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The Effect of Inorganic Fertilizer and Liquid Fertilizer Applications on the Growth and Yield of Maize (*Zea Mays* L.) in Makurdi, Nigeria

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Abstract

The study was conducted at the Teaching and Research Farm, Joseph Sarwuan Tarka University Makurdi (JOSTUM), Nigeria, during the late growing seasons of 2023 and 2024 to evaluate the effects of different fertilizer combinations on the growth and yield of maize. The study adopted randomized complete block design (RCBD) with five treatments: NPK (200kg/ha), NPK (200kg/ha) and AgriLife AgriBoom(1ltr/ha), NPK (200kg/ha) and AgriLife AgriBoom (2ltr/ha), AgriLife AgriBoom(3ltr/ha) and NPK (200kg/ha) and Urea (100kg/ha) as control). Data was investigated using two-way ANOVA, and means were compared employing the Least Significant Difference (LSD) test at P ≤ 0.05. The study found no significant differences in days to 50% tasseling and silking across treatments. However, significant differences were observed in plant height, ear height, number of leaves, and leaf area index at eight weeks after planting. NPK (200kg/ha) and Urea (100kg/ha) recorded the highest values for these growth parameters, followed by (200kg/ha NPK) and NPK (200kg/ha), and AgriLife AgriBoom (2ltr/ha), while AgriLife AgriBoom(3ltr/ha) performed the lowest. Yield parameters such as cob yield, grain yield, biomass weight, harvest index, and shelling percentage showed significant differences among treatments. NPK (200kg/ha) and Urea (100kg/ha) outperformed all other treatments, while AgriLife AgriBoom(3ltr/ha) recorded the lowest yield. Although the number of lines per cob showed no statistical difference, NPK with Urea still recorded the highest values. No significant seasonal effect was observed between the 2023 and 2024 trials. The study concluded that split application of NPK (200kg/ha) and Urea (100kg/ha) significantly enhances maize yield and is more effective than NPK blends or liquid fertilizer alone. For resource-limited farmers, NPK (200kg/ha) and AgriLife AgriBoom(2ltr/ha) is a cost-effective alternative. The study recommends adopting NPK (200kg/ha) and Urea (100kg/ha) or NPK (200kg/ha) and AgriLife AgriBoom(2ltr/ha) for optimal maize yield in Makurdi.

Keywords: *Maize, NPK, Urea, Agriboom, growth and yield*

1.0 INTRODUCTION

Soil nutrient depletion is a global environmental issue that poses significant threats to food security and soil health [21]. It refers to the decline in soil organic matter and essential nutrient levels [28, 21], which can result in decreased crop productivity and the degradation of arable land. To guarantee sustained agricultural output and protect the environment, it is crucial to maintain and enhance soil quality [17].

Maize production in Africa's sub-Saharan region has been significantly constrained by a variety of factors, with climate change and declining soil fertility being the most notable challenges. Among these, poor soil fertility stands out as the most persistent and pressing issue that has plagued the region for decades. This persistent degradation of soil health has played a central role in exacerbating food insecurity, as reflected in the steadily decreasing food production per capita, especially among smallholder farmers [24, 4, 19, 21, 7]. The causes of low soil fertility in SSA are multifaceted, involving both human-induced and natural processes. Human activities such as overgrazing, widespread deforestation, and uncontrolled removal of vegetation have contributed to soil degradation. Additionally, natural processes such as wind and water erosion play a significant role, stripping away vital nutrients like nitrogen and phosphorus from the soil. Leaching, particularly of nitrogen and potassium, due to heavy rainfall or poor soil structure, also contributes to nutrient losses in tropical regions, including SSA [33]. Furthermore, unsustainable agricultural practices especially the frequent use of continuous cropping systems without proper soil management have led to progressive nutrient depletion. The situation is worsened by the limited or incorrect use of fertilizers, which fails to replenish the lost nutrients effectively. These practices collectively diminish soil productivity and threaten the long-term sustainability of agriculture in the region [6].

