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Response of maize (*Zea mays* L.) to combined application of organic and inorganic (soil and foliar applied) fertilizers

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A field trial was carried out in the 2013 cropping season at the Teaching and Research Farm of Kwara State University, Malete, Nigeria (08° 42" 48.5N and 004° 26 17.9" E) to assess the response of early maturing maize variety (TZEE-Y) when using organic poultry manure (pm) alone or in combination with inorganic (NPK) and foliar fertilizer (ff) (boost xtra). The treatments were: pm 5.0 t ha^{-1} + ff, pm 2.5 t ha^{-1} + NPK 30 kg N + ff, NPK 60 kg N + ff, pm 5.0 t ha^{-1} + NPK 60 kg N, pm 10.0 t ha^{-1} + 60 kg N, NPK 120 kg N/ha, pm 10.0 t ha^{-1} and control. The treatments were arranged in a randomized complete block design and replicated three times. Applications of poultry manure at 10.0t ha^{-1} produced the highest plant height (119.57 cm^2), leaf area (362.10 cm^2) and cob length (17.47 cm^2). However, significantly, was at par with integrated application of poultry manure at 2.5 t ha-^{1} mixed with NPK 30 kgN ha^{-1} and foliar fertilizers. As compared to other treatments, significantly shorter days (38) to 50% flowering was obtained where 2.5 t ha^{-1} poultry manure was combined with NPK 30 kgN/ha and foliar fertilizer. The highest grain yield (3.206 t ha^{-1}) was obtained when pm was applied alone at 10.0 t ha^{-1}. This was also similar to the combined application of pm at 2.5t ha^{-1} mixed with NPK 30 kgN ha^{-1} and foliar fertilizer. The results of the study indicated that combined application of pm, NPK and ff enhanced the growth and yield of maize. This integrated application will be a good soil management practice for tropical soils. Combination of pm at 2.5 t ha^{-1} with NPK 30 kgN ha^{-1} and foliar fertilizer (boost xtra) is therefore recommended for early maturing maize production in the study area.

Key words: Poultry manure, foliar fertilizer, mixing, NPK fertilizer, application rate.

INTRODUCTION

Maize is an important cereal crop in Nigeria, mainly as an energy giving food with a total production of 7.3 million tons (FAO, 2007). Being a versatile crop, constituting about fifty percent in the poultry feed ingredients, it is

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widely cultivated in all the agro-ecological zones in Nigeria. The diverse use of maize as food for man and his livestock and raw materials for industries has made the crop in continuous production. Compared to other arable crops such as millet, the nutrients requirement of maize is quite higher and hence, constituting major constraints to its production.

Application of inorganic fertilizer to increase crop growth and yield is well known since the nutrients are readily available for plant use but continuous and inappropriate use of inorganic fertilizer is harmful both to the soil and the environment. It increases soil acidity, and nutrient imbalance and pollution of underground water. In view of the well documented detrimental effects of inorganic fertilizer, its rising cost and unavailability has limited its use among poor farmers in Nigeria (Taminu et al., 2007), hence, attention has been directed to the use of organic manure in recent times.

Historically, poultry manure (pm) has long being recognized as a source of enriching plant and amendments of soil nutrient. It contains all the essential nutrients including the micronutrients such as cupper, manganese and zinc and has been reported as a valuable source of plant nutrients (Garg and Bahla, 2008) and also improved the physical, chemical and biological properties of the soil (Abou El-Magd et al., 2006). Combination of pm with inorganic soil applied fertilizer has been extensively used on various crops to improve growth and yield. Mixing the two sources of fertilizer not only supply essential and micro nutrients for plant use, but also can have some positive interaction to increase their efficiency thereby reducing environmental hazards particularly soil pH (Bayu et al., 2006). Makinde and Ayoola (2001) observed that combined application of organic and inorganic fertilizer increased the yield of maize (*Zea mays* L.) than when any of the fertilizer was used alone. Similarly, Akande et al. (2003) reported significant improvement on the growth and yield of okra (*Abelmuschus esculenthus* Moench) when ground phosphorous rock phosphate was mixed with poultry manure. In a recent study on sweet maize (*Z. mays* L. var saccharata Strut), Uwah et al. (2011) reported that application of poultry manure at 10 t ha^{-1} mixed with 400 kg ha^{-1} NPK fertilizer out-yielded other treatments in biomass yield, harvest index and total grain yield.

