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VARIABILITY OF METEOROLOGICAL CONDITIONS AND LOCATIONS ON SEED YIELD AND YIELD COMPONENTS FROM WHOLE TUBERS AND MINISETTS

***AFOLABI, M.S.,[1] LAMIDI, W.A.[2] AND AKORODA, M.O.[3]**
[1]Department of Agronomy, College of Agriculture, Ejigbo, Osun State University, Osogbo, Nigeria
[2]Department of Agricultural Engineering, Faculty of Engineering, Osun State University, Osogbo, Nigeria
[3]Department of Agronomy, University of Ibadan, Nigeria
*Corresponding author: afolabimike97@gmail.com

Abstract
The research evaluated the effects of using whole tubers versus minisetts of various sizes to produce seed yams in four different locations namely, Ila-Orangun, Ilesa, Ilorin and Omu Aran in Nigeria. Three different sizes of whole and minisetts tuber (50 g, 100 g and 150 g) were used to determine how rainfall variability affect yield and yield components in yam. Studies were conducted for two consecutive years in randomized complete block design with three replications of each treatment in each location and year. Growth data collected were number of leaves, vine length (m), number of vines and number of tubers per plant. Also, numbers of harvested tubers, the mean weight (kg) and the fresh yield (t/ha) were recorded. Rainfall values within the months of May and October were recorded and analyzed descriptively. Results showed that plants from whole tubers produced higher yield (64.18%) than those from minisetts. Yields in the area of short rainfall were statistically reduced compare to area with high rainfall. Tuber yield mean values were increasing size by size as yam seeds' sizes were increasing in minisetts as well as whole yam tubers regardless of cultivation, seasons and locations. Small whole tubers' seed are more profitable than minisetts and therefore recommended to yam-growing-farmers.

Key Words: *Yam, Tuber, Minisetts, location, Soil fertility, Seed yield*

Introduction

Yam (*Dioscor*ea spp.) is a significant crop in West Africa and constitutes about 60% of the tuber crops produced in the region (FAOSTAT 2020). It is recognized as capable of providing income and dietary carbohydrate to many people. It is also tied to some socio-cultural lives of the peoples in the West Africa (Emokaro *et al*., 2008). Seventy-one percent of the yam produced in West Africa is from Nigeria alone (Aighewi 2015). As a result, the potential of this crop in Nigeria can help Nigeria ride out of the turmoil created by food price increases by contributing to export earnings. However, despite the seemingly higher percentage production compared with other tuber crops and its economic importance to the teeming populace in Nigeria, the production is still low, perhaps as a result of erratic rainfall pattern occasioned by climate change or lack of formal seed yam. Erratic pattern of rainfall would result to water shortage during the growth stage which could affect the plant growth and the yields on the long run. Besides, poor genetic, abiotic and biotic components of the planting materials; high post-harvest losses, and high rate of missing stands due to abiotic stress have also contributed to low yam production (Melteras *et al*., 2008).

The crop is majorly propagated vegetative using tubers through old methods that are liable to disease which could also affect its growth and yield. At propagation, yam tubers are seeded for another yam year planting, this has caused problems for growers because what should have been sold as whole tubers were planted through seeds that take larger share. Yam is majorly grown by rural farmers using tubers that they harvest aside from the food-yam crop and cut up into small-sized tubers of 200g to 500g. Thus, many farmers reserve about 35% of the harvest for next planting season (Ironkwe, 2005). Small size tubers that are planted are scarce to find, food-yam-tuber weighing even up to 2kg are cut into 200–300g setts for planting. This is the last option for any yam-growing farmer because it not only reduces food storage in the warehouse but also provide income to the farmer (Nweke *et al.,* 2016). Soils in most parts of West and Central Africa are inherently deficient in nitrogen because of the low level of organic matter and various climatic factors (Aduloju *et al*., 2014). The variation in soil composition is as a result of various factors including decomposition of organic materials, continuous cropping and erosion associated from loss in soil structure. The pH values recorded in the research sites that were slightly acidic and this will aid availability of soil-plant nutrients for plant roots uptake (Lal, 2009). Soil organic matter is very important in plant response to soil nutrient uptake particularly nitrogen and phosphorus (Melese and Yli-Halla, 2016).