Fertilizers, whether organic or inorganic, are substances applied to soil to provide essential nutrients that support plant growth and enhance soil health [5]. Their use has become a vital agricultural practice, significantly boosting crop productivity and encouraging the adoption of other sustainable farming methods. Consequently, fertilizer application is now a central component of many agricultural development programs across the globe [7]. According to [22], improving soil fertility is fundamental for increasing agricultural output. Enhanced soil fertility not only contributes to greater food security but also boosts farmers' incomes. To address nutrient loss in soils, it is essential to apply fertilizers, either organic or inorganic, in proper quantities and using the correct techniques [2, 21, 7].

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Researchers have extensively explored the use of various soil amendments as a strategy to combat declining fertility [34, 16, 25]. Inorganic fertilizers are known to improve crop yields, adjust soil pH, raise total nutrient levels, and increase nutrient availability. On the other hand, organic fertilizers such as animal manure enhance soil structure and maintain long-term fertility, especially under continuous cropping systems like maize cultivation [26].

Maize (*Zea mays*) is a vital staple crop in sub-Saharan Africa (SSA) and is considered the most significant cereal in the region, with Nigeria leading as the top maize producer on the continent [14]. Over time, maize has gained prominence, gradually replacing traditional grains like millet and sorghum in many areas [19]. In 2018, Nigeria produced approximately 10.2 million tons of maize from 4.8 million hectares of farmland, positioning it as Africa's largest maize producer [11]. Advances in agricultural research have contributed to the development of improved technologies, including high-yielding maize varieties with resistance to drought, diseases, low soil nitrogen, and parasitic weeds like *Striga* [20, 19, 7]. However, despite the availability of these improved varieties, maize yields in Nigeria's savanna regions remain low. This is largely due to declining soil fertility, a result of increasing pressure on land resources driven by population growth and limited fertilizer application [19]. Soils in these regions are often depleted of essential macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as important micronutrients like copper and zinc. Without adequate fertilization, the soil cannot support sustainable maize production, and yields may drop below 1 ton per hectare [10, 19, 7]. Given the strategic importance of maize, it is crucial to sustain its production at sufficient levels to support food security and self-sufficiency at both household and national scales [30]. To achieve this, efforts must be directed toward enhancing maize productivity by improving the soil's physical and chemical properties. This improvement can be accomplished through the adoption of effective farming practices, including the application of suitable fertilizers and the implementation of sound agronomic techniques. In light of this, the present study assessed the effectiveness of combining inorganic fertilizers with liquid fertilizer foliar sprays in influencing the growth and yield performance of maize cultivated in Makurdi, located within Nigeria's Southern Guinea Savannah ecological zone.

2.0 MATERIALS AND METHODS

2.1 Experimental Site

The study was carried out at Joseph Sarwuan Tarka University Makurdi's (JOSTUM) Teaching and Research Farm in Nigeria during the late seasons (August to November) of 2023 and 2024. The research location, located at latitude 7.41°N and longitude 8.28°E, is 98 meters above sea level in the Southern Guinea Savannah 'agro-ecological' zone of equatorial Nigeria'.

2.2 Experimental Treatments and Design

The experiment was conducted on a manually cleared field. A drought-tolerant maize variety, EVGT 2009, sourced from the Institute of Agricultural Research and Training in Zaria, was used. Fertilizers applied included NPK 20:10:10, Urea, and AgriBoom liquid fertilizer obtained from the registered agro-dealer in Makurdi. The study employed a randomized complete block design with five treatments: NPK (200kg/ha), NPK (200kg/ha) and AgriLife AgriBoom(1ltr/ha), NPK (200kg/ha) and AgriLife AgriBoom(2ltr/ha), AgriLife AgriBoom(3ltr/ha), and NPK (200kg/ha) and Urea (100kg/ha) as control and each treatment was replicated three times. Maize was planted at three seeds per hill, spaced 75 x 50 cm, and thinned to two plants per hill two weeks after sowing (WAS), targeting 53,333 plants per hectare. NPK was applied two weeks after planting, AgriLife AgriBoomliquid fertilizer foliar application at 4 weeks, 6 weeks, and 8 weeks after planting weeks after planting. Manual weeding was done at 3 and 6 WAS. All other agronomic practices were done when at various stages of the work. Pre-cropped soil samples were collected immediately before the planting season.

