ISSN (Online): 2349-1183; ISSN (Print): 2349-9265
TROPICAL PLANT RESEARCH
The Journal of the Society for Tropical Plant Research
8(1): 42–49, 2021
DOI: 10.22271/tpr.2021.v8.i1.007

**Research article**

# Seedbed types and effects on growth and yields of orange fleshed Sweet Potato varieties in a humid high rainfall area of Nigeria

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**Abstract:** The experiment was conducted to determine the effect of seedbed type on vegetative growth and tuber yields of two varieties of orange fleshed sweet potato (*Ipomoea batatas*). Treatments were 3 seedbed types - ridges, flat and mounds with 2 orange fleshed sweet potato varieties in a factorial arrangement in a Randomized Complete Block Design with 3 replications. This field experiment was conducted between May and November 2019 at the Teaching and Research Farm of the Rivers State Institute for Agricultural Research and Training, Rivers State University, Port Harcourt, Nigeria. The field was ploughed, harrowed and ridges and mounds prepared manually. Nodal vines of 2 varieties of orange fleshed sweet potato, UMUSPO 1 "*King J*" and UMUSPO 3 "*Mothers Delight*" were planted on the ridges, mounds and on the flat (ploughed and harrowed only). At harvest length of vine, number of secondary vine branches, and number of leaves, fresh weight of vines and fresh weight of leaves, number and weight of storage roots were recorded. The storage roots were graded into 2 categories according to sizes as marketable tubers (≥150 g) and seed tubers for propagation (<150 g). Seedbed type did not significantly (($P \geq 0.05$) affect all the vegetative growth and tuber yield parameters measured. There was no significant difference in the vegetative growth and tuber yields of the orange fleshed sweet potato varieties. There were no significant interaction effects between seedbed type and orange fleshed sweet potato varieties. A correlation matrix showed 16 significant positive correlations out of the possible 55 matches of vegetative and yield traits examined. To reduce cost of labour, stress and time, farmers could plant orange fleshed sweet potato varieties on the flat without significant loss in foliage and tuber yields in a high rainfall area after ploughing and harrowing.
**Keywords:** UMUSPO 1 - UMUSPO 3 - Marketable tubers - Seed tubers.

[Cite as: Gbaraneh LD & Wilson V (2021) Seedbed types and effects on growth and yields of orange fleshed Sweet Potato varieties in a humid high rainfall area of Nigeria. *Tropical Plant Research* 8(1): 42–49]

## INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) is a source of food, animal feed and bio-based industrial raw materials for production of plastics, sugar syrups, ethanol, butanol and flour, etc. for confectionaries (Klass 1988, Lebot 2009, Loebenstein & Thottappilly 2009, Ziska *et al*. 2009, George *et al*. 2011) especially in tropical countries where it is widely cultivated (Bovel-Benjamin 2007, Abidin *et al*. 2017). Sweet potato is rich in dietary fibre, minerals, vitamins and antioxidants, such as phenolic compounds (Lebot *et al*. 2016) and its anti-carcinogenic and cardiovascular disease-preventing properties are now in focus (Chandrasekara & Kumar 2016). It is one of the few tuber crops with a short growth cycle of 3–5 months providing smallholder farmers with invaluable adjustable planting and harvesting times in both high rainfall regions and drier areas or areas prone to droughts or floods, and is, therefore, able to adapt to different agro-ecological environments and agronomic and cultural practices under which it is cultivated (Sanginga 2015). Often grown without fertilizer or irrigation (Parwada *et al*. 2011), it can grow from sea level to altitudes of up to 2,500 m and temperatures of 15°C to 33°C, while providing good groundcover against erosion and weed infestation. In addition, it is a source of surplus green and dry feed for livestock, and affordable food during times of high food prices; needing little care, and maturing quickly making it an ideal crop for resource-poor farmers (Sanginga 2015, Stathers *et al*.