Planting materials comprise of whole yam and cut tubers. The cut tubers could be heads, middle or tail of food-yam tuber. This has serious influence on crop emergence and yield due to age of tubers as reported by Beatrice *et al.* (2020). Tail portion regenerate easily because it has the youngest tissues. Head is dormant and emerges late because it contains shoot primordium. Farmers used designated sharpened knife to cut yam tubers into yam setts because the cut surface part of the tubers have the tendency to rot especially if knife cut surfaces are too rough. In order to overcome these problems, scientists in National Root Crops Research Institute (NRCRI), Umudike, Nigeria and International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, developed the minisett techniques. With the techniques they concluded that possible multiplication ratio in yam sets' propagation may increase from the traditional 1:5 to 1:30 (Orkwor *et al*., 1998). The objective of this study was to determine the effect of variability of weather conditions and location on yields and yield structure in seed yam production from whole tubers and minisetts.

Materials and Methods

The experiments were carried out simultaneously in four different locations in South West region and North Central region in Nigeria. The locations are Ila Orangun (8.012° N, 4.90° E), Ilesa (7.16° N, 4.71° E) in South West Nigeria; Omu

Aran (8.14° N, 5.10° E) and Ilorin (8.53° N, 4.54° E) in North Central Nigeria. Ila Orangun and Ilesa are in Osun State of Nigeria and belong to the rainforest zone while Omu Aran and Ilorin are in Kwara State and they belong to Southern Guinea Savannah.

The experiment was done for two growing seasons in 2013 and 2014. White yam (*D. rotundata*) was used in the experiment. Each variety of yam tuber used in the research is the one popular to the area in consideration, planted by majority of farmers there and are majorly available in the local market and they have Yoruba names. Thus, a variety of yam tuber of a popular demand called *"Aro"* in Ilesa was used in Ilesa field. Another variety called "Gbakumo" in the Ila-Orangun, Omu-Aran and Ilorin were also used in these locations. These comprise of three different average sizes (50g, 100 g, and 150g) of whole tubers and minisetts containing skin. These planting materials were treated with 50ml of Cypermethrin in 10 litres of water for 15 mins to protect against rots and damage that may be caused through soil pests. They were naturally air-dried under shade for about 24 hours before planting.

Field plots for the experiment were prepared using traditional hoes and cutlasses. Soil samples were randomly taken with a soil auger at the depth of 0-30 cm from each of the research locations for the two years. The soil samples were packed separately and well labeled to avoid mixed up for analysis. The soil samples were analyzed at the laboratory of the Department of Crop Science, Landmark University, Omu Aran, Kwara State, Nigeria. The soil organic matter, carbon content, and nitrogen were presented in percentage in Table 1.

Ridges were made at a spacing of 100 cm apart, seed tubers were planted at a depth of about 10 cm in a single row of inter-row spacing of 50cm. In all the four locations, the field plots were laid out as a 2 × 3 factorial; a randomized complete block design with three replications and four treatment-combinations were used. Weed was controlled using small hoe to remove weeds and earth-up. Staking was done at 5 weeks after planting (WAP) on individual crop basis. No fertilizer, herbicides or pesticides were applied in all the fields.

Growth data collected at 10 WAP were number of leaves, vine length, number of vines, and number of tuber per plant. Tubers were harvested when senescence was complete. Tubers were harvested on 13 November, 28 November, 20 December and 27 December, 2013 and in 2014, harvesting was done on 28 November, 2 December, 26 December and 30 December in all locations. The numbers of harvested tubers and weight were recorded in all locations and both years, the mean weight (kg) found and the fresh yield (t/ha) were recorded.

