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OPTIMIZING YIELD, NITROGEN UPTAKE AND NITROGEN USE EFFICIENCY IN FLUTED PUMPKIN THROUGH FERTILIZER MICRODOSING

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Abstract: Due to severely weathered soils and copious amounts of rainfall, the timing and rate of fertilizer application to enhance yields, nitrogen use efficiency, and recovery of fluted pumpkin (*Telfairia occidentalis*) have been key concerns in southwestern Nigeria. The experiment was conducted using a 2 x 2 x 5 randomized complete block split plot design (RCBSPD) with four varieties. Ilesa and Ogbomoso made up the main plot, whereas the timing of urea fertilizer application and the five nitrogen levels 0, 20, 40, 60, and 80 kg ha^{-1} made up sub-plots. The base application of 5 tons ha^{-1} of organic fertilizer was added (0, 20, 40, 60 kg ha^{-1}) a week prior to planting. We calculated the biomass yield, recoveries, and nitrogen utilization efficiency. Regarding control, 20, 80 (kg N ha^{-1}) urea, the fresh yields in tons ha^{-1} were 7.7, 9.4, 10.7, and 3.3, 8.3, 9.5 (kg N ha^{-1}) for Ilesa and Ogbomoso, respectively. The highest nitrogen use efficiency (60.26 kg N ha^{-1}) was obtained at the rate of 40 kg N ha^{-1} in Ilesa, and at the rate of 20 kg N ha^{-1} (61.91 kg N ha^{-1}) in Ogbomoso. A higher fresh yield was obtained in Ilesa compared to the yield in Ogbomoso. It was determined that the best method for producing fluted pumpkin in southwestern Nigeria was to combine 5 tons of organic fertilizer with a microdosing of 20 to 40 kg N ha^{-1} as urea.

Key words: *Telfairia occidentalis,* biomass, fertilizer, microdosing.

Introduction

A suggested minimum daily consumption of 400 grams of fruits and vegetables has been indicated by Nishida et al. (2004) as a means to promote good health and general well-being. The fluted pumpkin, a native vegetable, is consumed

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by economically weaker women in southwestern Nigeria as a means to fulfil their usual vegetable intake. This vegetable serves as a source of essential minerals, vitamins and proteins, compensating for their limited access to foods rich in essential nutrients such as eggs, meat, milk, etc. Marketing of the indigenous vegetables also helps farmers in income generation (Gupta et al., 2011). However, most of the indigenous vegetables are collected from the natural environment. The genetic resources are gradually being eroded. Ten underutilized indigenous vegetables were selected by the Nigeria-Canada Underutilize Indigenous Vegetables Project (NICANVEG) in 2011 to provide means for better production, processing and marketing to enhance food security, economic growth and conservation of the vegetables. Six premium vegetables were finally selected from the ten underutilized indigenous vegetables based on their fertilizer requirements, agronomic practices, income generation and human consumption. Sustaining the nutrient status of soils in vegetable production was one of the challenges identified within the project. However, this study focused on the fluted pumpkin.

The fluted pumpkin requires a high amount of nitrogen for the production of leaves, stems and fruits (Walters, 2020). Excessive application of nitrogen at the expense of other nutrients, results in production of leaves that are light and have low water retention. Nitrate accumulation in vegetables has been previously described by Schaller (2020). Nitrogen is found mostly as nitrate in the soil solution and it is highly mobile. The leaching of nitrogen from vegetable lands to water bodies could lead to eutrophication and the blue bay syndrome (Karthik et al., 2021). There are inconsistent reports on the amount of nitrogen required by vegetables. According to Olaniyi et al. (2014), the nitrogen requirement for vegetables is 60 kg N ha^{-1}. In addition, 100 kg N ha^{-1} was reported to be suitable for vegetables that produce both leaves and fruits. Idowu et al. (2014) also observed the highest shoot yield with an application of 160 kg N ha^{-1} applied equally at planting and after the first harvest. Olatoberu et al., (2019) observed maximum yield at the rate of 60 kg N ha^{-1}, while the usual practice of farmers is 80 kg N ha^{-1}. However, most soils in the forest and savannah zones of southwestern Nigeria are highly weathered and therefore, have a low ability to hold nutrients for plant use, so there is a need for the addition of organic fertilizer to improve the soil organic matter.

Due to the high temperature and rainfall in tropical Africa, including Nigeria, the rapid decomposition of organic matter and leaching away of inorganic fertilizers have made the nutrients in fertilizers added to soils not optimal for improving plant growth, yield and nitrogen use efficiency. Fertilizer microdosing has been recommended as an alternative way of applying fertilizers. Microdosing refers to the application of small quantities of fertilizer with the seed at sowing time or as a top dressing three to four weeks after emergence (Twomlow et al., 2010; Aune and Ousman, 2011). It refers to the utilization of relatively low quantities of fertilizer through point placement in cropping systems. It is a technology where a small dose of fertilizer is applied at two to three different times instead of applying the entire quantity once. Fertilizer microdosing has been applied as a source of nitrogen for maize in some parts of Africa, but there is no study yet on its application to crops in Nigeria, including the African indigenous vegetables. Furthermore, nothing has been documented on the effects of fertilizer microdosing on the NUE of selected underutilized indigenous vegetables, especially in Nigeria, and there is limited information on the effects of timing of organic fertilizer application with or without urea on fluted pumpkin production. Hence, the primary aim of this research was to investigate the impact of nitrogen fertilizer application timing, both with and without organic fertilizer, on the development, yield, and nitrogen usage efficiency of fluted pumpkins in the rainforest and savanna regions of southwestern Nigeria.