Received: 06 August 2020 Published: 30 April 2021
https://doi.org/10.22271/tpr.2021.v8.i1.007

2015). Although Asia and Africa account for over 95% of the world's sweet potato production (Aswathy *et al*. 2017, FAOSTAT 2017), it is now increasingly cultivated in Europe and the biggest producers are Portugal, Spain, Italy and Greece (Chandrasekara & Kumar 2016, FAOSTAT 2017). The orange-fleshed sweet potato (OFSP) which contains beta-carotene is a strategic crop bred to overcome vitamin A deficiency (VAD) (Abidin 2012, Tumwegamire *et al.* 2014) and can supply significant amounts of vitamin A, a number of B vitamins, and vitamins C and K simultaneously all-year round and is a good source of energy (Tsou & Hong 1992, Gurmu *et al*. 2014, Sanginga 2015); thus helping to address the twin-problems of Vitamin A deficiency and under-nutrition in developing economies (Hotz 2012, Mitra 2012, Lebot 2013). Two of the most common OFSP varieties available in Nigeria are UMUSPO 1 commonly referred to as '*King J*' released in December 2012*;* and UMUSPO 3 locally referred to as '*Mothers Delight*' containing higher levels of beta-carotene than *King J*, released in June 2013 by Nigeria's National Root Crops Research Institute (NRCRI). The ability of sweet potato to adapt to marginal environments has made it popular with resource-poor farmers as yields of 15 t $ha^{-1}$ have been obtained with minimum use of fertilizers while with proper fertilization and sufficient moisture as much as 50 t $ha^{-1}$ have been achieved (Parwada *et al*. 2011). Sweet potato cultivation and consumption is increasing and new markets for sweet potato are developing around the world. However, as the possibility of a global food crisis in sub-Saharan Africa becomes more real with climate change, their continued viability will require a lower cost of production (George *et al*. 2011, Stathers *et al*. 2015, Van Ittersum *et al*. 2016). Although considered a low-labour, low-cost and low-risk crop and in some cultures a "*Women's Crop*" that help families during droughts and shocks, planting sweet potato on ridges and mounds, conventional practices adopted by many smallholder farmers, is labour-intensive and expensive although occasionally sweet potato is cultivated on flat lands in Nigeria (Aina 2002). Tillage for seedbed preparation is tedious, expensive, time-consuming, may increase soil erosion, and in some cases may not increase yields, therefore, depending on their experiences and locations, farmers use various seedbed types for cultivating sweet potato. Van Vugt & Franke (2018) declared that tillage methods and soil nutrient limitations may be critical factors responsible for the yield gap among smallholder farmers in Africa that prevents them from achieving attainable yield gains from improved sweet potato. Several studies in sub-Saharan Africa and other regions have explored the effects of seedbed types alone or in combination with other variables on yields, in order to determine the ideal seedbed type for the cultivation of sweet potato with \inconsistent results even within the same geo-ecological areas or similar environments and agro-climatic zones. Ahmed *et al*. (2012) found that in Ethiopia in the Danakil plains at Werer Agricultural Research Centre located at 9° 60′ N latitude, 40° 9′ E longitude and at an elevation of 740 m above sea level, with mean annual rainfall of 560 mm, planting sweet potato on ridges and harvesting the vines 105 days after planting (when about 60% of the growth phase of the plant was completed) led to optimum production of herbage for fodder without compromising the yield of tubers. Chagonda *et al*. (2014) stated that in Zimbabwe, in an area receiving an average annual rainfall of 674 mm, planting on ridges recorded longer mean storage root length and higher yields while those from mounds had shorter root length and lower yields. Mu'azu (2016) working in the northern guinea savannah region of Nigeria 686 m above sea level, reported that planting sweet potato on the mound performed better than planting on the ridges or on the flat with no significant differences between ridges and flats. Varying seedbed type did not affect vine length, number of branches per plant, LAI, CGR, RGR, and tuber yield but was significant only for number of branches per plant. Planting on mounds heobserved, provided a good environment for the spread of roots as well as proper aeration for growth and development of the tubers. However, Agbede & Adekiye (2009) in field trials in the forest-savannah transition zone of southwest Nigeria ($7^o$ 12′ N; $5^o$ 35′ E) with annual rainfall totals of 1,015 1,241 and 1,335 mm during the study period, observed that ploughing to a depth of 20 cm followed by harrowing and ridging resulted in the highest yield of sweet potato compared with manual ridging and manual mounding because it resulted in the lowest soil bulk density and highest porosity.