The practice of applying liquid fertilizer to plant leaves (foliar fertilization), is recently done in Nigeria, and it is gradually gaining popularity among peasant farmers in many cultivated crops. This method of fertilizer application has been reported to increase the growth, yield and quality of crops such as okra (Selvi and Rani, 2000), soybean (Barge, 2001) and tomato (Alexander et al., 2004) among others. Philips (2004) demonstrated that this technique apart from supplying the micronutrients it also acts as a catalyst in the uptake and use of certain macronutrients. Boost xtra, is a foliar fertilizers that is commonly used by farmers in Nigeria. It is manufactured by Candel Company and contain both the macro and micro nutrients in various combinations (20% N, P and K, 0.075% Zn, Cu and Mg, 1.5% Fe, 0.35% Mn, 0.035% Bo and 0.012% Mo with pH range of 4.0-4.5). Many studies had been carried out on the integration of pm and inorganic soil applied fertilizers, but limited information is available on the use of pm and inorganic fertilizer with foliar fertilizer (ff) in this particular area. Therefore, the objective of our study is to evaluate the growth and yield of an early maturing maize variety (TZEE-Y) with the combined application of organic pm, NPK and ff.

MATERIALS AND METHODS

A field trial was carried out in 2013 cropping season at the Teaching and Research Farm of Kwara State University, Malete, (08° 42" 48.5N and 004° 26 17.9"ı E) in the Southern Guinea Savannah ecological zone of Nigeria to evaluate the response of an early maturing maize (TZEE-Y) variety to the combined application of inorganic NPK (15:15:15), organic pm and inorganic foliar fertilizers (ff). The mean annual rainfall of the study area during the trial was 900 mm in 54 rainy days. The maximum temperature was 35.5°C while minimum was 22.8°C with relative humidity of 85.9% (PME, 2013). The treatment consists of poultry manure at 10 t ha^{-1}, NPK at 120 kg N ha^{-1}, pm at 5.0 t ha^{-1} plus ff, pm at 2.5 t ha^{-1} + NPK at 30 kg N/ha + ff, NPK at 60 kg N/ha + ff, pm at 5.0 t ha^{-1} + NPK at 60 kg N ha^{-1}, pm at 10 t ha^{-1} + NPK at 60 kgN ha^{-1} and the control where none of the fertilizers was applied. The treatments were arranged in a randomized complete block design and replicated three times.

Soil samples were collected at 0-15 cm depth at the experimental site before planting for laboratory analysis. After the experiment, that is, after harvesting of the crops, soil samples were also collected from each plot for laboratory analysis (Table 1). The land was ploughed and harrowed twice and planting was carried out on the flat at a spacing of 0.75 m between rows and 0.50 m within the rows. Each plot size measured 3 m x 3 m with 0.5 m between the plots and 1 m between the blocks. Poultry manure was applied two weeks before planting while NPK was split applied at three and six weeks after planting (wap). Foliar fertilizer was applied in a single application at the recommended rate of 3 l ha^{-1} at tasselling. Pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] was applied as a pre-emergence herbicide at the rate of 1.5 kg a.i ha^{-1} immediately after planting and followed by manual weeding at four weeks after planting. The following data were collected from five tagged plants at the two inner rows; plant height at 6 wap with a measuring tape from the ground level to the base of the last leaf, leaf area, stem girth using Vernier caliper, days to 50% tasselling and silking. Maize cobs from the two inner rows were harvested and the yield and yield components data were taken viz: cob length, number of cobs $plant^{-1}$, weight of 1000 grain and grain yield. The data were further subjected to analysis of variance (ANOVA) using Assistat Statistical package (2009) version and treatment means were separated using Duncan's multiple range test at 5% level of probability.

RESULTS

The physiochemical properties of the soil at the experimental site before planting and after harvesting the crop are presented in Table 1. The soil of the experimental site was predominantly sandy with above 88.9%

Table 1. Physico- and chemical properties of the soil at the experimental site before planting and after harvesting.

