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Seed yam production from whole tubers versus minisetts

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ABSTRACT

Yam (*Dioscorea rotundata* Poir.) is a major staple and cash crop for millions of households in West Africa, where about 93% of the world crop is produced. The tuber serves as food and seed. Depending on the size, seed tubers are often cut into setts, minisetts, or planted whole. An experiment was conducted to investigate the effects of using whole tubers versus minisetts to produce seed yams. Six treatments constituted combinations of whole tubers and minisetts, and three tuber-size classes, viz., 30–59 g, 60–89 g, and 90–120 g (averaged and referred to as 45 g, 75 g, and 105 g, respectively). The experiment was conducted as a randomized complete block design with three replications. Results showed that plants from whole tubers emerged from the soil faster and yielded 48% more than those from minisetts. The mean yield of 105 g minisetts (18.3 t/ha) was statistically similar to that of 45 g whole seed (17.9 t/ha). Using 45 g whole seed would save about 2 t/ha of the harvested crop for use as food instead of seed. So, planting small whole tubers is more profitable than minisetts and is recommended to yam growers.

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Dioscorea rotundata; minisetts; whole seed; seed yam; production

Introduction

Yam, a multi-species tuber crop of the family Dioscoreaceae, is considered one of the most important staple food crops to about 400 million people in West Africa and provides a valuable source of dietary carbohydrate and income to growers (Bhattacharjee et al. 2011; Nweke 2016). World production is estimated at 73 million tons, with West Africa producing more than 93% of the crop (FAOSTAT 2019). Nigeria, Ghana, and Ivory Coast together produce about 86% of the world's yam supply.

The crop is typically propagated vegetatively using tubers through methods that are described as being notoriously slow and prone to diseases because of recycling of diseased planting material. Although recent developments in the search for rapid means of propagating yam have led to the use and promotion of vine cuttings as an alternative source of planting material

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(Maroya et al. 2014; Balogun et al. 2017), the use of tubers continues to be the only means of propagation for millions of small-scale farmers. It is rare to find farmers who intentionally plant crops to produce only seed yam. Farmers' usual practice is to set aside small-sized tubers of 250 g to 1000 g from the food-yam crop as seed for the next crop, and as much as 30% of the harvest is reserved for planting next year's crop on a farm of similar size to that of the previous year. Thus, seed yams are not only scarce because they compete with food, but are also expensive (Ironkwe 2005), accounting sometimes for as much as 63% of the total variable cost of yam production (Ogbonna, Anyaegbunam, and Asumugha 2011).

Yam farmers prefer small-sized whole tubers as planting material, which are primarily selected at harvest (Aighewi 1998). Whether the yam crop is harvested only once at the end of the season or twice ("milking" or double harvesting), the size of tubers determines whether they will be used as seed or food. In "milking", a yam plant is harvested twice. At 6–7 months after plant emergence, the soil around the plant is carefully removed to avoid destroying the root system, and the tuber is detached from the corm to obtain food yam. The soil is replaced to cover the roots for the plant to continue its growth. At total crop senescence (2–3 months later), a second harvest of the same plant is done, and those tubers are used for seed. With the culture of recycling seed tubers across extended periods, there is a steady yield reduction across planting cycles because of biotic (e.g. disease) and abiotic stresses (e.g. environmental factors). The lack of awareness among farmers of the impact of these stresses, such as viruses and the difficulty in identifying affected tubers, implies that many tubers with poor quality could be selected as seed.

When seed-sized whole tubers are in short supply, ware size tubers weighing as much as 1.5 kg are cut into 250–500 g setts for planting, thus reducing food supply. With this practice, yam planting material is often a combination of cut tubers and whole tubers, and the cut portions are made up of setts from the head, middle and tail sections of the tuber. This has consequences for crop establishment, as was observed by Orkwor (1998), who noted that when yam tubers are cut and planted, setts from the head portion sprout and emerge earliest, followed by those from the tail portion and lastly setts from the middle, which emerge several weeks after those from the head portion. The difference in time to emergence may be attributable to the differential age of tuber tissues, where the head portion is oldest and contains the shoot primordium that is apically dominant; the tail has the youngest tissues that regenerate easily. Another possible problem with cutting tubers for use as planting material is the potential of spreading diseases. When one diseased tuber is cut, the number of infected plants in the field increases as per the number of setts cut from it, in addition to the possibility of infecting healthy seed through the use of unsterilized cutting implements.