Material and Methods

The study was carried out at two locations in the southwestern part of Nigeria: Ilesa (rainforest) which lies between latitude 7° 30' N to 7° 38' N and longitude 4° 30' E to 4° 45' E in Osun State and Ogbomosho (derived savanna), which lies between latitude 8° 2' N to 8° 14' N and longitude 4° 10' E to 4° 19' E in Oyo State, Nigeria. The MICROVEG experiments took place at these two locations. The climatic conditions prevailing in both locations are characterized by a hot and humid tropical environment, which shows clear demarcations between the dry and rainy seasons.

Bulk top soil at a depth of 0–15 cm was collected before the application of organic fertilizer. The samples were subjected to air-drying, crushing and subsequent sieving using a 2-mm screen. The portions that successfully passed through the 2-mm sieve were selected for further physical and chemical evaluations. The particle size distribution was determined using the modified method of Bouyoucos (1962) as described by Gee and Or (2002), using a 0.2 M NaOH solution as the dispersion agent.

Soil pH was determined in 0.01 M $CaCl_2$ and water as described by Peech (1965) and modified by Thomas (1996). Ten (10) g of air-dried soil was weighed into 100-mL beakers. The soils in the beakers were replicated twice, 10 mL of deionized water was added to the first replicate of the soils to obtain a 1:1 ratio of soil to water and 20 mL of 0.01 M $CaCl_2$ was added to the second replicate of the soils in the beakers to obtain a 1:2 ratio of soil to $CaCl_2$ solution. The mixtures were stirred thoroughly and allowed to stand for 30 minutes. The suspensions were swirled in the beakers and the pH meter (Eco Tester pH 1 model) was calibrated using a buffer solution with pH values of 4.0 and 7.0, the electrodes were inserted into the suspension. The pH of the first replicate was recorded as pHw, while the pH of the second replicates was recorded as $pHCaCl_2$.

This method was subsequently updated by Thomas (1996). The extraction of total nitrogen (N) was conducted following the digestion method outlined by Bremner and Keeney (1965), with modifications made by Bremner (1996). This analysis was carried out using an autoanalyzer, the Seal AA3 HR autoanalyzer.

Soil organic matter was determined according to the method described by Walkley and Black (1934) and modified by Nelson and Sommers (1996). One-half (0.5) g of air-dried soil was weighed and transferred to 500-ml Erlenmeyer flasks. Ten (10) ml of 1 N $K_2Cr_2O_7$ was added and swirled to mix, 20 ml of concentrated H_2SO_4 was added and swirled gently for 1 minute. The mixture was allowed to stand for 30 minutes. Then 200 ml of distilled water was added to dilute the suspension, 10 ml of 85% H_3PO_4, 0.2 g of NaF and 1 ml of diphenylamine indicator were added. The excess $Cr_2O_7^{2-}$ was back titrated with 0.5 N ferrous solution to a green end point. A reagent blank was run with the same procedure with no soil. The amount of organic carbon in the soil samples was calculated as follows:

$$\text{Milliequivalents of readily oxidizable material per gram of soil (meq/ox/g)} = \frac{(\text{ml of } Fe^{2+} \text{ blank} - \text{ml of } Fe^{3+} \text{ sample}) \times \text{normality of } Fe^{2+}}{\text{Weight of the soil in gram}}$$

$$\%\ \text{carbon} = \frac{\text{meq.ox/g} \times 12 \times 100}{4000 \times 0.77}$$

% organic matter = % organic carbon x 1.72;
where: 12/4000 = milliequivalent weight of carbon;
1/0.77 = factors for converting oxidized carbon to total carbon;
100 = factors for converting decimals to percentages;
1.72 = factors for converting carbon to organic matter (van Bemmelen factor).

The extraction of available phosphorus (P) was conducted using the method described by Bray and Kurtz (1965) and modified by Kuo (1996), namely, 2 g of the air-dried soil was weighed and transferred into a 50-ml conical flask. Twenty (20) ml of P-A solution (0.03 N NH_4F + 0.025 N HCl) was added and shaken for 5 minutes. The solution was filtered through a 9-cm Whatman No. 2 filter paper into funnel tubes. A 3-ml aliquot of the filtrate was transferred into a colorimeter tube, and the available P in the filtrate was determined using a spectrometer (Model 721 Visible Spectrophotometer, Axiom Mediral LMD, UK). The extraction of exchangeable cations was conducted using a 1 N-NH4OAc solution, as first described by Thomas (1982) and subsequently modified by Jones (1998). The concentrations of potassium (K) and sodium (Na) in the solution were measured using a flame photometer (specifically, the PG-FP902 microprocessor model). On the other hand, the concentrations of calcium (Ca) and magnesium (Mg) were assessed using an atomic absorption spectrophotometer (namely, the Pg-AA 500 model). The cation exchange capacity (CEC) of the soil was assessed using the effective approach, as described by Thomas (1982) and Black (1986) and modified by Sumner and Miller (1996).

