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Effect of NPK-enriched Rice Mill Waste (bran) forms on Growth and Yield of Sweet Potato Production in an Ultisol of Southeast Nigeria

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ABSTRACT

The potential contribution of orange fleshed sweet potato towards food security in Nigeria is underestimated as a huge gap due to the soil environment as an important yield determinant. The research into the soil nutrient conditions for sweet potato production has not been extensive. In response to this challenge, the objective of this study is to determine the response of orange-fleshed sweet potato to NPK-enriched rice mill waste (bran) forms for commercial sweet potato production. The study was conducted in the 2020 and 2021 cropping seasons at the Eastern research farm of National Root Crops Research Institute, Umudike, Abia State. The land was slashed, ploughed, harrowed and ridged mechanically. The experiment was a 4 x 2 x 2 factorial experiment laid out in Randomized Complete Block Design (RCBD). The plot size measured 3m x 3m with 0.5m space separating the plots and 1m space separating the replications. NPK 15:15:15 at levels of 0, 200, 400 and 600 kg/ha was factorially combined with carbonize RMW at 0 and 5 t/ha and uncarbonize RMW at 0 and 10 t/ha giving a total of 16 treatment combinations replicated three times. The rice mill wastes were applied to the plots two weeks before planting. Mineral fertilizer was applied at 4 weeks after planting. The test crop orange-fleshed sweet potato, UMUSPO/3 variety (Mother's Delight) was obtained from Sweet potato Research Programme of NRCRI, Umudike. The sweetpotato vine cuttings were planted on the crest of the ridge at a spacing of 0.3m within rows and 1m between rows giving a plant population of 33.333 stands/ha. The cuttings were planted 2 nodes down the soil and 2 nodes on the soil surface. Data were collected on yield performance, total root weight, weight of marketable roots, number of marketable roots and other useful agronomic traits. All the data collected were subjected to analysis of variance. The analysis was done following the procedures for randomized complete block design (RCBD) using the Genstat Discovery 12th edition. Significant treatment means were separated using least significant difference (LSD) at 5% probability level. The result of the experiment showed that there were significant ($P < 0.050$) difference among the treatments used. The study also showed that integrated nutrient management (combining organic and mineral fertilizers) holds the key to improving the growth and root yield of orange-fleshed sweet potato. The results showed that application of rice mill waste had varied effects on the chemical properties of the soil as its application showed superiority in improving the growth parameters at different sampling periods as well as an increase in both the total and marketable root yield of orange-fleshed sweet potato. Based on the findings reported in this study, orange-fleshed sweet potato for commercial root production in the study area can be improved by combining organic materials such as rice mill waste (bran) with mineral fertilizers.

Keywords: Orange fleshed, NPK, Rice mill waste, production, Sweet potato.

INTRODUCTION

Root and tuber crops are important sources of carbohydrate for millions of people throughout the tropics. Sweetpotato (*Ipomoea batatas* (L) Lam), a trailing perennial plant of the family Convolvulaceae (morning glory family), and the only member of the genus *Ipomoea* whose roots are edible, is undeniably one of the world's most important food crops due to its high nutritive value (Data and Eronico, 1987). It is believed to have originated from either Central America or within the tropical region of North Western

parts of Central America (Onwueme, 1978; Hahn and Hozzo, 1984). It is one of the major root crops that had suffered neglect in the past but now appears to be gaining a prime position as a source of food and industrial raw materials. Globally, sweet potato ranks third among root and tuber crops after potato (281 million tonnes) and cassava (164 million tonnes), with a production of about 122 million tonnes (FAO, 1996). China accounts for the highest production of sweet potato (2,883,408 tonnes) making Asia the world's leading producer of sweet potato (FAO, 2012),

followed by Uganda and then Nigeria in that order (FAO, 2004). In Nigeria, it is one of the four major root and tuber crops coming after cassava, yam and cocoyam (APMEU, 1996). These crops play important roles in both social and economic development of the country.

The potential contribution of this crop towards food security in Nigeria is underestimated as a huge gap exists between its potential yield of 20 - 40t/ha and actual yield of 3 - 5t/ha in farmers' fields (Akoroda and Egeonu, 2008). Unamma *et al* (1984), reported that the constraints responsible for farmer's low yields could be as a result of weed competition, poor soil management and very little attention given to its research.

The current revolution in the production of rice by the Federal government which has led to a sporadic rise in rice production in South-east Nigeria has made rice mill waste abundant. In fact, in many areas, rice mill wastes could constitute a very serious environmental problem if not handled and adequately removed as it stands to pollute the environment. Though presently considered as an environmental nuisance, interestingly, this organic material can be carbonized through the use of a carbonator machine. Carbonize rice mill waste has the potential of being used to improve soil pH and fertility especially when complemented with NPK fertilizer. It is also an energy source for bacteria, fungi and earthworm in the soil. The integrated application of organic and inorganic nutrient sources rather than total dependence on any of the sources is expected to ensure reduction in expenditure on chemical fertilizer, a more balanced plant nutrition and control of soil acidity.

Apart from diseases and other biotic stresses which affect the plant (Terry and Oyekan, 1976), the soil environment is an important yield determinant. Unfortunately, research into the soil nutrient conditions for sweet potato production has not been extensive. This may have been due to the notion that sweet potato is adapted to soil acidity and it is deep-rooting, with the ability to produce fairly good yield from poor soils. While the bulk of reported findings on soil nutrient studies dwelt largely on the type, time and methods of application of chemical fertilizers, studies on soil nutrient amendment through the use of organic fertilizer sources under the weathered soils of the high rainforest belt of the South-east Nigeria have been very scanty.

Therefore, an attempt to study the Response of Orange-fleshed sweet potato to NPK-enriched rice mill waste (bran) forms on South-eastern soils of Nigeria is to be made as there is lack of information in this regard.

MATERIALS AND METHODS

Location of the experiment: The study was conducted in the 2020 and 2021 cropping seasons at the Eastern farm of National Root Crops Research Institute,

Umudike, Abia State. Abia State is one of the states in the rain forest zone of the Southeastern geopolitical zone of Nigeria. The other states within the region include Anambra, Ebonyi, Enugu, and Imo. It lies within Latitude 4°15' and 7°N and Longitude 5°29' North and 7°33' east of the Equator with an elevation of 122m above sea level. It is therefore heated by the vertical rays of the sun all year round.

Rainfall: The study area has two distinct wet and dry seasons as shown in Tables 1.1 and 1.2. The general rainfall pattern within the area is bimodal, with peaks occurring in July and September, respectively. Rain falls virtually throughout the years in the area with more than ninety percent of the rains spread through eight months of March to October. The dry months are October, November, December, January and February. The area is characterized by heavy precipitation of over 2000mm per annum. The areas closest to the coast experience more rainfall than those further away. During the first two months of the rainy season, the rains come as violent thunderstorms. The same is time for the little rain that falls towards the end of the November and December.

Temperature: Temperatures are high and change only slightly during each year. The mean minimum and maximum temperatures of over 22° to 32C occur each year. Temperatures are generally highest in months of February through April, Tables 1.1 and 1.2. This coincides with the passage of the overhead sun. It also has a mean annual soil temperature of 25.8°C. In the 2020 and 2021 cropping seasons, when the trials were conducted, Umudike had an average rainfall of 2248.7mm in 98 days and 2061.1mm in 114 days respectively.

Relative Humidity: The relative humidity is generally high. The mean monthly relative humidity ranges from 63 to 80% (Agromet and Statistics Unit 2021). The least relative humidity values are recorded during the dry season months of November, December and January. During dry season, the dry dusty harmattan wind blows across the area and causes occasional reduction in relative humidity.

Sunshine: Generally the sunshine hour followed the bimodal rainy season of the area. A total of 54 sunshine hours during the 2020 cropping season with the highest sunshine of 6.5 hours on February with the least of 3.2 hours in July and September was observed. While in 2021, the total was 52.8, while January and December recorded the highest of 6 hours sunshine and least of 2.7hours in July.

Soils of the Study Area: The soils of the forest zone of Southeastern Nigeria are formed from three major geological formations (FDALR 1986). These are coastal plain sands/sand stone, the basement complex and the shale formations. Soils formed on coastal plain sands/sand stones occupy most of Imo, Abia and

Akwa-Ibom States a reasonable part of Rivers, Bayelsa and Ebonyi states and a little of Cross River State. These soils are referred to as “Acid sands”. The Cation Exchange Capacity and base saturation are low and they are of low natural fertility. They indicate multiple

deficiencies especially those formed from coasted plain sands due to low natural reserve and high leaching intensity and respond well to fertilizer application (Enwezor *et al*, 1989).

