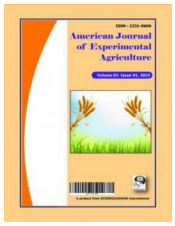

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Effect of Combination of Soil Granular NPK and Foliar Liquid Fertilizer on Nutrients Uptake and Maize Yield

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Authors' contributions

This work was carried out in collaboration between all authors. Author ONA designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors ONA, AOA and SOO reviewed the experimental design and all drafts of the manuscript. Author ONA managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Investigation to compare the effect of soil basal granular NPK fertilization to its combination with liquid foliar fertilization on maize nutrients uptake and yield was conducted on experimental station of the Institute of Agricultural Research and Training (IAR&T), Obafemi Awolowo University, Moor Plantation Ibadan located at Ikenne, Ogun state Nigeria; high rain forest agro-ecology and experimental farm of the Nigeria Institute For Oil Palm Research (NIFOR) at Ikoga, Badagry, Lagos state; coastal rain forest agro-ecology in 2009 cropping season. The experimental design was a randomized complete block design (RCBD) with three replications. The treatments consisted of different levels of soil applied NPK (20-10-10) fertilizer in combination with liquid foliar fertilizer from Vioryl products, sole 100 kg/ha NPK and sole liquid foliar fertilizer products. Application of 100 kg/ha granular NPK fertilizer combined with foliar fertilizer application resulted in higher dry matter, cob

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and grain weights, yield and more concentrations of N, P, K, Mg and Zn in maize tissues than individual application of NPK fertilizer or foliar fertilizer in both locations. The increase due to the soil application of NPK fertilizer at different levels (100, 80, 60 and 40 kg/ha) combined with foliar fertilizer compared to the sole application of 100 kg/ha NPK fertilizer varied from 16 to 60% at Ikenne and 17 to 48% at Badagry for maize grain weight, and 6 to 26% at Ikenne and 6 to 30% at Badagry for maize dry matter yield. Based on the results of this study, farmers are advised to use the foliar liquid fertilizer as a nutrient complement rather than as the basic fertilizer as is envisaged. Research needs to be conducted to ascertain the influence of seasons on various types of fertilizer applications on maize production.

Keywords: Cropping season; dry matter yield; investigation; maize production; nutrient complement; organic matter.

1. INTRODUCTION

Crop productivity in tropical regions is hindered by low soil fertility largely due to low organic matter, cation exchange capacity (CEC), nitrogen (N) and phosphorus (P) deficiencies prevalent in most soils [1,2]. The traditional method of maintaining soil fertility and crop productivity in the tropics and sub-tropics has been the bush-fallow system whereby arable land is allowed to revert after 3-4 years of continuous cultivation [3]. However, according to FAO [4], the traditional bush-fallow system does not sustain much crop productivity because of low nutrient availability, shortened fallow periods and shortage of land due to increased population. Thus, the bush-fallow system has been rendered unsustainable [4]. The bush fallow system was therefore replaced with the use of organic manures [5,6], mineral fertilizers [7] and combination of both organic manure and mineral fertilizer [8,9].

The application of foliar fertilizers was initiated a few years back with good results [10]. According to Rumbidzi and Justin [10] the high costs and environmental hazards caused by the use of mineral fertilizers increased the use of foliar fertilizers. These authors stated further that, the use of alternative fertilizer application strategies is essential to achieve maximum yields and to maximize the nutrient use efficiency which has been advocated for decades. Randall et al. [11] reported that foliar fertilizers act similarly as mineral fertilizers applied to the soil. A previous work [12] showed that direct application of P and potassium (K) to soybeans significantly improved the soybean yield. It has also been shown that in maize, liquid fertilizer applied as a band adjacent to the seeds at planting improves yield [13].

