Colloquia Series

Available online at www.publishingrealtime.com

Publishing Real Time

Colloquia SSSN 44 (2020)

Proceedings of the 44th Conference of Soil Science Society of Nigeria on Climate-smart soil management, soil health/quality and land management: synergies for sustainable ecosystem services

Influence of fertilizer microdosing on soil fertility status, growth and yield of *Solanum macrocarpon* in Southwest Nigeria.

[1]Oluwaponle Ifeoluwa Adesewa, [2]Akinremi Omotayo Rashidat and [3]Idowu Mary Kemi

[1]Forestry Research Institute of Nigeria, Ibadan

[2]Department of Soil Science and Land Resources Management, Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife, Nigeria.

[3]Department of Soil Science and Land Resources Management, Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife, Nigeria.

Abstract

This study examined the effect of fertilizer rate, time of application and the availability of soil phosphorus (P), Sulphur (S), Iron (Fe) and Zinc (Zn) for *S. macrocarpon* production using microdosing technology in southwest Nigeria. The experiment was located at the derived savanna (Ogbomoso) and the rainforest (Ilesha) in southwest Nigeria. The treatments were arranged in a 2 × 5 factorial combinations and laid out in a randomized complete block design with four replicates. The fertilizer rate; 0, 20, 40, 60, and 80 (without organic fertilizer) kg N ha^{-1}, the time of urea application (at planting and two weeks after planting) and *S. macrocarpon* was the test crops. Organic fertilizer (3.5 % N) at 5 tons ha^{-1} was applied a week before planting except for 80 kg N ha^{-1} plot. Total shoot above-ground biomass per plot was determined and dry matter estimated; P, S, Fe and Zn uptake were determined at the first harvest. The data generated were subjected to analysis of variance (ANOVA) and the means separated using Duncan's New Multiple Range Test at 5 % level of probability. The results showed that the average dry matter yield of *S. macrocarpon* in the derived savanna (2.62 t ha^{-1}) was higher than in the rainforest (1.15 t ha^{-1}) respectively. Although the time of fertilizer application had no significant effect on yields, application at two weeks after planting (2 WAP) produced higher yields (3.3 t ha^{-1}) at the derived savanna while the application at planting (AAP) produced highest (1.2 t ha^{-1}) at the rainforest. Availability of P, S, Fe, Zn to *S. macrocarpon* had similar trends with the yield. This study concluded that 20 kg N ha $^{-1}$ + 5 tons ha $^{-1}$ were the optimum fertilizer combination for *S. macrocarpon* production in southwest Nigeria.

Keywords: Fertilizer microdosing, Phosphorus, S, Fe and Zn availability, *S. macrocarpon*

Corresponding Author's E-mail Address:

https://doi.org/10.36265/colsssn.2020.4462

Peer-review under responsibility of 44th SSSN Conference LoC2020.

1.0. Introduction

Solanum macrocarpon (egg plant) is an indigenous vegetable called Igbagba by the Yorubas in Nigeria. It contains essential macro and micronutrients, vitamins, protein in considerable amounts and is economically, nutritionally and medicinally important (Idowu *et al*., 2014). Low soil fertility remains one of the major problem limiting the production of vegetables (Bello and Awwal, 2008; Hamden and Fadni, 2010).

Nitrogen (N), phosphorus (P), and sulphur (S) are an essential nutrient element needed for high yields and quality of vegetables. For example, N is vital for the photosynthetic activity, vegetative and reproductive metabolism; P is involved in energy storage needed for physiological processes and photosynthetic reaction while S is an essential component of chlorophyll, specific vitamins and protein in plants (Maschner, 1998; Adepetu *et al*., 2014). Moreover, attention is given to macronutrients such as N, P, K leaving out other micronutrients that are also essential to soil fertility and plant growth (Harvlin *et al*., 2009). Though required by plants in small amount, they are essential to plant and human nutrition (Govindaraj *et al.,* 2011). The deficiency of one or more of the micronutrients can lead to severe depression in growth, yield and crop quality (Halvin *et al*., 2009; White *et al*., 2012). Iron (Fe) helps in the maintenance of chlorophyll in the plant (Price *et al*., 1972) and Zinc (Zn) plays an essential role as enzymes activators (Marschner, 1998).

Nutrient elements are specific in function and have synergistic relationships; therefore, it is expedient that they are supplied in sufficient quantity to plant at the right time (Omotoso and Akinrinde, 2013). The practical placement and timing of fertilizers maximize both yield and nutrient use efficiency (Jones and Jacobsen, 2009); increases net return for vegetable farmers and reduce environmental pollution from fertilizers. Although vegetables respond positively to organic and/ inorganic fertilizer application in Nigeria (Idowu, 2008; Idowu, 2010; Ajibola *et al*., 2015; Ehigiator *et al.,* 2015), the question is, how many of the resource farmers in Southwest Nigeria can afford the fertilizers (Adebisi-Adelani *et al*., 2011; FEPSAN, 2014) and after that apply at the recommended rate. Consequentially, the nutrition, medicinal and economic benefits of these vegetables is forfeited.