Rainfall data for the period of the experiment were obtained from four different meteorological stations in each of the experimental towns for months between May and November each year in Landmark University, Omu Aran; Lower Niger River Basin, Ilorin; Osun State College of Education, Ila Orangun and Osun State College of Education, Ilesa in Osun State,. By the ending of November in each year, yam leaves were already dried and shedding which necessitated their harvesting in November through December. Temperature Humidity Index (THI) were computed from Temperature and Humidity values (Table 4).

Data were subjected to statistical analysis of variance (ANOVA) using SAS Institute (1995). Significant means were separated using Duncan Multiple Range test at 5% probability level. The least significant difference effect of size, locations, and seasons were calculated based on the collected data. Moreover, rainfall data values were reported using regression analysis and descriptive statistics

Results

Soil Analysis

The soil physical and chemical properties of the experimental sites are shown in Table 1. The soils in all the locations were not too different from one another and all were within acceptable limit for crops' use. The soil pH value at each of the experimental sites ranges from 5.00-5.90 across the four locations for the two years. The soil organic matter in the soils ranges from 1.30-1.88, carbon content ranges from 1.20-1.50 while the nitrogen level ranges from 1.04 - 1.58 across the locations. The result revealed that the soils across the locations were sandy loam.

Figures 1 and 2 show the rainfall distribution pattern across four different locations for the period of the study. Rainfall amount in Ila Orangun and Ilesa were consistently higher during the period of May to December, 2013 and 2014 because they are in rainforest zone. However, rainfall distribution pattern in Ilorin and Omu Aran during the two periods were consistently lower because they are in savanna zone and they have erratic lower rainfall values compared to Ila Orangun and Ilesa. As shown in Table 2, there were high variations in the rainfall intensities in all the locations in both years according to the standard deviation values. The temperatures and humidity values varied highly with the high values of standard deviation; thus, the rainfall, temperature and humidity were erratic and were always fluctuating in the locations monthly (Table 2).

Temperature Humidity Index (THI) values in Table 2 depict the interaction of the atmospheric conditions in the four locations and the ambient conditions of the yam growth parameters like stems, roots and leaves. THI relates the combined effects of dry-bulb temperatures and humidity to any living organism's comfort and performance. Although it is usually used for animals, it could by extension apply to plants because temperature and humidity also affect them (Lamidi and Afolabi, 2016). THI has been widely accepted as

$$THI = db^{o}\,C - \{[0.31 - 0.31 \left[\frac{RH}{100}\right]](db^{o}C\text{-}14)\}$$

where $db^{o}C$ = dry bulb temperature in Celcius and RH = relative humidity in %, (Lamidi and Afolabi, 2016). THI relates the combined effects of dry-bulb temperatures and humidity to any living organism's comfort and performance.

The average THI values were low in the months of the experiment which were evidence of good environment for the good performances of the yam. High values of rainfall intensities in the year could be the reason why the THI values were low and it was an avenue of providing comforts for the growing yam.

The R^2 values showing the closeness of the rainfall data to the regression lines of the monthly rainfall intensities at different locations, they were highest with values of 0.98 and 0.97 respectively at Ilesa and Ila-Orangun in 2014 and 0.93 and 0.91 respectively at Ilesa and Ila-Orangun in 2013. These values are high compared to R^2 values obtained in other two locations in both years. The model equations 1 – 8 below explain the variability of the response data around the rainfall mean values as independent variable versus dependent variable, months, as both fitted the regression lines. The error bars as depicted in both years are not short showing that the rainfall values were not concentrated, (this was also shown in their standard deviations values), thus showing the variability of the rainfall in all the locations in the research and this could have affected the yield of the yam tubers.