Hag and Mallarino [14] also suggested that a combination of broadcast and band applications coupled with foliar applications optimized nutrient uptake by crops in low fertile soils. Foliar nutrients are absorbed directly by the plant leaves, which is the goal of fertilization to begin with. It also increases the rate of photosynthesis and thereby also stimulates the absorption of nutrients by plant roots [15]. Based on their studies, Barel and Black [16] suggested that foliar fertilization is by far the most effective way to apply micro nutrients or trace elements, and supplement the major elements to the crops. According to them, the readily available nutrients in the foliar application are more easily utilized by the plants, because they need not dissolve in water or enter into the soil solution. In addition, foliar fertilization can correct nutrient deficiencies, strengthen weak or damaged crops, speed growth and grow better plants, which are of course, the bottom line [16].

Therefore the objective of the investigation was to compare the effect of soil basal granular NPK fertilization and its combination with liquid foliar fertilization on nutrients up-take and maize yield in two locations.

2. MATERIALS AND METHODS

The study was conducted in 2009 cropping season in two locations at the tropical rainforest agro-ecological zone of south-western Nigeria. The first location was the experimental station of the Institute of Agricultural Research and Training (IAR&T), Obafemi Awolowo University, Moor Plantation Ibadan located at Ikenne, Ogun state Nigeria; high rain forest agro-ecology (6.87°N, 3.72°E). The soil in Ikenne is classified as Oxic Haplustult [17]. Precipitation varies from 1500 to 1750mm annually, with most of the rainfall occurring in the wet season (April-October). The mean annual temperature is about 27ºC with high relative humidity (80%). The second location was on experimental farm of the Nigeria Institute for Oil Palm Research (NIFOR)

at Ikoga in the Badagry Local Government Area of Lagos State, Nigeria. The study area (6.42℃N, 2.88℃E), is situated in a low-lying coastal region with a general elevation of less than 20 m. The soil of Badagry is classified as Aquic Tropaquept [17]. Mean daily temperatures remain about 26° - 28℃. Mean annual rainfall is about 2000 mm with rainfall spreading throughout the year. The experimental plots were arranged in a randomized complete block design (RCBD) with three replications. The treatments were composed of the followings:

T1: 100 kgN/ha, 50 kgP/ha, 50 kgK/ha (NPK 20-10-10) + 3.5 L/ha Auxenol (5-5-9) + 2.5 L/ha Oligo-8Zn (12-0-0+8Zn) + 2.5 L/ha Oligo-8Mn (14-0-0+8Mn) applied at 1st leaves stage + 3.5 L/ha Operon (29-0-0) applied at tasselling stage.

T2: 80 kgN/ha, 40 kgP/ha, 40 kgK/ha (NPK 20-10-10) + 3.5 L/ha Auxenol (5-5-9) + 2.5 L/ha Oligo-8Zn (12-0-0+8Zn) + 2.5 L/ha Oligo-8Mn (14-0-0+8Mn) applied at 1st leaves stage + 3.5 L/ha Operon (29-0-0) applied at tasselling stage.

T3: 60 kgN/ha, 30 kgP/ha, 30 kgK/ha (NPK 20-10-10) + 3.5 L/ha Auxenol (5-5-9) + 2.5 L/ha Oligo-8Zn (12-0-0+8Zn) + 2.5 L/ha Oligo-8Mn (14-0-0+8Mn) applied at 1st leaves stage + 3.5 L/ha Operon (29-0-0) applied at tasselling stage.

T4: 40 kgN/ha, 20 kgP/ha, 20 kgK/ha (NPK 20-10-10) + 3.5 L/ha Auxenol (5-5-9) + 2.5 L/ha Oligo-8Zn (12-0-0+8Zn) + 2.5 L/ha Oligo-8Mn (14-0-0+8Mn) applied at 1st leaves stage + 3.5 L/ha Operon (29-0-0) applied at tasselling stage.

T5: Sole liquid fertilizers at 3.5 L/ha Auxenol (5-5-9) +2.5 L/ha Oligo-8Zn (12-0-0+8Zn) + 2.5 L/ha Oligo-8Mn (14-0-0+8Mn) applied at 1st leaves stage + 3.5 L Operon (29-0-0) applied at tasselling stage.

T6: Without fertilization (Control).