Conversely, in an experiment conducted in the semi-deciduous forest vegetative zone of Ghana when the total rainfall were 466.55 mm and 317.85 mm, Dumbuya *et al.* (2016) reported that plant growth and development were not significantly affected by seedbed type. However, in that study root ridges produced the significantly higher root yield compared to mounds. In the same forest agro-ecological zone of Ghana (longitude $06^o$ 34' E and $10^o$ 36' W) with rainfall of 659.2 mm, Brobbey (2015), showed that tuber yield was higher with ridges than with mounds. Earlier study in India, observed that tilled soils, especially mound significantly increased sweet potato root yield compared with flat planting (Ravindran & Mohankumar 1985). In Peru, studies by Midmore (1992) showed no significant differences in the root yield of sweet potato under row-ridge, two-row bed, on-the-flat and row furrow. Tillage method for crops is known to vary widely depending upon soil type and depth, micro-climate and topography (Agbede 2006, 2008). From the foregoing, it appears tuber and foliage yields from sweet potato seem to depend among other factors, on genotype/ cultivar/ variety (Githunguri & Mutuku 2013, Kathabwalika *et al*. 2013, Mekonnen *et al*. 2015), type of seedbed - on the flat, mounds, furrows and ridges (Agbede & Adekiye 2009, Githunguri & Mutuku 2013), nature of the soil (Agbede & Adekiya 2009, 2011), the agro-ecological conditions (Kathabwalika *et al*. 2013), soil fertility (Wassu *et al*. 2015), soil type and depth, micro-climate and topography (Agbede 2006, 2008) and agronomic practices. The objective of this research was to find out the most suitable seedbed type and effects on growth and yields of orange-fleshed sweet potato varieties in a high rainfall area of Nigeria.

## MATERIALS AND METHODS

This field experiment was conducted between May and November 2019 at the Teaching and Research Farm of the Rivers State Institute for Agricultural Research and Training (RIART), Rivers State University, Port Harcourt, Rivers State in Nigeria. Port Harcourt is situated on the eastern coast of Nigeria at latitude 4.51$^{o}$ North and longitude 7.01$^{o}$ East. Rainfall ranges from 2,000–4,500 mm per annum with a mean of 2,500 mm. The rains begin in February and continue till November with peaks in July and September. Relative humidity remains high all-year round with mean values of 75% in February, increasing to 86% in the months of July and September. Annual temperatures vary from 27.3$^{o}$C to 35$^{o}$C while solar radiation /sunshine lasts an average of 4 hours daily. The soil is a Typic Paleudult of sandy loam texture with a pH of 4.8 (1:1 soil:water) and contained 1.5% organic carbon, 0.11% total N, 37 ppm available P and 0.24, 0.43, and 0.08 me/100 g exchangeable K, Ca, and Mg, respectively. The soil was previously cropped to Mucuna Bean (*Mucuna pruriens* (L) DC.).

### *Experimental materials and treatments*

The experimental materials were two Orange fleshed Sweet potato (OFSP) varieties - OMUSPO 1 (*King J*) and OMUSPO 3 (*Mothers' Delight*). The treatments consisted of 3 seedbed types (ridge, flat and mound) and 2 OFSP varieties (UMSPO 1 – "*King J"* and UMUSPO 3 - "*Mothers' Delight*") laid out in a 3 × 2 factorial arrangement with three replications in a Randomised Complete Block (RCB) design. There were 6 treatment combinations with a total of 18 plots. Treatments were randomly assigned to the plots. Each plot was 23 m × 2 m in size with plots separated by a distance of 1.0 m and blocks separated by a distance of 2.0 m. Total experimental area was 73 m × 17 m.