Fertilizer micro-dosing involves the application of relatively small quantities of fertilizer at sowing time or within a short time after sowing, substantially reducing the recommended amount of fertilizer that subsistence farmers need to apply while giving plants enough nutrients for optimal growth (ICRISAT, 2009). The implementation of this technology has resulted in greater nutrient use efficiency and positive responses of increased production of crops like maize and pearl millet in some African countries (Tabo *et al*., 2006; INERA, 2010; Twomlow *et al*., 2010; Bagayoko *et al*., 2011) and it also permits a more precise and better-timed fertilizer placement, and hence appropriate management of fertilizer (Sanginga and Woomer, 2009). However, there is little information on the effect of urea and organic fertilizer application using micro-dosing technology on the yield and uptake of P, S, Fe and Zn in the selected vegetable crops, hence this study.

The specific objectives of this research study were to examine the effects of fertilizer rate and time of application on yield and soil P, S, Fe and Zn availability to *S. macrocarpon* to establish the optimum microdose-fertilizer application for vegetable production in southwest Nigeria.

2.0. Materials and Method

2.1. Description of the Study Area

The study was conducted in two locations; rainforest zone (Ilesha, Osun state) and derived savannah (Ogbomoso, Oyo state). These zones are part of the Nigeria-Canada-Vegetable/Micro-Veg project sites and have been under vegetable cultivation for 3 years. The experiment was conducted in 2015 at the experimental fields, Ogbomoso lies within Latitude 8^0 6’ 35” N and Longitude 4^0 18’ 41” E in Oyo state with a bimodal rainfall pattern that ranges between 1296 mm and 1306 mm while Ilesha lies within Latitude 7^0 38’ 36” N and Longitude 4^0 45’ 40” E in Osun state with a rainfall pattern that is bimodal which varies between 1600 and 2000 mm.

The experimental plots were prepared 3 m × 2 m with a spacing of 1 m (29 m × 15 m). The treatment consisted of a 2 x 5 factorial combination of five nitrogen levels (0, 20, 40, 60, and 80 (without organic fertilizer) kg N ha^{-1}), two times of urea application (at planting and two weeks after planting). Organic fertilizer (3.5 % N, 1 % P, and 1.2 % K) was applied at 5 tons ha^{-1} as basal fertilizer a week before urea application except for 80 kg N ha^{-1}. All the treatments were replicated four times.

2.2. Soil Sampling, Preparation and Analysis

Bulk surface soil samples were randomly collected at 0 – 15 cm depth from the unfertilized plots for routine analysis. Soil samples were air-dried, crushed in an agate mortar and passed through a 2-mm sieve to remove roots, stones and other debris. The fraction that passed through the sieve was kept in an airtight container and analyzed for following properties. Particle size distribution was determined by the modified hydrometer method (Bouyoucos, 1962) using 0.2 M NaOH solution as the dispersing agent. Soil pH was determined using a glass electrode pH meter in 0.01 M $CaCl_2$ solution, using 1:2 soils: $CaCl_2$ solution (Peech *et al*., 1953). Soil organic carbon was determined by the chromic acid digestion method (Walkey Black, 1934). The total N concentration was determined by macro-Kjeldahl method (Bremner, 1996), available S was extracted using KH_2SO_4 and was determined using the turbidimetric method (Tabatabai, 1974) and the available P was extracted by Bray-1 method (Bray and Kutz, 1945) and extracted P was measured colourimetrically at 660 nm using visible spectrophotometer 721-Axiom Ltd. U. K. Exchangeable K, Ca, Na and Mg were extracted with neutral (pH 7) solution of 1N NH_4OAc. Potassium, Ca and Na were determined using the flame photometer (flame photometer model 2655-00 Digital Flame Analyzer, Cole-Parmer Instrument Company, Chicago, Illinois 60061) and Mg by the atomic absorption spectrophotometer (PG-900 Atomic Absorption Spectrophotometer Model, PG-instrument Ltd. the United Kingdom). Soil available Fe and Zn were extracted by 0.1 N HCl and determined using atomic absorption spectrophotometer Pg AA-500 model at wavelength 248.33 and 213.86 nm, respectively.

2.4. Data Collection

S. macrocarpon shoot was harvested at seven weeks after planting (WAP). The shoots were harvested by cutting the stem at about 8 cm to the soil surface. Subsequent harvest was done fortnightly, the fresh weight of harvested edible shoots was determined per plot and immediately transported to the Soil Science Laboratory of Obafemi Awolowo University, Ile-Ife, Nigeria.

2.5. Determination of Nutrient Composition

The vegetable leave samples were collected randomly from each harvested shoots. Samples were weighed, labelled accordingly and placed in an oven (OV-440 Gallenkamp model) at 65^{o}C until a constant weight was obtained. Dry weight was also determined, and 0.5 g of the ground vegetable tissues were digested using the wet ashing method (Piper, 1944). The ash was extracted with 2 ml of 6 N H_2SO_4, and the extract was quantitatively transferred to 50 ml volumetric flask and made up to the mark. Appropriate dilutions were made and the elements analyzed against their standards. All the samples were analyzed along with a blank solution. Phosphorus content was determined using vanadomolybdate method (Kuo,1996) and absorbance was read using the visible Spectrophotometer at 440 nm wavelengths while S content was determined using the Turbidimetric method (Tabatabai, 1974), absorbance was read at 420 nm wavelength using the visible Spectrophotometer. Standard solutions of P and S with different concentrations were also read. A standard curve was plotted with the concentrations of the standards against the absorbance readings, and this was used to determine the concentration of P and S in the samples.

