

Article

Effects of Variety and Sett Weights on Sprout Emergence and Seed Tuber Yield in *Dioscorea alata* L. and *Dioscorea rotundata* Poir.

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Abstract: Yam is a staple crop in Africa that is constrained by its low multiplication rate. This results in a short supply of seed tubers, which is a challenge to increased production. This study assessed the influence of different minisett weights (10, 20, 30, 40, and 50 g) on tuber production and seed categorization in twelve *Dioscorea rotundata* and four *Dioscorea alata* varieties over two planting seasons in a Randomized Complete Block Design ($r = 3$). The yield parameters were collected and analyzed using ANOVA. The effects of varieties, the minisett weight (SW), and the variety $\times$ SW interaction were significant for the proportion of setts that produced seed tubers and ranged from $40.2 \pm 5.0\%$ (50 g) to $56.4 \pm 5.0\%$ (10 g) in 2013, from $46.4 \pm 0.8\%$ (40 g) to $60.5 \pm 0.8\%$ (30 g) in 2014, from 23% (TDa00/00194, 30 g) to 93.7% (Ojuyawo, 10 g) in 2013, and from 39.7% (TDa00/00194, 30 g) to 100% (TDr89/02665, 20 g) in 2014. The 10 g and 30 g produced more seed yam in 2013 and 2014, respectively, while 50 g produced more ware yam sizes (>300 g) and is thus recommended to farmers for intended yam production category. *D. rotundata* varieties produced a higher proportion of seed yam, while *D. alata* varieties produced are a higher proportion of yams above seed class.

Keywords: seed yam tuber; minisett technique; improved varieties; landraces; minisett weights



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1. Introduction

Yam is an essential source of carbohydrates, vitamins, essential minerals, and fiber, sustaining the livelihood of an estimated 50 million people [1,2]. It enhances food security and alleviates hunger [3]. The yam value chain provides income-earning opportunities for producers, processors, and sellers [2]. However, yam production is declining substantially due to seed scarcity and the attendant high costs, among other factors [4,5].

The high cost of seed yam tubers (SYTs) has reduced yam production by 40%, accounting for as much as 63% of the total variable cost of yam production [6,7]. Seed yam tubers sorted from the previous harvest, seeds from the second harvest, and setts generated from table-size tubers (ware yam; tubers weighing above 500 g) have been used to obtain planting materials for yam propagation among farmers. Moreover, farmers specializing in SYT production are rare [8]. Hence, farmers' continuous crop production is sustained by setting aside up to 33% of the total harvest as planting materials [9,10]. Farmers often set aside SYT weighing 250 g to 1000 g from the previous harvest and use the same seed in the next cropping season [8]. Tubers of this category typically emerge as an addition to the

main tuber, with multiple but smaller tubers and diseased plants. The positive selection technique that ensures SYT is sourced from clean and healthy plants is not widely known among farmers, though highly recommended for profitable yam production [11]. Tubers from diseased plants are unsuitable as they further reduce field plant establishment and fresh tuber yield. The food competition (e.g., the processing of small tubers into flakes for yam flour) also affects SYT availability [12].

Farmers often cut ware tubers into setts to meet their seed needs. The sett multiplication ratio is low for yam (<1:10) compared with other root tuber crops [13]. In cassava and sweet potato, food organs are not used as propagules. However, the demand for yam tubers both as planting materials and as a food source is critical. However, there are indications that yam has excellent prospects for alleviating Africa's projected food deficit in the 21st century if efforts are made to identify and overcome its SYT constraints. Therefore, there is a need to improve methods that will increase the amount of SYT produced yearly, ensuring availability and affordability.

To address this challenge, the yam minisett technique (YMT) was developed by the International Institute of Tropical Agriculture (IITA) and the National Root Crops Research Institute (NRCRI), Umudike, Nigeria [10,14]. The primary aim of the technique is to increase the quantity and quality of seed tubers available to farmers. This development was based on the principle that any tuber section cut into small pieces/minisetts can develop buds and sprout, provided it has a portion of the periderm [10]. Aside from YMT, other techniques have been deployed for SYT production; these include the aeroponics system, in vitro propagation, Temporary Immersion Bioreactor System, Semi-Autotrophic Hydroponics, and vine-cutting techniques, among others. Among these techniques, YMT is most applicable at the farmers' level.