The materials used for the research were: *Telfairia occidentalis* seeds, sunshine organic fertilizer, urea fertilizer and neem extract. The sunshine organic fertilizer was composed of 3.5% nitrogen (N), 1.00% phosphorus (P), and 1.2% potassium (K).

The experimental design employed in this study was a 2 x 5 split plot arrangement, following a randomized complete block design framework. The entire experiment was reproduced four times. The main plot revolved around two distinct environments, namely Ilesa, characterized by a rainforest environment, and Ogbomoso, characterized by a derived savanna environment. Additionally, the sub-plot focused on the timing of inorganic fertilizer application, namely at the time of planting and two weeks subsequent to planting. The experimental treatments consisted of five different levels of inorganic fertilizers (specifically urea) applied at varying rates: 0, 20, 40, and 60 kg N ha^{-1}, as well as 80 kg N ha^{-1}. The initial four levels of nitrogen applications (ranging from 0 to 60 kg N ha^{-1}) involved the pre-planting application of organic fertilizer (OF) at a rate of 5 tons per hectare, one week prior to planting. In contrast, the application of 80 kg N ha^{-1} corresponded to the conventional farming practices employed by farmers. The crop selected for the experiment was *Telfairia occidentalis*, commonly known as fluted pumpkin or ugu. Each crop was cultivated on a plot of size 3 m by 2 m, with a spacing of 1 meter between each plot. The treatments were replicated four times to give total experimental units of 40 per location. The deep placement method was incurred for the application of the fertilizer. The seeds of fluted pumpkin were sown at a spacing of 0.5 x 0.75 m and there were twenty (20) seeds per plot.

The management of weeds involved hand picking and the use of a hoe. According to a study conducted by Idowu et al. (2014), the utilization of neem (*Azadirachta indica*) leaf extract was employed as a means to manage insect pests.

The fluted pumpkin was harvested five weeks after planting for the first harvest, the second harvest took place two weeks after the first harvest, and the third harvest two weeks after the second harvest. The harvesting was done by cutting the vegetables off at the shoot. The fresh weight of the harvested vegetables was measured on-site and a subsample was dried in the oven at a temperature of $60^{\circ C}$ until a stable weight was achieved. The dry matter yield percentage was determined following the methodology outlined in the study by Sally et al. (2008).

The nitrogen content of the plant samples was determined using the previously mentioned digestion method outlined by Bremner and Keeney (1965), which was later modified by Bremner (1996). The plant extract was analyzed for nitrogen content using an autoanalyzer, specifically the Seal AA3 HR autoanalyzer. The nitrogen content was multiplied by the dry matter yield to determine the nitrogen uptake, according to Sally et al. (2008).–Nitrogen use efficiency was determined according to Eivazi and Abibi (2013) and % N recovery according to Vanlauwe et al. (2011). The acquired data were statistically analyzed employing analysis of variance (ANOVA).

Results and Discussion

The physical and chemical properties of the soil shown in Table 1 were sandy loam, slightly acidic. The pH values of the two locations were within the optimum range for major vegetable production. Total N, organic carbon, available P and exchangeable Ca, Mg, K and Na were above the critical values (Adepetu et al., 2014). The values were higher in Ilesha compared with Ogbomoso. This might be due to the fact that Ilesa (rainforest) received more rainfall, resulting in a dense forest compared to Ogbomoso (derived savanna). These results are in line with the observation of Bala (2015) that more rainfall in the rainforest zone leads to a dense plant population and hence to a high organic matter content.

Table 1. Physical and chemical properties of the soils at the locations before planting.

Properties	Location	
	Ilesa (Rainforest)	Ogbomoso (Derived savanna)
Sand (g kg^{-1})	760	820
Silt (g kg^{-1})	90	50
Clay (g kg^{-1})	150	130
Textural class	Loamy sand	Loamy sand
pH (0.01 M $CaCl_2$)	5.4	5.7
Total N (g kg^{-1})	23.0	18.0
Organic carbon (g kg^{-1})	16.6	8.4
Available P (mg kg^{-1})	23.48	19.03
Exchangeable acidity	0.07	0.08
Exchangeable cations (cmol kg^{-1})		
Ca	1.78	1.30
Mg	0.49	0.43
K	0.48	0.40
Na	0.11	0.1
CEC (cmol kg^{-1})	2.86	2.23

The study by Idowu et al. (2017) also corroborated the finding. However, the need for rapid growth of vegetable crops for many harvests necessitates N application because vegetable crops require high amounts of nitrogen in the soil, which can be met through the addition and mineralization of inorganic and organic fertilizers (Subramanian et al., 2010), and N undergoes quick chemical and biochemical transformations in the soil, which affects its availability to the plants, and it is subject to soil-plant system losses, causing damage to the environment. Therefore, this study found that fertilizer microdosing technology could help to reduce the impact of excess N effect on soil fertility and the environment.

The timing of nitrogen fertilizer application had no effect on any of the parameters determined, yield, nutrient uptake, N use efficiency and N recovery. The rainforest had a greater fresh yield in comparison to the derived savanna. This could be due to the fact that more nitrogen was available in the rainforest compared to the savanna. In the rainforest, the application of 40 kg N ha^{-1} urea combined with 5 tons ha^{-1} organic fertilizer resulted in the highest fresh yields. Conversely, in the derived savanna, the combination of 20 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer produced the highest fresh yields when compared to the other application rates (Figure 1).