Based on the traditional practice of cutting tubers into large chunks of up to 500 g to plant the ware crop, the yam minisett (tuber pieces of 25 to 50 g) technique (YMT) was developed to rapidly multiply yams (Aighewi et al. 2015). This technique has generally had low rates of adoption after more than 30 years of its development and promotion (IITA 1985; Morse 2018). One of the reasons given for farmers' low level of adoption was the small size of seed yams produced. The YMT was later refined by allowing for more flexibility in the size of minisetts of up to 100 g, depending on the seed yam size required (Morse 2018). This modification led to the development of the adaptive yam minisett technique (AYMT). Even though the yam farmers' first choice of planting material is the whole tuber, the practice of cutting mother seed tubers into pieces is widespread; the consequences of which are unknown.

The objective of the current study was to evaluate the relative performance of whole tubers and minisetts of different sizes for seed yam production. The results should guide seed-yam producers regarding the type of planting materials to use for yam production. In this paper, the term "whole seed" refers to the small tuber that is planted without cutting, whereas "minisett" is the piece that is cut from a whole tuber for use as planting material.

Materials and methods

The experiment was conducted during the 2015 and 2016 cropping seasons on the experimental fields of the International Institute of Tropical Agriculture (IITA), Abuja station (latitude 09° 09.976′, longitude 007° 20.606′; 424 m above sea level), in the yam-producing region of Nigeria (Figure 1). In 2015, rainfall occurred between February and November, with a total of 945.7 mm, and in 2016, it occurred between March and October, with a total of 1552.2 mm (Figure 2). Both crops were planted when rainfall was well established. In 2015 and 2016, the average minimum air temperatures were 21.0 and 21.1°C, respectively, and the average maximum air temperatures were 32.4 and 33.3°C, respectively.

In 2015, the experimental field had gone through a yearly rotation of yam-*Aeschynomene histrix*-Mucuna spp., whereas the experimental field in 2016 had a crop of maize (*Zea mays* L.) during the previous cropping season, after a fallow of about 20 years. Soil samples from both the fields were collected and analyzed.

Tubers of a popular commercial landrace called "Meccakusa", whose dormancy had been broken and which had visible shoot buds, were used for the study. Whole tubers were sorted into three categories by size: 30–59 g, 60–89 g, and 90–119 g, which are, for simplification, hereafter, referred to as 45, 75, and 105 g, respectively. Whole mother tubers weighing between 500–1000 g were cut into minisetts to give 30–59 g, 60–89 g, and 90–119 g, with each piece containing a portion of the periderm (skin). The whole

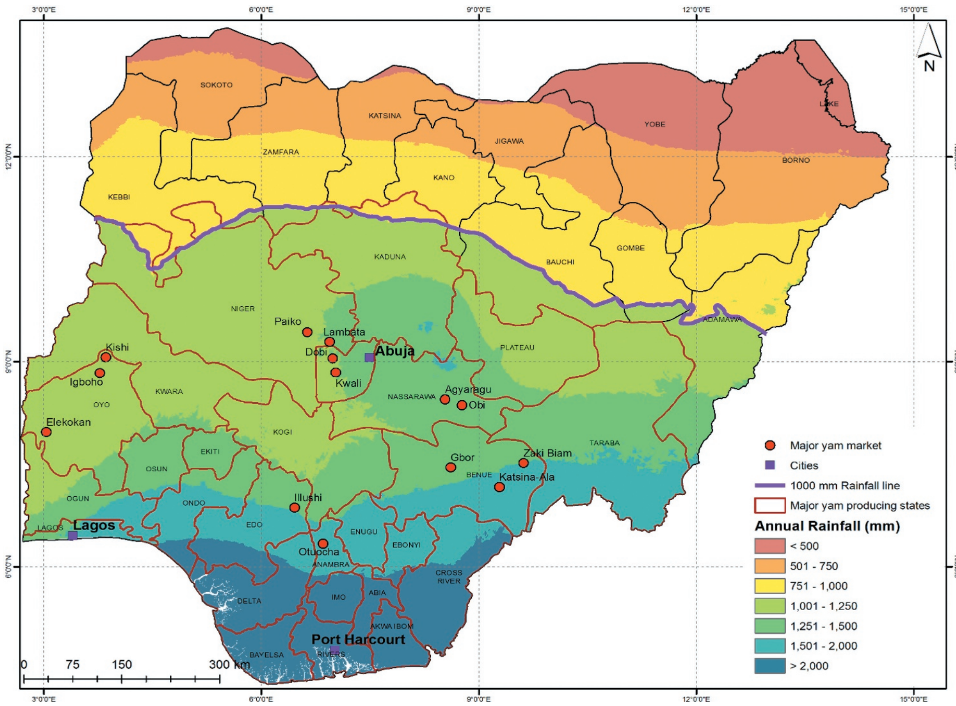

Figure 1. Yam-producing region of Nigeria.