Despite the potential of minisett technology in addressing the seed yam constraint, only 46.6% of farmers were aware of the technology in Nigeria, and only about 22.4% were using it [15]. The following probably accounts for their low adoption and use rates: the sprouting rate is low, partly because of inadequate rainfall, planting time, and required minisett weight (SW). Also, a poor understanding of the technique threatens its adoption, constituting a significant problem among 79% of the respondents nationwide [16]. Other issues reported by farmers included ignorance of technical details (39.7%), the labor-intensive nature of the technology (38.3%), adverse weather (34.4%), the lack of farm inputs (17.8%), and poor storage facilities (1.7%) [15]. Ayankanmi et al. [17] also reported failures in terms of poor sprouting and sensitivity to moisture stress in the soil as constraints. McNamara and Morse [18] recommended the Adapted Yam Minisett Technique (AYMT) using a minisett size as high as 80 g to address this problem of poor sprouting. However, Emokaro and Law-Ogbomo [19] had earlier reported that the cost of the mother seed tubers increases by 60% by doubling the sett weight. It became clear that minisett adoption and practice would be enhanced by understanding varietal responses and suitable sett weights instead of a blanket standard SW of 25–30 g for seed yam production. Even though the YMT has existed for about four decades and is well documented, information on varietal responses and variety by sett weight interaction is limited. This should provide the relative performances of the improved varieties, known chiefly to yam researchers, and the landraces often referred to as market-preferred varieties. This study provides information on the performance of these popular varieties across yam-growing regions in Nigeria and the improved elite varieties, thus establishing appropriate minisett weights for seed production with the likelihood of high economic returns. Therefore, information on varietal response to minisett and variety by SW interaction can potentially improve production and alleviate the deficit of seed yam. This study aimed to assess the influence of sett weights on plant emergence, establishment, and fresh tuber yield among yam varieties of two species.

This study thus hypothesized that if the sett weight of yam tubers for planting is small, then a higher number of seed yam tubers for planting purpose will be produced.

2. Materials and Methods

2.1. Study Location

This study was conducted at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria. IITA–Ibadan (7°26' N latitude and 3°54' E longitude) is 210 m above sea level with average annual rainfall, temperature range, and relative humidity range in 2013 (108.33 mm, 22.78–31.39 °C, and 51.5–94.01%) and 2014 (144.25 mm, 22.49–31.91 °C, and 52.75–92.50%) observed [20].

2.2. Preparation of Experimental Materials

Minisetts were generated from selected non-dormant yam tubers weighing between 100 and 400 g. These seed tubers were screened for nematodes and rot during selection to ensure quality. Five sett weights (10, 20, 30, 40, and 50 g) were used for 12 varieties of *Dioscorea rotundata* and four varieties of *Dioscorea alata* (Table 1). Two varieties listed in Table 1 had been used in preliminary miniset (multiplication) trials and were, therefore, chosen as controls (unpublished data). The weights of cut minisetts were determined using a sensitive weighing balance, ensuring a ratio of 1:1 to 1:2 for the cut surface to the periderm area. Generated minisetts were loosely bagged using a net bag to avoid bruising and then treated with Mancozeb 80% WP (Ethylene Bis-dithiocarbamate) applied at 200 g/L of water. Karate CS (lambda-cyhalothrin) was used at 20 mL/L for 10 min. Setts were air-dried in a cool, dry place for 24 h.

Table 1. Varieties of *Dioscorea rotundata* and *Dioscorea alata* yam species evaluated.

Varieties	Source	Status	Country of Release/Origin
<i>Dioscorea rotundata</i>			
TDr 95/18544	YIP–IITA	Improved line	Benin
TDr 89/02677	YIP–IITA	Improved line	Nigeria
TDr 95/19177	YIP–IITA	Improved line	Nigeria
TDr 89/02665	YIP–IITA	Improved line	Nigeria
TDr 89/02475	YIP–IITA	Improved line	Nigeria
Ojuyawo	YIP–IITA	Landrace	Nigeria
TDr 04–219 (Amula)	YIP–IITA	Landrace	Nigeria
Pona	YIP–IITA	Landrace	Ghana
Obiaturugo	Ilushi	Landrace	Nigeria
Alumaco	YIP–IITA	Landrace	Nigeria
Danacha	Ilushi	Landrace	Nigeria
Meccakusa	Ilushi	Landrace	Nigeria
<i>Dioscorea alata</i>			
TDa 00/00194	YIP–IITA	Improved line	Nigeria
TDa 93–36	YIP–IITA	Landrace	Nigeria
TDa 98/01176	YIP–IITA	Improved line	Nigeria
TDa 291	YIP–IITA	Landrace	Nigeria

Source: National Centre for Genetic Resources and Biotechnology (NACGRAB 2012); YIP: Yam Improvement Program; IITA: International Institute of Tropical Agriculture.

2.3. Field Establishment and Experimental Layout

The field was established in the first week of June when rainfall became steady. Steady rain or a well-moistened but not saturated soil condition is most suitable for the YMT. The experimental design used was a Randomized Complete Block Design (RCBD) in a split-plot arrangement with three replications. The main plot was assigned to “SW”, while “varieties” was the subplot. Plots of 10 m² were mapped in the field, and 20 minisetts were planted per plot, separated by 1 m alleys between blocks and 1 m spacing within plots. Intra-row

spacing of 0.25 m and inter-row spacings of 1 m each were utilized. Varieties of *D. rotundata* and *D. alata* used in this study were planted in separate plots to avoid excessive shading.

2.4. Agronomic Operations

Emerged yam vines were trellised on 2 mm diameter nylon ropes vertically attached to horizontal 10 mm diameter nylon ropes attached to the top of 2 m high bamboo poles. Each pair of the bamboo poles was placed at both ends of each plot. The 10 mm nylon rope was at the top ends to form a line. The 2 mm nylon ropes were loosely tied to each emergent vine just above the first node and then attached to the horizontal 10 mm rope, which is 2 m above ground level. Weeding on the field were carried out at intervals of 25–30 days, and these were supplemented with roguing during data collection to maintain a weed-free field. Commercial N:P:K 15:15:15 fertilizer 2 g per stand was applied at 2 and 4 months after planting to supplement the soil nutrient, and harvesting was completed 7 months after planting.

