR had the highest yield 4026.6 kg ha^{1} with 10 tonnes CM+NK treatment while the ND4420 had the lowest yield of 473.96 kg ha^{1}. The highest interaction effect on grain yield (4026 kg ha^{-1}) was obtained from Suwan-1-SR fertilized with 10 tonnes CM+NK and this was significantly ($P<0.05$) higher than values of 3854.50 kg ha^{-1} (4%), and 3423.58 kg ha^{-1} (17%) obtained from Obatanpa, and Calabar White respectively (Figure 5).

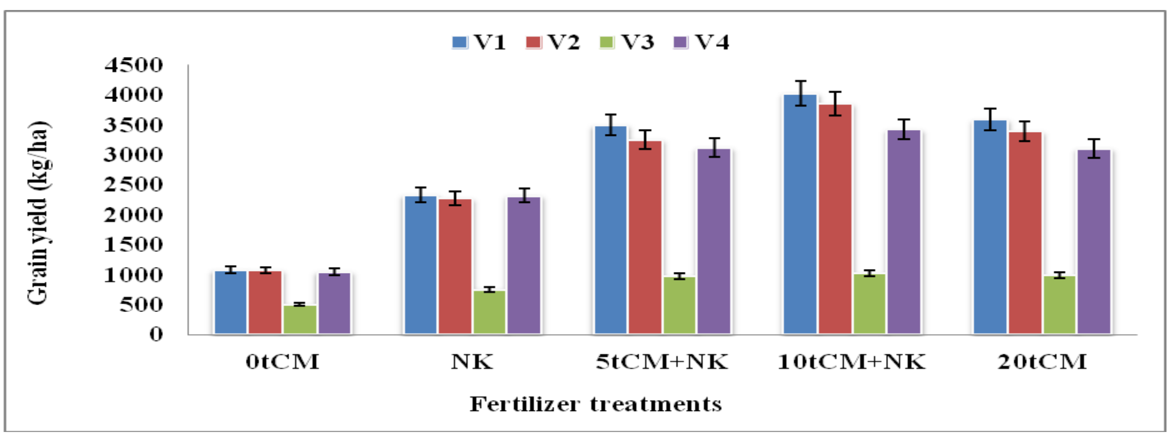

Fig. 6. Fertilizer and variety interaction effect on grain yield of four maize varieties. Varieties V_1, V_2, V_3 V_4 indicate Suwan-1-SR, Obatanpa, ND4420 and Calabar White respectively.

Agronomy Efficiency (AE), partial factor productivity (Pfp) and Sustainability Index (SI)

The effects of chicken manure and NK on agronomic efficiency, partial factor productivity and sustainable index are shown in Table III. The source of fertilizer influenced the agronomic efficiency and partial factory productivity. The AE due to fertilizer treatments ranged from 8.58 kg ha^{-1} with 20 tonnes CM to 316.51 kg ha^{-1} with NK treatment. Generally, the NK treatment had the highest AE followed by 10 tonnes CM+NK, 5tCM+NK and 20 tonnes CM. The highest value (658 kg) of partial factor productivity (Pfp) which is yield of crop in relation to the fertilizer applied was obtained from NK followed by 10 tonnes CM+NK with (285.5 kg) accounting for 130% increase and the lowest value (13 kg) was obtained from 20 tonnes CM.

The sustainability of production of the four maize varieties varied significantly with fertilizer regime. The highest SI (73%) was obtained from 10 tonnes CM+NK treatment followed by 5tCM+NK (48%), 20 tonnes CM (41%) and NK (38%). The SI of the 10 tonnes CM+NK treatment was better than other treatments, indicating high level of productivity and sustainability.

TABLE III. Agronomic efficiency, partial factor productivity. and sustainability index as influenced by chicken manure and NK fertilizer

Fertilizer	AE kg ha^{-1}	Pfp Kg	SI %
0 CM	-		-
NK	316.51	658.00	38.00
5 tonnes CM+NK	28.41	46.00	48.50
10 tonnes CM+NK	195.42	285.50	72.50
20 tonnes CM	8.58	13.00	41.00
Mean	137.23	250.62	

AE indicates agronomy efficiency; Pfp, partial factor productivity and SI, sustainability index; CM, chicken manure; NK, nitrogen (urea - 46% N) and potassium (muriate of potash K_2O- 60%) fertilizers.

Correlation Analysis

Table IV shows the correlation, matrix among some yield attributes and grain yield evaluated under the fertilizer treatments. The seed yield, cob fresh weight and number of seeds per cob; correlated more positively with grain yield than other parameters. However, mean seed weight (0.96), cob fresh weight (0.71) and number of seeds/cob (0.82) were highly significant. A high correlation coefficient (0.95) was also found between seed weight/plant and number of seeds per cob.

TABLE IV. Correlation analysis among yield attributes of four maize varieties

Variable	Yield	SWP	500 SWT	CFWT	CDWT	NKC
Yield	1	0.96**	0.21*	0.71**	0.22*	0.82**
Seed weight/plant		1	0.20*	0.75**	0.07NS	0.95**
500 seed weight			1	0.10*	0.008NS	0.082*
Cob Fresh weight				1	0.17*	0.71*
Cob Dry Weight					1	0.08*
Number of Kernels/cob						1

* Significant at 0.05;** significant at 0.01; NS not significant.