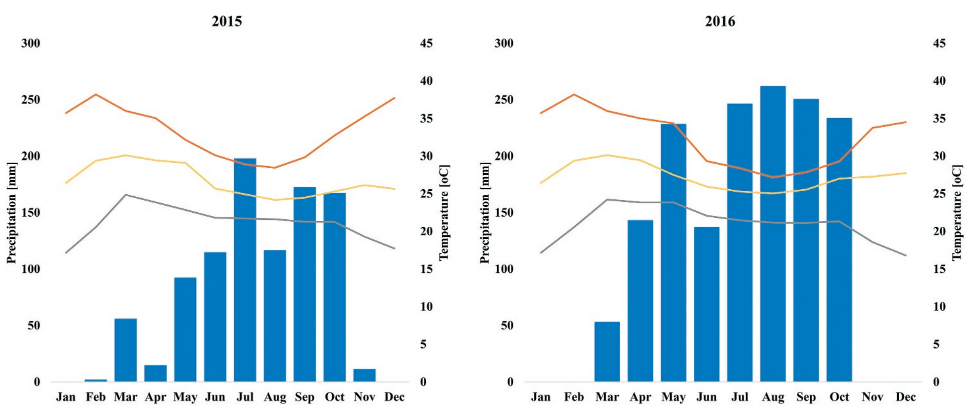

Figure 2. Monthly rainfall and temperature during the cropping seasons of 2015 and 2016 in Abuja, Nigeria.

tubers and minisetts were treated with a chemical mix containing 100 g of Mancozeb and 40 ml of Cypermethrin in 10 L of water for 10 min to protect against rots and damage by soil pests. They were air-dried under shade for about 24 h before planting.

The experimental fields were disc-harrowed and made into 9-m long ridges, spaced 100 cm apart. Seeds were planted to a depth of about 7 cm in single rows on top of the ridges at a spacing of 30 cm on 5 June 2015 and

6 May 2016. The experiment was laid out as a 2 × 3 factorial; a randomized complete block design with three replications and six treatment combinations was used. The experimental fields were kept free of weeds by applying herbicides [Premextra (290 g/L S-Metolachlor, 370 g/L Atrazine) at 5 L/ha and Gramoxone (200 g/L Paraquat) also at 5 L/ha] two weeks after planting (WAP). After that, a handheld hoe was used to remove weeds, earth-up the plants, and reform the ridges. Plants were staked at 6 WAP using the trellis system, where ropes were tied between two strong bamboo poles placed at the beginning and end of each ridge. No fertilizer was applied. The data collected 8 WAP included stem length (m), and the number of leaves and vines. The number of emerged plants was recorded weekly, whereas the leaf area index (LAI) was measured three months after planting (MAP) using the CI-110 digital plant canopy imager (CID Bio-Science Inc., Camas, WA, USA). At the end of the season, when vine senescence was complete, tubers were harvested on 22 December 2015 and 13 December 2016, and sorted into four weight categories, namely, >1000 g, 500 to <1000 g, 200 to <500 g and <200 g. In each category, the number of tubers was recorded, and tubers were weighed, treated, and stored. The tubers produced in 2015 were used to plant the 2016 crop. Analysis of variance was performed on the data using the Statistical Analysis System (SAS) (SAS Institute Inc. 2016). Means were separated using the least significant difference (LSD) at $p \leq 0.05$.

Results

Although the amount of rain was more in 2016, it was distributed across an extended period in 2015. The abrupt end of the rains in 2016 caused a rapid loss of foliage; the foliage was still full and lush in October, without the gradual process of senescence. Analysis indicated that the soil in the 2015 experimental field was loamy sand and had a pH(H_2O) of 4.8, soil organic carbon of 0.56%, total N of 0.04%, Mehlich P of 5.97 mg kg^{-1}, exchangeable K of 0.23 cmol kg^{-1}, and cation exchange capacity (CEC) of 1.92 cmol kg^{-1}. In 2016, the field had a sandy loam soil with pH($H_2 0$) of 6.0, soil organic carbon of 0.90%, total N of 0.08%, Mehlich P of 3.10 mg kg^{-1}, exchangeable K of 0.09 cmol kg^{-1} and CEC of 3.26 cmol kg^{-1}. This showed higher availability of organic carbon and nitrogen in the experimental field used in 2016.