Table 1.1 Agro-meteorological data of the study area in 2020 and 2021

| | Rainfall (mm) | | Temperature (°c) | | Rel. Humidity (%) | | Radiation (ml) |
|-------------|---------------|-------------|------------------|-------------|-------------------|-----------|----------------|
| | Amt | Days | Max | Min | 0900Z | 1500Z | |
| Jan | 0 | 0 | 34.5 | 21.4 | 48 | 34 | 6.2 |
| Feb | 0 | 0 | 36.1 | 22.2 | 60 | 31 | 6.5 |
| March | 126.1 | 5 | 33.7 | 25.1 | 80 | 59 | 5.4 |
| April | 116.6 | 6 | 33.6 | 23.4 | 83 | 62 | 4.6 |
| May | 270.9 | 8 | 31.8 | 23.2 | 85 | 66 | 4.5 |
| June | 340.6 | 13 | 32 | 22 | 85 | 72 | 3.6 |
| July | 482.7 | 21 | 30.8 | 21.8 | 88 | 78 | 3.2 |
| Aug | 92.4 | 9 | 31.5 | 84 | 70 | 3.9 | |
| Sept | 433.7 | 20 | 30.6 | 22.3 | 88 | 75 | 3.2 |
| Oct | 185.48 | 31.7 | 21.2 | 86 | 70 | 3.4 | |
| Nov | 200.3 | 8 | 32.1 | 22.3 | 77 | 63 | 4.4 |
| Dec | 0 | 0 | 34.1 | 22.6 | 81 | 58 | 4.8 |
| Total | 2248.7 | 98 | 391.8 | 279.6 | 948 | 744 | 54 |
| Mean | 187.39 | 8.17 | 32.7 | 23.3 | 79 | 62 | 4.5 |

2021 Climatic Weather Data

| | Rainfall (mm) | | Temperature (°c) | | Rel. Humidity (%) | | Radiation (ml) |
|-------------|---------------|-----------|------------------|-----------|-------------------|-----------|----------------|
| | Amt | Days | Max | Min | 0900Z | 1500Z | |
| Jan | 0 | 0 | 35 | 22 | 73 | 46 | 5.6 |
| Feb | 0 | 0 | 36 | 21 | 72 | 41 | 6 |
| March | 36.3 | 4 | 35 | 22 | 82 | 54 | 5.1 |
| April | 75.5 | 10 | 34 | 21 | 79 | 62 | 5.4 |
| May | 47.9 | 5 | 33 | 21 | 84 | 71 | 4.4 |
| June | 272 | 14 | 31 | 22 | 84 | 74 | 3.8 |
| July | 301.4 | 17 | 30 | 23 | 87 | 75 | 2.7 |
| Aug | 556.8 | 23 | 30 | 22 | 89 | 77 | 2.9 |
| Sept | 344.2 | 19 | 32 | 21 | 83 | 77 | 3.2 |
| Oct | 328 | 15 | 33 | 22 | 86 | 75 | 3.5 |
| Nov | 99 | 7 | 33 | 23 | 82 | 72 | 4.6 |
| Dec | 0 | 0 | 33 | 21 | 65 | 47 | 6 |
| Total | 2061.1 | 144 | 396 | 264 | 972 | 768 | 52.8 |
| Mean | 171.8 | 10 | 33 | 22 | 81 | 64 | 4.4 |

Source: Agromet and Statistical Unit, NRCRI Umudike

Land preparation: The land was slashed, ploughed, harrowed and ridged mechanically. Before planting, stumps were removed from the plots using simple tools like hoes and cutlasses and the field was demarcated into plots and replicates.

Experimental design/treatment: The experiment was a 4 x 2 x 2 factorial experiment laid out in Randomized Complete Block Design (RCBD). The plot size measured 3m x 3m with 0.5m space separating the plots and 1m space separating the replications. The materials for the experiment were mineral fertilizer

(NPK 15:15:15), carbonized rice mill waste and uncarbonized rice mill waste. The NPK 15:15:15 fertilizer was sourced from the Abia State Ministry of Agriculture and Natural Resources, Umuahia while the rice mill waste was sourced from rice mill industry, Bende L.G.A of Abia State. NPK 15:15:15 at levels of 0, 200, 400 and 600 kg/ha was factorially combined with carbonize RMW at 0 and 5 t/ha and uncarbonize RMW at 0 and 10 t/ha giving a total of 16 treatment combinations replicated three times. The rice mill wastes were applied to the plots two weeks before

planting. Mineral fertilizer was applied at 4 weeks after planting.

Planting material: The test crop orange-fleshed sweet potato, UMUSPO/3 variety (Mother's Delight) was obtained from Sweet potato Research Programme of NRCRI, Umudike. The sweetpotato vine cuttings were planted on the crest of the ridge at a spacing of 0.3m within rows and 1m between rows giving a plant population of 33.333 stands/ha. The cuttings were planted 2 nodes down the soil and 2 nodes on the soil surface.

Field maintenance: Pre- and post-emergence herbicides were applied to the field one week before planting. Weeding was carried out manually only at 8 weeks after planting

Data Analysis: All the data collected were subjected to analysis of variance. The analysis was done following the procedures for randomized complete block design (RCBD) using the Genstat Discovery 12th edition (Genstat, 2009). Significant treatment means were separated using least significant difference (LSD) at 5% probability level according to Obi (2001).

RESULTS

The physical and chemical properties of the soil:

The experiment was carried out at the eastern farm of NRCRI, Umudike in 2020 and was repeated in 2021. The physical and chemical properties of the soils of the experimental site in the 2020 and 2021 cropping seasons are presented in Table 2. In the 2020 cropping season the pH (H₂O) in both experiments was slightly acidic 5.4, but in 2021 the pH was more acidic (4.7). This is in line with the description of the soil of the area as acid "sand" (Ojanuga 1996, Kamalu *et al.*, 1991 and Attoe and Amalu 2005). Also the soil history indicates the use of inorganic fertilizer in the previous year which could have resulted in this acidity (Aduayi *et al.*, 2002). The level of phosphorous was lower in 2020 than in 2021 cropping season. This could be attributed to the previous use of the soil or cropping practices and processes of soil formation. The previously applied soil amendment may not have been fully exhausted by the crops. The percentage nitrogen during the 2021 was a bit higher; this could probably be due also to previous cropping practices in the case of nitrogen such factors as leaching and denitrification could be responsible. The percentage organic carbon in

both 2020 and 2021 differed slightly. What usually results to such variation is an increase in soil organic matter according to (Opara-Nadi *et al.*, 1987). The percentage organic matter in the soil during the 2020 cropping season was less than in 2021 cropping season. As stand above there may have been less mineralization of the organic matter by the previous crops.

Generally, the values of the chemical properties of the soils of the experimental area were less in 2020 than in 2021 except percentage base saturation and pH. This could be attributed to crop removal as yields were higher in the 2020 than 2021 cropping seasons (Laura Van Scholl 2018). It could be due to the nature of the crops and treatment applied to these two areas in the previous years. The effective cation exchange capacity in the soils was generally low. They were generally lower than 10.0cmol/kg⁻¹. This is a characteristic of low activity clays of the Southeastern Nigeria, as reported by (Udo 1977; Juo 1981; Ojanuga 1996 and Agbede 2011). The low cation exchange capacity (CEC) of these soils indicated the poor ability of the soils to retain nutrients within the soils and hence facilitating high leaching rate (Agbede, 1996). The cation exchange capacity was dominated to the high degree of weathering of soil and the high rainfall pattern of the area resulting in the displacement of the basic cations with acidic cations such as hydrogen and aluminum (Juo, 1981 and Udo, 1977). The lower base saturation in 2020 resulted in more acidic nature of the area. With a mean value of 78% of sand, 11% silt and 17% clay, the soil for the area classifies as Typic Tropudult (Lekwa, 2006). Sandy soil is generally very porous with high infiltration rate, fragile and therefore easily prone to erosive forces (Enwezor *et al.*, 1989 and Lekwa, 1986). This could be responsible for the low yield of root crops especially sweet potato. The exceptionally low organic matter content of the soil in both 2020 and 2021cropping seasons being below 20g kg⁻¹ (Sys,C 1975), implied that there is need to add soil amendment materials capable of improving the productive capacity of the soil more than 10gkg⁻¹. Aune and Lal (1997), indicated that in soils with organic matter of less than 0.37% yields were reduced by 50%. Generally soil organic matter was less than the critical level set by Adeoye and Agboola (2014), for optimum crop production in the tropics.

Table 2: Physical and chemical properties iof soils of the experiment area during 2020 and 2021 cropping season.

| Soil characteristics | 2020 | 2021 |
|----------------------------|------|------|
| Physical properties | | |
| Sand (%) | 74 | 72 |
| Silt (%) | 10 | 11 |

| | | |
|--|-----------------|-----------------|
| Clay (%) | 16 | 17 |
| Texture class | Sandy clay loam | Sandy clay loam |
| Chemical properties | | |
| pH (H ₂ O) | 5.4 | 4.7 |
| Available P (Mg kg ⁻¹) | 31.2 | 42.32 |
| Total N (%) | 0.08 | 0.09 |
| Organic carbon (%) | 0.71 | 0.79 |
| Organic matter (%) | 1.22 | 1.36 |
| Exchangeable base (c mol kg⁻¹) | | |
| Ca | 1.60 | 1.93 |
| Mg | 1.20 | 0.93 |
| K | 0.087 | 0.90 |
| Na | 0.113 | 0.15 |
| Exchangeable acidity | 0.96 | 0.96 |
| Effective CEC | 3.96 | 4.09 |
| Base saturation (%) | 72.50 | 75.75 |

Source: National Root Crops Research Institute (NRCRI) Soil Laboratory Umudike

Table 3: Chemical properties of the rice mill waste (bran) used in the experiments

| Parameter | 2020 | | 2021 | |
|--------------------------------------|----------------|------------------|----------------|------------------|
| | Carbonized RMW | Uncarbonized RMW | Carbonized RMW | Uncarbonized RMW |
| pH (H ₂ O) | 7.69 | 6.84 | 7.43 | 6.52 |
| pH KCl | 7.12 | 6.16 | 6.94 | 6.05 |
| Organic carbon (g kg ⁻¹) | 20.40 | 24.70 | 23.50 | 29.00 |
| Organic matter (g kg ⁻¹) | 55.00 | 42.60 | 40.50 | 49.90 |
| Total N (g kg ⁻¹) | 0.90 | 0.98 | 0.80 | 0.83 |
| C:N | 22.70 | 25.20 | 29.40 | 34.90 |
| Available P (mg kg ⁻¹) | 3.71 | 6.90 | 4.12 | 5.11 |
| Exch. K | 4.20 | 2.90 | 5.02 | 3.06 |
| ECEC (c mol kg ⁻¹) | 18.60 | 13.90 | 17.50 | 13.70 |

Source: National Root Crops Research Institute (NRCRI) Soil Laboratory Umudike

Vine length: The results from the analysis of variance indicated that N:P:K fertilizer, carbonized rice mill waste and un-carbonized rice mill waste significantly ($P < 0.05$) affected vine length of sweet potato in the 2020 and 2021 cropping seasons (Table 4). The application of N:P:K fertilizer at 400 kg/ha gave the highest vine length of 5.31m followed by 600 kg/ha that gave 4.62m while the least of 3.77m was obtained from the control at 12 weeks after planting (WAP). The trend was the same in 2021 where N:P:K fertilizer at 400 kg/ha gave the highest vine length of 4.81m followed by 600 kg/ha that gave 4.70m while the control had 4.08m. The application of carbonized rice mill waste at 5 t/ha increased the vine length of sweet potato at all the sampled dates in 2020 and 2021 cropping seasons when compared to no application. Furthermore, the application of un-carbonized rice mill waste to the test crop increased the vine length at all the sampled dates in the 2020 cropping season. The trend was the same in the 2021 cropping season.