T7: Sole 100 kgN/ha, 50 kgP/ha, 50 kgK/ha (NPK 20-10-10) applied at 1st leaves stage + 46 kgN/ha (Urea 46% N) applied at tasselling stage.

Before planting, surface (0-15 cm) soil samples were collected using auger and bulked for analysis. The soil sample was air-dried and allowed to pass through 2 mm sieve. Analyses were carried out according to Juo [18]. The land was disc ploughed and harrowed to a fine tilt. Plots were marked just before planting in April, 2009. The plot size was 30 m^2 with rows of maize spaced at 0.75 m inter-row and 0.30 m intra-row at two plants per stand. Crop management practices included weed control with pre-emergence application of herbicide (Atrazine of 80% wettable powder). The herbicide was applied at the rate of 100 ml to 20 liters of water and was supplemented by one manual hoe weeding. The foliar application of the liquid fertilizers were carried out at 1st leaves (two weeks after planting), while the soil basal dressing of granular NPK 20-10-10 mineral fertilizer was carried out after the first weeding operation (four weeks after planting). At tasselling, liquid fertilizer (Operon (29-0-0) was applied to the necessary plots and granular Urea (46%) was applied to the necessary plots, both were applied as top dressing to boost the availability of nitrogen. For the control, no fertilizers were applied to the plots. At harvest (12 weeks after planting), 10 plants per plot were randomly selected to determine maize cob weight and grain yield (12% moisture content). For tissue analysis, four out of ten tagged plants per plot were uprooted and severed, placed in brown envelopes and dried in an oven at 75ºC to a constant weight. The dried plant samples were ground with a Willey mill to pass through 0.5 mm sieve and used for analysis. Total N was determined by Kjeldahl procedure [19]. The P and K contents were determined by ash method. The P concentration was determined by vanado-molybdate yellow colorimetric method [20]. Digested samples were diluted and used to determine the concentration of K using flame photometry [19]. Micronutrients (Mn and Zn) were determined by extracting with 0.1 N HCL and read using atomic absorption spectrophotometer. Concentrations of nutrients were expressed on the basis of percentage dry plant material. The nutrient uptake was computed by multiplying the respective grain/straw yield with nutrient contents and expressed as kg/ha. The nutrient uptake was calculated using the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (kg ha}^{-1}\text{) x Yield (kg ha}^{-1}\text{)}}{100}$$

The data collected were statistically analyzed using analysis of variance procedure [21]. Means were compared using Duncan Multiple Range Test (DMRT) at 5% level of probability.

3. RESULTS AND DISCUSSION

Table 1 shows the summary of the physical and chemical properties of the soils at Ikenne and Badagry. Sand accounts for 70 to 80% of the inorganic fragments of the soils, the soils are quite homogeneous texturally, being mainly sandy. The high proportion of sand in the soils may be attributed to the fact most of the soils in the area are developed on sandy ridges and deposits. The Ikenne soil pH was 5.1 while the Badagry soil pH was 4.9, the Ikenne and Badagry soils reaction was acid. Such low soil pH at Badagry could be attributed to the high rainfall specific to the coastal areas, which leaches the basic cations from the soil.

The basal application of granular NPK 20-10-10 mineral fertilizer along with foliar application of liquid fertilizer in Ikenne and Badagry significantly (*P = 0.05*) enhanced the tissue concentrations of N, P, K, Mn and Zn (Tables 2 and 3). Soil basal application of different levels of granular NPK 20-10-10 fertilizer combined with foliar application of liquid fertilizer improved the plant tissue nutrient concentrations than individual application of these fertilizers. Treatment that involved basal application of 100kg/ha granular NPK 20-10-10 fertilizer to soil combined with foliar application of liquid fertilizer resulted in the highest concentrations of N, P, K, Mg and Zn in maize tissue in both the soils. There were an increase in the micronutrient (Mn and Zn) concentrations in all the treatments that involved foliar application of the liquid fertilizer compared to sole application of granular NPK 20-10-10 fertilizer in Ikenne and Badagry (Tables 2 and 3). This might be related to the Mn and Zn content in the applied foliar liquid fertilizer, therefore, it is ascertained that the applied foliar liquid fertilizer released both the macro and micro nutrients for maize growth and development.