2013

$Y_{\text{Ila Orangun}} = -1.84\, x^3 + 11.446\, x^2 + 421.146\, x + 136.86 \quad R^2 = 0.91$ (Equation 1)

$Y_{\text{Ilesa}} = -3.159\, x^3 + 28.957\, x^2 - 48.604\, x + 205.36 \quad R^2 = 0.93$ (Equation 2)

$Y_{\text{Ilorin}} = -x^3 + 3.5\, x^2 + 25.024\, x + 117.14 \quad R^2 = 0.88$ (Equation 3)

$Y_{\text{Omu Aran}} = -1.215\, x^3 + 69.28\, x^2 + 10.166\, x + 127 \quad R^2 = 0.76$ (Equation 4)

where Y = independent variable representing the rainfall in a particular location
x = dependent variable representing the months variations from May to December when rain stopped and dependent variable were raised to third order polynomial fitted regression.

Table 1: Physical and chemical characteristics of the soils in the experimental sites: (Ilesa, Ila Orangun, Ilorin, Omu Aran)

Properties	Locations 2013				Locations 2014			
	Ilesa	Ila-Orangun	Ilorin	Omu Aran	Ilesa	Ila-Orangun	Ilorin	Omu Aran
Sand (%)	60	56	62	60	60	61	64	62
Clay (%)	19	18	23	18	18	19	20	19
Silt (%)	21	20	21	22.5	20	17	20	20
Textural class	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
pH	5.80	5.90	5.55	5.78	5.10	5.00	5.04	5.81
Carbon (%)	1.50	1.20	1.29	1.47	1.20	1.00	1.49	1.52
Organic matter (%)	1.88	1.60	1.64	1.76	1.58	1.30	1.58	1.83
Nitrogen (%)	1.53	1.24	1.46	1.34	1.56	1.45	1.23	1.04
Phosphorus (mg kg^{-1})	10.62	9.83	12.54	11.60	10.12	9.23	13.00	11.90
Ca^{2+} (C mol kg^{-1})	1.70	1.45	1.92	1.65	1.40	1.15	1.20	1.89
Mg^{2+}(C mol kg^{-1})	0.70	0.68	0.84	0.81	0.60	0.61	0.93	0.71

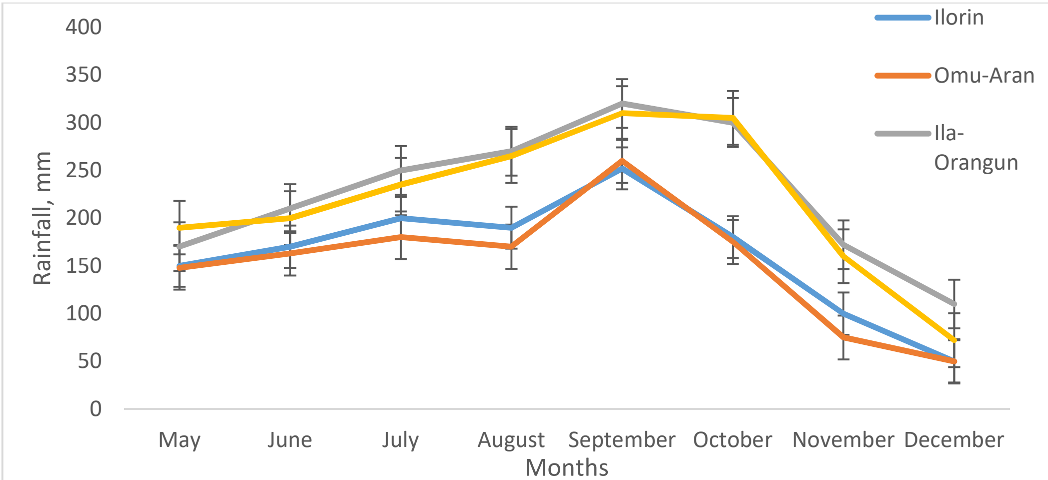

Fig. 1: Rainfall pattern from May to December 2013 in four different locations (Ilesa, Ila Orangun, Ilorin, Omu Aran)

2014

$Y_{Ila\ Orangun} = -2.495\ x^3 + 20.396\ x^2 - 10.68\ x + 162.64$ $R^2 = 0.97$ (Equation 5)