Treatment	pH in H_20 (1:1)	N (%)	OC (%)	OM (%)	Sand (%)	Silt (%)	Clay (%)	P	Ca	Mg	Na	K
Before planting	5.8	0.40	0.43	0.74	88.9	6.0	5.04	1.40	2.4	1.1	0.74	1.53
After harvesting												
pm 10 t + NPK 60 N/ha	6.0	0.21	0.39	0.67	80.9	12.0	7.04	3.50	2.2	0.5	0.95	2.00
pm 10 t/ha	6.7	0.18	0.32	0.55	84.9	10.0	5.04	2.90	1.9	0.6	0.86	2.46
pm 5 t + ff	6.0	0.14	0.29	0.50	84.9	8.0	7.04	2.80	1.3	1.3	1.13	1.89
pm 2.5 t + NPK 30 N + ff	6.3	0.14	0.37	0.64	84.9	8.0	7.04	3.50	0.3	0.3	1.08	1.85
pm 5 t + NPK 60 N/ha	6.4	0.15	0.28	0.48	84.9	8.0	7.04	3.5	0.8	0.8	1.26	2.05
NPK 60 kg N/ha + ff	6.5	0.11	0.36	0.62	80.9	12.0	7.04	2.80	0.5	0.5	0.74	1.74
NPK 120 kg N/ha	6.7	0.14	0.24	0.41	82.9	10.0	7.04	0.70	0.8	0.8	0.78	2.15
No fertilizer	6.0	0.11	0.19	0.33	84.9	8.0	7.04	0.70	0.7	0.7	1.21	1.64

OC, organic carbon; OM, organic manure.

Table 2. Effect of combined application of poultry manure, NPK and foliar fertilizer on plant height, stem girth, leaf area and days to 50% tasseling of maize.

Treatment	Plant height (cm)	Stem girth (cm)	Leaf area (cm^2)	Days to 50% tasseling
pm10 t/ha	119.57a	7.47a	362.1a	43.15b
pm10 t/ha + NPK 60 N/ha	116.90a	7.57a	331.3bc	40.67c
pm 5 t/ha + NPK 60 N/ha	74.27f	7.10a	348.7b	43.07b
pm 2.5 t/ha + NPK 30 + ff	115.27ab	7.20a	353.07a	38.03d
pm 5 t/ha + ff	100.10cd	7.60a	308.4de	46.78a
NPK 60 + ff	83.37e	6.23b	295.97e	46.00a
NPK 120 kg N/ha	110.20b	6.23b	329.60bc	44.2b
Control	46.9h	5.80b	248.47f	47.11a

Values with the same letter in the column are not statistically different at 5% level of probability using Duncan multiple range test. Pm = poultry manure; ff = foliar fertilizer.

sand, 6.0% silt and 5.04% clay, slightly acidic and low in some macro and micro nutrients. Integrated application of pm and inorganic fertilizers significantly influenced the growth of maize (Table 2). The greatest plant height (199.57 cm) and leaf area were recorded at the treatments where pm was applied alone at 10 t ha^{-1}. Comparable plant heights were obtained with the integrated application of pm at 2.5 t ha^{-1} mixed with NPK 30 kg N ha^{-1} plus ff and the combined application of pm at 5.0 t ha^{-1} and foliar fertilizer. Significantly, shorter plants were observed at the control treatments as compared to other treatments. Stem girth followed similar trends with the plant height, but the application of pm alone at 10 t ha^{-1} was only

Table 3. Effect of combined application of poultry manure, NPK and foliar fertilizer on cob length, number of cobs per plant, weight of 1000 grains and yield.

Treatments	Cob length (cm)	Number of Cobs per plant	Weight of 1000 grains (g)	Yield (t/ha)
pm 10 t	17.47a	1.33ab	32.50a	3.206a
pm 10 t + NPK 60 N/ha	17.0ab	1.53a	30.87b	3.170a
pm 5 t + NPK 60 N/ha	14.70d	1.13ab	25.27e	2.559b
pm 2.5 t + NPK 30 + ff	16.97ab	1.20ab	30.76b	3.1567a
pm 5t + ff	16.17bc	1.40ab	29.27c	2.502b
NPK 60 + ff	14.60d	1.20ab	29.10c	2.106bc
NPK 120	16.18b	1.20ab	30.43b	2.90ab
Control	11.83e	1.00b	27.33d	1.29d

Values with the same letter in the column are not statistically different at 5% level of probability using Duncan multiple range test Pm = poultry manure; ff = foliar fertilizer.

only superior to the control. Integrated application of pm (10 t ha^{-1} + NPK 60 kg N ha^{-1}), pm (5 t ha^{-1} + NPK 60 kg N ha^{-1}) and pm (2.5 t ha^{-1} + NPK 30 kg N ha^{-1} + ff) produced similar leaf areas. Plots treated with combined application of pm at 2.5 t ha^{-1} mixed with NPK 30 kg N ha^{-1} and foliar fertilizer commenced tasselling earlier at 38 days after planting. Late tasselling was recorded at the control treatments.