### *Preparation of seedbeds and planting material*

The field was ploughed and harrowed before each type of seed bed was prepared. Two of the seedbed types - the ridge and mound-were prepared manually using spades and traditional hoes. Each ridge measured 2 m × 0.6 m and a height of 60 cm. Each mound measured 0.5 m × 0.3 m × 0.6 m The flat seedbed did not require further preparation after ploughing and harrowing before planting. Excess leaves were trimmed from each cutting until eight leaves were left and the cuttings were placed in bundles in an upright position in a bucket half-filled with water to avoid wilting during planting in the field (Ahmed *et al*. 2012). An equal number of vine cuttings each measuring 30 cm length with 3 nodes were planted in each seedbed type using a horizontal orientation. Vine cuttings were obtained from a vine multiplication nursery. Weeds were controlled by weeding manually with hoe at 4 and 8 weeks after planting. No fertiliser or pesticides were applied in order to simulate farmers' practices and the experiment was conducted under rain-fed conditions. All plots were harvested 4 months after planting.

### *Data collection and statistical analyses*

The following data were collected at harvest - length of vine (cm), number of secondary vine branches, and number of leaves, fresh weight of vines (Kg ha$^{-1}$) and fresh weight of leaves (kg ha$^{-1}$). Also, the number and weight of tubers were recorded. The tubers free from rot, insect or disease damage were graded into 2 categories by weighing according to sizes as (1) marketable tubers (≥150 g) and (2) seed tubers for propagation (<150 g) (Ahmed *et al*. 2012, Wilson 2019) and each category counted and the total number weighed (t ha$^{-1}$). All data were subjected to analysis of variance using the General Linear Model procedure of the statistical analysis system (SAS 2010) to determine main factor effects and treatment interactions. Means were separated by Fisher's protected Least Significant Difference test at the 0.05 level of probability (Gomez & Gomez 1984).

## RESULTS AND DISCUSSION

### *Effects of seedbed types on vegetative traits of OFSP varieties*

Seedbed types - ridge, flat or mound did not significantly (P≥0.05) affect the total number of leaves, number of secondary branches and length of vines of the OFSP varieties (Table 1) although planting on mounds

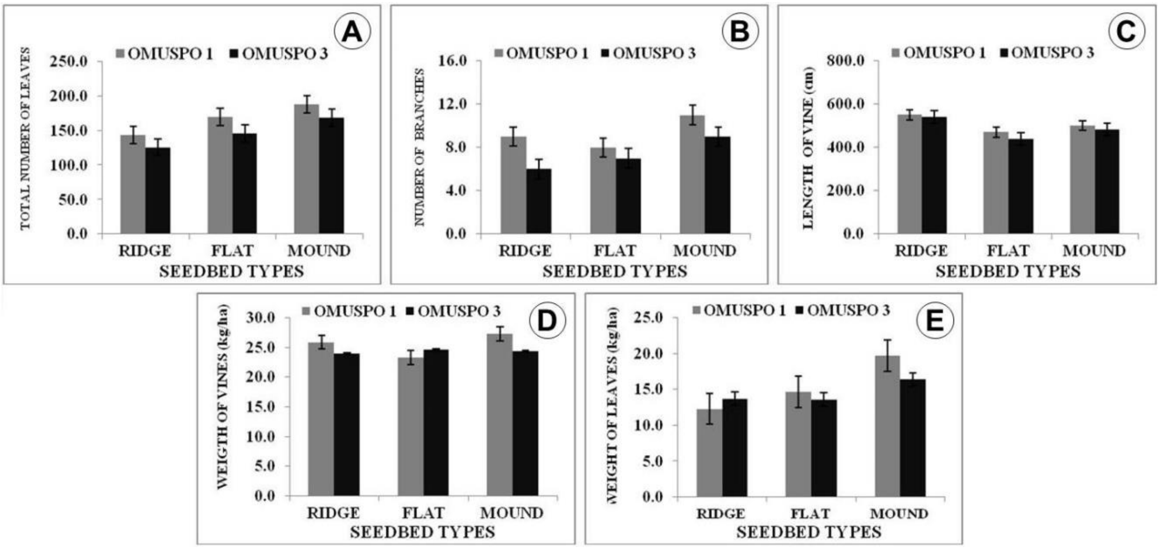


**Figure 1.** Effects of seedbed type on vegetative traits: **A**, Number of leaves; **B**, Number of Branches; **C**, Length of vines (cm); **D**, Weight of vines (kg ha$^{-1}$); **E**, Weight of leaves (kg ha$^{-1}$) of OFSP varieties.