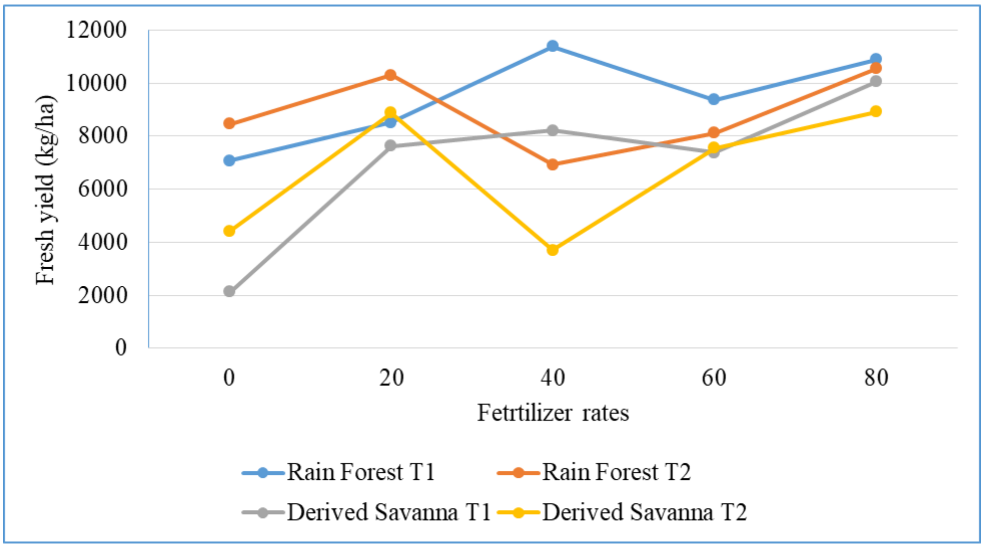

Figure 1. Effects of timing and rate of nitrogen fertilizer application on fresh yield (kg ha^{-1}) of fluted pumpkin in rainforest and derived savanna regions of southwestern Nigeria.

This could be due to the fact that the application of fertilizer at low rate (fertilizer microdosing) reduces the risk of nutrient loss by leaching. This is in line with the work of Oluoch et al. (2009), who reported that the microdosing technique would help farmers to use little fertilizer and support sustainability. This practice was found to result in reduced input costs and minimized investment risks, while increasing crop yields. However, the findings of Tovihoudji et al. (2017) suggest that the use of fertilizer microdosing in the absence of organic fertilizer may not be a viable long-term fertilization approach. Therefore, the organic fertilizer could be applied as a basal application before applying fertilizer microdosing, as it was done in this research. The organic fertilizer was used in this experiment, at a rate of 5 tons per hectare.

The rate of nitrogen absorption was found to be greater in the rainforest ecosystem of Ilesa compared to the derived savanna ecosystem of Ogbomoso (Figure 2). This was corroborated by the results of the native soils in Table 2. The dense vegetation found in the rainforest (Ilesa) as a result of more moisture (Adepetu et al., 2014) when decomposed could lead to the higher content of nitrogen in Ilesa soil which eventually might result in higher nitrogen uptake in Ilesa compared with Ogbomoso (derived savanna).

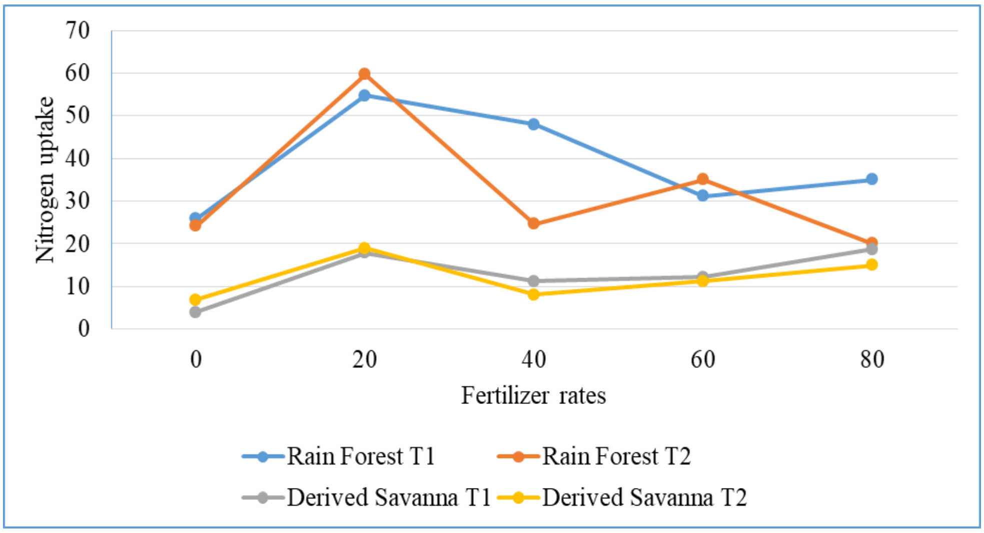

Figure 2. Effects of the timing and rate of nitrogen fertilizer application on the nitrogen uptake of fluted pumpkin in rainforest and derived savanna regions of southwestern Nigeria.