2.6. Data Analysis

Data collected were subjected to analysis of variance (ANOVA) to assess treatment effects and time of application on fresh yield and the uptake of Phosphorus and Sulphur by the vegetable. Means were separated using Duncan's Multiple Range Test at 5% level of probability (SAS 9.1).

3.0. Results and Discussion

3.1. Characteristics of the soil used for the study

The soils (Table 1) were strongly acidic pH (5.4) for rainforest savanna (Ilesha) and medium acidic pH (5.70) for the derived savanna (Ogbomoso) in 0.01 M $CaCl_2$. The textural classification of the soil was loamy sand for the two locations. The organic carbon and total N content of soils at the rainforest zone (8.4 and 2.3 gkg^{-1}) and the derived savanna (16.6 and 1.8 gkg^{-1}) were within the medium

Soil properties	RAINFOREST	DERIVED
Sand ($mgkg^{-1}$)	760	820
Silt "	90	50
Clay "	150	130
Textural class	Loamy sand	Loamy sand
pH (0.01M $CaCl_2$)	5.4	5.7
Total N (gkg^{-1})	2.3	1.8
Organic C (gkg^{-1})	16.6	8.45
Available P ($mgkg^{-1}$)	24	19
Available S ($mgkg^{-1}$)	3.59	3.31
Available Fe ($mgkg^{-1}$)	98.30	86.08
Available Zn ($mgkg^{-1}$)	8.87	3.36
Exchangeable Ca ($cmolkg^{-1}$)	1.78	1.30
" Mg "	0.49	0.43
" K "	0.48	0.40
" Na "	0.11	0.10

-fertility class (Sobulo and Adepetu, 1987; Adepetu, 1990). The available P was high at the rainforest and medium at the derived savanna. The available S in the two agro-ecologies was low (Adetunji and Adepetu, 1987). Exchangeable Ca, Mg, K, and Na was higher than the critical levels (0.03 cmol kg^{-1}) established for maize in the region (Adepetu *et al.,* 2014). The Fe content in the soil of both locations was very high while Zn was high in Ilesha (8.87 mg kg^{-1}) and Ogbomoso (3.36 mg kg^{-1}) falls within the medium range.

3.2. Effect of time and fertilizer rates on the fresh yield of Solanum macrocarpon at the two agro-ecologies.

Table 2 shows that the fertilizer treatment using microdosing technology had a significant effect on the fresh yield of *S. macrocarpon.* The application of organic and inorganic fertilizer (20,40 and 60 kg N ha^{-1}) significantly increased yields, though not significantly different from the yields obtained with 80 kg N ha^{-1}, compared to the control. This is in line with the findings of Liu *et al.* (2013) and Ibrahim *et al.* (2015) who reported that the application of organic and inorganic fertilizer under micro-dosing accelerates the improvement of soil fertility and significantly improves crop yields in the short term. Furthermore, Akintoye *et al.* (2006) reported that the use of inorganic fertilizer alone is not sustainable for the production of *S. macrocarpon.* Furthermore, this result substantiated the findings of Ncube et al. (2007) that more considerable average gains could be obtained by combining nitrogen fertilizer with a basal application of manure and Twomlow *et al*. (2010) reported significant increases in cereal grain yield with 17 kg N ha^{-1} (approximately 25 % of recommended levels) compared to recommended rates of 55 kg

Table 2: Effect of time and fertilizer rates on the fresh yield of *Solanum macrocarpon* at the two agro-ecologies

Fertilizer Rate ($kg\ ha^{-1}$)	DERIVED SAVANNA T1	T2 ($kg\ ha^{-1}$)	Mean	RAINFOREST T1	T2 ($kg\ ha^{-1}$)	Mean
0	333b	1750b	1042	604b	417b	511
20	4583a	3792ab	4188	1104ab	1229ab	1167
40	1417ab	3458ab	2438	1833a	750ab	1292
60	1333ab	4750a	3042	1771ab	1292ab	1532
80	2167ab	2625ab	2396	775ab	1708a	1242
Mean	1967	3275	2621	1218	1079	1149
LSD	3137	2142	-	1038	1140	-

Means with the same alphabets are not significantly different from each one at $p \leq 0.05$. LSD - Least Significant difference. Where, 0 – Organic fertilizer (OF) only, 20 – OF + 20 kg N ha^{-1}, 40 – OF + 40 kg N ha^{-1}, 60 – OF + 60 kg N ha^{-1}, 80 – 80 kg N ha^{-1} only. T 1 – Fresh yield at planting, T 2 - Fresh yield at 2 WAP.

ha $^{-1}$ under micro-dosing. In this study, significant increases in the yield of the vegetables with 20 kg N ha^{-1} was observed compared to recommended rates of Nafiu *et al*. (2011) who established that 30 kg N ha^{-1} is optimum for *S. macrocarpon* production. Although, the time of application did not have a significant difference on the yields of *S. macrocarpon;* it was observed that application at 2 WAP was more favourable at the derived savanna while the application at AAS was favourable at the rainforest. This result is in line with the findings of Hayashi *et al*. (2008).