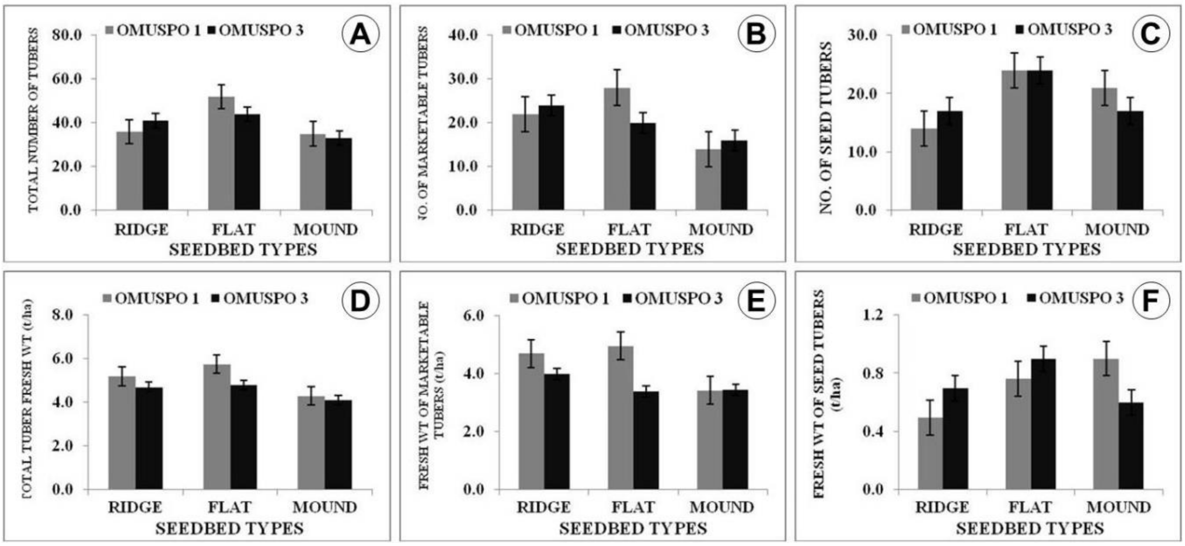


**Figure 2.** Effects of seedbed type on yield traits: **A**, Total number of tubers; **B**, Number of marketable tubers; **C**, Number of seed tubers; **D**, Total tuber fresh wt. (t ha$^{-1}$); **E**, Fresh wt. of marketable tubers (t ha$^{-1}$), **F**, Fresh wt. of seed tubers (t ha$^{-1}$) of OFSP varieties.

produced numerically higher number of leaves, and branches whereas planting on ridges resulted in the longest vines (Fig. 1). With respect to the OFSP varieties, OMUSPO 1 had more leaves, and branches and longer vines than OMUSPO 3 although the differences were not statistically significant (Table 1). There were no significant interaction effects between seedbed types and OFSP varieties in any of these traits. Also, there were no significant differences (P≥0.05) in the effects of seedbed types on fresh weight of vines and leaves although mounds produced numerically the highest fresh weights of vines and leaves (Fig. 1). Although OMUSPO 1 had higher fresh weight of vines and leaves than OMUSPO 3, the differences were not statistically significant (Table 1). There were no significant interaction effects between seedbed types and OFSP varieties with respect to number of secondary branches, length of vines, fresh weight of vines and leaves. Other studies on sweet potato seedbed types found no significant interaction effects with other factors on shoot/ vegetative growth (Ahmed *et al*. 2012, Chagonda *et al.* 2014) while others indicated no significant interactions between varieties and other factors (Akpaniniyang *et al.* 2013, Ogbologwung *et al*. 2016). The various seedbed types did not significantly affect the vegetative traits of sweet potato measured in this study. Dumbuya *et al*. (2016) reported similar findings for sweet potato vegetative growth and development while Mu'azu (2016) found no significant effects of seedbed types for all vegetative traits measured except for number of branches. Since the experiment was conducted close to the peak of the rains, perhaps, water was not a limiting factor because of the high rainfall (Nedunchezhiyan *et al*. 2012, Van Vugt & Franke 2018) and the land was previously cropped to mucuna bean which could have supplied enough nitrogen to crops to promote good vegetative growth irrespective of seedbed type.