2.3 Analysis of soil properties

The following physical and chemical properties of the sampled soil were determined using standard methods [29]. The Dwyer model WPH1 waterproof pH tester was used to measure the pH of the soil in a 1:1 soil-to-water solution. The hydrometer technique was used to determine the particle size distribution. The Walkley and Black technique was used to calculate the organic carbon content of the soil. As an extractant, 1 M ammonium acetate buffered at pH 7.0 was used to identify the exchangeable cations. A Perkin-Elmer Model 403 atomic absorption spectrophotometer (AAS) was used to measure the concentrations of Ca^{2+} and Mg^{2+} in the soil extracts, while a Gallenkamp flame photometer was used to measure the amounts of K^+ and Na^+ in the soil. Exchangeable acidity was determined by the titration method after extraction with KCl. Total nitrogen was determined using macro- Kjedahl method. Available phosphorus was determined by the ascorbic acid molybdate blue method as described by Murphy and Riley. Micronutrients (Zn, Mn, Cu, B, and Fe) were extracted using 0.1 M HCl [18], and their concentrations in the soil extracts were read on the AAS.

2.4 Data Collection

The following parameters were collected during the study period;

Days to 50% tasselling: the period of time from seeding until at least 50% of the plants in a plot have tasseled. Days to 50% silking is the amount of time that passes between seeding and the silking of at least 50% of the stand plants in a plot. Ear length (cm): 8WAP Each plot included ten tagged ears, each of whose length was measured using a measuring tape from base to tip and reported in cm. Eight weeks after planting (8WAP), 10 plants were tagged in each plot, and the height of each plant was measured from the base to the flag leaf. For data analysis, the average height of the plants was employed. The calculation of the Leaf Area Index (LAI) involved dividing the total area of leaves by the land area. At the conclusion of the experiment, the biomass yield for every plot was determined using a weighing scale. Measurements were also made of the cob diameter, weight, length, and number of lines each row. Grain yield was divided by biomass weight to determine the harvest index (HI). A digital scale was used to measure the 100-grain weight, and a scale was used to quantify the total grain yield from each plot at less than 15% moisture content.

2.5 Statistical analysis

Growth and yield data were accurately recorded and analyzed using two-way ANOVA in GENSTAT software. Significant differences among treatment means were compared using the Least Significant Difference (LSD) test at a 5% probability level ($P \leq 0.05$). Results were presented in tables.

3.0 RESULTS AND DISCUSSION

3.1 Experimental site

The soil texture was sandy loam with 71.60%, 13.20%, and 21.20% of sand, clay, and silt, respectively (Tab. 1). The soil pH (1:1 soil-H_2O) of the experimental site was 6.18, indicating an alkaline condition. Other soil properties included: 1.34% of organic carbon, 0.09% of total nitrogen, Ca^{2+} and Mg^{2+} predominate, with 3.61 mg kg^{-1} of accessible phosphorus and 7.20 cmol kg^{-1} of cation exchange capacity. In this study, the soil organic carbon and total nitrogen are considered low, according to the ratings of the Developing Agri-input Markets in Nigeria (DAIMINA) [32] cited in [21]. However, it may not be adequate for optimum production of maize, as the low grain yield of maize is the current realizable scenario by most resource-poor Nigerian farmers [14]. [31], [21], and [23] worked extensively on nutrient requirements for enhanced grain yield of maize in Nigeria and Brazil, respectively. These authors observed that near-moderate soil organic matter can be related to the inherently high sandy nature of the parent material and low capacity to store carbon. This could also be the reason for low total N and cation exchangeable capacity, as soil organic carbon plays a vital role in soil fertility maintenance. Similar findings have been reported by [15] working on cowpea in Makurdi, southern Guinea 'agro-ecological' zones of Nigeria'.