3.3. The effect of fertilizer rate and time of application on the availability of soil P to S. macrocarpon.

Table 3 shows that the fertilizer treatment at both locations had no significant effect on the uptake of phosphorus. Following the same trend with the yield, fertilizer rate at 20 kg N ha^{-1} gave the highest uptake value. Also, the highest P uptake was observed at the derived savanna compared to the rainforest, and this can be attributed to the fact that soils in the rainforest are richer in nutrient compared to those in the derived savanna which are fragile and low in organic matter content (Abiala, 2013) hence, the higher

Table 3: The effect of fertilizer rate and time of application on the availability of soil P to *S. macrocarpon*

Fertilizer Rate (kg ha^{-1})	DERIVED SAVANNA T1	T2 (kg ha^{-1})	Mean	RAINFOREST T1	T2 (kg ha^{-1})	Mean
0	0.02a	0.64 a	0.33	0.05 a	0.03 a	0.04
20	3.50a	2.21 a	2.85	0.13 a	0.27 a	0.20
40	0.32a	1.45 a	0.88	0.38 a	0.08 a	0.23
60	0.33a	2.44 a	1.38	0.36 a	0.16 a	0.26
80	0.56a	0.80 a	0.67	0.11 a	0.30 a	0.21
Mean	0.95	1.51	1.23	0.21	0.17	0.19
LSD	3.30	1.86		0.34	0.33	

Means with the same alphabets are not significantly different from each other at $p \leq 0.05$. Where, 0 – Organic fertilizer (OF) only, 20 – OF + 20 kg N ha^{-1}, 40 – OF + 40 kg N ha^{-1}, 60 – OF + 60 kg N ha^{-1}, 80 – 80 kg N ha^{-1} only; T 1 – phosphorus availability at plant-

response to fertilizer treatments at the derived savanna compared to the rainforest zone. Photosynthetic reactions are dependent on temperature (Azam-Ali, 2013); with higher exposure to solar radiation and less cloud cover, increased N and assimilation will be expected. Although no significant differences were observed at the time of fertilizer application, application time at 2 WAP was favourable for higher P uptake at the derived savanna while AAS was favourable at the rainforest. This can be attributed to varying climatic conditions that exist across ecological zones which is in line with the findings of Hamden and Fadni, (2010).

3.4. The effect of fertilizer rate and time of application on the availability of soil P to *S. macrocarpon*.

Table 3 shows that the fertilizer treatment at both locations had no significant effect on the uptake of phosphorus. Following the same trend with the yield, fertilizer rate at 20 kg N ha^{-1} gave the highest uptake value. Also, the highest P uptake was observed at the derived savanna compared to the rainforest, and this can be attributed to the fact that soils in the rainforest are richer in nutrient compared to those in the derived savanna which are fragile and low in organic matter content (Abiala, 2013) hence, the higher

Table 3: The effect of fertilizer rate and time of application on the availability of soil P to *S. macrocarpon*

Fertilizer Rate (kg ha^{-1})	DERIVED SAVANNA T1	T2 (kg ha^{-1})	Mean	RAINFOREST T1	T2 (kg ha^{-1})	Mean
0	0.02a	0.64 a	0.33	0.05 a	0.03 a	0.04
20	3.50a	2.21 a	2.85	0.13 a	0.27 a	0.20
40	0.32a	1.45 a	0.88	0.38 a	0.08 a	0.23
60	0.33a	2.44 a	1.38	0.36 a	0.16 a	0.26
80	0.56a	0.80 a	0.67	0.11 a	0.30 a	0.21
Mean	0.95	1.51	1.23	0.21	0.17	0.19
LSD	3.30	1.86		0.34	0.33	

Means with the same alphabets are not significantly different from each other at $p \leq 0.05$. Where, 0 – Organic fertilizer (OF) only, 20 – OF + 20 kg N ha^{-1}, 40 – OF + 40 kg N ha^{-1}, 60 – OF + 60 kg N ha^{-1}, 80 – 80 kg N ha^{-1} only; T 1 – phosphorus availability at plant-

response to fertilizer treatments at the derived savanna compared to the rainforest zone. Photosynthetic reactions are dependent on temperature (Azam-Ali, 2013); with higher exposure to solar radiation and less cloud cover, increased N and assimilation will be expected. Although no significant differences were observed at the time of fertilizer application, application time at 2 WAP was favourable for higher P uptake at the derived savanna while AAS was favourable at the rainforest. This can be attributed to varying climatic conditions that exist across ecological zones which is in line with the findings of Hamden and Fadni, (2010).