The interaction between N:P:K fertilizer and carbonized rice mill waste (RMW) as well as N:P:K fertilizer and un-carbonized rice mill waste indicated significance in the vine length at all the sampled dates in both cropping seasons while the interaction between carbonized RMW and un-carbonized RMW had no significant ($P > 0.05$) effect on vine length of sweetpotato at all the sampled dates in the two cropping seasons. The interaction between 0 kg/ha of N:P:K-fertilizer and 0 t/ha of carbonized RMW gave the least vine length at all sampled dates in both years compared with the other interactive treatments at the sampled dates in the two cropping years. The interaction between 400 kg/ha of N:P:K-fertilizer and 10 t/ha un-carbonized RMW gave the highest vine length at all the sampled dates in the 2020 cropping season. However, the trend was not same in 2021 cropping season.

Table 4: Effect of NPK-enriched rice mill waste forms on the vine length of orange-fleshed sweet potato in 2020 and 2021 cropping seasons

| Treatment | Weeks after planting | | | | | |
|--|----------------------|--------|--------|--------|--------|--------|
| | 2020 | | | 2021 | | |
| | 4 | 8 | 12 | 4 | 8 | 12 |
| Fertilizer (NPK) (kg/ha) | | | | | | |
| 0 | 1.38 | 2.62 | 3.77 | 1.31 | 2.94 | 4.08 |
| 200 | 1.59 | 3.14 | 4.46 | 1.54 | 3.43 | 4.68 |
| 400 | 2.00 | 3.69 | 5.31 | 1.45 | 3.46 | 4.81 |
| 600 | 1.81 | 3.16 | 4.62 | 1.44 | 3.27 | 4.70 |
| LSD _(0.05) | 0.2502 | 0.4397 | 0.4915 | 0.1735 | 0.4467 | 0.5253 |
| Carbonized rice mill waste (C) | | | | | | |
| 0 (t/ha) | 1.56 | 2.98 | 4.22 | 1.35 | 3.12 | 4.24 |
| 5 (t/ha) | 1.85 | 3.33 | 4.87 | 1.52 | 3.44 | 4.90 |
| LSD _(0.05) | 0.1770 | 0.3109 | 0.3475 | 0.1227 | 0.3159 | 0.3714 |
| Un-carbonized rice mill waste (U) | | | | | | |
| 0 (t/ha) | 1.54 | 2.98 | 4.42 | 1.39 | 3.09 | 4.46 |
| 10 (t/ha) | 1.85 | 3.33 | 4.66 | 1.49 | 3.47 | 4.68 |
| LSD _(0.05) | 0.1770 | 0.3109 | 0.3475 | 0.1227 | 0.3159 | 0.3714 |
| NPK × C | | | | | | |
| 0 × 0 | 1.02 | 1.97 | 2.64 | 1.07 | 2.48 | 3.26 |
| 0 × 5 | 1.75 | 3.28 | 4.90 | 1.54 | 3.40 | 4.91 |
| 200 × 0 | 1.71 | 3.41 | 4.76 | 1.45 | 3.46 | 4.68 |
| 200 × 5 | 1.48 | 2.87 | 4.17 | 1.64 | 3.41 | 4.69 |
| 400 × 0 | 2.00 | 3.77 | 5.39 | 1.47 | 3.33 | 4.42 |
| 400 × 5 | 1.99 | 3.61 | 5.23 | 1.44 | 3.59 | 5.21 |
| 600 × 0 | 1.52 | 2.76 | 4.07 | 1.42 | 3.19 | 4.60 |
| 600 × 5 | 2.10 | 3.56 | 5.17 | 1.46 | 3.35 | 4.81 |
| LSD _(0.05) | 0.3539 | 0.6219 | 0.6951 | 0.2454 | 0.6317 | 0.7428 |

Table 4: Continued

| | 2020 | | | 2021 | | |
|-----------------------|----------------------|--------|--------|--------|------|--------|
| | Weeks after planting | | | | | |
| Treatment | 4 | 8 | 12 | 4 | 8 | 12 |
| NPK × U | | | | | | |
| 0 × 0 | 1.22 | 2.48 | 3.78 | 1.03 | 2.36 | 3.52 |
| 0 × 10 | 1.55 | 2.77 | 3.76 | 1.58 | 3.52 | 4.65 |
| 200 × 0 | 1.65 | 3.21 | 4.53 | 1.64 | 3.43 | 4.82 |
| 200 × 10 | 1.54 | 3.07 | 4.40 | 1.45 | 3.44 | 4.55 |
| 400 × 0 | 1.75 | 3.28 | 4.82 | 1.50 | 3.43 | 4.84 |
| 400 × 10 | 2.25 | 4.11 | 5.80 | 1.41 | 3.49 | 4.78 |
| 600 × 0 | 1.55 | 2.96 | 4.56 | 1.38 | 3.12 | 4.67 |
| 600 × 10 | 2.01 | 3.37 | 4.69 | 1.51 | 3.42 | 4.74 |
| LSD _(0.05) | 0.3539 | 0.6219 | 0.6951 | 0.2454 | NS | 0.7428 |
| C × U | | | | | | |
| 0 × 0 | 1.43 | 2.79 | 4.02 | 1.28 | 2.85 | 4.03 |
| 0 × 10 | 1.69 | 3.17 | 4.41 | 1.42 | 3.38 | 4.45 |
| 5 × 0 | 1.65 | 3.17 | 4.82 | 1.49 | 3.33 | 4.89 |
| 5 × 10 | 2.01 | 3.49 | 4.91 | 1.55 | 3.55 | 4.91 |
| LSD _(0.05) | NS | NS | NS | NS | NS | NS |

The second-order interaction of N:P:K-fertilizer \times carbonized rice mill waste (CRMW) \times un-carbonized rice mill waste (URMW) effect on vine length of orange-fleshed sweet potato in 2020 and 2021 cropping seasons were significant ($P < 0.05$) in all the sample dates (Table 4.1). The application of N:P:K-fertilizer at 600 kg/ha \times 5 t/ha CRMW \times 10 t/ha URMW gave the highest vine length at 4 weeks after planting (WAP) in 2020 and 2021 cropping seasons while at 8 and 12 WAP, sweet potato highest vine lengths were recorded under the application of N:P:K-fertilizer 400 kg/ha \times 5 t/ha CRMW \times 10 t/ha URMW with the highest vine lengths of 4.28m and 3.81m at 8WAP in 2020 and 2021 cropping seasons respectively while at 12 WAP, the highest vine lengths recorded were 6.17m and 5.63m in 2020 and 2021 cropping seasons, respectively compared with the other treatment interactions at the sampled dates.

Table 4.1: Interaction of NPK fertilizer \times carbonized rice mill waste \times un-carbonized rice mill waste effect on vine length of orange-fleshed sweet potato in 2020 and 2021 cropping seasons

| Fertilizer (NPK) (kg/ha) | 2020 | | | | 2021 | | | |
|--------------------------------|-----------------------------------|-------|--------|-------|--------------------------------------|-------|--------|-------|
| | Carbonized rice mill waste (t/ha) | | | | Un-carbonized rice mill waste (t/ha) | | | |
| | 0 | | 5 | | 0 | | 5 | |
| | 0 | | 10 | | 0 | | 10 | |
| | 0 | 10 | 0 | 10 | 0 | 10 | 0 | 10 |
| 4 weeks after planting | | | | | | | | |
| 0 | 0.510 | 1.523 | 1.927 | 1.577 | 0.580 | 1.563 | 1.483 | 1.597 |
| 200 | 1.823 | 1.590 | 1.473 | 1.483 | 1.580 | 1.320 | 1.693 | 1.580 |
| 400 | 1.863 | 2.140 | 1.627 | 2.353 | 1.543 | 1.387 | 1.460 | 1.423 |
| 600 | 1.530 | 1.517 | 1.573 | 2.633 | 1.413 | 1.423 | 1.337 | 1.587 |
| LSD_(0.05) | | | 0.5005 | | | | 0.3470 | |
| 8 weeks after planting | | | | | | | | |
| 0 | 1.263 | 2.680 | 3.690 | 2.863 | 1.377 | 3.590 | 3.350 | 3.457 |
| 200 | 3.550 | 3.273 | 2.873 | 2.860 | 3.403 | 3.517 | 3.463 | 3.353 |
| 400 | 3.600 | 3.943 | 2.950 | 4.277 | 3.490 | 3.163 | 3.370 | 3.813 |
| 600 | 2.737 | 2.787 | 3.173 | 3.943 | 3.117 | 3.267 | 3.123 | 3.573 |
| LSD_(0.05) | | | 0.8794 | | | | 0.8934 | |
| 12 weeks after planting | | | | | | | | |
| 0 | 1.777 | 3.500 | 4.27 | 4.023 | 1.880 | 4.640 | 4.78 | 4.660 |
| 200 | 4.720 | 4.803 | 4.337 | 3.997 | 4.700 | 4.657 | 4.933 | 4.437 |
| 400 | 5.367 | 5.417 | 5.78 | 6.173 | 4.897 | 3.937 | 5.15 | 5.630 |
| 600 | 4.220 | 3.927 | 4.900 | 5.443 | 4.647 | 4.547 | 4.683 | 4.930 |
| LSD_(0.05) | | | 0.9830 | | | | 1.0505 | |

Number of leaves: The results from the analysis of variance (Table 4.2) indicated that N:P:K-fertilizer rate, carbonized rice mill waste and uncarbonized rice mill waste significantly ($P<0.05$) affected the number leaves per sweet potato plant in 2020 and 2021 cropping seasons. The interaction between N:P:K-fertilizer rate and carbonized rice mill waste showed significant ($P<0.05$) difference in the number leaves per plant at 4 and 8 WAP in 2020 and at 4 WAP in 2021 only. Furthermore, except at 12 WAP in the 2020 and 4 WAP in the 2021 cropping seasons, the interaction between N:P:K-fertilizer rate and uncarbonized rice mill waste had no significant effect on the number of leaves per plant at the other sampled dates in both years. The interaction between carbonized rice mill waste (CRMW) and uncarbonized rice mill waste (URMW) had no significant effect on the number of leaves per plant at all the sampled dates in the two cropping seasons.