Table 1: Characteristics of the experimental site's soil, both physically and chemically, prior to planting

Parameters	Quantity in soil
Physical properties	
Sand (%)	71.60
Clay (%)	13.20
Silt (%)	21.20
Textural Class	Sandy loam
pH (H_2O)	6.18
Chemical Properties	
Organic carbon (%)	1.34
Organic Matter (%)	2.46
Total Nitrogen (%)	0.09
Available P (Mgl^{-1})	3.61
K ($Cmol/kg^{-1}$)	0.23
Na ($Cmol/kg^{-1}$)	0.18
Mg ($Cmol/kg^{-1}$)	2.23
Ca ($Cmol/kg^{-1}$)	2.61
TEB ($Cmol/kg^{-1}$)	6.10
EA ($Cmol/kg^{-1}$)	1.10
CEC ($Cmol/kg^{-1}$)	7.20
BS (%)	88.70

3.2 Effect of Different Fertilizer Treatment Combinations on the growth Parameters of Maize grown under two seasons in Makurdi, Nigeria

The results in Table 2 showed no significant difference in tasseling and silking days to 50% for various fertilizer combinations. However, there were notable differences in ear height, plant height, number of leaves, and leaf area index (LAI) at 8 weeks after planting, with the NPK (200kg/ha) and Urea (100kg/ha) combination showing the best performance. This was followed by NPK (200kg/ha) alone and NPK (200kg/ha) and AgriLife AgriBoom(2ltr/ha), while AgriLife AgriBoom(3ltr/ha) produced the lowest growth parameters. The differences among the fertilizer treatments were statistically significant. When comparing the two seasons, there were no significant variations across all growth parameters. Similar trends were seen in the interaction effects (Table 4). The NPK (200kg/ha) and Urea (100kg/ha) combination resulted in significantly higher growth parameters for maize during both cropping seasons due to its ability to release nutrients more quickly than most organic fertilizers, leading to better maize growth and yield. This finding supports the work of [21] who noted that NPK fertilizers are highly effective in boosting grain yield. [36] also highlighted that Nigerian savanna soils are particularly deficient in nitrogen (N) and phosphorus (P), which negatively impact maize productivity, and recommended combining N and P fertilizers for optimal maize growth and yield. Other studies have found that such fertilizer combinations significantly improve maize growth and yield in Nigerian savannas. [1] suggested that after applying chicken manure, split-applying urea according to plant development patterns is recommended in line with plant growth patterns to prevent nutrient loss due to leaching. [3] reported that AgriBoom fertilizer applied at 4000ml/ha achieved the highest values for onions in Sokoto. [8] also found that combining Biofertilizer with NPK substantially improved vegetative growth in Gladiolus crops.

Table 2: Effect of Different Fertilizer Treatment Combinations on the growth Parameters of Maize grown under two seasons in Makurdi, Nigeria

Fertilizer Treatments	D50%T	D50%S	Ear Height (cm)	Plant Height (cm)	Number of Leaves @8WAP	Leaf Area Index @8WAP
3SP	58.00	63.67	66.00	140.00	12.17	1.31
NPK	58.00	63.67	79.67	176.33	13.67	1.80
NPK/1SP	58.00	63.50	72.33	154.33	13.00	1.76
NPK/UREA	57.67	64.50	92.67	193.00	15.67	2.39
NPK/2SP	57.33	64.67	76.67	163.33	13.67	2.10
F-LSD (P≤0.05)	NS	NS	5.92	13.16	0.97	0.58
Season (Yr)						
2023	57.80	64.33	76.87	164.60	13.57	1.87
2024	57.33	63.27	78.20	166.00	13.70	1.87
F-LSD (P≤0.05)	NS	0.58	NS	NS	NS	NS

D50%T = 'Days to 50% Tasseling; D50%S = 'Days to 50% Silking; 'WAP = Weeks after planting; NS = Not significant at 5% level of significant; 3SP = (3ltr/ha Agriboom); 2SP = (2ltr/ha Agriboom); 1SP = (1ltr/ha Agriboom)