Although, the time of fertilizer application had no significant effect on P uptake; higher uptake, attributed to wellestablished root hairs and well-decomposed organic material, was observed at the derived savanna with the application at 2 WAP while higher P uptake was obtained at AAS, owing to higher precipitation and soil type, at the rainforest zone.

3.5. The effect of fertilizer rate and time of application on the availability of soil S

to *S. macrocarpon*

Table 4 shows the effect of fertilizer rate and time of application on the availability of soil S to *S. macrocarpon*. The fertilizer rate had no significant effect on S uptake by the vegetable. Sulphur uptake increased with increasing fertilizer rate, but the highest uptake was obtained with treatment with 20 kg N ha^{-1} while the control had the least uptake by *S. macrocarpon*. The time of fertilizer application had no significant effect on the uptake of S at both locations. The application at 2 WAP was favourable for S uptake at the derived savanna while AAS was favourable for the uptake of S at the rainforest. A slight decline in S uptake, similar for P uptake, was observed with the application of 80 kg N ha^{-1} though not significantly different from 60 kg N ha^{-1}. This result is in line with the findings of Islam *et al.* (2011), who observed that higher nutrient uptake (N, P, K and S) by radish-stem-amaranth was significantly influenced by the integrated treatment of organic

Table 3: The effect of fertilizer rate and time of application on the availability of soil P to S. macrocarpon

Fertilizer Rate (kg ha^{-1})	DERIVED SAVANNA T1 →	T2 (kg ha^{-1})	Mean ←	RAINFOREST T1 →	T2 (kg ha^{-1})	Mean ←
0	0.11b	0.49b	0.30	0.18a	0.07ab	0. 12
20	1.26a	1.30a	1.28	0.32 a	0.37ab	0.35
40	0.52ab	1.00ab	0.76	0.51 a	0.21ab	0.36
60	0.45ab	1.33a	0.89	0.47 a	0.31ab	0.39
80	0.65ab	0.68ab	0.66	0.23 a	0.43a	0.33
Mean	0.60	0.96	0.57	0.34	0.28	0.31
LSD	0.82	0.65		0. 33	0. 31	

Means with the same alphabets are not significantly different from each other at $p \leq 0.05$. Where, 0 – Organic fertilizer (OF) only, 20 – OF + 20 kg N ha^{-1}, 40 – OF + 40 kg N ha^{-1}, 60 – OF + 60 kg N ha^{-1}, 80 – 80 kg N ha^{-1} only; T 1 – sulphur availability at planting, T 2 - sulphur availability at 2 WAP.

and inorganic fertilizers. Moreover, Wilkinson *et al*. (2000) and Fageria, (2009) explained that the addition of nitrogen could increase P concentration in plants by increasing root growth and by increasing the ability of roots to absorb and translocate P. Also, the acidifying effect of N fertilizers could enhance N concentration in plants (Malhi *et al*., 1988) and P solubility in soil (Prasad and Power, 1997) which improves photosynthetic efficiency

Table 5: Effect fertilizer microdosing rate and time of application on the availability of soil Fe (g ha-1) to *Solanum macrocarpon*

Fertilizer Rate (kg ha^{-1})	DERIVED SAVANNA T1 →	T2 (kg ha^{-1})	Mean ←	RAINFOREST T1 →	T2 (kg ha^{-1})	Mean ←
0	21.08b	97.11b	59.10	53.83ab	20.47a	35.67
20	189.25a	306.03a	247.64	79.17a	39.85a	59.51
40	86.71ab	196.46ab	141.58	53.33ab	23.92a	38.63
60	80.87ab	214.98ab	147.92	56.11ab	50.13a	53.12
80	121.44ab	136.80ab	129.12	36.58b	50.62a	45.93
Mean	99.87	190.28		55.85	37.30	
LSD						

Means with the same alphabets are not significantly different from each other at $p \leq 0.05$. Where, 0 – Organic fertilizer (OF) only, 20 – OF + 20 kg N ha^{-1}, 40 – OF + 40 kg N ha^{-1}, 60 – OF + 60 kg N ha^{-1}, 80 – 80 kg N ha^{-1} only; T 1 – Iron availability at planting, T 2 – Iron availability at 2 WAP.

and nitrogenous metabolism by enhancing the synthesis of new chloroplast thylakoids (Menghini *et al*., 1998) these results in increased assimilation of P and S (Osman, 2013) as observed in this study.

3.6. Effect of fertilizer rate and time of application on the availability of soil Fe (g ha^{-1}) to Solanum macrocarpon.

Table 5 shows the effect of fertilizer rate and application time on the availability of soil Fe (g ha^{-1}) to *S. macrocarpon*. Fertilizer application rate at 20 kg N ha^{-1} had the highest average Fe uptake while the control had the least uptake by *S. macrocarpon* at both locations.

Table 6: Effect fertilizer rate and time of application on the availability of Zinc to Solanum macrocarpon.