The nitrogen uptake increased significantly when applied at a rate of 20 kg N ha^{-1} urea in combination with 5 tons ha^{-1} organic fertilizer, surpassing the uptake observed at other rates (0, 40, and 60 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer, as well as 80 kg N ha^{-1}) in a rainforest environment. This supports further the earlier result from Figure 1 that applying inorganic fertilizer at reduced rates (fertilizer microdosing) with organic fertilizer reduced the risk of nutrient mining and made more nutrients available for plant uptake. This could mean that the fluted pumpkin absorbed nitrogen from the existing sources of nitrogen as organic matter apart from urea applied. This is in line with the work of Courtney et al. (2005) who reported that crop N needs could be met through existing N sources such as soil organic matter. Parrish and Fike (2005) have reported in their study that not all the N appearing in the shoot biomass is accumulated from recently applied N and that significant amounts of N in the biomass may not be taken up directly from the soil, but may reach the shoots from root N reserves, making the plants relatively unresponsive to recently applied N. This is also in line with the work of Sheu (2014), who reported a higher N uptake of *Sesamum indicum* L. with a reduced nitrogen fertilizer application of 75 kg N ha^{-1} compared to 112.5 kg N ha^{-1}.

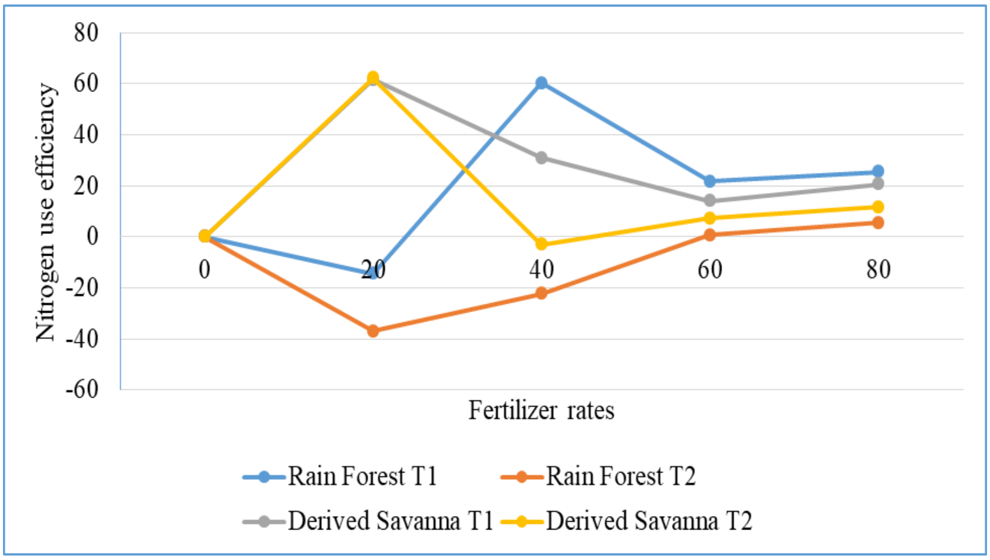

Figure 3. Effects of timing and rate of nitrogen fertilizer application on nitrogen use efficiency of fluted pumpkin in rainforest and derived savanna regions of southwestern Nigeria.

Nitrogen use efficiency was higher in the derived savanna (Ogbomoso) compared with the rainforest (Ilesa) (Figure 3). This was an indication that the small percent of N uptake was used for the production of biomass by the fluted pumpkin in the rainforest compared to derived savanna, though N uptake was higher in the rainforest compared to the savanna. This could be due to the dilution effect in the fluted pumpkin, that is, the inability of the plants to make use of all the nitrogen taken up by the plant for yield production. Ciampitti et al. (2013) reported that close planting of maize resulted in high grain yield due to the efficient use of nitrogen (N) and the comparatively low application of N.

The highest nitrogen use efficiency was obtained at the rate of 40 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer in the rainforest, which corresponded to the microdosing at recommended rate of 40 kg N ha^{-1}, whereas in the derived savanna, the rate of 20 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer gave significantly the highest NUE compared to the other rates (0, 60 kg N ha^{-1} urea with 5 tons ha^{-1} fertilizer and 80 kg N ha^{-1}). This could be due to the fact that the application of much nitrogen fertilizer had no effect on the NUE and the application of excess N could lead to lodging of the vegetable as well as environmental pollution. This could be due to the dilution effect in the fluted pumpkin, that is, inability of the plants to make use of all the nitrogen taken up by the plant for yield production. Cui et al. (2009) and Ciampitti et al. (2013) observed high maize grain yields through high NUE and relatively low N application under close planting because of high biomass or N accumulation and allocation to grain. This is also in line with the work of Whitbread et al., (2013), who recorded the highest agronomic efficiency use of nitrogen at the application rates of 15 and 30 kg N ha^{-1} compared with application at 0, 60 and 120 kg N ha^{-1}.