3.2 Effect of Different Fertilizer Treatment Combinations on the yield Parameters of Maize grown under two seasons in Makurdi, Nigeria

Table 3 presents the yield results from the experiment, showing significant differences in cob weight, cob diameter, and cob yield among the various fertilizer treatments. The NPK/Urea combination achieved the highest cob yield, followed by NPK (200kg/ha) and NPK (200kg/ha) and AgriLife AgriBoom (1ltr/ha), while AgriLife AgriBoom (3ltr/ha) produced the lowest cob yield. Although there was no statistically significant difference in the number of lines per cob, NPK (200kg/ha) and Urea (100kg/ha) had the highest number of lines per cob, and AgriLife AgriBoom(3ltr/ha) had the fewest. Similarly, grain yield and biomass weight followed the same trend, with NPK (200kg/ha) and Urea (100kg/ha) yielding the highest, followed by NPK (200kg/ha) and NPK (200kg/ha) and AgriLife AgriBoom(2ltr/ha), while AgriLife AgriBoom (3ltr/ha) resulted in the lowest grain yield and biomass weight, with a statistically significant difference between the treatments. Harvest index and shelling percentage showed similar patterns to grain yield and biomass weight, with significant differences among the treatment combinations. The season (year) did not significantly affect the yield parameters of maize in Makurdi.

The interaction table (Table 4) also showed no significant differences among the treatment combinations. Studies indicate that the timely application of balanced fertilizers promotes plant growth, leading to taller, greener plants, robust growth, and higher yields. This is supported by [35], who found that applying NPK at 240 kg/ha at 2 weeks after sowing (WAS) and urea at 46% at 6 WAS where optimal for boosting maize yield. [9] concluded that fertilizing onion plants with farmyard manure and Agrispon sprays increased onion yield. Similar results were reported by [3] in Sokoto, Nigeria, using AgriBoom fertilizers. According to [27], biofertilizers can positively impact growth by promoting nitrogen fixation, increasing growth-promoting chemicals, and enhancing nutrient absorption. [12] shown that growth regulators including auxins, cytokinins, and gibberellins are produced by biofertilizers and enhance nutrient absorption and root biomass formation. These findings align with [8] and [13], who reported that biofertilizer EM1 combined with NPK improved the growth and mineral fertilization of Gladiolus. Additionally, [36] and [25] emphasized that Nigerian savanna soils are deficient in nitrogen and phosphorus, which negatively impacts maize productivity, and recommended applying both N and P fertilizers for optimal maize growth and yield.

Table 3: Effect of Different Fertilizer Treatment Combinations on the Yield Parameters of Maize grown under two seasons in Makurdi, Nigeria

Fertilizer Treatments	Biomass Weight (kg/ha)	Cob Diameter (cm)	Cob Length (cm)	Cob Weight (kg/ha)	No. of Lines/Cob	Grain Yield (kg/ha)	Harvest Index (%)	Shelling (%)
3SP	1778.83	10.53	9.98	1033.17	12.33	732.33	30.88	70.66
NPK	2908.17	11.33	10.67	2185.17	13.33	1822.33	40.36	83.67
NPK/1SP	2984.17	11.73	9.97	1518.83	13.67	1248.17	30.62	82.45
NPK/UREA	4155.17	13.06	14.48	2588.83	14.50	2302.17	39.19	88.88
NPK/2SP	3067.83	10.56	11.51	1790.50	13.00	1413.83	32.22	79.06
F-LSD (P≤0.05)	802.90	1.44	1.59	251.92	NS	88.79	6.58	7.26
Season (Yr)								
2023	3008.73	11.28	11.26	1844.80	13.20	1554.13	35.73	82.97
2024	2948.93	11.61	11.39	1801.80	13.53	1453.40	33.58	78.91
F-LSD (P≤0.05)	NS	NS	NS	NS	NS	NS	NS	NS

'NS = 'Not significant at 5% 'level of significant; 3SP = (3ltr/ha Agriboom); 2SP = (2ltr/ha Agriboom); 1SP = (1ltr/ha Agriboom)