Table 4.2: Effect of NPK-enriched rice mill waste forms on the number of leaves per plant of orange-fleshed sweet potato in 2020 and 2021 cropping seasons

| Treatment | Weeks after planting | | | | | |
|-------------------------|----------------------|-------|-------|-------|------|-------|
| | 4 | 8 | 12 | 4 | 8 | 12 |
| Fertilizer (NPK) | | | | | | |
| 0 | 10.6 | 45.6 | 55.6 | 7.17 | 23.9 | 49.4 |
| 200 | 12.7 | 56.1 | 65.9 | 7.00 | 20.0 | 38.8 |
| 400 | 21.2 | 71.0 | 92.8 | 8.00 | 21.9 | 50.2 |
| 600 | 14.4 | 65.7 | 75.8 | 7.58 | 20.2 | 43.0 |
| LSD(0.05) | 10.33 | 18.23 | 20.11 | 1.283 | 6.36 | 16.81 |
| CRMW | | | | | | |
| 0 | 11.8 | 51.8 | 62.2 | 7.38 | 20.8 | 42.6 |
| 5 | 17.7 | 67.4 | 82.8 | 7.50 | 22.3 | 48.2 |
| LSD(0.05) | 7.31 | 12.89 | 14.22 | 0.907 | 4.50 | 11.89 |
| URMW | | | | | | |
| 0 | 12.2 | 54.1 | 64.8 | 7.12 | 20.8 | 42.3 |
| 10 | 17.2 | 65.0 | 80.2 | 7.75 | 22.3 | 48.5 |
| LSD(0.05) | 7.31 | 12.89 | 14.22 | 0.907 | 4.50 | 11.89 |
| NPK×CRMW | | | | | | |
| 0 × 0 | 7.3 | 25.7 | 35.5 | 7.00 | 21.2 | 37.7 |
| 0 × 5 | 13.8 | 65.5 | 75.7 | 7.33 | 26.7 | 61.2 |
| 200 × 0 | 13.2 | 60.7 | 70.8 | 7.17 | 22.0 | 42.2 |
| 200 × 5 | 12.2 | 51.5 | 61.0 | 6.83 | 18.0 | 35.5 |
| 400 × 0 | 13.8 | 61.8 | 74.4 | 7.67 | 21.8 | 53.7 |
| 400 × 5 | 28.7 | 80.2 | 111.3 | 8.33 | 22.0 | 46.8 |
| 600 × 0 | 12.7 | 59.0 | 68.5 | 7.67 | 18.0 | 36.8 |
| 600 × 5 | 16.2 | 72.3 | 83.0 | 7.50 | 22.5 | 49.2 |
| LSD(0.05) | NS | 25.78 | 28.44 | 1.814 | NS | NS |

Table 4.2: Continued

| | 2020 | | | 2021 | | |
|--------------------|----------------------|------|-------|-------|------|------|
| | Weeks after planting | | | | | |
| | 4 | 8 | 12 | 4 | 8 | 12 |
| NPK × UCMW | | | | | | |
| 0 × 0 | 10.0 | 37.0 | 48.0 | 6.83 | 21.0 | 40.8 |
| 0 × 10 | 11.2 | 54.2 | 63.2 | 7.50 | 26.8 | 58.0 |
| 200 × 0 | 12.0 | 51.5 | 61.0 | 6.83 | 20.5 | 39.8 |
| 200 × 10 | 13.3 | 60.7 | 70.8 | 7.17 | 19.5 | 37.8 |
| 400 × 0 | 11.5 | 57.7 | 68.8 | 7.50 | 24.8 | 55.0 |
| 400 × 10 | 31.0 | 84.3 | 116.7 | 8.50 | 19.0 | 45.5 |
| 600 × 0 | 15.3 | 70.3 | 81.3 | 7.33 | 16.7 | 35.5 |
| 600 × 10 | 13.5 | 61.0 | 70.2 | 7.83 | 23.8 | 52.5 |
| LSD(0.05) | NS | NS | 28.44 | 1.814 | NS | NS |
| CRMW × URMW | | | | | | |
| 0 × 0 | 10.3 | 43.3 | 53.9 | 7.33 | 19.5 | 39.6 |
| 0 × 10 | 13.2 | 60.3 | 70.6 | 7.42 | 22.0 | 45.6 |
| 5 × 0 | 14.2 | 64.9 | 75.7 | 6.92 | 22.0 | 45.0 |
| 5 × 10 | 21.2 | 69.8 | 89.8 | 8.08 | 22.6 | 51.3 |
| LSD(0.05) | NS | NS | NS | NS | NS | NS |

The three-way interaction of N:P:K-fertilizer rate \times CRMW \times URMW (Table 4.3) indicated significant ($P < 0.05$) difference in number of leaves per plant only at 8 WAP in 2020 cropping season while the interaction, had no significant effect on the parameter at the other sampled dates. The results further showed that the application of 400 kg/ha of N:P:K-fertilizer rate at 4, 8 and 12 WAP gave the highest number of leaves per plant compared with the other treatments. The application of carbonized RMW at 5 t/ha gave the highest number of leaves per plant compared with no application at all the sampled dates in both years. The same trend was recorded with the application of un-carbonized RMW at 10 t/ha at the sampled dates in 2020 and 2021 cropping seasons. The interaction of N:P:K-fertilizer and CRMW at 400 kg/ha \times 5 t/ha CRMW gave the highest number of leaves per plant in 2020 and 2021 cropping seasons compared to the others. Also, the effect of interaction of N:P:K-fertilizer \times URMW on number of leaves per plant indicated significant increase in number of leaves with the application of 400 kg/ha NPK \times 10 t/ha in both the two cropping years.

Table 4.3: Interaction of NPK fertilizer \times carbonized rice mill waste \times un-carbonized rice mill waste effect on number of leaves per plant of orange fleshed sweet potato in 2020 and 2021 cropping seasons

| Fertilizer (NPK) (kg/ha) | 2020 | | | | 2021 | | | |
|-----------------------------|-----------------------------------|------|------|-------|--------------------------------------|------|------|-------|
| | Carbonized rice mill waste (t/ha) | | | | Un-carbonized rice mill waste (t/ha) | | | |
| | 0 | | 5 | | 0 | | 5 | |
| | 0 | 10 | 0 | 10 | 0 | 10 | 0 | 10 |
| | 4 weeks after planting | | | | | | | |
| 0 | 6.67 | 7.33 | 7.00 | 7.67 | 6.67 | 7.33 | 7.00 | 7.67 |
| 200 | 7.00 | 7.33 | 6.67 | 7.00 | 7.00 | 7.33 | 6.67 | 7.00 |
| 400 | 8.33 | 7.00 | 6.67 | 10.00 | 8.33 | 7.00 | 6.67 | 10.00 |
| 600 | 7.33 | 8.00 | 7.33 | 7.67 | 7.33 | 8.00 | 7.33 | 7.67 |
| LSD _(0.05) | NS | | | | NS | | | |
| 8 weeks after planting | | | | | | | | |
| 0 | 16.7 | 25.7 | 25.3 | 28.0 | 16.7 | 25.7 | 25.3 | 28.0 |
| 200 | 22.7 | 21.3 | 18.3 | 17.7 | 22.7 | 21.3 | 18.3 | 17.7 |
| 400 | 24.3 | 19.3 | 25.3 | 18.7 | 24.3 | 19.3 | 25.3 | 18.7 |
| 600 | 14.3 | 21.7 | 19.0 | 26.0 | 14.3 | 21.7 | 19.0 | 26.0 |
| LSD _(0.05) | 12.72 | | | | NS | | | |
| 12 weeks after planting | | | | | | | | |
| 0 | 1.88 | 4.64 | 5.15 | 4.43 | 25.0 | 50.3 | 56.7 | 32.7 |
| 200 | 4.70 | 4.66 | 4.93 | 4.66 | 41.3 | 43.0 | 38.3 | 43.7 |
| 400 | 4.90 | 3.94 | 4.78 | 5.63 | 60.0 | 47.3 | 50.0 | 65.7 |
| 600 | 4.65 | 4.55 | 4.68 | 4.93 | 32.0 | 41.7 | 35.0 | 63.3 |
| LSD _(0.05) | NS | | | | NS | | | |

Number of branches: The result from the analysis of variance of the effect of N:P:K-fertilizer enriched rice mill waste forms on the number of branches of orange fleshed sweet potato is presented in Table 4.4. The results obtained in both the 2020 and 2021 cropping seasons indicated significant increase in the number of branches across the different levels of treatment applied. The application of N:P:K-fertilizer at 400 kg/ha gave the highest number of sweet potato branches at 12 WAP in both sampled years. The application of carbonized and un-carbonized RMW showed an increase in the number of branches of sweetpotato in both cropping seasons. The interaction between N:P:K-fertilizer \times CRMW showed a significant difference ($P < 0.5$) at 4 WAP in 2020 and at 8 WAP in 2021. No significant difference ($P > 0.5$) was recorded in both interactions between N:P:K-fertilizer \times URMW and CRMW \times URMW.