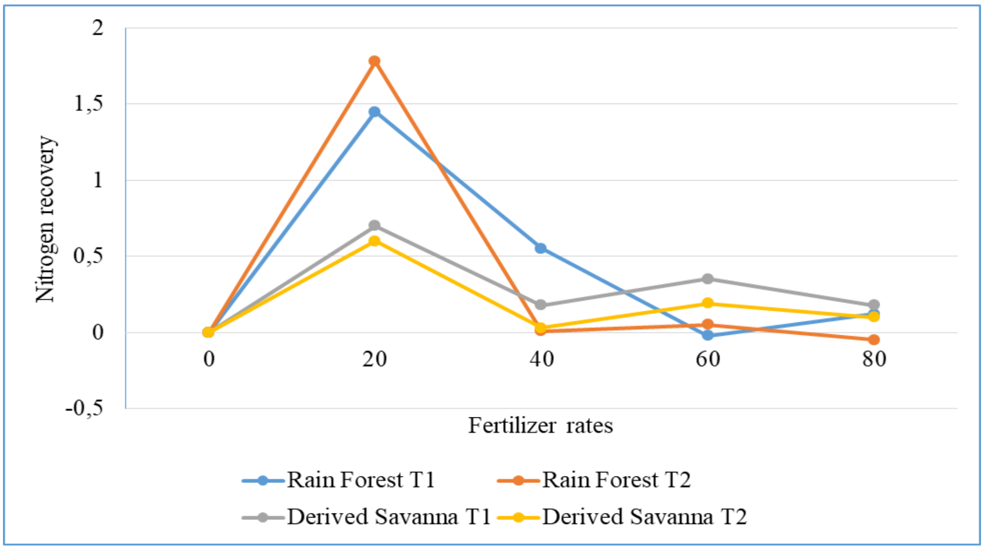

Figure 4. Effects of the timing and rate of nitrogen fertilizer application on the nitrogen recovery of fluted pumpkin in rainforest and derived savanna regions of southwestern Nigeria.

The effects of N supply on the physiological and morphological development of the fluted pumpkin under different ecosystems need to be further investigated to avoid excessive nitrogen application.

Higher nitrogen recovery was obtained in the rainforest (Ilesa) compared to the derived savanna (Ogbomoso) (Figure 4). This corroborated the higher nitrogen uptake in the rainforest in Figure 2, that is, all the factors favored higher nitrogen uptake in Ilesa. This also enhanced higher nitrogen recovery in Ilesa compared with Ogbomoso. A significantly higher N recovery was obtained at the rate of 20 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer application both in the rainforest and the derived savanna. In addition, all the factors favoring the highest nitrogen uptake at the rate of 20 kg N ha^{-1} urea with 5 tons ha^{-1} also promoted the highest nitrogen recovery at the rate of 20 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer compared with other rates (0, 40, 60 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer and 80 kg N ha^{-1}).

Conclusion

The optimal production of fluted pumpkin in southwestern Nigeria was observed when the microdosing approach was applied, using 20 to 40 kg N ha^{-1} urea in combination with 5 tons ha^{-1} organic fertilizer. This study demonstrated that the utilization of a combined approach involving fertilizer microdosing and the application of organic fertilizer was a more favorable alternative for achieving optimal fluted pumpkin production, while concurrently mitigating the excessive use of fertilizers by farmers. Further research is required to include other underutilized indigenous vegetables in Africa to establish the efficacy of microdosing for all underutilized indigenous vegetables in Africa.

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References

Adepetu, J.A., Adetunji, M.T., & Ige, V. (2014). *Soil fertility and crop nutrition.* Jumak Publishers. Ring Road, Ibadan, Nigeria.

Aune, J.B., & Ousman, A. (2011). Effect of Seed Priming and Micro-dosing of Fertilizer on Sorghum and Pearl Millet in Western Sudan. *Experimental Agriculture, 47*, 419-430.

Bala, A. (2015). *Description of cropping systems, climate, and soils in Nigeria*. Global yields Cap Atlas Nigeria, University of Nebraska, Lincoln, NE.

Black, C.A. (1986). *Methods of soil analysis. Part I. Physical and mineralogical properties including statistics of measurement and samplings Part II.* Chemical and Microbiological properties. Agronomy series. American Society of Agronomy, Madison, WI.

Bouyoucos, G.H. (1962). Hydrometer method improved for making particle size analysis of soils. *Agronomy Journal*, *54*, 464-465. doi:10.2134/agronj1962.00021962005400050028x

Bray, R.H., & Kurtz, L.T. (1965). Determination of total, organic, and available forms of phosphorus in soils. *Soil Science*, *59*, 39-45. doi: 10.1097/00010694-194501000-00006

Bremner, J.M. (1996). Nitrogen-total. In D.L. Sparks, A.L. Page, P.A. Helmke, R.H. Loeppert, P., Soltanpour, N., Tabatabai, M. A., Johnston, C. T. & Sumner M. E. (Eds.), *Methods of soil analysis. Part 3. Chemical method.* (pp. 1085-1122). Soil Science Society of America and American Society of Agronomy Madison, WI.

Bremner, J.M., & Keeney, D.R. (1965). Steam distillation methods for determination of ammonium, nitrate and nitrite. *Analytica Chimica Acta*, *32*, 485-495. doi:10.1016/S0003-2670(00)88973-4.

Ciampitti, I.A., Murrell, S.T., Tuinstra, M., Camberato, J.J., Xia, Y., & Friedemann, P. (2013). Physiological dynamics of maize nitrogen uptake and partitioning in response to plant density and N-stress factors: II. Reproductive phase. *Crop Science*, *53*, 2588-2602. doi:10.2135/cropsci2013.01.0041.