Effects of the size and type of planting material on crop emergence

The rate of emergence of plants from the minisetts and whole seed tubers of different sizes is presented in Figure 3. Sprouts from the whole seed emerged from the soil and reached their peak faster than those from the minisetts, and they had a higher final percentage of crop establishment. The sprouts from

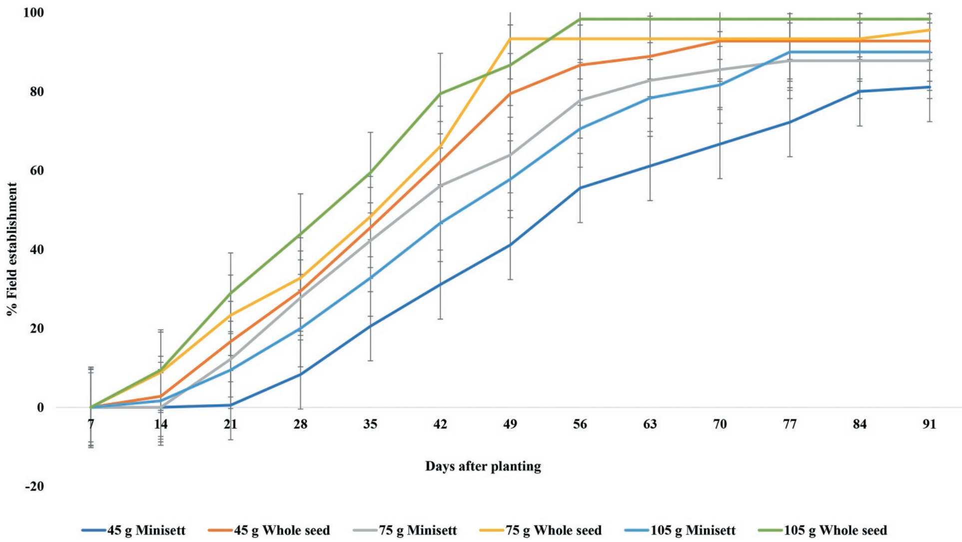

Figure 3. Field emergence of whole seed and minisetts of different sizes of yam, *Dioscorea rotundata.*

the whole seeds of 75 g and 105 g started emerging from the soil less than 10 days after planting (DAP), reached 50% emergence at 37 and 35 days, respectively, and peaked at 49 (93%) and 56 days (98%), respectively. Minisetts of the same sizes had their peak emergence at 77 DAP (88% for 75 g and 90% for 105 g). The slowest sprout emergence was observed from minisetts of 45 g, which started after 21 DAP, reached 50% at 54 DAP, and a maximum of 81% 84 DAP. The whole seed of 45 g had its highest emergence of 93% about 70 DAP. The earliest significant differences between the treatments were observed 14 DAP, whereas the average time to 50% emergence for the entire crop was 42 DAP. The size and sett type were significantly different for the number of days to 50% emergence and the final percentage of crop establishment, but no differences were seen when the two cropping seasons, and all the four types of interactions, namely, size × sett type, size × year, sett type × year, and size × sett type × year, were considered (Table 1). The wide variation observed in the time to emergence was apparent in the disparity in the size of foliage of the plants that emerged from minisetts, especially during the first 12 weeks of growth (Figure 4).

The effect of whole seed and minisett on the yield and yield-related parameters

The type and size of planting material used significantly ($p \leq 0.05$) influenced the fresh tuber yield and its related parameters, such as length and number of vine, number of leaves, leaf area index (only for seed type), sett multiplication ratio (SMR), and number of tubers per plant, as detailed in

Table 1. Analysis of variance [sum of squares (S.S.) and mean squares (M.S.)] for the yield and yield-related traits of seed yam produced from different sizes of whole seed tubers and minisetts in Abuja, Nigeria during the 2015 and 2016 cropping seasons.