Table 4.4: Effect of NPK-enriched rice mill waste forms on number of branches of orange fleshed sweet potato in 2020 and 2021 cropping seasons

| Treatment | Weeks after planting | | | | | |
|--|----------------------|-------|-------|--------|--------|-------|
| | 2020 | | | 2021 | | |
| | 4 | 8 | 12 | 4 | 8 | 12 |
| Fertilizer (NPK) | | | | | | |
| 0 | 1.42 | 3.58 | 4.33 | 1.67 | 2.42 | 4.08 |
| 200 | 1.50 | 4.42 | 5.17 | 1.42 | 2.33 | 3.83 |
| 400 | 1.42 | 3.92 | 5.33 | 1.42 | 2.42 | 4.33 |
| 600 | 1.67 | 4.42 | 5.08 | 1.58 | 2.25 | 3.83 |
| LSD _(0.05) | 0.621 | 1.416 | 2.184 | 0.4804 | 0.4681 | 0.854 |
| Carbonized rice mill waste (C) | | | | | | |
| 0 | 1.38 | 3.92 | 4.58 | 1.54 | 2.25 | 4.00 |
| 5 | 1.62 | 4.25 | 5.38 | 1.50 | 2.46 | 4.04 |
| LSD _(0.05) | 0.439 | 1.001 | 1.544 | 0.3397 | 0.3310 | 0.604 |
| Un-carbonized rice mill waste (U) | | | | | | |
| 0 | 1.46 | 4.00 | 4.75 | 1.42 | 2.33 | 4.00 |
| 10 | 1.54 | 4.17 | 5.21 | 1.63 | 2.38 | 4.04 |
| LSD _(0.05) | 0.439 | 1.001 | 1.544 | 0.3397 | 0.3310 | 0.604 |
| NPK × C | | | | | | |
| 0 × 0 | 1.00 | 2.67 | 3.17 | 1.67 | 2.33 | 4.00 |
| 0 × 5 | 1.83 | 4.50 | 5.50 | 1.67 | 2.50 | 4.17 |
| 200 × 0 | 1.67 | 4.83 | 5.83 | 1.67 | 2.00 | 3.67 |
| 200 × 5 | 1.33 | 4.00 | 4.50 | 1.17 | 2.67 | 4.00 |
| 400 × 0 | 1.67 | 3.83 | 5.00 | 1.33 | 2.67 | 4.67 |
| 400 × 5 | 1.17 | 4.00 | 5.67 | 1.50 | 2.17 | 4.00 |
| 600 × 0 | 1.17 | 4.33 | 4.33 | 1.50 | 2.00 | 3.67 |
| 600 × 5 | 2.17 | 4.50 | 5.83 | 1.67 | 2.50 | 4.00 |
| LSD _(0.05) | 0.878 | NS | NS | NS | 0.6621 | NS |

Table 4.4: Continued

| Treatment | 2020 | | | 2021 | | |
|-----------------------|----------------------|------|------|------|------|------|
| | Weeks after planting | | | | | |
| | 4 | 8 | 12 | 4 | 8 | 12 |
| NPK × U | | | | | | |
| 0 × 0 | 1.50 | 3.67 | 4.83 | 1.50 | 2.33 | 4.17 |
| 0 × 10 | 1.33 | 3.50 | 3.83 | 1.83 | 2.50 | 4.00 |
| 200 × 0 | 1.50 | 4.17 | 5.00 | 1.33 | 2.33 | 3.83 |
| 200 × 10 | 1.50 | 4.67 | 5.33 | 1.50 | 2.33 | 3.83 |
| 400 × 0 | 1.17 | 3.33 | 4.00 | 1.67 | 2.17 | 3.83 |
| 400 × 10 | 1.67 | 4.50 | 6.67 | 1.17 | 2.67 | 4.83 |
| 600 × 0 | 1.67 | 4.83 | 5.17 | 1.17 | 2.50 | 4.17 |
| 600 × 10 | 1.67 | 4.00 | 5.00 | 2.00 | 2.00 | 3.50 |
| LSD _(0.05) | NS | NS | NS | NS | NS | NS |
| C × U | | | | | | |
| 0 × 0 | 1.25 | 3.67 | 4.42 | 1.33 | 2.25 | 4.00 |
| 0 × 10 | 1.50 | 4.17 | 4.75 | 1.75 | 2.25 | 4.00 |
| 5 × 0 | 1.67 | 4.33 | 5.08 | 1.50 | 2.42 | 4.00 |
| 5 × 10 | 1.58 | 4.17 | 5.67 | 1.50 | 2.50 | 4.08 |
| LSD _(0.05) | NS | NS | NS | NS | NS | NS |

The second-order interaction of N:P:K-fertilizer × carbonized rice mill waste (CRMW) × un-carbonized rice mill waste (URMW) effect on number of branches of orange fleshed sweet potato in 2020 and 2021 cropping seasons were not significantly different ($P>0.05$) in all the sample dates (Table 4.5). The application of N:P:K-fertilizer at 400 kg/ha x 5 t/ha CRMW x 10 t/ha URMW at 12WAP gave the highest number of sweet potato branches for 2020 and 2021 cropping seasons.

Table 4.5: Interaction of NPK fertilizer \times carbonized rice mill waste \times un-carbonized rice mill waste effect on number of branches of orange-fleshed sweet potato in 2020 and 2021 cropping seasons

| Fertilizer (NPK) (kg/ha) | 2020 | | | | 2021 | | | |
|--------------------------------|--------------------------------------|------|------|------|------|------|------|------|
| | Carbonized rice mill waste (t/ha) | | | | | | | |
| | 0 | | 5 | | 0 | | 5 | |
| | Un-carbonized rice mill waste (t/ha) | | | | | | | |
| | 0 | 10 | 0 | 10 | 0 | 10 | 0 | 10 |
| 4 weeks after planting | | | | | | | | |
| 0 | 1.00 | 1.00 | 2.00 | 1.67 | 1.33 | 2.00 | 1.67 | 1.67 |
| 200 | 1.67 | 1.67 | 1.33 | 1.33 | 1.33 | 2.00 | 1.33 | 1.00 |
| 400 | 1.33 | 2.00 | 1.00 | 1.33 | 1.65 | 1.00 | 1.67 | 1.33 |
| 600 | 1.00 | 1.33 | 2.33 | 2.00 | 1.00 | 2.00 | 1.33 | 2.00 |
| LSD _(0.05) | Ns | | | | Ns | | | |
| 8 weeks after planting | | | | | | | | |
| 0 | 2.33 | 3.00 | 5.00 | 4.00 | 2.33 | 2.33 | 2.33 | 2.67 |
| 200 | 4.67 | 5.00 | 3.67 | 4.00 | 2.00 | 2.00 | 2.67 | 2.67 |
| 400 | 3.00 | 4.67 | 3.67 | 4.33 | 2.33 | 3.00 | 2.00 | 2.33 |
| 600 | 4.67 | 4.00 | 5.00 | 4.00 | 2.33 | 1.67 | 2.67 | 2.33 |
| LSD _(0.05) | Ns | | | | Ns | | | |
| 12 weeks after planting | | | | | | | | |
| 0 | 3.33 | 3.00 | 6.33 | 4.67 | 4.00 | 4.00 | 4.33 | 4.00 |
| 200 | 6.00 | 5.67 | 4.00 | 5.00 | 3.33 | 4.00 | 4.33 | 3.67 |
| 400 | 3.67 | 6.33 | 4.33 | 7.00 | 4.67 | 4.67 | 3.00 | 5.00 |
| 600 | 4.67 | 4.00 | 5.67 | 6.00 | 4.00 | 3.33 | 4.33 | 3.67 |
| LSD _(0.05) | Ns | | | | Ns | | | |

Stem girth: The results from analysis of variance for the effect of N:P:K-enriched rice mill waste forms on the stem girth per plant of orange-fleshed sweet potato is presented in Table 4.6. The results obtained in the 2020 cropping season, showed that the application of N:P:K-fertilizer at 400 kg/ha gave the highest sweet potato stem girth per plant of 0.87mm at 12WAP and was followed very closely by the application of N:P:K-fertilizer at 600 kg/ha that gave 0.81mm per plant when compared to the control that had the least value for sweet potato stem girth of 0.69mm per plant. In 2021, the application of N:P:K-fertilizer at 400 and 600 kg/ha produced same increment of 0.68mm per plant when compared to the control treatment that gave 0.31mm. The application of CRMW increased the stem girth in the 2020 cropping season but had no effect in the 2021 cropping season. Same trend was observed with the application of URMW in both 2020 and 2021 cropping seasons. However the interaction between N:P:K-fertilizer and CRMW showed a significant difference ($P<0.05$) within the sample periods of 2020 but no significant difference ($P>0.05$) was observed in the 2021cropping season. No significant differences ($P>0.05$) were observed in the interaction of N:P:K-fertilizer x URMW and CRMW x URMW for both cropping seasons.