2.5. Data Collection

Plant emergence: Plant emergence at 2 months after planting (2 MAP) was recorded by counting the emergent sprouts in the whole plots per variety.

Yield estimate: Yield parameters (number of stands harvested, total weight of tubers harvested per plot, number of tubers, and categories of tubers) were collected and evaluated at harvest.

- i. **Number of stands harvested:** The total number of plant stands per variety with yam tubers at harvest.
- ii. **Tuber count at harvest:** Total number of tubers harvested per plant in a plot at harvest.
- iii. **Weight of tubers at harvest:** The measured weight of the tubers harvested per variety per plot at harvest (measured in g).

Weight of tubers per ha was obtained by converting the weight per plot to hectare.

Seed classification: The harvested tubers were sorted into three categories: seed (harvested tubers ranging from 100 g to 300 g in weight), less than seed (harvested tubers that are less than 100 g in weight), and greater than seed (harvested tubers that are bigger than 300 g in weight). All tubers harvested were sorted and counted according to the above classification, and the percentage per class was obtained by dividing the number obtained per class over the total number of tubers harvested and multiplying the result by 100.

2.6. Statistical Analysis

Data were analyzed using a two-way Analysis of Variance (ANOVA) and correlation (Statistical Analysis Software 9.4 version). Means generated in a mixed model were separated using least significant differences at 5% level of probability. Also, the relationship between the agronomic and yield parameters taken were determined using the Pearson correlation matrix (SAS Software 9.4 version).

3. Results

3.1. Plant Stand

In 2013, the results obtained on plants emergence (sprouts) at 2 MAP among the SW in the 2013 planting season showed that the highest percentage of plant emergence was recorded in the 40 g SW ($82.9 \pm 4.6\%$), which was only significantly higher than the 10 g SW ($64.5 \pm 4.5\%$) (Table 2). At harvest, the 40 g SW ($81.5 \pm 4.5\%$) had the highest percentage of plant stands, which was significantly higher than the 10 g and 20 g SW. However, in 2014, the percentage of plant emergence was highest in the 30 g SW ($62.8 \pm 4.0\%$), which was significantly higher than the 10 g SW but was statistically similar to the rest SW. At harvest,

the 50 g SW had the highest percentage stand ($73.6 \pm 5.1\%$), which was significantly higher than the 10 g sett weight and statistically similar to the rest SW. On the varietal performances in 2013, TDa 98/01176 ($98.0 \pm 5.4\%$) had the highest plant emergence at 2MAP, and it was significantly higher than Alumaco, Amula, Danacha, Ojuyawo, Meccakusa, Obiaturugo, Pona, and TDr 95/19177, respectively (Table 3). Also, the number of stands at harvest, TDa 98/01176, had the highest percentage ($99.0 \pm 4.7\%$), which was not significantly higher than TDa 291, Tda 00/00194, and TDr 89/02475, respectively. However, in 2014, TDa 98/01176 had the highest percentage of emerged plants at 2MAP ($95.3 \pm 4.7\%$), which was significantly higher than Pona, Obiaturugu, Meccakusa, Ojuyawo, Danacha, Amula, TDr 89/02475, and Alumaco, respectively. Also, the percentage of plant stands at harvest recorded in TDa 98/01176 ($91.7 \pm 5.8\%$) was significantly higher than Alumaco, Amula, Danacha, Obiaturugo, Pona, TDa 93–36 and TDr 89/02475, respectively.

Table 2. Effect of tuber set weight on percentages of emerged plants and plant stands of *Dioscorea rotundata* and *Dioscorea alata* yam species two months after planting evaluated in 2013 and 2014 planting seasons.

Sett Weight (g)	Plant Emergence (%)		Number of Stands Harvested (%)	
	2013	2014	2013	2014
10	64.5 b	50.5 b	57.0 c	53.7 b
20	71.4 ab	55.0 ab	65.2 bc	64.5 ab
30	78.5 a	62.8 a	75.3 ab	70.6 a
40	82.9 a	57.5 ab	81.5 a	66.0 ab
50	79.1 a	60.3 ab	80.0 a	73.6 a
LSD (0.05)	12.8	11.1	12.5	14.2
SE	4.6	4.0	4.5	5.1
GXSett weight	ns	***	ns	*

GXSett weight: Interaction between sett weight and the genotypes. SE: standard error, and LSD: least significant differences. ***: LSD is significant at 0.001 level of significance, *: Significant interaction between variety and sett weight. Means followed by the same letter are not significantly different from one another, ns: not significant.

Table 3. Percentages of emerged plants and plant stands of *Dioscorea rotundata* and *Dioscorea alata* yam species evaluated in 2013 and 2014 planting seasons.