$Y_{Ilesa} = -4.293\ x^3 + 44.53\ x^2 - 103.8\ x + 262.14$ $R^2 = 0.98$ (Equation 6)

$Y_{Ilorin} = -1.37\ x^3 + 7.957\ x^2 + 12.53\ x + 128.88$ $R^2 = 0.87$ (Equation 7)

$Y_{Omu\ Aran} = -1.169\ x^3 + 6.647\ x^2 + 9.816\ x + 121.86$ $R^2 = 0.80$ (Equation 8)

where Y = independent vairiable representing the rainfall in a particular location
x = dependent variable representing the months variations from May to December when rain stopped and dependent variable were raised to third order polynomial fitted regression.

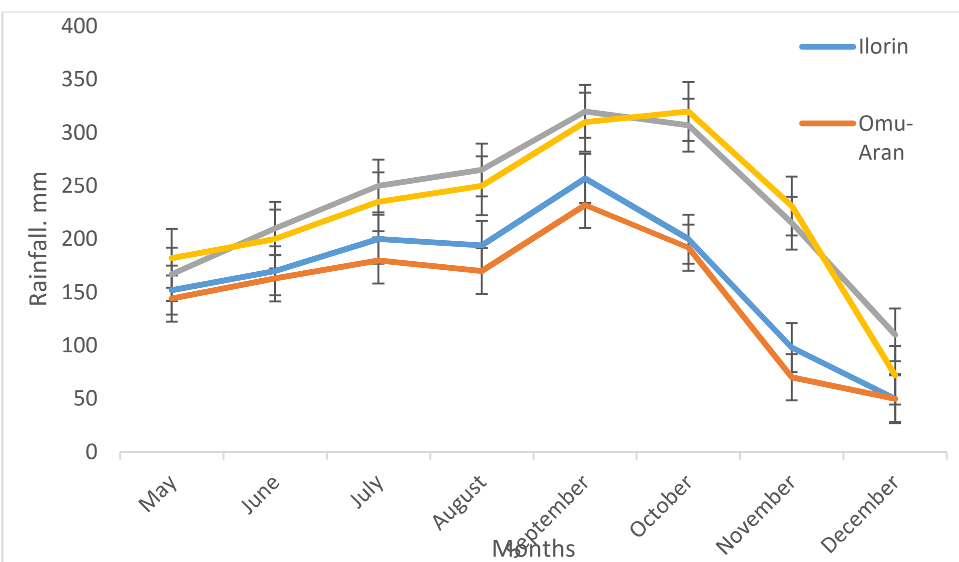

Fig. 2: Rainfall pattern from May to December 2014 in four different locations (Ilesa, Ila Orangun, Ilorin, Omu Aran)

Table 2: Mean values of Precipitation, Temperature and Humidity in months of planting with their THI values in different locations

Year	Location	Precipitation, mm	Temperature °C	Humidity, %	THI, °C
2013	Ilesa	217.13 ± 79.56	26.20 ± 1.68	35.15 ±1.21	26.69
	Ila-Orangun	225.25 ± 72.29	24.78 ± 0.68	33.50 ±2.81	25.04
	Omu-Aran	152.63 ± 65.21	22.75 ± 7.39	31.93 ±3.96	22.83
	Ilorin	161.50 ± 62.39	27.20 ± 1.13	36.08 ±2.10	27.85
2014	Ilesa	225.00 ± 78.28	27.38 ± 0.92	37.90 ±0.42	28.28
	Ila-Orangun	230.50 ± 70.35	25.90 ± 2.20	34.58 ±4.02	26.31
	Omu-Aran	150.13 ± 61.40	26.70 ± 1.31	36.75 ±2.13	27.41
	Ilorin	165.13 ± 65.10	25.23 ± 1.75	33.43 ±3.22	25.49

Table 3: Growth and yield performance of different sizes of minisett and whole yam tubers at 4 different locations in 2013 and 2014