Fertilizer Rate (kg ha^{-1})	DERIVED SAVANNA T1 →	T2 (kg ha^{-1})	Mean ←	RAINFOREST T1 →	T2 (kg ha^{-1})	Mean ←
0	1.14b	11.23b	6.19	2.86b	1.29b	2.13
20	20.79a	37.22a	29.00	5.18ab	4.74ab	4.96
40	7.77b	12.74b	10.25	10.96a	2.67ab	6.81
60	5.28b	23.21ab	14.24	7.25ab	5.43ab	6.34
80	11.24ab	9.56b	10.40	4.28ab	6.61a	5.76
Mean	9.24	18.79		6.27	4.13	
LSD						

Means with the same alphabets are not significantly different from each other at $p \leq 0.05$. Where, 0 – Organic fertilizer (OF) only, 20 – OF + 20 kg N ha^{-1}, 40 – OF + 40 kg N ha^{-1}, 60 – OF + 60 kg N ha^{-1}, 80 – 80 kg N ha^{-1} only; T 1 – zinc availability at planting, T 2 – zinc availability at 2 WAP.

The time of fertilizer application had no significant effect on the uptake of Fe at both locations. The application at 2 WAP was favourable for Fe uptake at the derived savanna while AAS was favourable for the uptake of Fe at the rainforest. A slight decline in Fe uptake, similar for P and S uptake, was observed with the application of 40, 60 and 80 kg N ha^{-1} though not significantly different from each other. This result is in line with Fageria (2014), who reported that the application of nitrogen fertilizer decrease soil pH and hence, might increase Fe uptake. Also, the findings of Kutman *et al.* (2011) on wheat plant revealed that N-application enhanced the uptake of Fe.

3.7. Effect fertilizer rate and time of application on availability of soil Zn to S. macrocarpon.

Table 6 shows that the combined application of organic and inorganic fertilizer increases the availability of Zinc (Zn). Fertilizer rate at 20 kg N ha^{-1}up till 80 kg N ha^{-1} significantly increased Zn uptake compared to the control treatment, which had the least uptake at both locations. The time of fertilizer application had no significant effect on the uptake of Zn at both locations though application at 2 WAP was favourable for Zn uptake at the derived savanna while AAS was favourable for the uptake of Zn at the rainforest. This result disclosed that as fertilizer increased, Zn uptake also increased which was in line with the study of Fageria and Baligar, (2005) who reported that N fertilization significantly increased Zn uptake in the shoot of dry bean.

4.0 Conclusion

This study concluded that using microdosing technology increases yield and availability of soil P, S, Fe and Zn for *Solanum macrocarpon* production at optimum fertilizer rate of 20 kg N ha^{-1} in southwest Nigeria. The time of fertilizer application had no significant effect on yield and availability of P, S, Fe and Zn by *S. macrocarpon*, a delayed timing (2 WAP) are therefore recommended.

5.0.Acknowledgements

The study was funded by the IDRC (International Development Research Centre) grant number 107983 under MICRO-VEG project. The authors are thankful to IDRC for the research grant.

References

Abiala, M. A., Odebode, A. C., Adeoye, G. O., Hsu, S. and Blackwood, C. B. (2014). Soil Chemical Dynamics in Maize Field of Southwestern Nigeria. *American-Eurasian Journal of Agriculture* and *Environmental Science*, 13 (2): 234-243.

Adebisi-Adelani, O., Olajide-Taiwo, F. B., Adeoye, I. B. and Olajide-Taiwo, L. O. (2011). Analysis of production constraints facing Fadama vegetable farmers in Oyo State, Nigeria. *World Journal of Agricultural Sciences*, 7(2): 189-192.

Adepetu, J. A., Adetunji, M. T. and Ige, D. V. (2014). *Soil Fertility and Crop Nutrition.* Ibadan: Jumak 361-422. .ISBN: 978-978-944-218-8.

Adepetu, J.A. (1990). Soil test data interpretation in soil testing programme. Paper presented at National Workshop on soil testing service for efficient fertilizer use in Nigeria. Moor plantation, Ibadan.

Ajibola, B. O., Komolafe, S. E. and Akangbe, J. A. (2015). Constraints faced by women vegetable farmers in Kwara State, Nigeria and its Agricultural practices. *Jordan Journal of Agricultural Science, 11(4): 995-1006.*

Akintoye, H. A., Olaniyan, A. B. and Olasanmi, B. (2006). Effect of different sources of nitrogen on growth and yield of *Solanum macrocarpon* in derived savanna of Nigeria. *Journal of Agronomy,* 5(2): 182-185.

Azam-Ali, S. (2013). Plant and crop science. In Gregory, P. J. and Northcliff, S. (Eds). *Soil condition and plant growth*. Wiley-Blackwell UK. 22-46.

Bagayoko, M., Maman, N., Pale, S., Sirifi, S., Taonda, S. J. B. and Traore, S. (2011). Microdose and N and P fertilizer application rates for Pearl millet in West Africa. *African Journal of Agricultural Research,* 6(5): 1141-1150.

Bello, W. B. and Muhammed Awwal, (2008). Effects of Nitrogen, rate and timing of application on growth and yield of Beetroot (Beta vulgaris). *African Journal of Biotechnology* vol. 7(15).

Bouyoucos, G. F. (1965). Hydrometer method improved for making particle size analysis of soils. *Soil Science Society of America Proceedings* 26: 464-465.