Table 4.6: Effect of NPK-enriched rice mill waste forms on stem girth of orange-fleshed sweet potato in 2020 and 2021 cropping seasons

| Treatment | Weeks after planting | | | | | |
|--|----------------------|--------|--------|--------|-------|-------|
| | 2020 | | | 2021 | | |
| | 4 | 8 | 12 | 4 | 8 | 12 |
| Fertilizer (NPK) | | | | | | |
| 0 | 0.43 | 0.59 | 0.69 | 0.27 | 0.46 | 0.31 |
| 200 | 0.48 | 0.62 | 0.75 | 0.20 | 0.37 | 0.63 |
| 400 | 0.60 | 0.71 | 0.87 | 0.12 | 0.18 | 0.68 |
| 600 | 0.56 | 0.66 | 0.81 | 0.20 | 0.48 | 0.68 |
| LSD _(0.05) | 0.0702 | 0.0733 | 0.0832 | 0.2826 | 0.646 | 0.925 |
| Carbonized rice mill waste (C) | | | | | | |
| 0 | 0.49 | 0.61 | 0.72 | 0.22 | 0.44 | 0.69 |
| 5 | 0.55 | 0.68 | 0.83 | 0.18 | 0.30 | 0.46 |
| LSD _(0.05) | 0.0496 | 0.0518 | 0.0588 | 0.1998 | 0.457 | 0.654 |
| Un-carbonized rice mill waste (U) | | | | | | |
| 0 | 0.51 | 0.64 | 0.76 | 0.22 | 0.44 | 0.67 |
| 10 | 0.53 | 0.65 | 0.79 | 0.18 | 0.30 | 0.48 |
| LSD _(0.05) | 0.0496 | 0.0518 | 0.0588 | 0.1998 | 0.457 | 0.654 |
| NPK × C | | | | | | |
| 0 × 0 | 0.31 | 0.46 | 0.53 | 0.16 | 0.22 | 0.29 |
| 0 × 5 | 0.56 | 0.72 | 0.84 | 0.38 | 0.70 | 1.06 |
| 200 × 0 | 0.53 | 0.69 | 0.81 | 0.32 | 0.61 | 1.05 |
| 200 × 5 | 0.44 | 0.55 | 0.68 | 0.09 | 0.14 | 0.22 |
| 400 × 0 | 0.70 | 0.79 | 0.91 | 0.13 | 0.18 | 0.36 |
| 400 × 5 | 0.50 | 0.63 | 0.82 | 0.12 | 0.18 | 0.26 |
| 600 × 0 | 0.42 | 0.49 | 0.63 | 0.29 | 0.75 | 1.07 |
| 600 × 5 | 0.71 | 0.84 | 0.99 | 0.12 | 0.20 | 0.30 |
| LSD _(0.05) | 0.0992 | 0.1036 | 0.1176 | NS | NS | NS |

Table 4.6: Continued

| | 2020 | | | 2021 | | |
|-----------------------|----------------------|------|------|------|-------|-------|
| | Weeks after planting | | | | | |
| Treatment | 4 | 8 | 12 | 4 | 8 | 12 |
| NPK × U | | | | | | |
| 0 × 0 | 0.45 | 0.61 | 0.70 | 0.15 | 0.22 | 0.33 |
| 0 × 10 | 0.42 | 0.57 | 0.68 | 0.39 | 0.70 | 1.02 |
| 200 × 0 | 0.50 | 0.61 | 0.70 | 0.33 | 0.61 | 0.98 |
| 200 × 10 | 0.47 | 0.63 | 0.79 | 0.08 | 0.13 | 0.29 |
| 400 × 0 | 0.57 | 0.68 | 0.83 | 0.13 | 0.19 | 0.33 |
| 400 × 10 | 0.63 | 0.74 | 0.90 | 0.12 | 0.17 | 0.29 |
| 600 × 0 | 0.54 | 0.67 | 0.81 | 0.28 | 0.74 | 1.03 |
| 600 × 10 | 0.59 | 0.66 | 0.86 | 0.13 | 0.21 | 0.33 |
| LSD _(0.05) | NS | NS | NS | NS | 0.913 | NS |
| C × U | | | | | | |
| 0 × 0 | 0.47 | 0.60 | 0.71 | 0.33 | 0.70 | 1.05 |
| 0 × 10 | 0.51 | 0.61 | 0.73 | 0.11 | 0.18 | 0.34 |
| 5 × 0 | 0.56 | 0.68 | 0.81 | 0.11 | 0.18 | 0.29 |
| 5 × 10 | 0.55 | 0.69 | 0.86 | 0.25 | 0.42 | 0.63 |
| LSD _(0.05) | NS | NS | NS | NS | NS | 0.925 |

The three-way interaction of N:P:K-fertilizer rate × CRMW × URMW (Table 4.7) indicated no significant differences ($P>0.05$) in the sweetpotato stem girth across the parameters sampled in 2020 and 2021 cropping seasons. However in the 2020 cropping season, the application of N:P:K-fertilizer at 600 kg/ha × 5 t/ha CRMW × 10 t/ha URMW gave the biggest stem girth of 1.05mm per plant while N:P:K-fertilizer at 600 kg/ha × 0 t/ha CRMW × 0 t/ha URMW had the biggest stem girth of 1.79mm per plant in 2021 cropping season.

Table 4.7: Interaction of NPK fertilizer \times carbonized rice mill waste \times un-carbonized rice mill waste effect on stem girth of orange-fleshed sweet potato in 2020 and 2021 cropping seasons

| Fertilizer (NPK) (kg/ha) | 2020 | | | | 2021 | | | |
|--------------------------------|--------------------------------------|------|------|------|------|------|------|------|
| | Carbonized rice mill waste (t/ha) | | | | | | | |
| | 0 | | 5 | | 0 | | 5 | |
| | Un-carbonized rice mill waste (t/ha) | | | | | | | |
| | 0 | 10 | 0 | 10 | 0 | 10 | 0 | 10 |
| 4 weeks after planting | | | | | | | | |
| 0 | 0.25 | 0.37 | 0.65 | 0.48 | 0.17 | 0.13 | 0.13 | 0.63 |
| 200 | 0.57 | 0.49 | 0.44 | 0.44 | 0.55 | 0.08 | 0.12 | 0.07 |
| 400 | 0.61 | 0.80 | 0.53 | 0.49 | 0.14 | 0.12 | 0.12 | 0.13 |
| 600 | 0.46 | 0.37 | 0.61 | 0.81 | 0.47 | 0.10 | 0.08 | 0.15 |
| LSD(0.05) | 0.1403 | | | | NS | | | |
| 8 weeks after planting | | | | | | | | |
| 0 | 0.45 | 0.46 | 0.76 | 0.68 | 0.22 | 0.21 | 0.22 | 1.18 |
| 200 | 0.67 | 0.71 | 0.36 | 0.54 | 1.07 | 0.15 | 0.16 | 0.11 |
| 400 | 0.73 | 0.85 | 0.63 | 0.62 | 0.20 | 0.15 | 0.17 | 0.18 |
| 600 | 0.56 | 0.42 | 0.77 | 0.90 | 1.31 | 0.20 | 0.18 | 0.22 |
| LSD(0.05) | 0.1466 | | | | NS | | | |
| 12 weeks after planting | | | | | | | | |
| 0 | 0.54 | 0.52 | 0.85 | 0.83 | 0.30 | 0.29 | 0.37 | 1.76 |
| 200 | 0.75 | 0.87 | 0.64 | 0.72 | 1.72 | 0.38 | 0.24 | 0.20 |
| 400 | 0.86 | 0.97 | 0.80 | 0.83 | 0.38 | 0.33 | 0.27 | 0.26 |
| 600 | 0.70 | 0.56 | 0.93 | 1.05 | 1.79 | 0.36 | 0.28 | 0.31 |
| LSD(0.05) | NS | | | | NS | | | |

Total root yield weight: The results obtained from analysis of variance for the effect of N:P:K-enriched rice mill waste forms on the fresh total root yield of orange-fleshed sweet potato is presented in Table 5. The results obtained in the 2020 cropping season showed a variation in the application of N:P:K-fertilizer at 400 kg/ha when compared with other rates of N:P:K-fertilizer applied which gave a total root weight of 16.82 t/ha. Same trend was observed in 2021 cropping season where the application of N:P:K-fertilizer at 400 kg/ha gave the highest total root yield weight of 6.80 t/ha. The application of CRMW and UCRMW showed an increase in the total root yield weight with 15.28 t/ha and 16.59 t/ha respectively in 2020 cropping season and same trend was observed in 2021 cropping season where CRMW had an increase in the total root yield weight of 6.15 t/ha when compared to the control that had 4.82 t/ha and URMW having 6.41 t/ha of total root yield weight of sweet potato. No significant difference ($P>0.05$) was observed in the interaction between N:P:K-fertilizer x CRMW in both 2020 and 2021 cropping seasons. However the application of N:P:K-fertilizer at 400 kg/ha x 5 t/ha CRMW gave the highest total root yield weight of 19.09 t/ha and 7.43 t/ha respectively in 2020 and 2021 cropping seasons. A significant difference ($P<0.05$) was observed in the interaction between N:P:K-fertilizer x URMW in 2020 cropping season but none in 2021 cropping season as well in the interactions between CRMW x URMW for both 2020 and 2021 cropping seasons.

Marketable root yield: The results of the effect of the application of N:P:K-enriched rice mill waste forms on the marketable root yield of orange-fleshed sweet potato are presented in Table 5. In the 2020 planting season, the application of N:P:K-fertilizer at 400 kg/ha showed superiority over the others, giving a marketable root yield weight of 13.87 kg/plant, followed by the application of 600 kg/ha that gave 13.47 kg/plant while the control had the least of 8.12 kg/plant. The same trend was observed in the 2021 cropping season where N:P:K-fertilizer at 400 kg/ha gave the highest marketable root yield of sweet potato at 5.28 kg/plant. Both cropping seasons in 2020 and 2021, respectively, recorded an increase in the weight of marketable roots when CRMW and URMW were applied. However, the interaction between N:P:K-fertilizer x CRMW did not record any significant difference ($P>0.05$) on the weight of marketable root yield of orange-fleshed sweet potato in the two years of cropping, although the interaction between N:P:K-fertilizer x URMW recorded significant difference ($P<0.05$) in 2020 cropping season. No significant difference ($P>0.05$) was recorded in the interaction between CRMW x URMW in both 2020 and 2021 cropping seasons.