	Source of variation→	Size	Sett type	Year	Size × Sett type	Size × Year	Sett type × Year	Size × Sett type × Year	Error
	D.F.†	2.00	1.00	1.00	2.00	2.00	1.00	2.00	22.00
Days to 50% emergence	**S.S.**	347.39	950.69	6.25	185.06	4.50	2.25	50.17	817.61
	M.S.	173.69	950.69	6.25	92.53	2.25	2.25	25.08	37.16
	Pr > F	0.020	<.001	0.686	0.106	0.941	0.808	0.519	
Establishment at 12 WAP ‡ (%)	**S.S.**	265.6	1033.94	6.48	43.81	11.89	19.14	29.90	415.81
	M.S.	132.8	1033.94	6.48	21.91	5.95	19.14	14.95	18.9
	Pr > F	0.004	<.001	0.564	0.332	0.733	0.325	0.466	
Vine length (m)	**S.S.**	2.56	1.79	0.68	0.011	0.06	0.01	0.10	1.56
	M.S.	1.28	1.79	0.68	0.01	0.03	0.01	0.05	0.07
	Pr > F	<.001	<.001	0.005	0.929	0.659	0.679	0.500	
Number of vines	**S.S.**	130.18	169	96.69	17.38	5.60	3.36	10.18	95.24
	M.S.	65.09	169	96.69	8.69	2.80	3.36	5.09	4.33
	Pr > F	<.001	<.001	<.001	0.158	0.534	0.388	0.327	
Number of leaves	**S.S.**	8951	8070	7832.2	33.9	109.0	113.8	527.5	6085.5
	M.S.	4475.5	8070	7832.2	17.0	54.5	113.8	263.8	276.6
	Pr > F	<.001	<.001	<.001	0.941	0.823	0.528	0.401	
Leaf area index	**S.S.**	7.267	29.75	31.39	2.13	5.05	31.73	8.88	38.04
	M.S.	3.633	29.75	31.39	1.06	2.53	31.73	4.44	1.73
	Pr > F	0.146	<.001	<.001	0.550	0.254	<.001	0.009	
Sett multiplication ratio	**S.S.**	672.39	157.38	446.83	14.66	145.29	9.11	3.73	95.21
	M.S.	336.20	157.38	446.83	7.33	72.64	9.11	1.86	4.33
	Pr > F	<.001	<.001	<.001	0.207	<.001	0.161	0.656	
Fresh tuber yield (t/ha)	**S.S.**	342.20	486.35	1600	7.38	11.19	0.34	5.35	155.33
	M.S.	171.10	486.35	1600	3.69	5.60	0.34	2.67	7.06
	Pr > F	<.001	<.001	<.001	0.600	0.465	0.828	0.689	
Mean weight (kg)	**S.S.**	0.39	0.431	1.00	0.01	0.016	0.02	0.003	0.26
	M.S.	0.19	0.431	1.00	0.004	0.01	0.02	0.002	0.01
	Pr > F	<.001	<.001	<.001	0.698	0.532	0.237	0.873	
Number of tubers plant^{-1}	**S.S.**	0.19	1.39	0.14	0.02	0.002	0.03	0.02	0.48
	M.S.	0.10	1.39	0.14	0.01	0.001	0.03	0.01	0.02
	Pr > F	0.024	<.001	0.018	0.542	0.957	0.254	0.673	

†D.F. = degrees of freedom.
‡WAP = Weeks after planting.

Figure 4. Disparity in growth attributable to the long duration of plant emergence in a plot planted with 45 g yam minisetts. Plant “y” has five small leaves, whereas plant “x” has more than 50 large leaves.

Tables 1 and 2. The use of whole seed as planting material increased the LAI by more than 100% compared with minisetts. Fewer plants were lost when whole seed tubers were planted, and the mean length of vines (2.2 m) was significantly more than that of plants grown from minisetts (1.8 m). The same trend was observed for the number of vines and leaves, as well as for the SMR (Table 2). Fresh seed tuber yield was 48% higher for the whole seed (22.5 t/ha) compared with that from minisetts (15.2 t/ha).

An analysis of the vine number and length, and number of leaves showed significant differences ($p \leq 0.05$) between the different sizes of planting

Table 2. The performance of whole seed tubers and minisetts of different sizes on seed yam yield and yield-related traits in Abuja, Nigeria during the 2015 and 2016 cropping seasons.

	Factor	Days to 50% emergence	Establishment at 12 WAP† (%)	Length of vine (m)	Number of vines	Number of leaves	Leaf Area Index	Sett Multiplication Ratio	Fresh tuber yield (t/ha)	Mean weight (kg)	Number of tubers plant^{-1}
Minisett Size (g)	**45**	46.3b	88.0a	1.65a	5.0a	52.9a	2.3a	19.7 c	14.8a	0.6a	1.3a
	75	39.3a	91.4ab	2.0b	8.3b	76.9b	2.2a	12.6b	19.4b	0.8b	1.4ab
	105	40.2a	94.7b	2.3 c	9.5b	91.1 c	3.2a	9.4a	22.3 c	0.9 c	1.5b
	LSD	5.16	3.68	0.23	1.76	14.08	1.11	1.76	2.25	0.09	0.13
Sett type	**Cut**	47.1b	86.0a	1.77a	5.4a	58.6a	1.7a	11.8a	15.2a	0.6a	1.2a
	Whole	36.8a	96.7b	2.2b	9.7b	88.6b	3.5b	16.0b	22.5b	0.8b	1.6b
	LSD	4.21	3.01	0.18	1.44	11.50	0.91	1.44	1.84	0.08	0.10
Season	**2015**	42.4a	91.8a	1.9a	5.9a	58.9a	1.6a	10.4a	12.2a	0.6a	1.4a
	2016	41.6a	90.9a	2.1b	9.2b	88.4b	3.5b	17.4b	25.5b	0.9b	1.5b
	LSD	4.21	3.01	0.18	1.44	11.5	0.91	1.44	1.84	0.08	0.1

Means with the same alphabet along rows are not significantly different at $p = \leq 0.05$. †WAP = Weeks after planting.

materials. Between the sett types, there were highly significant differences ($p \leq 0.01$) for the number and the length of vine, number of leaves, and LAI. Also, between the two years, there were significant differences ($p \leq 0.05$) for the four variables. They were all highest for the 105 g, followed by the 75 g and 45 g. Fresh tuber yield was also highest when 105 g planting material was used (22.3 t/ha), being about 51% and 15% more than those from the 45 g and 75 g seed, respectively. For the 45 g planting materials, only the SMR was better than that for the other sizes (Table 2).