**Table 1.** Mean squares from ANOVA of effects of seedbed type on vegetative traits, yield and yields components of OFSP varieties.

| Sources of Variation | df | Number of leaves | Number of branches | Vine length (cm) | Fresh weight of leaves (kg) | Vine fresh weight (kg) | Total number of tubers | Number of marketable tubers | Number of Seed tubers | Total tuber weight (t ha$^{-1}$) | Marketable tuber weight (t ha$^{-1}$) | Seed tuber weight (t ha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Block (Rep) | 2 | 55.2$^{NS}$ | 5.1$^{NS}$ | 8773.0$^{NS}$ | 2123.4$^{NS}$ | 2252.1$^{NS}$ | 152.7$^{NS}$ | 92.2$^{NS}$ | 15.2$^{NS}$ | 2.9$^{NS}$ | 2.8$^{NS}$ | 0.153$^{NS}$ |
| Seedbed Type (A) | 2 | 1315.2$^{NS}$ | 2.9$^{NS}$ | 3074.7$^{NS}$ | 3069.4$^{NS}$ | 2176.9$^{NS}$ | 24.5$^{NS}$ | 10.7$^{NS}$ | 23.2$^{NS}$ | 0.6$^{NS}$ | 0.6$^{NS}$ | 0.011$^{NS}$ |
| OFSP Variety (B) | 1 | 364.5$^{NS}$ | 5.6$^{NS}$ | 3901.4$^{NS}$ | 1250.0$^{NS}$ | 8234.7$^{NS}$ | 12.5$^{NS}$ | 10.9$^{NS}$ | 0.1$^{NS}$ | 1.2$^{NS}$ | 1.0$^{NS}$ | 0.002$^{NS}$ |
| Seedbed Type X OFSP Variety | 2 | 241.2$^{NS}$ | 0.2$^{NS}$ | 643.5$^{NS}$ | 443.2$^{NS}$ | 696.9$^{NS}$ | 26.2$^{NS}$ | 22.2$^{NS}$ | 5.1$^{NS}$ | 0.6$^{NS}$ | 0.6$^{NS}$ | 0.028$^{NS}$ |
| Error | 10 | 945.5 | 5.2 | 2370.8 | 2262.1 | 2503.7 | 84.3 | 35.7 | 22.6 | 1.2 | 1.0 | 0.022 |
| CV (%) | | 11.65 | 14.9 | 5.25 | 21.57 | 15.84 | 10.88 | 14.3 | 11.13 | 12.38 | 13.86 | 9.98 |

**Note:** Significant at P = 0.05; NS = Not Significant; cv (%) = coefficient of variation.

**Table 2.** Correlation matrix showing the correlation coefficients (r) between and among vegetative and yield traits.

| Traits | Number of branches | Fresh leaf weight | Vine length | Fresh vine weight | Total Tuber weight | Marketable tuber weight | Seed tuber weight | Number of total tubers | Number of marketable tubers | Number of seed tubers |
|---|---|---|---|---|---|---|---|---|---|---|
| Total number of leaves | 0.398 | **0.871**** | 0.246 | **0.762**** | 0.030 | 0.042 | -0.043 | 0.079 | 0.154 | -0.045 |
| Number of branches | | 0.359 | 0.457 | **0.579*** | -0.015 | -0.012 | 0.040 | -0.054 | -0.069 | -0.014 |
| Leaf weight | | | 0.296 | **0.839**** | 0.281 | 0.296 | 0.029 | 0.334 | 0.428 | 0.084 |
| Vine length | | | | 0.420 | **0.609**** | **0.628**** | 0.096 | 0.357 | **0.582**** | -0.064 |
| Vine weight | | | | | 0.195 | 0.195 | 0.095 | 0.291 | 0.330 | 0.127 |
| Total tuber weight | | | | | | **0.994**** | 0.306 | **0.796**** | **0.932**** | 0.310 |
| Marketable tuber weight | | | | | | | 0.208 | **0.751**** | **0.932**** | 0.226 |
| Seed tuber weight | | | | | | | | **0.648**** | 0.270 | **0.858**** |
| Number of total tubers | | | | | | | | | **0.860**** | **0.774**** |
| Number of marketable tubers | | | | | | | | | | 0.343 |