Table 1. Pre-planting physio-chemical characteristics of the top soil (0-15cm) at the experimental sites

	Ikenne	**Badagry**
Sand (%)	76.6	80.6
Silt (%)	10.9	8.9
Clay (%)	12.4	10.4
Organic C (%)	0.8	0.2
Total N (%)	0.08	0.02
Available P (ppm)	7.1	5.8
Exchangeable K (me/100 g)	0.1	0.1
Exchangeable Ca (me/100 g)	1.3	1.2
Exchangeable Mg (me/100 g)	0.6	0.6
Exchangeable Na (me/100 g)	0.6	0.6
Exchangeable H+ (me/100 g)	0.6	0.7
Exchangeable Cation Exchange Capacity (ECEC) (me/100g)	5.0	3.1
Available Zn (ppm)	4.9	5.5
Available Fe (ppm)	11.2	12.1
Available Cu (ppm)	1.8	1.9
p^H (H_2O)	5.9	4.1

Table 2. Effect of different fertilizer types and levels on nutrient concentration in maize from Ikenne experimental site

Treatment	**N**	**P**	**K**	**Mn**	**Zn**
	<---------	**--%--**	**--------->**	**< ----- mgkg^{-1} ----- >**	
T1 - 100kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	1.78a	0.66a	1.76a	17.7a	57.9a
T2 - 80kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	1.64a	0.59a	1.65a	16.6a	50.3a
T3 - 60kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	1.56a	0.47a	1.59a	14.4a	48.9a
T4 - 40kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	1.29b	0.28c	1.30d	10.4c	35.7b
T5 - Sole *Liquid folia fertilizer products	0.64c	0.22d	0.96c	12.5c	32.5b
T6 – Sole100kg/ha N, P, K (20-10-10)	1.21b	0.35b	1.42b	08.3d	22.8c

Means in a column followed by the same letter(s) are not significantly different according to DMRT (P = 0.05)
** Auxenol (5-5-9) + Oligo-8Mn (14-0-0-8Mn) + Oligo 8Zn (12-0-0-8Zn) + Operon (29-0-0)*

Table 3. Effect of different fertilizer types and levels on nutrient concentration in maize from Badagry experimental site

Treatment	N	P	K	Mn	Zn
	<---------	--%--	-------->	< ----- mgkg-^{1} ----- >	
T1 - 100kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	1.72a	0.68a	1.74a	18.7a	55.5a
T2 - 80kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	1.65a	0.66a	1.61a	16.9a	52.1a
T3 - 60kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	1.53a	0.57a	1.57a	15.4a	42.5a
T4 - 40kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	1.26b	0.30c	1.32d	11.8c	33.2b
T5 - Sole *Liquid folia fertilizer products	0.78c	0.22d	0.99c	12.1c	31.6b
T6 – Sole100kg/ha N, P, K (20-10-10)	1.23b	0.37b	1.46b	08.7d	20.3c

Means in a column followed by the same letter(s) are not significantly different according to DMRT (P = 0.05)
** Auxenol (5-5-9) + Oligo-8Mn (14-0-0-8Mn) + Oligo 8Zn (12-0-0-8Zn) + Operon (29-0-0)*

Table 4. Effect of different fertilizer types and levels on nutrient uptake (kgha^{-1}) in maize from Ikenne experimental site

Treatment	N	P	K
	<----------	kgha^{-1}	---------- >
T1 - 100kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	144.2a	53.5a	142.6a
T2 - 80kg/ha N, P, K (20-10-10) *Liquid folia fertilizer products	121.4a	47.7a	122.1a
T3 - 60kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	109.2a	32.9b	111.3a
T4 - 40kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	79.9b	17.4c	80.6b
T5 - Sole *Liquid folia fertilizer products	32.6c	11.2d	48.9c
T6 – Sole100kg/ha N, P, K (20-10-10)	66.6b	19.3c	78.1b