Unmarketable root yield: The results from the analysis of variance on the effect of the application of N:P:K-enriched rice mill waste forms on the weight of unmarketable root yield of orange-fleshed sweet potato in 2020 and 2021 cropping seasons are presented in Table 5. Both years showed no significant difference ($P>0.05$) in the 2-way interaction: N:P:K-fertilizer x CRMW; N:P:K-fertilizer x URMW and CRMW x URMW, but the application of N:P:K-fertilizer at 400 kg/ha produced the highest unmarketable root weight of 1.275 kg/plant in 2020 cropping season while the application of 200 kg/ha of N:P:K-fertilizer produced the highest unmarketable root weight of 1.39 kg/plant in 2021 cropping season. Application of CRMW and that of URMW did not produce any effect on the unmarketable root weight in 2020 cropping season but did so in 2021.

Number of marketable roots: The effect of N:P:K-enriched rice mill waste forms on number of marketable roots of orange-fleshed sweet potato in 2020 and 2021 cropping season is shown in Table 5. The results obtained in 2020 and 2021 planting seasons revealed no significant differences ($P>0.05$) among the treatments that were applied. However the application of N:P:K-fertilizer at 400 kg/ha produced the highest number of marketable roots of 47.4 and 23.8 roots/plant respectively in the two years. The application of RMW forms also increased the number of marketable roots in the two years.

Number of Unmarketable roots: The results showed a significant difference ($P<0.05$) only on the interaction between N:P:K-fertilizer x URMW in 2020 cropping season while the rest of sampled parameters did not show any significant difference both in 2020 and 2021 cropping seasons.

Table 5: Effect of NPK-enriched rice mill waste forms on root yield attributes of orange-fleshed sweet potato in 2020 and 2021 cropping seasons

| Treatment | 2020 | | | | | 2021 | | | | |
|--|----------------------------------|------------------------------------|---------------------------------------|---|-------------------------|----------------------------------|------------------------------------|---------------------------------------|---|-------------------------|
| | Number of marketable roots/plant | Number of unmarketable roots/plant | Weight of marketable roots/plant (kg) | Weight of unmarketable roots/plant (kg) | Fresh root yield (t/ha) | Number of marketable roots/plant | Number of unmarketable roots/plant | Weight of marketable roots/plant (kg) | Weight of unmarketable roots/plant (kg) | Fresh root yield (t/ha) |
| Fertilizer (NPK) | | | | | | | | | | |
| 0 | 30.5 | 25.7 | 8.12 | 1.04 | 10.32 | 19.9 | 11.2 | 3.81 | 0.64 | 4.86 |
| 200 | 43.2 | 22.4 | 11.43 | 1.13 | 13.77 | 17.9 | 10.8 | 3.52 | 1.39 | 4.56 |
| 400 | 47.4 | 26.0 | 13.87 | 1.28 | 16.82 | 23.8 | 14.8 | 5.28 | 0.83 | 6.80 |
| 600 | 42.0 | 26.4 | 13.47 | 1.21 | 15.38 | 21.0 | 16.0 | 4.47 | 0.84 | 5.72 |
| LSD _(0.05) | 12.27 | 8.31 | 3.298 | 0.3849 | 3.834 | 9.87 | 6.20 | 1.043 | 1.210 | 2.515 |
| Carbonized rice mill waste (C) | | | | | | | | | | |
| 0 | 36.6 | 24.5 | 10.40 | 1.19 | 12.87 | 18.5 | 11.2 | 3.69 | 1.17 | 4.82 |
| 5 | 45.0 | 25.8 | 13.04 | 1.17 | 15.28 | 22.8 | 15.2 | 4.86 | 0.68 | 6.15 |
| LSD _(0.05) | 8.67 | 5.88 | 2.332 | 0.2722 | 2.711 | 6.98 | 4.39 | 0.738 | 0.855 | 1.778 |
| Un-carbonized rice mill waste (U) | | | | | | | | | | |
| 0 | 35.4 | 24.6 | 9.64 | 1.19 | 11.56 | 18.5 | 13.3 | 3.54 | 1.09 | 4.56 |
| 10 | 46.1 | 25.6 | 13.80 | 1.17 | 16.59 | 22.8 | 13.1 | 5.00 | 0.77 | 6.41 |
| LSD _(0.05) | 8.67 | 5.88 | 2.332 | 0.2722 | 2.711 | 6.98 | 4.39 | 0.738 | 0.855 | 1.778 |
| NPK × C | | | | | | | | | | |
| 0 × 0 | 21.8 | 24.8 | 6.10 | 1.22 | 8.09 | 16.0 | 8.0 | 2.97 | 0.78 | 4.00 |
| 0 × 5 | 39.2 | 26.5 | 10.13 | 1.17 | 12.56 | 23.8 | 14.3 | 4.65 | 0.50 | 5.72 |
| 200 × 0 | 43.0 | 22.8 | 11.68 | 1.08 | 14.19 | 12.7 | 7.2 | 2.67 | 2.15 | 3.56 |
| 200 × 5 | 43.3 | 22.0 | 11.18 | 1.00 | 13.35 | 23.2 | 14.5 | 4.38 | 0.63 | 5.57 |
| 400 × 0 | 40.8 | 24.3 | 11.82 | 1.28 | 14.56 | 25.7 | 14.7 | 4.77 | 0.78 | 6.17 |
| 400 × 5 | 54.0 | 27.7 | 15.92 | 1.27 | 19.09 | 22.0 | 15.0 | 5.80 | 0.88 | 7.43 |
| 600 × 0 | 40.7 | 26.0 | 12.02 | 1.17 | 14.56 | 19.5 | 15.0 | 4.35 | 0.98 | 5.56 |
| 600 × 5 | 43.3 | 26.8 | 14.92 | 1.25 | 16.11 | 22.5 | 17.0 | 4.60 | 0.70 | 5.89 |
| LSD _(0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

Table 5: Continued

| | 2020 | 2020 |
|--|------|------|
|--|------|------|

| Treatment | Number of marketable roots/plant | Number of unmarketable roots/plant | Weight of marketable roots/plant (kg) | Weight of unmarketable roots/plant (kg) | Total root yield (t/ha) | Number of marketable roots/plant | Number of unmarketable roots/plant | Weight of marketable roots/plant (kg) | Weight of unmarketable roots/plant (kg) | Fresh root yield (t/ha) |
|-----------------------|----------------------------------|------------------------------------|---------------------------------------|---|-------------------------|----------------------------------|------------------------------------|---------------------------------------|---|-------------------------|
| NPK × U | | | | | | | | | | |
| 0 × 0 | 17.5 | 21.2 | 4.60 | 1.033 | 6.22 | 15.3 | 12.8 | 2.68 | 0.68 | 3.57 |
| 0 × 10 | 43.5 | 30.2 | 11.63 | 1.350 | 14.43 | 24.5 | 9.5 | 4.93 | 0.60 | 6.15 |
| 200 × 0 | 42.3 | 20.8 | 10.90 | 1.033 | 13.26 | 15.8 | 9.2 | 3.33 | 2.13 | 4.28 |
| 200 × 10 | 44.0 | 24.0 | 11.97 | 1.050 | 14.28 | 20.0 | 12.5 | 3.72 | 0.65 | 4.85 |
| 400 × 0 | 41.3 | 24.8 | 9.98 | 1.217 | 12.44 | 24.8 | 17.3 | 4.38 | 0.73 | 5.69 |
| 400 × 10 | 53.5 | 27.2 | 17.75 | 1.333 | 21.20 | 22.8 | 12.3 | 6.18 | 0.93 | 7.91 |
| 600 × 0 | 40.5 | 31.7 | 13.07 | 1.467 | 14.30 | 18.2 | 14.0 | 3.77 | 0.80 | 4.70 |
| 600 × 10 | 43.5 | 21.2 | 13.87 | 0.950 | 16.46 | 23.8 | 18.0 | 5.18 | 0.88 | 6.74 |
| LSD _(0.05) | NS | 11.75 | 4.664 | NS | 5.423 | NS | NS | NS | NS | NS |
| C × U | | | | | | | | | | |
| 0 × 0 | 30.9 | 22.7 | 8.52 | 1.108 | 10.68 | 13.8 | 10.6 | 2.89 | 1.62 | 3.84 |
| 0 × 10 | 42.2 | 26.3 | 12.29 | 1.267 | 15.06 | 23.2 | 11.8 | 4.48 | 0.73 | 5.80 |
| 5 × 0 | 39.9 | 26.6 | 10.76 | 1.267 | 12.44 | 23.3 | 16.1 | 4.19 | 0.56 | 5.28 |
| 5 × 10 | 50.0 | 24.9 | 15.32 | 1.075 | 18.12 | 22.4 | 14.3 | 5.52 | 0.80 | 7.03 |
| LSD _(0.05) | NS | NS | NS | NS | NS | 2.29 | NS | NS | NS | NS |

The 3-way interaction between N:P:K-fertilizer × carbonized rice mill waste × un-carbonized rice mill waste effects on yield and yield components of orange-fleshed sweet potato in 2020 and 2021 cropping seasons is represented in Table 5.1. The number of marketable roots per plant did not show any significant differences ($P>0.05$) in both 2020 and 2021 cropping seasons. However the application of N:P:K-fertilizer at 400 kg/ha x 5 t/ha CRMW x 10 t/ha URMW gave the highest number of marketable roots/plant in 2020 cropping season, while the application of N:P:K-fertilizer at 600 kg/ha x 5 t/ha CRMW x 10 t/ha URMW gave the highest in 2021 cropping season. Significant differences ($P<0.05$) were recorded in the number of unmarketable roots per plant in 2020 cropping season with the application of N:P:K-fertilizer at 0 kg/ha x 5 t/ha CRMW x 10 t/ha URMW having the highest number of 33.7 roots. No significant differences ($P>0.05$) were recorded in the number of unmarketable roots per plant in 2021 cropping season. Moreover, both weight of marketable roots per plant, weight of unmarketable roots per plant and total root yield did not record any significant differences ($P>0.05$) in the both years of the experiment.