IV. DISCUSSION

The yield attributes of maize greatly improved with the application of chicken manure in combination with inorganic fertilizer. There was 9.5% increase in cob fresh weight and 76% increase in seed weight when nutrient was increased from 5 tonnes CM+NK to 10 tonnes CM + NK. However, when the nutrient was further changed from 10 tonnes CM + NK treatment to 20 tonnes CM, there was 8.2% decrease in cob fresh weight and 27% decrease in seed weight. Probably, more nutrients were mineralized and utilized under 10 tonnes CM + NK treatment than 20 tonnes CM. The application of 10 tonnes CM + NK fertilizer treatment was therefore, the best treatment for agronomic characteristics. The grain yields were statistically better under combined application of NK and poultry manure fertilizer than application of NPK fertilizer alone. A study by [13] showed that organic and inorganic fertilizer combination enhanced the yield of maize. The yields of cassava, maize and melon were found to be best under poultry manure + NPK fertilizer treatments [4]. According to [15] the most satisfactory approach to increasing maize yield was by judicious combination of organic wastes and inorganic fertilizers. Better farming systems which employ a combination of organic and inorganic fertilizers to increase maize production, was advocated [16]. It may be that nutrients from inorganic fertilizers enhanced the establishment of crops while those from mineralization of organic manure promoted yield when both fertilizers were combined. The lowest yield observed for 0 CM was a reflection of the inherent low fertility status of the soil studied. The lower yield under NK relative to combined fertilizer may be attributed to the fact that the inorganic fertilizer dissolved quicker and released nutrients faster than the period of peak nutrient demand compared with the chicken manure which released nutrient throughout the growing stage [3]. The crop yield from 20 tonnes CM (chicken manure alone) compared favourably with that from 10 tonnes CM+NK combination, possibly due to high mineralization. The highest yield obtained from Suwan-1-SR variety could be attributed to its profuse root growth giving it an advantage of faster absorption of nutrients and than others [4]. The ND4420 is a super sweet variety grown for fresh consumption; hence it had the lowest dry grain yield due to its low carbohydrate and high soluble sugar content.

Correlation analysis for yield and yield components showed that grain yield had reasonable association with most of the traits measured.

The report of [17] advocated for agronomic use efficiency as the basis for economic and environmental efficiency as it improves economic and environmental benefits. The source of fertilizer influenced the agronomic efficiency and partial factory productivity which is the ratio of grain yield (kg ha^{-1}) per unit of fertilizer applied. The Pfp followed the same trend as the agronomic efficiency. Based on Pfp, the NK was more productive than other treatments and 20 tonnes CM was the least productive. The partial productivity declined with increasing levels of organic fertilizer which is in line with the report of [18]. The report of [10] stated that in the short term, Pfp ratios increased as rates of fertilizer application are decreased, even to levels well below the economic optimum. This might cause one to falsely conclude that the lowest fertilizer rate results in the most efficient cropping system which is untrue.

The impact of chicken manure and NK on maize productivity and sustainability was remarkable. The highest values of sustainability index (73%) were obtained with 10 tonnes CM+NK treatment, indicating its suitability for stable production of the maize varieties over many years. Sustainability index followed the order 10 tonnes CM+NK > 20 tonnes CM > 5 tonnes CM+NK > NK. It was noted that NK treatment with the highest AE and Pfp had the lowest SI, indicating that complete reliance on inorganic fertilizer alone will not guarantee sustainable maize production in the study area. The sustainability index provides the best information for fertilizer application that will minimize environmental pollution. In [19], it was reported that use of inorganic fertilizers requires financial capital and the production of organic manure is limited by available land and labor; it is necessary that appropriate soil and crop management systems be developed so as to reduce the amount and frequency of their application, while also increasing efficiency of their utilization by crops. Sustainable maize production is not only to increase yield but to consider environmental protection, farmers' livelihood and social welfare for household food security [1]. Combining organic and inorganic fertilizer had been proved to be an effective and sustainable soil management strategy in many countries of the world [2] for increased yield and safe environment. In this study, 10 tonnes CM+NK was found to be appropriate for ensuring high yield productivity and environmental sustainability according to criteria reported by [11].

V. CONCLUSION

Maize growth parameters yield and yield attributes under 10 tonnes CM+NK treatment were the best compared with other fertilizer treatments and were consistent with agronomic efficiency and sustainability index. Crop yield under NK alone was low but higher than the 0 CM treatment. Among the maize varieties, Suwan and Obatampa were the most promising in terms of yield for fresh consumption and industrial use. The yield of Calabar white under the treatments greatly improved when compared with local yield of < 1.5tonnes ha^{-1} that is common in low-input farms. Evidently, the use of chicken manure in the acid soil improved the yield potentials of maize, thus enhancing the chances of its adoption by farmers as a component of their farming system. This study demonstrated the importance of combination of chicken manure and inorganic fertilizer to enhancing maize growth and yield in the acid coastal plain sands.

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