Genotype	Plant Emergence (%)		Number of Stands Harvested (%)	
	2013	2014	2013	2014
Alumaco	68.3 c	58.0 d	75.0 bc	52.7 c
Amula	49.3 d	60.0 d	46.0 cd	49.0 c
Danacha	28.3 e	50.7 e	28.3 e	34.7 d
Ojuyawo	76.3 bc	80.7 b	70.7 bc	69.7 ab
Meccakusa	62.7 c	77.3 bc	56.3 c	69.0 ab
Obiaturugo	56.3 d	59.7 d	52.7 c	49.7 c
Pona	43.0 d	42.0 e	45.7 cd	42.0 cd
TDa 00/00194	94.3 a	94.0 a	91.0 ab	82.3 a
TDa 291	95.0 a	93.7 a	96.0 a	89.7 a
TDa 93–36	92.3 a	93.3 a	83.3 b	63.7 b
TDa 98/01176	98.0 a	95.3 a	99.0 a	91.7 a
TDr 89/02475	93.0 a	63.3 d	90.0 ab	52.3 c
TDr 89/02665	86.0 ab	85.7 ab	80.7 b	70.7 ab
TDr 89/02677	87.3 ab	85.3 ab	76.7 bc	69.7 ab
TDr 95/18544	94.0 a	91.3 a	82.7 b	80.0 a
TDr 95/19177	80.0 b	94.0 a	74.7 bc	84.33 a
LSD (0.05)	15.2	13.1	13.2	16.2
SE	5.4	4.7	4.7	5.8

SE: standard error, and LSD: least significant differences. Means followed by the same letter are not significantly different from one another.

The interaction between the genotypes evaluated and the SW was not significant in the 2013 planting season on the plant emergence and plant stand at harvest (Figure 1), while the interactive effect was significant on the number of emerged plants at 2MAP and the percentage of plant stands at harvest in 2014. In 2014, the interaction between genotypes and SW on the plant emergence ranged from 35.0% (Danacha, 40 g) to 100% (TDr 95/18544 and TDr 95/19177, 50 g), while the percentage of plant stands at harvest ranged from 23.3% (TDr 89/02475, 10 g) to 100% (TDa 291, 50 g) (Figure 2).

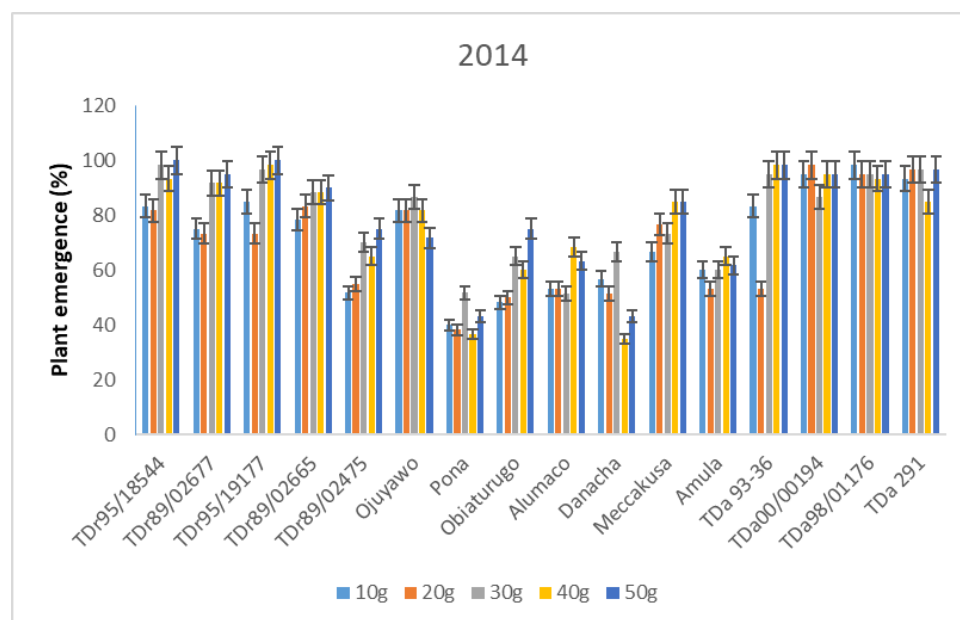


Figure 1. Genotype by sett weight interaction on plant emergence at 2 months after planting in 2014 planting season.