The combined integration of pm, NPK and foliar ff on the cob length, 1000 grain weight, number of cobs per plant and yield of maize is presented in Table 3. Application of pm alone at 10 t ha^{-1} was superior in cob length as compared to other treatments except when it was combined with NPK 60 kg N ha^{-1}. Foliar fertilizer mixed with pm at 5.0 t ha^{-1} produced similar cob length with when NPK was applied alone at 120 kg N ha^{-1}. The numbers of cobs produced per plant in all the treatments were statistically alike. The highest grain weight (32.50 g) was recorded when pm was applied alone at 10 t ha^{-1}. Mixing pm (2.5 t ha^{-1} + NPK 30 kg N ha^{-1} + ff) and pm (10.0 t ha^{-1} + NPK 60 kg N ha^{-1}) had similar 1000 grain weight. These values were however similar to when NPK was applied alone at 120 kg N ha^{-1}. Applications of pm alone at 10 t ha^{-1} or in combination with NPK 60 kg N ha^{-1} and at a reduced rate of 2.5 t ha^{-1} mix with NPK 30 kg N ha^{-1} plus foliar fertilizer statistically out-yielded other treatments. Minimum grain yield (1.29 t ha^{-1}) was observed at the control treatments.

DISCUSSION

The low essential plant nutrient content of the soil at the experimental site indicated the need for external soil amendment for sustainable yield to increase maize yield in the study area. The inherent low nutrient soil condition at the experimental site was reported by Adejobi and Kormawa (2002) which could be due to negative nutrient imbalance that is often associated with intensive cropping and inappropriate application of inorganic fertilizer in the traditional cropping in the tropics. Generally, all the treatments improved the textural properties of the soil (sand, silt and clay), the available phosphorous and the soil pH. This further confirmed the earlier findings of Akande et al. (2003, 2010) that application of organic materials could ameliorate slightly acidic tropical soils to improve crop production. The overall results of the study indicated that application of pm alone or in combination with inorganic NPK and ff improved the growth, yield and yield components of maize. These findings were consistent with the findings of other researchers (Khaliq et al., 2004; Uwah et al., 2011).

Application of pm at high rate of 10 t ha^{-1} though improved the growth and yield, similar values were recorded when it was mixed at a reduced rate of 2.5 t ha^{-1} with NPK 30 kg N ha^{-1} plus foliar fertilizer. This combination also compared favorably with the recommended NPK 120 kg N ha^{-1} in all the observed parameters. This clearly suggests that the recommended high dose of 10 t ha^{-1} pm and 120 kg N ha^{-1} could be reduced to one quarter when mixed with foliar fertilizer to achieve reasonable maize yield. This reduced rate however, contradicted the earlier recommendation of Akande et al. (2010) that one half each of pm and NPK is ideal for maize yield. The contrast is explainable with the mixture of ff that was not included in the earlier study.

Nutrient availability and use for maize appeared to be better with the combination of the three sources of fertilizers. The slow release of nutrients from pm was complemented with the application of NPK and ff as evident in the early tasselling in the plots treated with the combined application of the three sources. Application of plant nutrients to the leaves where chemical processes of photosynthesis takes place is the quickest way of nutrient utilization by plant. This is because the nutrients are delivered at the site where they are quickly used by the plant. This method of fertilizer application in addition to the replenishment of micronutrients also acts as a catalyst in the uptake and use of macronutrients (Phillips, 2004). Earlier, Boateng et al. (2006) recommended the

combined application of pm and NPK on the growth and yield of maize because of its complementary and synergistic effects. These positive attribute appeared to be further strengthened with the application of ff.

Based on the results of this study, combined application of pm, NPK and ff enhanced the growth and yield of maize. Mixing ff with pm and NPK will reduce the high dosage of each of the fertilizers required per unit area, improve soil properties and could be a sound soil management strategy for sustainable maize production in the tropics. Hence, 2.5 t ha^{-1} PM plus 30 kg N ha^{-1} and full rate of foliar fertilizer is therefore recommended in the study area.

Conclusion

Combined application of pm, inorganic and ff enhance the growth and yield of maize. However, application of 2.5 t ha^{-1} of pm plus 30 kg N ha^{-1} and full rate of ff (boost xtra) was found to give similar yield with recommended pm and inorganic N fertilizer.

Conflict of interests

The author(s) did not declare any conflict of interest.

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