Bray, R. H. and Kurtz, L. T. (1945). Determination of total organic and available forms of phosphorus in soils. *Soil science* 59: 39-45.

Bremner, J. M. (1996). Total Nitrogen. In: Sparks, D.L., Ed., Methods of Soil Analysis, Part 3, Chemical Methods, *Soil Science Society of America and ASA, Madi-*

son, 1123-1184.

Bremner, J. M. (1996). Total nitrogen. In: Sparks, D.L., Ed., *Methods of Soil Analysis*, *Part 3*, *Chemical Methods*, Madison, SSSA and ASA, 1085-1121. DOI: 10.1080/00380768.2016.1194169

Ehigiator, J. O. Ariyo, A. D. and Imasuen, E. E. (2015). Soil fertility and nutritional studies on citrus, fruit and vegetable crops in Nigeria (1975 to 2005). *Nigerian Journal of Agriculture, Food and Environment*, 11(2): 103-114.

Fageria, N. K. (2014). *Nitrogen management in crop production* (online). Boca Raton, New York: CRC Press, 245-274.

Fageria, N. K. and Baligar, V. C. (2005). Enhancing nitrogen use efficiency in crop plants. *Advance Agronomy*88:97-185.

Fageria, N.K. (, 2009). The use of nutrients in crop plants. Boca Raton, Florida: CRC Press. 234-260.

Fertilizer suppliers association of Nigeria, (FEPSAN) (2014). 4(5): 1-4. (www.fepsannigeria.com).

Govindaraj, M., Kannan, P. and Arunachalam, P. (2011). The implication of micronutrients in agriculture and health with particular reference to iron and zinc. *International Journal of Agricultural Management and Development* 1(4): 207-220.

Hamden, M. I. K. and Fadni, O. E. (2010). Effect of different types of organic fertilizers on growth, quality and yield of tomatoes in sandy soil. Agriculture Research Corporation. Second RUFORUM Biennial Meeting 20-24 September 2010, Entebbe, Uganda.

Havlin, J. L., Beaton, J. D., Tisdale, S. L, and Nelson, W.L. (2009). *Soil fertility and fertilizers-An introduction to nutrient management*, 7th edition PHI Learning Private Limited.New Delhi.

Hayashi, K., Abdoulaye, T., Gerard, B., Bationo, A. (2008). Evaluation of application timing in fertilizer micro-dosing technology on millet production in Niger, West Africa. *Nutrient Cycling Agroecosystem* 80(3): 257–265. doi:10.1007/s10705-007-9141-3.

Ibrahim, A., Abaidoo, R.C., Fatondji, D. and Opoku, A. (2015). Determinants of fertilizer micro dosing-induced yield increment of pearl millet on an acid sandy soil. *Experimental Agriculture* 1:1-17. doi:10.1017/S00144797150002.

ICRISAT (2009). Fertilizer micro Dosing-Boosting production in unproductive lands. Access online at www.icrisat.org/impacts/impact-stories/icrisat-is-fertilizer micro-dosing.

Idowu, M. K. (2009). Does gender affect the quality of the soil and vegetable amaranth under peri-urban of Osun state, Nigeria? *Agricultural Journal*. 40(2): 312-320.

Idowu, M. K. (2010). Effect of fertilizer use and Gender of farmers on soil/ plant nitrogen and crude protein content of vegetable amaranth in Osun state, Nigeria. *Acta Agronomica Nigeriana,* 10(2): 102- 109.

Idowu, M. K., Oyedele, D. J., Adekunle, O. K., Akinremi, O. O. and Eilers, B. (2014). Effects of planting methods and seed density on vegetable yield and nutrient composition of *Solanum macrocarpon* and *Solanum scabrum* in Southwest Nigeria. *Food and Nutrition Sciences*, 5:1185-1195.

Institut de l'Environnement et de Recherches Agricoles (INERA), (2010). AGORA: Helping Burkina Faso's researchers develop innovative agricultural solutions. In applying micro-dose Technology in Burkina Faso to boost smallholder farmers' livelihoods and improve food security.

Islam, M. M., Karim, A. J. Jahiruddin, M. S., Nik, M., Majid, M., Mustaque, M. G., Ahmed, M. and Hakim, M.A. (2011). Effects of organic manure and chemical fertilizers on crops in the radish-stem amaranth Indian spinach cropping pattern in homestead area. *African Journal of Crop Science*, 5(11): 1370-1378.

Jones, C. and Jacobsen, J (2009). Fertilizer placement and timing. In: nutrient management, a case study course from Montana state university extension continuing education series. Bozeman. In: nutrient management module (11): 1-15.

Kuo, S. (1996). Phosphorus. In: Sparks, D. L. (ed) Methods of soil analysis: Part 3, Chemical methods. *Soil Science Society of America*, Madison, USA: 869-919.

Kutman, U. B., Yildiz, B. and Cakmak, I. (2011). Effect of nitrogen on uptake, remobilization and partitioning of zinc and iron throughout the development of durum wheat. *Plant Soil* 342:149–164.