Means in a column followed by the same letter(s) are not significantly different according to DMRT (P = 0.05)
** Auxenol (5-5-9) + Oligo-8Mn (14-0-0-8Mn) + Oligo 8Zn (12-0-0-8Zn) + Operon (29-0-0)*

Table 5. Effect of different fertilizer types and levels on nutrient uptake (kgha^{-1}) in maize from Badagry experimental site

Treatment	N	P	K
	<----------	kgha^{-1}	---------- >
T1 - 100kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	118.7a	46.9a	120.1a
T2 - 80kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	99.0a	39.6a	96.6a
T3 - 60kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	87.2a	32.5a	89.5a
T4 - 40kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	60.5b	14.4b	63.4b
T5 – Sole *Liquid folia fertilizer products	31.2c	8.8c	39.6c
T6 – Sole100kg/ha N, P, K (20-10-10)	51.7b	15.5b	61.3b

Means in a column followed by the same letter(s) are not significantly different according to DMRT (P = 0.05)
** Auxenol (5-5-9) + Oligo-8Mn (14-0-0-8Mn) + Oligo 8Zn (12-0-0-8Zn) + Operon (29-0-0)*

The N, P and K uptake by maize was significantly influenced by soil basal application of granular NPK 20-10-10 fertilizer combined with foliar application of liquid fertilizer in both Ikenne and Badagry (above Tables 4 and 5). There were an increase in the uptake of N, P, and K by maize plants fertilized with 100, 80 and 60 kg/ha of granular NPK 20-10-10 mineral fertilizer combined with foliar application of liquid fertilizer compared to the application of sole liquid fertilizer and sole granular 100 kg/ha NPK 20-10-10 fertilizer in both the soils. Therefore, it has been ascertained that a combination of broadcast and band applications coupled with folia applications could provide optimum nutrients uptake in soils of low fertility [14].

Application of granular NPK mineral fertilizer at different levels combined with foliar fertilizer significantly increased maize cob weight (P = 0.05) than either individual application of these fertilizers in both the locations (Table 6). At Ikenne, the increase in cob weight due to the soil application of granular NPK fertilizer at different levels along with foliar fertilization was 13-48% compared to sole application of the granular fertilizer. While at Badagry, the increase in cob weight due to the combined application of granular NPK fertilizer and foliar fertilizer was 14 - 64% higher than the sole application of the granular fertilizer.

Soil basal application of NPK 20-10-10 granular fertilizer at different levels combined with foliar

application of liquid fertilizer resulted in significantly (*P =0 .05*) higher maize grain weight than individual application of these fertilizers in both the locations (Table 7). At Ikenne, the grain weight increase in response to dual application of granular and foliar fertilizers was 16-60% compared to the sole application of the granular fertilizer. While at Badagry, the seed weight increases in response to dual application of granular and foliar fertilizers was 17–48% compared to the sole application of the granular fertilizer. Hag and Mallarino [14] indicated that, a combination of broadcast and band application coupled with foliar application can optimize the nutrient uptake by crops in low soil fertility conditions. However, under current reduced tillage systems advocated for increasing crop yields, broadcasted nutrients can remain on the wheel traffic compacted soil surface limiting its availability to the roots [22]. This means that alternative strategies must be considered [23]. Rumbidzai and Justin [10] suggested that this may be corrected through some combination of starter and foliar fertilizer application, fertilizer rate adjustment of both macro and micronutrients.