Table 5.1: Interaction of NPK fertilizer \times carbonized rice mill waste \times un-carbonized rice mill waste effects on yield and yield components of orange-fleshed sweet potato in 2020 and 2021 cropping seasons

| Fertilizer (NPK) (kg/ha) | 2020 | | | | 2021 | | | |
|---------------------------------------|--------------------------------------|-------|-------|-------|-------|-------|-------|-------|
| | Carbonized rice mill waste (t/ha) | | | | | | | |
| | 0 | | 5 | | 0 | | 5 | |
| | Un-carbonized rice mill waste (t/ha) | | | | | | | |
| | 0 | 10 | 0 | 10 | 0 | 10 | 0 | 10 |
| Number of marketable roots/plant | | | | | | | | |
| 0 | 7.70 | 36.00 | 27.30 | 51.00 | 6.70 | 25.30 | 24.00 | 23.70 |
| 200 | 38.00 | 48.00 | 46.70 | 40.00 | 5.70 | 19.70 | 26.00 | 20.30 |
| 400 | 35.70 | 46.00 | 47.00 | 61.00 | 23.70 | 27.70 | 26.00 | 18.00 |
| 600 | 42.30 | 39.00 | 38.70 | 48.00 | 19.00 | 20.00 | 17.30 | 27.70 |
| LSD _(0.05) | NS | | | | NS | | | |
| Number of unmarketable roots/plant | | | | | | | | |
| 0 | 23.00 | 26.70 | 19.30 | 33.70 | 3.59 | 12.59 | 8.85 | 16.26 |
| 200 | 17.00 | 28.70 | 24.70 | 19.30 | 12.96 | 15.41 | 13.56 | 13.15 |
| 400 | 18.00 | 30.70 | 31.70 | 23.70 | 11.70 | 17.41 | 13.19 | 25.00 |
| 600 | 32.70 | 19.30 | 30.70 | 23.00 | 14.44 | 14.85 | 14.15 | 18.07 |
| LSD _(0.05) | 16.62 | | | | NS | | | |
| Weight of marketable roots/plant (kg) | | | | | | | | |
| 0 | 2.13 | 10.07 | 7.07 | 13.20 | 1.03 | 4.90 | 4.33 | 4.97 |
| 200 | 10.70 | 12.67 | 11.10 | 11.27 | 1.77 | 3.57 | 4.90 | 3.87 |
| 400 | 9.60 | 14.03 | 10.37 | 21.47 | 4.10 | 5.43 | 4.67 | 6.93 |
| 600 | 11.63 | 12.40 | 14.50 | 15.33 | 4.67 | 4.03 | 2.87 | 6.33 |
| LSD _(0.05) | NS | | | | NS | | | |

Table 5.1: Continued

| | | 2020 | | | | 2021 | | | |
|---|--------------------------------------|------|------|------|------|------|------|------|--|
| Treatment | Carbonized rice mill waste (t/ha) | | | | | | | | |
| | 0 | | 5 | | 0 | | 5 | | |
| | Un-carbonized rice mill waste (t/ha) | | | | | | | | |
| Fertilizer (NPK) (kg/ha) | 0 | 10 | 0 | 10 | 0 | 10 | 0 | 10 | |
| Weight of unmarketable roots/plant (kg) | | | | | | | | | |
| 0 | 1.17 | 1.27 | 0.90 | 1.43 | 0.77 | 0.80 | 0.60 | 0.40 | |
| 200 | 0.97 | 1.20 | 1.10 | 0.90 | 3.77 | 0.53 | 0.50 | 0.77 | |
| 400 | 0.93 | 1.63 | 1.50 | 1.03 | 0.80 | 0.77 | 0.67 | 1.10 | |
| 600 | 1.37 | 0.97 | 1.57 | 0.93 | 1.13 | 0.83 | 0.47 | 0.93 | |
| LSD _(0.05) | NS | | | NS | | | | | |
| Total root yield (t/ha) | | | | | | | | | |
| 0 | 23.0 | 26.7 | 19.3 | 23.7 | 1.67 | 6.33 | 5.48 | 5.96 | |
| 200 | 17.0 | 28.7 | 24.7 | 19.3 | 2.56 | 4.56 | 6.00 | 5.15 | |
| 400 | 18.0 | 30.7 | 31.7 | 33.7 | 5.44 | 6.89 | 5.93 | 8.93 | |
| 600 | 32.7 | 19.3 | 30.7 | 23.0 | 5.70 | 5.41 | 3.70 | 8.07 | |
| LSD _(0.05) | NS | | | NS | | | | | |

Discussion

The increase in the vine length recorded in the study might be attributed to the role of organic manure application, which made the soil more fertile and favourable leading to the release of organically-bound nutrients. This obviously was responsible for the rates of plant metabolic processes are improved leading to increased vine length. The findings corroborate similar results by Atayese *et al* (2013), with the application of 10 t/ha poultry manure; Abdissa *et al* (2012), with increasing rate of farm yard manure. Similarly, increasing poultry manure rates have been reported to show significant differences in the vine length of orange-fleshed sweet potato (Magagula *et al.*, 2010 and Abou-Hussein *et al.*, 2003). Mineral fertilizer applications have also been shown to significantly affect the vine length of orange-fleshed sweet potato (Haliru *et al.*, 2015; Kumar *et al.*, 2007 and Zalalem *et al.*, 2009)

The increase in the number of leaves might be due to more organic matter in the soil, which improved the water holding capacity and release of more nutrients in the soil for plant vegetative growth. The results are in tandem with the findings of Nwite and Eke (2006), who confirmed that the application of organic manure on cocoyam improved the physical conditions of the soil for plant growth and development. The results also agree with those reported by Onweremmadu *et al.*, (2003), where the application of dehydrated pig manure on maize enhanced all the developmental parameters.

The combination of N:P:K fertilizer enriched with rice mill waste forms produced an increase in the number of branches per plant. Atayese *et al.*, (2013), reported an increase in the number of branches of sweet potato per plant with the application of 10 t/ha poultry manure. A similar response had been reported by Anozie *et al.*, (2008), with the application of animal manures and inorganic fertilizer on growth and yield of fluted pumpkin.

The highest total root yield obtained with the application of composite manure and mineral fertilizer in this study might be as a result of improvement in the physiochemical properties of the soil which led to the release of nutrients for crop uptake. Similar results were reported by Agyarkor *et al.*, (2014), with incorporation of organic manure and N:P:K fertilizer on sweet potato yield; Akinmutimi, (2014), with the application of cocoa pod husk ash and N:P:K-fertilizer on the yield of sweet potato as well as Onunka *et al.*, (2012), with the application of organic and inorganic manure on root yield of sweet potato and Asawalam and Onwudiwe, (2011), with complimentary use of cow dung and mineral fertilizer on sweet potato; Yeng *et al.*, (2012), also reported similar results with the integrated application of

chicken manure and inorganic fertilizer on the growth and yield of sweet potato while Ojeniyi *et al.*, (2012), with integrated application of N:P:K fertilizer and poultry manure on cassava. Santhi and Selvakumari (2000), have proposed that the application of organic manure sources to chemical fertilizer could increase the yield of crops through improving soil productivity and higher fertilize use efficiency. Moreover, Ayoola and Makinde (2007), also suggested that an integrated nutrient management programme in which both organic manure and inorganic fertilizer are used is a rational strategy. The combined use of organic manure and inorganic fertilizer will increase synchrony and reduce losses by converting inorganic N into organic forms (Kramer *et al.*, 2002). It also reduces the environmental problems that may arise from the use of inorganic fertilizers alone and improve the microbial properties of the soil (Belay *et al.*, 2001).

The improved marketable root yield obtained with the combination of composite manure and mineral fertilizer could be attributed to improved physical and biological properties of soil which resulted in the supply of nutrients for the uptake by the sweet potato. This result is in line with those results by Yeng *et al.*, (2012), who obtained higher marketable root yield of sweet potato with integrated application of chicken manure and inorganic manure. Hartemink (2003), reported that poultry manure in combination with mineral fertilizer increased the marketable root yield of sweet potato.

Unmarketable roots can arise either as a result of unavailability of required nutrients at the required time or varietal response to nutrient levels (Onunka *et al.*, 2003). The results from the unmarketable root yield still showed that combination of two nutrient sources had better effect on root size of orange-fleshed sweet potato than only one source. The fact that the different rice mill waste forms gave similar unmarketable root weight could be attributed to other factors that were not investigated here. This result is in line with the findings of Hartemink (2003), that poultry litter and inorganic fertilizer increased marketable sweet potato root number. Tisdale *et al.*, (1990), reported that organic matter from manure provides energy for microbial activity, increases water-holding capacity and yields of crops. This in turn increases the vegetative growth; accelerate the division of meristematic tissue and metabolic reactions and the plant takes more food as a result of which there is increase in the number of marketable roots per plant.

CONCLUSIONS

This study showed that integrated nutrient management (combining organic and mineral fertilizers) holds the key to improving the growth and

root yield of orange-fleshed sweet potato. The results showed that application of rice mill waste had varied effects on the chemical properties of the soil as its application showed superiority in improving the growth parameters at different sampling periods as well as an increase in both the total and marketable root yield of orange-fleshed sweet potato.

RECOMMENDATIONS

Based on the findings reported in this study, orange-fleshed sweet potato for commercial root production in the study area can be improved by combining organic materials such as rice mill waste (bran) with mineral fertilizers. This will help in a big way to improve the soil properties and enhance an increase in sweet potato growth and yield.

Consequently,

- ❖ Application of 400kg/ha NPK + 5t/ha CRMW + 10t/ha URMW is recommended for good commercial root production of orange-fleshed sweet potato in the study area
- ❖ For vine multiplication, the application of still 400kg/ha NPK + 5t/ha CRMW + 10t/ha URMW is equally recommended.
- ❖ The economics of using organic and mineral fertilizer sources in crop production should also be part of soil studies in order to balance nutrient input with cost.

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