4.0 CONCLUSION

This study demonstrates that improving fertilizer delivery strategies, particularly split applications of mixed fertilizers, may greatly improve maize yields and economic returns in Makurdi, Nigeria. The split application of NPK (200 kg/ha) and Urea (100 kg/ha) resulted in greater maize yields than NPK blends and AgriLife AgriBoom liquid fertilizer applied alone, making it effective for achieving optimal maize production. The research also indicated that farmers who are unable to pay for fertilizers due to their high cost can improve maize yield by combining NPK (200kg/ha) and AgriLife AgriBoom(2ltr/ha). For optimal maize production, the study recommends that farmers use NPK (200kg/ha) and Urea (100kg/ha) or NPK (200kg/ha) and AgriLife AgriBoom(2ltr/ha) fertilizers.

Conflict of interest statement: The authors confirm that there is no conflict of interest concerning the publication of this article.

Author's contributions: IT, UTR, and MP designed the experiments. The research method was carried out by UTR and MP, who performed the experiments and collected the data, analyzed the study data using statistical techniques, and wrote the original paper. IT directed and led the design and implementation of research activities, as well as ensuring the overall replication/reproducibility of results/experiments and other research outcomes. IT and MP also reviewed the text. All authors reviewed the final version of the text.

Table 4: Interaction Effect of Different Fertilizer Treatment Combinations on the Growth and Yield Parameters of Maize grown under two seasons in Makurdi, Nigeria

Season (Yr)	Fertilizer Treatments	D50% T	D50% S	Ear Hgt (cm)	PlH (cm)	NOL @ 8WAP	LAI @ 8WAP	BM (kg/ha)	Cob Diam (cm)	Cob Len (cm)	Cob Wgt (kg/ha)	NLPCB	GY (kg/ha)	HI (%)	Shelling (%)
2023	3SP	58.00	64.33	61.00	131.00	12.17	1.31	1873.67	10.53	8.82	1064.67	12.67	797.33	31.41	74.15
	NPK	58.00	64.33	79.33	175.67	13.33	1.80	2919.67	11.33	10.67	2133.33	13.67	1826.00	41.39	86.03
	NPK/1SP	58.00	64.00	72.67	161.67	13.00	1.76	2995.67	11.57	9.97	1583.67	13.67	1337.00	32.28	85.09
	NPK/UREA	57.67	64.67	94.67	192.00	15.67	2.39	4166.67	13.06	15.32	2653.67	13.00	2391.00	40.57	90.11
	NPK/2SP	57.33	64.33	76.67	162.67	13.67	2.10	3088.00	9.89	11.52	1788.67	13.00	1419.33	32.99	79.48
2024	3SP	58.00	63.00	71.00	149.00	12.17	1.31	1684.00	10.53	11.15	1001.67	12.00	667.33	30.44	67.16
	NPK	58.00	63.00	80.00	179.00	14.00	1.80	2896.67	11.33	10.67	2237.00	13.00	1818.67	39.33	81.31
	NPK/1SP	58.00	63.00	72.00	147.00	13.00	1.76	2972.67	11.91	9.97	1454.00	13.67	1159.33	28.96	79.81
	NPK/UREA	57.67	64.33	90.67	194.00	15.67	2.39	4143.67	13.06	13.65	2524.00	16.00	2213.33	37.82	87.66
	NPK/2SP	58.00	63.00	77.33	164.00	13.67	2.10	3047.67	11.22	11.51	1792.33	13.00	1408.33	31.45	78.63
F-LSD (P≤0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

D50%T = 'Days to 50% Tasseling; D50%S = Days to 50% Silking; 'WAP = Weeks after planting; NS = 'Not significant at 5% level of significant; NOL = Number of Leaves; PlH = Plant Height; Hgt = Height; BM = Biomass Weight; Diam = Diameter; Len = Length; Wgt = Weight; NLPCB = Number of Lines per cob; GY = Grain Yield; HI = Harvest index; 3SP = (3ltr/ha Agriboom); 2SP = (2ltr/ha Agriboom); 1SP = (1ltr/ha Agriboom)

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