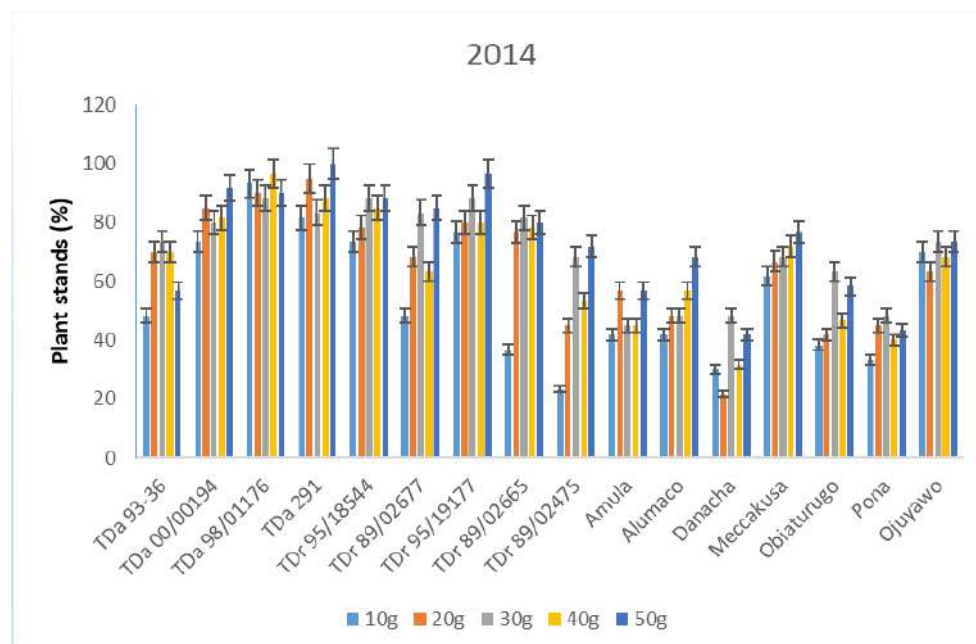


Figure 2. Genotype by SW interaction on plant stands at harvest in 2014 planting season.

3.2. Yield at Harvest

In the 2013 planting season, the number of tubers obtained at harvest was highest in the 40 g SW (19.7 ± 1.1), but it was not significantly higher than the 50 and 30 g SW

(Table 4). However, the yield was heaviest in the 50 g SW ($25.7 \pm 1.7 \text{ t ha}^{-1}$), which was statistically similar to the 40 g ($24.2 \pm 1.7 \text{ t ha}^{-1}$). In 2014, the number of tubers obtained in the 50 g SW (21.6 ± 1.9) was significantly higher than the 10 g SW (13.2 ± 1.9) but was statistically similar to the rest SW. Also, the tuber weight of the 50 g SW ($15.6 \pm 1.8 \text{ t ha}^{-1}$) was significantly higher than the 10 g SW ($7.6 \pm 1.8 \text{ t ha}^{-1}$), but it was statistically similar with the rest SW. In 2013, TDa 98/01176 had the highest number of tubers (31.06 ± 1.6), which was significantly higher than the rest varieties (Table 5). The tuber weight was heaviest in TDa 00/00194 ($39.9 \pm 3.0 \text{ t ha}^{-1}$), which was not significantly heavier than TDa 98/01176 but was significantly heavier than the rest genotypes. In 2014, the number of tubers harvested in TDa 291 (35.13 ± 3.01) was significantly higher than the rest varieties except TDa 98/01176 (32.3 ± 2.5). However, the weight of tubers harvested in TDa 00/00194 ($27.2 \pm 2.1 \text{ t ha}^{-1}$) was significantly heavier than the rest genotypes except TDa 98/01176 ($25.6 \pm 2.1 \text{ t ha}^{-1}$). The interaction between the varieties and the sett weights was not significant on the number of tubers harvested per plot in 2013 and 2014 planting seasons. Also, the interaction between the varieties evaluated and the sett weight was not significant on the tuber weight in 2013, but it was significant on the tuber weight at harvest in 2014 and ranged from 2.1 t ha^{-1} (TDr 89/02475, 10 g) to 31.1 t ha^{-1} (TDa 98/01176, 40 g) (Figure 3).

Table 4. Effect of tuber sett weight on number of tubers and tuber weight of *Dioscorea rotundata* and *Dioscorea alata* yam species evaluated in 2013 and 2014 planting seasons.

Sett Weight (g)	Number of Tubers/Plot		Tuber Weight t ha^{-1}	
	2013	2014	2013	2014
10 g	12.9 c	13.2 b	9.5 c	7.6 b
20 g	15.3 bc	16.4 ab	14.7 bc	11.9 ab
30 g	17.5 ab	19.3 ab	18.4 b	13.2 a
40 g	19.7 a	19.1 ab	24.2 a	14.4 a
50 g	19.0 a	21.6 a	25.8 a	15.6 a
LSD (0.05)	3.0	5.3	4.9	4.9
SE	1.1	1.9	1.7	1.7
GXSett weight	ns	ns	ns	*

GXSett weight: Interaction between set weight and the genotypes. SE: standard error, and LSD: least significant differences. Means followed by the same letter are not significantly different from one another. *: significant interaction between sett weight and the genotypes. ns: not significant.

Table 5. Number of tubers harvested and tuber weight of *Dioscorea rotundata* and *Dioscorea alata* yam species evaluated in 2013 and 2014 planting seasons.

Genotypes	Number of Tubers/Plot		Tuber Weight (t ha^{-1})	
	2013	2014	2013	2014
Alumaco	15.6 d	12.2 cd	13.3 d	8.1 c
Amula	10.0 e	11.8 cd	6.8 e	7.2 c
Danacha	6.5 e	8.2 d	3.1 e	4.6 c
Ojuyawo	14.7 d	15.2 bc	16.9 d	11.5 bc
Meccakusa	11.8 de	14.9 bc	10.3 de	9.9 c
Obiaturugo	11.4 de	11.5 cd	9.8 de	6.8 c
Pona	9.3 e	8.9 d	9.0 de	6.0 c
TDa 00/00194	20.4 c	23.0 b	39.9 a	27.2 a
TDa 291	26.3 b	35.1 a	28.3 b	18.3 b
TDa 93-36	17.4 cd	14.3 cd	30.9 b	11.8 bc
TDa 98/01176	31.1 a	32.3 a	36.6 ab	25.6 a
TDr 89/02475	20.9 c	12.2 cd	20.6 cd	8.4 c
TDr 89/02665	18.1 cd	19.8 bc	17.3 d	13.3 bc
TDr 89/02677	19.6 c	19.3 bc	14.2 d	10.3 c
TDr 95/18544	20.9 c	25.4 b	17.6 d	14.9 bc
TDr 95/19177	16.4 cd	22.5 b	21.2 c	16.6 bc
LSD (0.05)	4.5	6.9	8.4	5.9
SE	1.6	2.4	3.0	2.1

SE: standard error, and LSD: least significant differences. Means followed by the same letter are not significantly different from one another.