Treatment	Sizes of yam tuber seeds (g)	No of leaves	Vine length (m)	No of vines	No of tuber per plant	Mean weight (kg)	Fresh yield (t/ha)
Minisett	50	62.23c	1.23c	2.12c	1.13c	0.40c	9.40c
	100	75.54b	2.13b	4.22b	1.52b	0.62b	12.32b
	150	90.44a	2.97a	5.72a	1.75a	0.75a	14.70a
Whole yam	50	74.60c	1.93c	4.23b	1.57c	0.65b	17.50c
	100	93.75b	2.51b	5.72a	1.72b	0.73a	20.32b
	150	130.42a	2.84a	9.32c	2.15a	1.00c	24.70a
Season	2013	73.42b	1.93b	5.41b	1.97b	0.32b	29.30b
	2014	84.75a	2.01a	8.32a	2.15a	0.75a	32.12a
Location	Ilorin	89.45b	1.71c	4.27c	1.23c	0.65b	17.40c
	Omu Aran	72.33c	1.65c	3.92d	1.05d	0.52c	14.32d
	Ilesa	97.23a	2.42a	9.75a	1.72a	0.93a	32.43a
	Ila Orangun	88.42b	2.13b	7.32b	1.54b	0.71b	21.32b

^{abc} Mean values with the same letters along the same column for a specific parameter are not significantly different at $p < 0.05$

The mean length of vines for the whole seed tubers planted was 2.43 ± 0.46m, this was significantly more than that of plants grown from minisetts (2.11 ± 0.87m). The same trend was observed for the number of vines and leaves, as well as number of tubers per plant (Table 3). Fresh seed tuber yield was 71.66% higher for the whole seed (20.84 ± 3.63t/ha) compared with that from minisetts (12.14 ± 2.66t/ha).The performance of the number of vines and length of vines, and number of leaves showed statistical differences ($p < 0.05$) within different sizes of planting materials (Table 3).

Moreover, the two years of the field research confirmed significant differences ($p<0.05$) for the number of leaves, vine length, number of vines and number of tuber per plant. All variables were significantly higher in 2014 than in 2013. Comparing the four locations, Ilesa yield (32.43t/ha) was significantly higher than the remaining locations and was 52% more than the next high yield in Ila-Orangun (21.32t/ha) and was 126% more than the least tuber yield which was recorded in Omu Aran (14.32t/ha). All variables were all highest for the 150g, followed by the 100g and 50g. The 150g planting material yielded 24.70t/ha, being about 55% and 25% more than in 50g and 100g seed, respectively (Table 3).

Discussion

The seed yams planted in Ilesa and Ila Orangun sprouted earlier than those in the Ilorin and Omu Aran location, this may not be as a result of the soil factors but the rainfall, this was in agreement with what was observed by Aighewi *et al.* (2015, 2020) in their experiment on improvement of yam propagation. The full and lush appearance of foliage of yam leaves in Ila-Orangun and Ilesa is as a result of a high rainfall pattern in the areas, this is in agreement with Anzaku *et al*. (2019) (in their fourteen years research on yam tubers performances versus climatic effects), they concluded that variability of moisture (rainfall and temperature) indices appears as most significant factor in yam tuber production in the humid tropics. Early senescence experienced in Omu Aran and Ilorin could have resulted from gradual reduction and variability in rainfall. The rainfall, temperature and humidity patterns were erratic and were always fluctuating in the locations, this could be surmised to have been part of the growth discrepancies recorded in the yam seeds in Omu Aran and Ilorin locations and in the years.

The higher R^2 values recorded in the interaction between data obtained for rainfall and location with their model equations reveals the variability of the response data around the mean rainfall values, the higher R^2 values show their closeness and how fittingly the regression model fits in. highest R^2 value depicts that 98% of rainfall mean values fit the regression model and therefore the rainfall have significant effects on the tuber yield of yam in Ilesa and similarly could be said about Ila Orangun with 97% rainfall mean values. Equations 1, 2, 5, and 6 with high R^2 value also reveal that independent variable, rainfall and the dependent variable, months, explain how in different months in each of the years, there were different intensities of rainfall which eventually led to differences in the yield components and evidenced in the overall yields.