Interactions between the type and size of planting material

There was no significant interaction between the size and type of planting materials for tuber yield and all its related variables. The percentage of plants that had emerged by 12 WAP was highest for 105 g whole seed (98.5%) although this was not significantly different from that for 75 g whole seed (96.2%); emergence from the 45 g whole seed was better than those of 75 g and 105 g minisetts. The mean values of the parameters measured for whole seed within a size range were always significantly higher than those for the minisetts (Table 3). The highest fresh tuber yield was thus obtained from the 105 g whole seed (34.4 t/ha) in 2016, whereas the least was from the 45 g minisetts (5.4 t/ha) in 2015, although the latter was not significantly different from that of 75 g minisetts in the same season. Whether using whole seeds or minisetts, the performance was better with an increase in weight of the planting material. This trend was similar to that for the mean weight of seed tubers produced. The mean yield of 105 g minisetts (18.3 t/ha) was found to be statistically identical to that of 45 g whole seed (17.9 t/ha). The bigger the planting material, the smaller its SMR, and the whole seed had larger values than minisetts of similar weight. Hence, 45 g whole seed tubers had the highest SMR (22.7), whereas the 105 g minisetts had the least (8.0) (Table 3). The trend of the mean size of the tuber produced was opposite to that of the SMR, increasing with an increase in the size of the planting material.

The distribution of different weight categories of seed tubers at harvest

The whole seeds produced the highest proportion of seed tubers that could also be classified as ware tubers (>1000 g) and the least in the seed category that were less than 200 g. Minisetts produced more tubers that are typically preferred by farmers for ware yam production (300–1000 g) than did whole seed tubers (Figure 5). The proportion of tubers, in the range of seed yam that can be planted without cutting (200–500 g) to produce ware yam, was highest for minisetts of 45 g (31.7%) and least for 105 g whole tubers (13.3%). The tubers that can be cut into two setts (500–1000 g) to produce an average

Table 3. Interactions between whole seed, minisetts and size on the yield and yield-related traits of seed yam in Abuja, Nigeria during the 2015 and 2016 cropping seasons.

Sett size	Sett type	Season	Days to 50% emergence	Establishment at 12 WAP† (%)	Main vine length (m)	Number of vines	Number of leaves	Leaf Area Index	Sett Multiplication Ratio	Fresh tuber yield (t/ha)	Mean weight (kg)	Number of tubers plant^{-1}
45 g	**Cut**	**2015**	53.3de	82.1a	1.3a	2.2a	27.5a	1.5a	9.6bc	5.4a	0.3a	1.1a
		2016	54.7e	81.1a	1.6ab	5.3abc	51.0abc	1.8ab	24.0 g	18.2 c	0.7 cd	1.2ab
	Whole	**2015**	40.7abc	96.2de	1.8bc	4.0ab	51.0abc	1.8ab	17.2 f	11.5b	0.5b	1.4bc
		2016	36.7abc	92.8 cde	1.9bcd	8.3 cde	82.0de	4.0bc	28.1 h	24.3d	0.9ef	1.6 cd
75 g	**Cut**	**2015**	43.7abcd	83.3ab	1.6ab	3.3a	40.8ab	1.3a	7.8ab	8.9ab	0.5b	1.2ab
		2016	39.3abc	87.8abc	2.0bcd	7.5bcd	81.2de	1.4a	13.5de	21.9 cd	0.8de	1.3ab
	Whole	**2015**	36.3abc	98.7e	2.2 cd	11.0def	78.5 cd	1.6a	12.8cd	17.5 c	0.8de	1.6 cd
		2016	38.0abc	95.6de	2.3d	11.2ef	107.0ef	4.5 c	16.4ef	29.1e	1.0fg	1.7d
105 g	**Cut**	**2015**	46.3cde	91.7cde	1.9bcd	4.8abc	68.7bcd	2.1ab	6.0a	11.4b	0.6bc	1.2ab
		2016	45.3bcde	90.0bcd	2.2 cd	9.2de	82.7de	1.8ab	10.0bcd	25.1de	0.9ef	1.3ab
	Whole	**2015**	34.0a	98.7e	2.3d	10.2def	86.7de	1.3a	8.9ab	18.3c	0.8de	1.7d
		2016	35.3ab	98.3e	2.8e	13.7 f	126.3 f	7.5d	12.5 cd	34.4 f	1.1 g	1.8d
		LSD	10.32	7.36	0.45	3.52	28.16	2.23	3.52	4.50	0.19	0.25

Means with the same alphabet along rows are not significantly different at p = ≤0.05; †WAP = Weeks after planting.