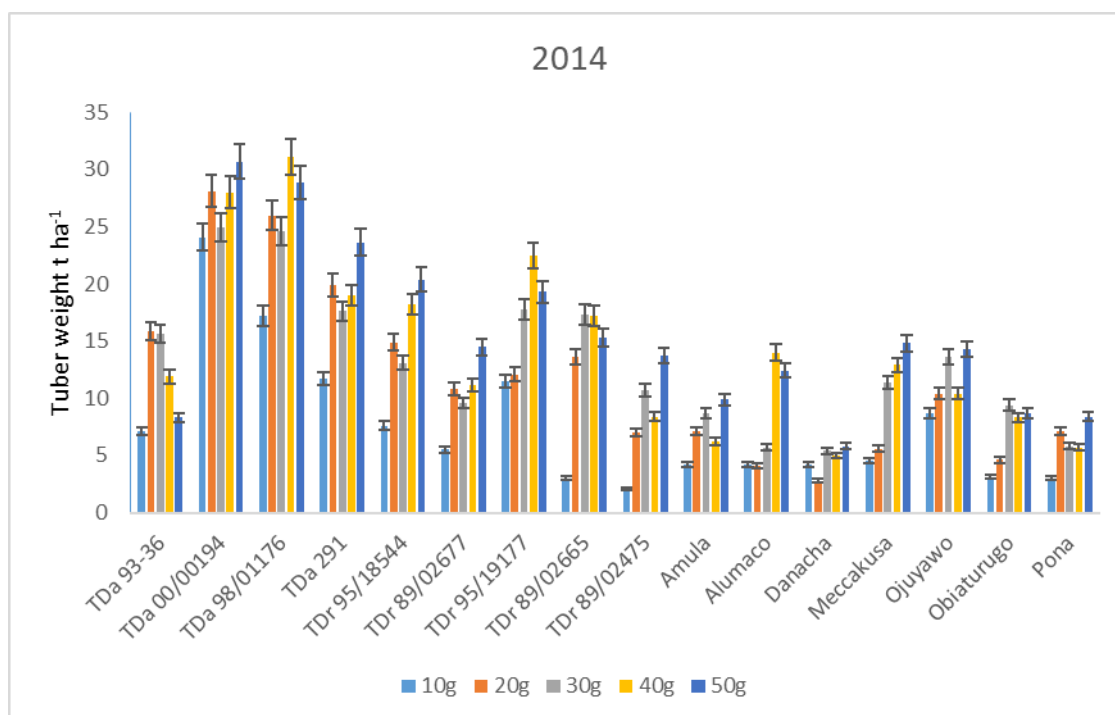


Figure 3. Genotypes by sett weight interaction on the weight of tubers harvested in t ha^{-1} in 2014 planting season.

3.3. Seed Categories

In 2013, the percentage of harvest tubers within the seed category was highest at the 10 g SW ($56.4 \pm 5.0\%$), which was significantly higher than the 50 g sett weight ($40.2 \pm 5.0\%$) (Table 6). The percentage of tubers harvested above the seed category was highest in the 50 g SW ($57.6 \pm 4.4\%$), which was significantly higher than the 10 g and 20 g SW, respectively. However, the percentage of harvest tubers below the seed category in the 10 g SW ($17.5 \pm 2.0\%$) was the highest and it was significantly higher than the rest SW. In 2014, the percentage of harvested tubers within the seed category recorded in the 30 g SW ($60.5 \pm 0.8\%$) was significantly higher than the rest SW. The 50 g SW produced the highest percentage of tubers above the seed category ($12.0 \pm 1.6\%$), which was significantly higher than the rest SW except 40 g sett weight ($9.4 \pm 1.6\%$). However, the 40 g SW produced the highest percentage of tubers below the seed category ($44.2 \pm 1.0\%$), which was significantly higher than the rest SW. In 2013, the percentage of harvested tubers weighing above the seed category was highest in Amula ($72.2 \pm 7.9\%$), and it was significantly higher than Danacha, TDa 00/00194, TDa 291, TDa 93-36, TDa 98/01176, and TDr 95/19177, respectively (Table 7). The highest percentage of tuber harvested within the seed category was observed in TDa 00/00194 ($91.9 \pm 6.4\%$), which was similar to TDa 291, TDa 93-36 and TDa 98/01176, respectively. The percentage of harvested tubers above the seed category was highest in Danacha ($35.5 \pm 4.3\%$), which was significantly higher than the rest genotypes. In the 2014 planting season, Ojuyawo produced the highest percentage of tubers within the seed category ($83.5 \pm 8.2\%$), which was significantly higher than TDa 98/01176 but was significantly similar to the rest genotypes. TDa 00/00194 produced the highest percentage of tubers above the seed category ($25.5 \pm 5.2\%$), but it was not significantly higher than Alumaco, TDa 93-36, and TDa 98/01176, respectively. However, Danacha produced the highest percentage of harvested tubers below the seed category ($34.7 \pm 7.3\%$), which was significantly higher than Ojuyawo, Meccakusa, and TDr 95/19177, respectively.