At tuberisation, buds are formed, without pre-formed buds, it takes longer for yam setts that are cut from tuber sections other than the head portions to produce sprouts that would grow into vines in all locations tuberisation were good and the vines developed as they should, but the variability in the rainfall thereafter in each of the locations as they are different from one another and from location to location resulted into discrepancies in the yield recorded. biotic and abiotic stress could also have set in especially in Ilorin and Omu Aran where lower rainfall were recorded with higher temperature and higher THI, thus in agreement with Agidi *et al*. (2017) who found out that stress may set in as a result of variability in rainfall and tuber yield will be affected negatively.

In the study, the plants that have reduced number of vine length photosynthate less than plants that have long vine length, this resulted in wide variability of tuber yields at harvest), these could have been caused by the rainfall, temperature and humidity that were erratic and were always fluctuating in the locations during the months. (Agidi *et al*., 2017, Ayanlade *et al*., 2009). The rainfall fluctuations also could be responsible for variations in the vine lengths which could possibly evidence from varied sizes of yam seeds that were planted and which could have statistically different tuber yields.

In West Africa and Nigeria in particular, yam is majorly cultivated as a rainfed crop. When there is paucity of rainfall or less rainfall than necessary, the crop senescence early, irrespective of its stage of growth. The rainfall intensities in Ilorin and Omu Aran were lesser in both years and through the months, the results were evidence in the performances of the tubers' fresh yield in the two locations. In these area, farmer's dependence on rainfall and the uncertainty of its duration causes reduction in the yield of yam just like early cessation of rain creates low yield just like it could in any rainfall-dependent crop. It could also as much cause anxiety for yam farmers. From this study, areas with inadequate rainfall experienced yield reduction, it could be surmised that using whole tubers in the area may produce tubers that will yield higher than when minisett is planted. In such two locations, Ilorin and Omu Aran, farmers may be advised to sort whole seed size tubers for the next planting.

The vine length (plant height) that influence fresh tuber yield and the positive correlation observed between tuber weight and the yield components could be as a result of the longer the vine recorded and it has been that the more the branches and leaves, the more the tuber yield (Sartie *et al*., 2012). Increased number of leaves and other yield components of the tubers contribute to the weight of the tuber at harvest especially those in Ilesa and Ila-Orangun.

The tubers' yield was directly connected to the seed size planted on the field, thus tuber yield is a function of the seed size, as it was recorded that the higher the seed size, the higher the tuber yield. Thus the interaction among the tuber size, the locations and the years of planting does seem to be significant. Yam seeds as planting materials also had a significant influence on the vegetative growth. This result agrees with the findings of Cornet *et al.* (2014), who reportedly found high coefficient of variation between plant size and yield variability and that yam species resulted into high interplant coefficient of variation for tuber yield. One advantage of using larger planting material is that it is more likely to produce more sprouts than smaller ones, and if the main sprout is damaged, an alternative one that will sprout from another spot on the tuber will take over (Onwueme, 1973). Also, the bigger setts have a better establishment, with more vigorous plants that have longer vines and more leaves. There were also early sprouting and faster development of roots and vines in the earliest phase of crop growth. This could be attributed to rainfall intensities, healthiness of the tubers and other factors as were also observed by O'Sullivan (2010). Just like yam sett planted influence the number of vines, larger sett size planted also results in larger leaf areas.

Conclusion

This study highlights the fact that rainfall and seed tuber have a large role to play in plant growth and tuber yield.

Yields were reduced due to erratic pattern of rainfall in the areas where there was water shortage during the growth which affected the growth rate. Also, seed tuber sizes affected the overall yield of the yam, also the interaction of location by year and the differences in amount of rainfall response affected the tuber yield.

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