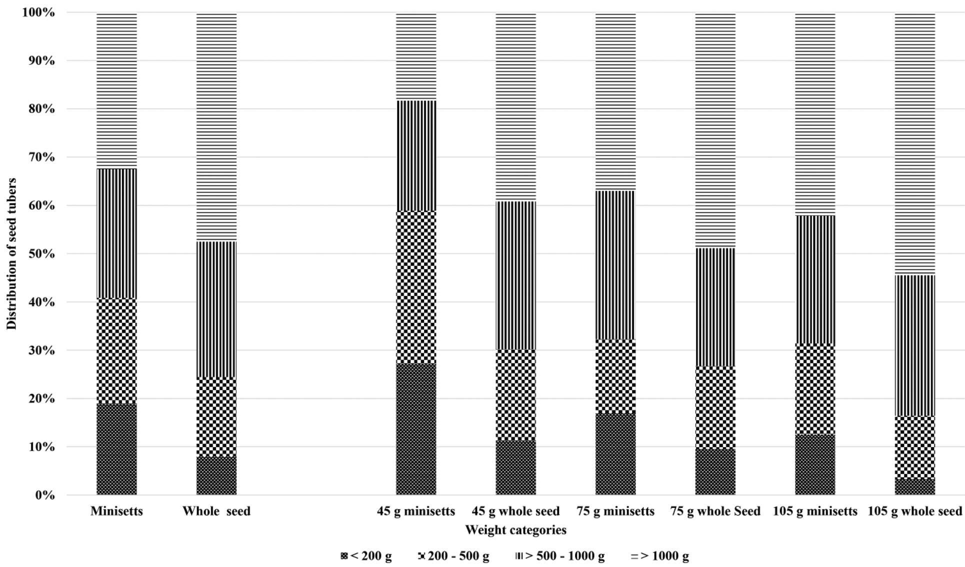

Figure 5. Percentage of seed tubers of different categories produced from whole seed tubers or minisetts of various sizes.

ware size tuber or planted whole for extra-large ware yam tubers ranged from 23% for the 45 g minisetts to 29% for 105 g whole seed. Although the intention was to produce seed size tubers, a reasonable proportion of ware size tubers (>1000 g) was also produced, with whole seed tubers of 105 g having up to 55% in this category; in contrast, the 45 g cut setts had only 18%. The large proportion of tubers of more than 1000 g substantially raised the average size of tubers from the whole seeds.

Discussion

Although yam is classified as a tuber, it does not have the characteristics of a modified stem, such as the visible pre-formed buds ("eyes"), scale leaves, or nodes found on the surface of typical tubers (Craufurd et al. 2001). At the end of its period of dormancy, the whole yam tuber usually produces buds from the proximal end or head region of the tuber. Some varieties are more likely to produce only one bud, whereas others can produce several buds. Where there is a unitary bud or sprout, if it is destroyed, multiple sprouts will emerge, also mostly around the head region (Aighewi 1998). However, all parts of the tuber can produce buds (provided there is a healthy periderm) because after cutting, cellular reorganization occurs to produce a bud at points on the periderm. This principle underlies the widespread practice of cutting yam tubers for use as planting material.

The process of sprouting in yam tubers has been described by Onwueme (1973) and Craufurd et al. (2001) It takes between 7 and 15 days from cell division to the emergence of a bud. However, this process was described for whole tubers in storage, signifying that when tubers are cut, bud formation will take longer. The physiological changes during wound healing involve suberization and periderm formation across a period of about three days (Passam, Read, and Rickard 1976). So, when seed tubers are cut before planting, the process of wound healing will take place before cell differentiation occurs at a locus on the tuber where a bud will eventually emerge. 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. This explains the extended period of sprout emergence and crop establishment seen in this study, which is typical of yam fields. Yam farmers usually do not sort cut-portions according to the source of the sett, whether form the head, middle or tail portions of the tuber, although it has been established that setts from the middle part could take several weeks to sprout after those of the head and tail portions (Orkwor 1998) because of the differential age of tissues by tuber section, and the apical dominance exhibited by the head of the tuber.

In our study, the plants that emerged late had less foliage, which produced less photosynthate for a shorter period than plants that emerged early, thus producing lower yields. The extended period of crop establishment resulted in differences in individual plant growth periods, hence the wide variability of tuber size at harvest. This agrees with the findings of Cornet et al. (2014), who reported a high coefficient of variation of 42–71% for tuber yield and concluded that it was attributable to the uneven emergence that took place across a long period of 51 and 47 days for *D. alata* and *D. rotundata*, respectively. Although Cornet et al. (2014) did not describe the type of planting material used in their study, in traditional yam-cropping systems, the planting materials per farm are typically a mixture of whole and cut setts of different sizes. Apart from the extended period of crop establishment when minisetts are planted, it has been established that the sites of cuts and abrasion on yam tubers provide points of entry for pathogens (Passam, Read, and Rickard 1976; Coyne, Claudius-Cole, and Kikuno 2010), and without adequate treatment, as is the case in traditional systems of cultivation, there is a resultant poor crop establishment on account of tuber rots.