Table 6. Effect of tuber sett weight on harvested seed categories of *Dioscorea rotundata* and *Dioscorea alata* yam species evaluated in 2013 and 2014 planting seasons.

Sett Weight (g)	Seed Tubers Harvested (%)		Proportion of Seed Tubers Heavier Than Seed Category (%)		Proportion of Seed Tubers Lighter Than Seed Category (%)	
	2013	2014	2013	2014	2013	2014
10 g	56.4 a	58.0 b	26.1 b	5.3 b	17.5 a	36.7 c
20 g	56.1 a	55.6 c	33.3 b	5.5 b	10.7 b	38.9 bc
30 g	55.5 a	60.5 a	38.3 ab	6.4 b	6.3 bc	33.1 d
40 g	44.5 ab	46.4 d	50.5 a	9.4 ab	4.9 c	44.2 a
50 g	40.2 b	48.4 d	57.6 a	12.0 a	2.2 c	39.6 b
LSD (0.05)	14.2	2.3	12.4	4.6	5.7	2.6
SE	5.0	0.8	4.4	1.6	2.0	1.0
GXSett weight	ns	ns	ns	*	ns	*

SE: standard error, and LSD: least significant differences. GXSett weight: interaction between sett weight and the genotypes. Means followed by the same letter are not significantly different from one another. *: significant interactions between sett weight and the genotypes. ns: not significant.

Table 7. Harvested seed categories of *Dioscorea rotundata* and *Dioscorea alata* yam species evaluated in 2013 and 2014 planting seasons.

Genotypes	Seed Tubers Harvested (%)		Proportion of Seed Tubers Heavier Than Seed Category (%)		Proportion of Seed Tubers Lighter Than Seed Category (%)	
	2013	2014	2013	2014	2013	2014
Alumaco	68.8 a	64.3 ab	22.4 bc	17.0 ab	8.8 bc	18.7 ab
Amula	72.2 a	76.8 a	15.6 c	2.5 b	12.2 b	20.7 ab
Danacha	56.3 b	64.4 ab	8.2 c	0.8 b	35.5 a	34.7 a
Ojuyawo	68.2 a	83.5 a	28.4 b	6.2 b	3.5 c	10.4 b
Meccakusa	65.5 a	83.0 a	21.7 bc	3.5 b	12.8 b	13.5 b
Obiaturugo	71.6 a	73.7 a	19.1 c	2.4 b	9.3 bc	23.9 ab
Pona	61.6 ab	73.3 a	27.1 b	4.4 b	11.4 bc	22.3 ab
TDa 00/00194	8.2 c	59.9 ab	91.9 a	25.5 a	0.0 c	14.7 ab
TDa 291	12.8 c	69.4 ab	86.5 a	2.6 b	0.7 c	28.0 ab
TDa 93-36	10.5 c	66.9 ab	89.0 a	12.9 ab	0.5 c	20.3 ab
TDa 98/01176	12.6 c	55.0 b	87.4 a	17.7 ab	0.0 c	27.3 ab
TDr 89/02475	62.6 ab	78.4 a	32.0 b	5.5 b	5.4 bc	16.1 ab
TDr 89/02665	64.8 ab	70.5 ab	27.8 b	9.4 b	7.3 bc	20.1 ab
TDr 89/02677	63.3 ab	79.1 a	30.6 b	1.9 b	6.1 bc	19.0 ab
TDr 95/18544	59.2 ab	75.9 ab	32.4 b	6.2 b	8.4 bc	17.9 ab
TDr 95/19177	50.4 b	82.9 a	38.6 b	5.2 b	11.0 bc	11.9 b
LSD (0.05)	22.0	23.0	17.8	14.5	11.9	20.4
SE	7.9	8.2	6.4	5.2	4.3	7.3

SE: standard error, and LSD: least significant differences. Means followed by the same letter are not significantly different from one another.

The interaction between the genotypes evaluated and the sett weight was not significant in the percentage of seed tuber classes in 2013 and 2014, the proportion of harvested tubers above the seed class in 2013, and the proportion of tubers below the seed class in 2013 (Table 6). However, the interactive effect between the genotypes and sett weight was significant in the percentage of tuber harvest above the seed category in 2014 (Figure 4) and below the seed category in 2014 (Figure 5).