**Note:** *Significant at 5%; **Significant at 1%.

*Effects of seedbed types on yield traits of OFSP varieties*

Type of seedbed did not significantly (P≥0.05) affect total number of tubers produced, number of marketable tubers, number of seed tubers, weight of marketable tubers, weight of seed tubers and weight of total number of tubers irrespective of OFSP variety (Table 1). This finding is similar to those of Midmore (1992), Githunguri & Mutuku (2013) & Dumbuya *et al*. (2016), who observed that seedbed types did not significantly affect tuber yields of sweet potato especially of the elite cultivars. However, planting on the flat produced numerically the highest marketable tubers, seed tubers and total tubers compared with planting on ridges and mounds (Fig. 2). Moreover, seedbed type did not result in significant differences in the OFSP varieties although the variety OMUSPO 3 was numerically better than OMUSPO 1 when planted on ridges with respect to marketable tubers, seed tubers and total tubers. On average, however, OMUSPO 1 was numerically better than OMUSPO 3 when planted on the flat and mounds with respect to these 3 traits (Fig. 2). The variety OMUSPO 1 had higher fresh weight of marketable tubers and fresh weight of total tubers than OMUSPO 3 on all seedbed types but had higher fresh seed tuber weight only when planted on mounds. Ahmed *et al*. (2012) and Chagonda *et al.* (2014) also reported no significant interaction effects between seedbed type and other factors on tuber yield traits.

*Correlation among vegetative (aboveground) and yield (underground) traits*

Results of the correlation matrix showed 16 significant positive correlations out of the possible 55 combinations/ matches of vegetative and yield traits examined (Table 2). Correlation analyses showed that there were positive and highly significant linear correlations between total number of leaves and fresh weight of leaves (r = 0.871**); total number of leaves and fresh weight of vines (r = 0.762**); fresh weight of leaves and fresh weight of vines (r = 0.839**); vine length and total tuber fresh weight (r = 0.609**); vine length and marketable tuber fresh weight (r = 0,628**); total tuber fresh weight and marketable tuber fresh weight (r = 0.994**); total fresh weight of tubers and total number of tubers (r = 0.796**); fresh weight of marketable tubers and total number of tubers (r = 0.751**); fresh weight of seed tubers and total number of tubers (r = 0.648**); total number of tubers and number of marketable tubers (r = 0.932**); fresh weight of marketable tubers and number of marketable tubers (r = 0.932**); total number of tubers and number of marketable tubers (r = 0.860**); fresh weight of seed tubers and total number of seed tubers (r = 0.858**) and between total number of tubers and number of seed tubers (r = 0.774**) (Table 2). Also there were significant linear correlations between number of secondary branches and fresh weight of vines (r = 0.579*) and between vine length and number of marketable tubers (r = 0.582*). The r value indicates the degree of association between any two traits; the higher the value of r, the higher the strength of the association. In this study, weight of total number of tubers and weight of marketable tubers showed the strongest positive association (r = 0.994**).

## CONCLUSION

The results of this experiment showed that seedbed type - ridge, flat and mound- did not significantly affect vegetative growth and tuber yields of the two OFSP varieties in a high rainfall area. Thus, farmers could plant on the flat after ploughing and harrowing without significant loss in foliage and tuber yields, in order to avoid the additional costs, stress and time required for making ridges and mounds.

## ACKNOWLEDGEMENTS

Authors thank the field staff of the Teaching and Research Farm of the Rivers State Institute for Agricultural Research and Training (RIART) for their assistance during the study.

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