Courtney, J., Greg, A., Quirine, K., Jen, B., & Kristen, S. (2005). *Nitrogen B basics – The nitrogen cycle*. Agronomy Fact Sheet Series. Cornell University Cooperation Extension.

Cui, Z., Zhang, F., Mi, G., Chen, F., Li, F., & Chen, X. (2009). Interaction between genotypic difference and nitrogen management strategy in determining nitrogen use efficiency of summer maize. *Plant and Soil, 317*, 267-276.

Eivazi, A., & Hbibi, F. (2013). Evaluation of nitrogen use efficiency in corn (*Zea mays* L.) *Varieties, 21*, 63-68. doi:10.5829/idosi.wasj.2013.21.1.2423

Gee, G.W., & Or, D.B. (2002). Particle size analysis, In Dane J.H. & G.C. Topp (Eds.), *Method of Soil Analysis Part 4, Physical methods.* Soil Science Society of America Book Series No. 5, (pp. 255-293). Soil Science Society of America and American Society of Agronomy Madison, WI.

Gupta, S., Gowri, B.S., Lakshmi, A., & Prakash, A. (2011). Solar drying of coriander and methi leaves. *J. F. Science Technology*, *23*, 639-641.

Idowu, M.K., Oyedele, D.J., Adekunle, O.K., Akinremi, O.O., & Eilers, B. (2014). Effects of planting methods and seed density on vegetable yield and nutrient composition of *Solanum macrocarpon* and *Solanum scabrumin* southwest Nigeria. *Food Nutritional Science, 5*, 1185-1195. doi:10.4236/fns.2014.513129

Idowu, M.K., Oyedele, D.J., & Oladele, A.O. (2017). Influence of nitrogen fertilizer application on organic carbon content of underutilized vegetable grown soils in southwestern Nigeria. *Proceedings of Global Symposium on Soil Organic Carbon*, (p 4). Rome, Italy.

Jones, J.B. (1998). Soil test methods: Past, present, and future use of soil extractants. *Communication in Soil Science*, *29*, 1543-1552. doi:10.1080/ 00103629809370048

Karthik, V., Selvakumar, P., Ponnusamy, S., Dai-Viet, N., Jaisankar, S., Dhanaba, S., & Balakrishnan, S. (2021). Advanced techniques to remove phosphates and nitrates from waters: A review. *Environmental Chemistry Letters*, *19,* 3165-3180. doi:10.1007/s10311-021-01239-2

Kuo, S. (1996). Phosphorus. In D.L. Sparks, A.L. Page, P.A. Helmke, R.H. Loeppert, P.N. Soltanpour, M.A. Tabatabai, C.T. Johnston, & M.E. Sumner (Eds.). *Methods of soil analysis. Part 3. Chemical method.* (pp. 869-919). Soil Science Society of America and American Society of Agronomy Madison, WI.

Nelson, D.W., & Sommers, L.E. (1996). Total carbon, organic carbon, and organic matter. In. Page, A.L. (Ed.). *Methods of soil analysis. Part 2. Agronomy Monogronomy, 9, 2nd ed.* (pp. 539-579). ASA and SSSA, Madison, WI.

Nishida, C., Uauy, R., Rumanyika, S., & Shetty, P. (2004). The Joint WHO/FAO Expert consultation on diet, nutrition and the prevention of chronic disease: Process, product and policy Implications. *Public Health Nutrition*, *7*, 245-250. doi:10.1079/phn2003592

Olaniyi, J.O., Modupeola, T.O., Idowu-Agida, O.O., Bidmos, F.A., Egbekunle, K.O., & Ogunsakin, I.F. (2014). Effects of nitrogenous and phosphatic fertilizer on yield, nutrient uptake and nutritional values of *Telfairia occidentalis* Hook f. *American Journal of Plant Nutrition and Fertilization Technology, 4*, 18-26. doi:10.3923/ajpnft.2014.18.26

Olatoberu, F.T., Idowu, M.K., Adepetu, J.A., & Akinremi O.O. (2019). Differential response of biomass production and nitrogen uptake of vegetable amaranth to two types of poultry manure from Nigeria and Canada. *Food and Nutrition Sciences, 10,* 694-711.

Oluoch, M.O., Pichop, G.N., Silué, D., Abukutsa-Onyango, M.O., Diouf, M., & Shackleton, C.M. (2009). Production and harvesting systems for African indigenous vegetables. In Shackleton, C.M., W. Pasquini, and A.W. Drescher (Eds.). *African indigenous vegetables in urban agriculture*. (pp. 145-176). Earthscan, London, UK.

Parrish, D.J., & Fike, J.H. (2005). The biology and agronomy of switchgrass for biofuels. Crit Rev *Plant Science*, 24, 423-459.

Peech, M. (1965). Hydrogen-ion activity. In C.A. Black (Ed.) *Methods of soil analysis. Part 2.* Agron. Monogr, 9. (pp. 914-926). ASA and SSSA, Madison, WI.

Sally L., Dave, C., Demie M., & Teferi, T. (2008). Soil science: Step-by-step field analysis. *Soil Science Society of America*. (pp. 159-180). Madison, WI, doi:10.2136/2008, Soilsciencestepbystep.

Schaller (2020). Influence of rootstock and site on nitrate accumulation. *Mitteilungen Klosterneuburg., 36*, 238-244.