Table 6. Effect of different fertilizer types and levels on maize cob weight at Ikenne and Badagry experimental sites

Treatments	Maize cob weight at Ikenne (t/ha)	Difference as compared with sole NPK at Ikenne (%)	Maize cob weight at Badagry (t/ha)	Difference as compared with sole NPK at Badagry (%)
T1 - 100kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	8.1a	+47.3	6.9a	+64.3
T2 - 80kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	7.4ab	+34.6	6.0abc	+42.9
T3 - 60kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	7.0abc	+27.3	5.7abc	+35.7
T4 - 40kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	6.2cd	+12.7	4.8bc	+14.3
T5 – Sole *Liquid folia fertilizer products	5.1e	-7.3	4.0b	-4.8
T6 – No treatments	3.9f	-29.1	2.9d	-30.9
T7 – Sole100 kg/ha N, P, K (20-10-10)	5.5e	-	4.2bc	-

Means in a column followed by the same letter(s) are not significantly different according to DMRT (P = 0.05)
** Auxenol (5-5-9) + Oligo-8Mn (14-0-0-8Mn) + Oligo 8Zn (12-0-0-8Zn) + Operon (29-0-0)*

Table 7. Effect of different fertilizer types and levels on maize grain weight at Ikenne and Badagry experimental sites

Treatments	Maize grain weight at Ikenne (t/ha)	Difference as compared with sole NPK at Ikenne (%)	Maize grain weight at Badagry (t/ha)	Difference as compared with sole NPK at Badagry (%)
T1 - 100kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	4.0a	+60	3.4a	+47.8
T2 - 80kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	3.8ab	+52	3.3a	+43.5
T3 - 60kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	3.6ab	+44	3.4a	+47.8
T4 - 40kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	2.9c	+16	2.7ab	+17.4
T5 – Sole *Liquid folia fertilizer products	2.5cd	0	2.3b	0
T6 – No treatments	1.0e	-60	1.4c	-39.1
T7 – Sole100 kg/ha N, P, K (20-10-10)	2.5cd	-	2.3b	-

Means in a column followed by the same letter(s) are not significantly different according to DMRT (P = 0.05)
** Auxenol (5-5-9) + Oligo-8Mn (14-0-0-8Mn) + Oligo 8Zn (12-0-0-8Zn) + Operon (29-0-0)*

Table 8. Effect of different fertilizer types and levels on maize dry matter yield (g/plant) at Ikenne and Badagry experimental sites

Treatments	Maize dry matter yield at Ikenne (g/plant)	Difference as compared with sole NPK at Ikenne (%)	Maize dry matter yield at Badagry (g/plant)	Difference as compared with sole NPK at Badagry (%)
T1 - 100kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	3.64a	+25.9	3.53a	+29.7
T2 - 80kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	3.52a	+21.7	3.36a	+23.5
T3 - 60kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	3.47ab	+20.1	3.28ab	+20.5
T4 - 40kg/ha N, P, K (20-10-10) + *Liquid folia fertilizer products	3.07b	+6.2	2.88b	+5.8
T5 – Sole *Liquid folia fertilizer products	2.24c	-22.4	2.37c	-12.8
T6 – No treatments	1.95d	-32.5	1.53d	-43.7
T7 – Sole100 kg/ha N, P, K (20-10-10)	2.89c	-	2.72b	-

Means in a column followed by the same letter(s) are not significantly different according to DMRT (P = 0.05)
** Auxenol (5-5-9) + Oligo-8Mn (14-0-0-8Mn) + Oligo 8Zn (12-0-0-8Zn) + Operon (29-0-0)*

Soil application of granular NPK fertilizer at different levels combined with foliar fertilizer application significantly (*P = 0.05*) increased the maize dry matter yield than individual application of either NPK 20-10-10 mineral granular fertilizer or foliar fertilizer at both the locations (above Table 8). At Ikenne, the increase in maize biomass due to the combined application of granular and foliar fertilizers was 6- 26% compared to the sole application of the granular fertilizer. While at Badagry, the biomass increase in response to the application of granular fertilizer along with foliar fertilizer was 6–30% compared the sole application of the granular fertilizer.

4. CONCLUSION

The results of the study have shown that the foliar application of the liquid fertilizer cannot compete equally with the basal applied granular mineral fertilizer since the yields obtained were far less than those of the soil applied mineral fertilizer. From the results of this study farmers can be recommended to use the foliar liquid fertilizer as a nutrient supplement rather than as the basic fertilizer as envisaged. More research needs to be carried out with various application periods (early and late maize) of the foliar fertilizer than the application to the early maize production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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