In West Africa, yam is mostly cultivated as a rainfed crop. In Abuja, for example, within about three weeks after the last rainfall in a cropping season, the entire yam crop senesces, irrespective of the age of the plants. The dependence on rainfall and the uncertainty of its duration, for a long-duration crop like yam, create much anxiety for yam farmers, as they wait to harvest the crop after the rains. From our study, it was evident that using whole tubers produced a crop that established faster, was more uniform, made more efficient use of the cropping season, and resulted in better yields than when minisetts were used. This explains why whole seed size tubers that are sorted by farmers from the harvest of a food crop for use as seed are rarely sold in markets. Farmers place a high premium on this type of seed-yam tubers and would instead use them on their farms. However, since this type of seed rarely meets the entire requirement of farmers, some larger tubers are cut to make up for any shortfall.

The vine length (plant height) has been shown to influence fresh tuber yield, and the positive correlation observed between tuber weight, and agronomic traits was expected because the longer the vine, the more the branches and leaves (Sartie et al. 2012) that contribute to the weight of the tuber harvested. This study showed that the type of planting material, cut or whole, also had a significant influence on the vegetative growth and tuber yield. Although the minisetts produced more tubers in the category that farmers prefer for planting with minimal or no cutting (200–1000 g), they also had a high proportion of tubers (27.2%) that were too small; the size that farmers would either discard or plant for further increase in size before they are used to produce food tubers.

One advantage of using larger planting material is that it is more likely to produce more sprouts, and if the main sprout is damaged, an alternative one will take over (Onwueme 1973). Also, the bigger setts have a better establishment, with more vigorous plants that have longer vines and more leaves. This is attributable to earlier sprouting, and faster development of roots and vines in the earliest phase of crop growth (O'Sullivan 2010). It has been reported that a larger sett size results in a larger leaf area at the end of the sett-dependent phase of growth, which is about one-tenth of the final leaf area achievable (Chowdhury 1998; Melteras et al. 2008). However, Enyi (1972) showed that the large setts had an advantage at the end of the sett-dependent growth phase because the relative growth rate of plants from all sett sizes was subsequently similar. The 105 g planting materials demonstrated a faster increase in LAI, which contributed to the higher yield of tubers.

Previous studies on the effect of sett size on yam yield have observed a positive correlation between the sizes of the setts planted and the tubers harvested (Aighewi 1998; Emokaro and Law-Ogbomo 2008). However, the increase in minisett size was not proportional to the increase in tuber yield, as was also observed by Lyonga et al. (1973), who noted that doubling the sett size from 125 g to 250 g only increased tuber yield by 20–30%. Consequently, the SMR is higher for smaller setts, since the additional yield from larger setts is usually greater than the additional weight of the planting material. In another study, Iseki and Matsumoto (2019) found that tuber yield from 200 g setts was higher than that of 50 g setts. Still, the yield advantage was not sufficient to compensate for the additional cost of the larger setts. However, in the quest to produce more yam, farmers plant big-size seed without regard to whether it is cut or whole. This reduces the number of tubers available for food, but the seed rate of yam can be reduced by using smaller-size whole tubers.

The yield differences observed between the two crops can partly be explained by the difference in the cropping history of the experimental fields. The soil, which had been fallow for a long time, with only one crop planted after the fallow and used in the 2016 experiment, had more nutrients, especially nitrogen that was needed by the crop for early development of the foliage. This was later translated into a better yield of tubers than in 2015 when the field had only an improved fallow for two years before the experiment. Because of limited access and use of soil-enhancing treatments, most yam farmers prefer to use lands that have been under fallow for extended periods for yam cultivation.

Conclusion

In traditional yam production, the planting material is usually a mixture of cut and whole tubers, with resultant crops that are made up of plants of different ages even when planted on the same date. This study revealed that small whole-seed tubers were better than cut setts. Since the yield of 45 g whole seed tuber was not significantly different from that of the 105 g minisetts, much savings will result by using smaller-size whole seed. Other advantages of using whole seed include faster and more even crop establishment, especially where there is a threat of early cessation of rainfall, better management of crop for uniformity of yield with more usable tubers at harvest, and reduction in the spread of diseases, especially those caused by viruses. Further investigations are necessary to develop agronomic packages that would encourage seed-yam entrepreneurs to produce whole seed tubers of appropriate sizes.

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