Sheu, H.E. (2014). Uptake and agronomy efficiencies of nitrogen, phosphorus and potassium in sesame (*Sesamum indicum* L.). *American Journal of Plant Nutrition and Fertilizer Technology*, *4*, 41-56.

Subramanian, S., Sivarajan, M., & Saravanapriya, S. (2010). Chemical Changes during Vermicomposting of Sago Industry Solid Wastes. *Jounal of Hazardous Materials, 179*, 318-322.

Sumner, M.E., & Miller, W.P. (1996). Cation exchange capacity and exchange coefficient In D.L. Sparks, A.L. Page, P.A. Helmke, R.H. Loeppert, P.N. Soltanpour, M.A. Tabatabai, C.T. Johnston, M.E. Sumner (Eds) *Methods of soil analysis. Part 3. Chemical method*. (pp. 475-490). Soil Science Society of America and American Society of Agronomy. Madison, WI.

Thomas, G.W. (1982). Exchangeable cations. In A.L Miller. R.H., & Keeney. D.R., (Eds), Part 2, 2nd ed. Agronomy Monographs, 9, (pp. 159-165). Soil Science Society of America and American Society of Agronomy, Madison, WI.

Thomas, G.W. (1996). Soil pH and soil acidity. In D.L. Sparks, A.L. Page, P.A. Helmke, R.H. Loeppert, P.N. Soltanpour, M.A. Tabatabai, C.T. Johnston, & M.E. Sumner (Eds), *Methods of soil analysis. Part 3. Chemical methods.* (pp. 475-490). Soil Science Society of America and American Society of Agronomy, Madison, WI.

Tovihoudji, P.G., Akponikpè, P.B.I., Agbossou, E.K., Bertin, P., & Bielders, C.L. (2017). Fertilizer microdosing enhances maize yields but may exacerbate nutrient mining in maize cropping systems in northern Benin. *Field Crop Research, 213,* 130-142. doi:10.1016/j. fcr.2017.08.003

Twomlow, S., Rohrbach, D., Dimes, J., Rusike, J., Mupangwa, W., Ncube, B., Hove, L., Moyo, M., Mashingaidze, N. & Mahposa, P. (2010). Micro-dosing as a pathway to Africa's Green Revolution: Evidence from broad-scale on-farm trials. *Nutrient Cycling Agroecosystem, 88,* 3-15.

Vanlauwe, B., Kihara, J., & Chivenge, P. (2011). Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa within the context of integrated soil fertility management. *Plant Soil 339*, 35–50 https://doi.org/10.1007/s11104-010-0462-7

Walkley, A., & Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science, 37*, 29-38. doi:10.1097/00010694-193401000-00003

Walters, A. (2020). Impact of nitrogen fertilizer on yield and associated revenues in no-tillage Pumpkin. *Horticulture, 55,* 522-527. doi:10.21273/HORTSCI14512-19

Whitbread, A., Sennhenn, A., & Grotelüschen, K. (2013). *Nitrogen-use-efficiency in Maize based farming systems in Malawi: A simulation study and meta-analysis of literature. Crop Production Systems in the Tropics.* Faculty of Agricultural Sciences University of Göttingen Göttingen, Germany.

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OPTIMIZACIJA PRINOSA, USVAJANJA I EFIKASNOSTI USVAJANJA AZOTA KOD REBRASTE TIKVE PRIMENOM MIKRODOZIRANJA ĐUBRIVA

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R e z i m e

Zbog izrazitog ispranja zemljišta i obilnih padavina, vreme i doza primene đubriva radi povećanja prinosa, efikasnosti usvajanja azota i njegovog iskorišćenja kod rebraste tikve (*Telfairia occidentalis*) predstavljaju ključna pitanja u jugozapadnoj Nigeriji. Eksperiment je sproveden koristeći potpuno slučajni blok dizajn sa potparcelama (2 x 2 x 5), sa četiri sorte. Ilesa i Ogbomoso su činili glavne varijante, dok su vreme primene đubriva uree i pet nivoa azota (0, 20, 40, 60 i 80 kg ha^{-1}) činili podvarijante. Osnovna primena organskog đubriva u količini od 5 tona po hektaru (0, 20, 40, 60 kg ha^{-1}) izvršena je nedelju dana pre setve. Izračunati su prinos biomase, iskorišćenje i efikasnost upotrebe azota. Kada je reč o kontrolnom tretmanu, 20 i 80 kg N ha^{-1} uree, sveži prinosi u tonama po hektaru iznosili su 7,7, 9,4 i 10,7 za Ilesu, odnosno 3,3, 8,3 i 9,5 za Ogbomoso. Najveća efikasnost upotrebe azota (60,26 kg N ha^{-1}) postignuta je pri primeni 40 kg N ha^{-1} u Ilesi, dok je u Ogbomosu najveća efikasnost (61,91 kg N ha^{-1}) ostvarena pri dozi od 20 kg N ha^{-1}. Viši sveži prinos ostvaren je u Ilesi u poređenju sa prinosom u Ogbomosu. Utvrđeno je da je najbolji način za proizvodnju rebraste tikve u jugozapadnoj Nigeriji kombinacija 5 tona organskog đubriva i mikrodoziranja uree u količini od 20 do 40 kg N ha^{-1}.

Ključne reči: *Telfairia occidentalis,* biomasa, đubrivo, mikrodoziranje.

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