Liu, C. A., Li, F. R., Zhou, L. M., Zhang, R. H., Lin, S. L., Wang, L. J., Siddique, K. H. and Li, F. M. (2013). Effect of organic manure and fertilizer on soil water and crop yields in newly-built terraces with loess soils in a semi-arid environment. *Agriculture Water Management*, 117: 123–132.

Malhi, S. S., Nyborg, M., Jahn, H. G. and Penney, D. C. (1988). Yield and nitrogen uptake of rapeseed (*Brassicacampestris* L.) with ammonium and nitrate. *Journal of Plant and Soil Science*, 105: 231–240.

Marschner, H. (1998). *Mineral nutrition of higher plants*. 3rd edition. London: Academic Press, 313-347.

Menghini, A., Pocceshi, N., Venani, G. and Palladini, T. (1998). Effect of nitrogen fertilization on photosynthesis rate, nitrogenous metabolites and α, β- asarone accumulation in triploid Acorus calamus L. leaves. *Flavour and Fragrance Journal* 13: 319- 323.

Nafiu, A. K., Togun, A. O., Abiodun, M. O. and Chude, V. O. (2011). Effects of NPK fertilizer on growth, dry matter production and yield of eggplant in Southwestern Nigeria. *Agriculture and Biology Journal of North America,* (2)7: 1117-1125.

Ncube, B., Dimes, J. P., Twomlow, S. J., Mupangwa, W. and Giller, K. E. (2007). Participatory on-farm trials to test the response of maize to small doses of manure and nitrogen in smallholder farming systems in semi-arid Zimbabwe. *Nutrient Cycling in Agroecosystems,* 77: 53 - 67.

Oboh, G., Ekperigin, M. M. and Kazeem, M. I. (2005). Nutritional and haemolytic properties of eggplants (*Solanum macrocarpon*) Leaves. *Journal of Food Composition and Analysis* 18(2-3): 153–160.

Olajire, A. A. and Azeez, L. (2012). Protective effects of *Solanum macrocarpon* against Oxidative Stress. *Advances in Chemical Science* 1(1):1-11.

Omotoso, S. O., Akinrinde, E. A. (2003). Effect of nitrogen fertilizer on some growth, yield and fruit quality parameters in pineapple (*Ananas comosus* L. Merr.) plant at Ado- Ekiti Southwestern, Nigeria. *International Research Journal of Agricultural Science and Soil Science,* 3(1): 11-16.

Osman, K. H. (2013). *Soils* - Principles, properties and management. New York. London.

Piper, C. S. (1944). Dry ashing. Soil and plant analysis. New York: Inter-science Publishers Incorporation, 221-222.

Piper, C. S. (1944). Dry ashing. Soil and plant analysis.

New York: Inter-science Publishers Incorporation, 221 -222.

Prasad, R. and Power, J. F. (1997). *Soil fertility management for sustainable agriculture*. CRC Press, London.

Price, C. A., Clark, H. E. and Funkhouser, E.A. (1972). Function of micronutrients in plants. In: Mortvedt, J. J., Giordano, P. M. and Lindsay, W. L. (Eds.). *Micronutrients in Agriculture*. USA. Soil Science Society of America, 231-239.

Sangainga, N. and Woomer, P. L. (eds) (2009*). Integrated Soil Fertility Management in Africa: Principles, Practices and Development Process.* Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture, Nairobi, 13- 79.

SAS (2002). SAS Online Version 9.0. SAS Institute Inc., Cary, NC, USA.

Shafea, L. and Saffari, M. (2011). Effects of zinc and nitrogen on chemical composition of maize grain. *International Journal of Agricultural Science*, 1: 323-328.

Sobulo, R. A. and Adepetu, J. A. (1987). Soil testing and fertilizer formulation for crop production in Nigeria. In: Towards efficient fertilizer use and development in Nigeria. Federal Ministry of Agriculture Lagos.

Tabo, R., Bationo, A., Gerald, B., Ndjeunga, J., Marchal, D., Amadou, B., Annou, M. G., Sogodogo, D., Taonda, J. B. S., Hassane, O., Diallo, M. K. and Koala, S. (2006). Improving cereal productivity and farmers' income using a strategic application of fertilizers in West Africa. In: Bationo A., Waswa B.S., Kihara J. and Kimetu J. (Eds). *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities*. Springer, Netherlands, 201–208

Twomlow, S., Rohrbach, D., Dimes, J., Rusike, J., Mupangwa, W., Ncube, B., Hove, L., Moyo, M., Mashingaidze, N. and Mahposa, P. (2010). Microdosing as a pathway to Africa's Green Revolution: Evidence from Broad-Scale On-farm Trials. *Nutrient cycling agroecosystem*, 83:3-15.

Walkey, A. C. and Black T. A (1935). Estimation of soil organic carbon by chromic acid titration method. *Journal of Soil Science*. 47:29-38.

White, P. J. Broadley, M. R. and Gregory, P. J. (2012). Managing the nutrition of plants and people. *Applied and Environmental Soil Science* 1-14.

Wilkinson, S. R., Grunes, D. L. and Sumner, M. E. (2000). Nutrient interaction in the soil and plant nutrition. In: Handbook of soil science.