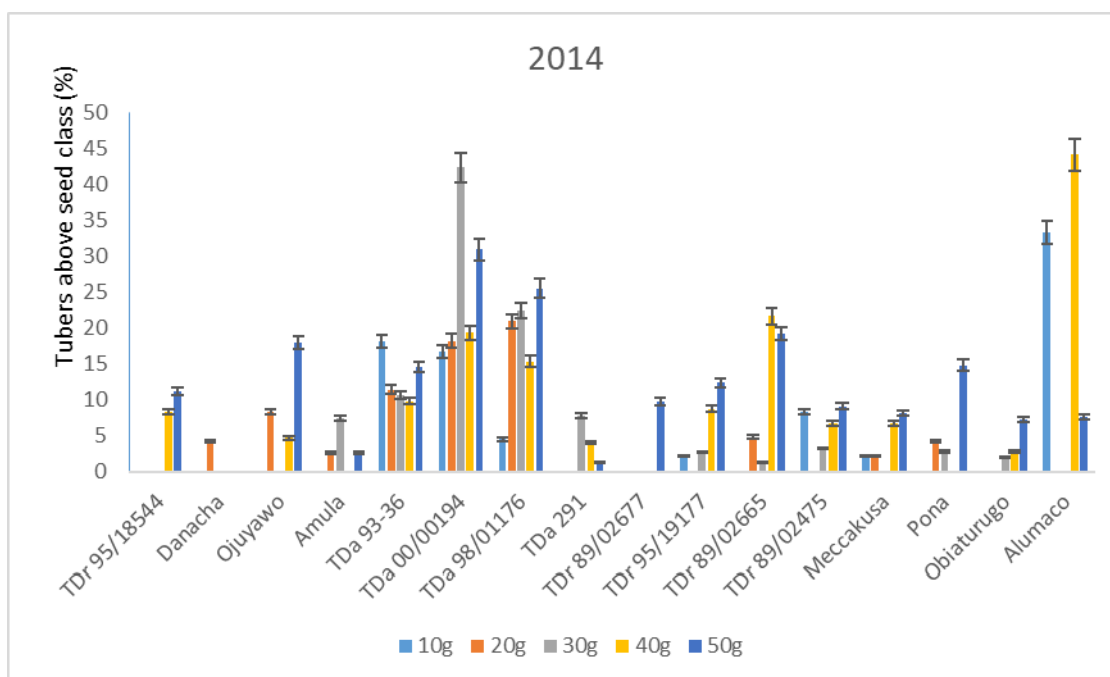


Figure 4. Genotypes by sett weight interaction on the proportion of tubers harvested grouped above the seed class in 2014 cropping season.

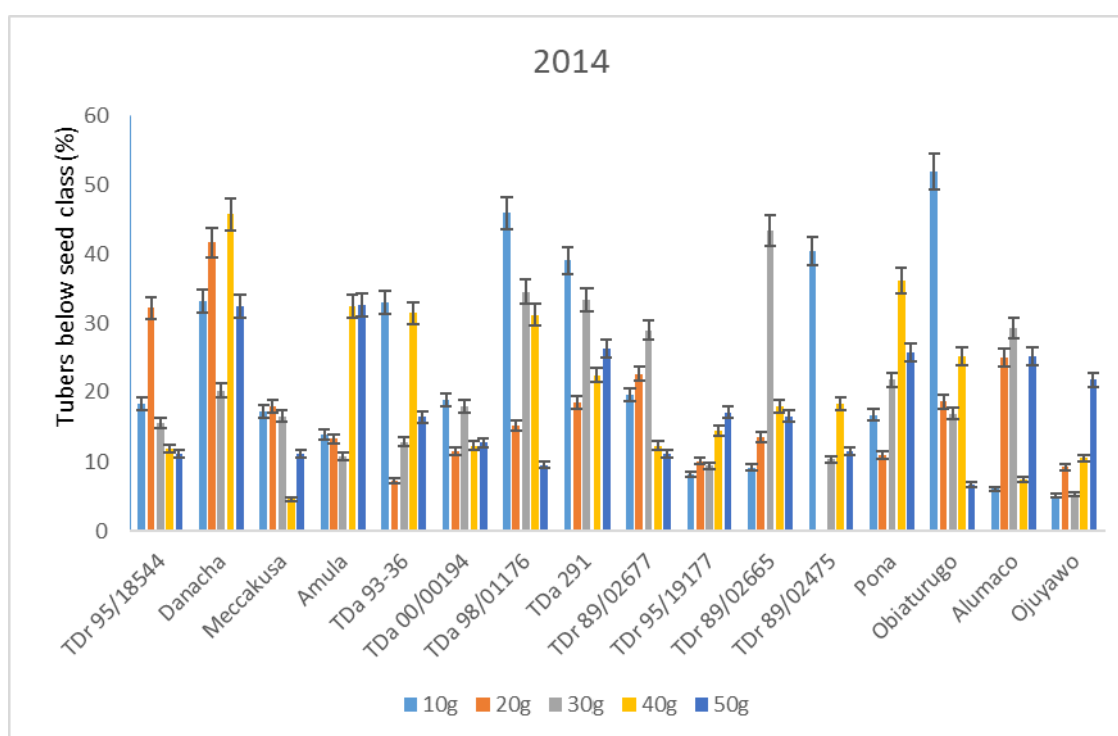


Figure 5. Genotypes by sett weight interaction on the proportion of tubers harvested grouped below the seed class in 2014 planting season.

3.4. Relationships Between the Growth and Yield Parameters

In 2013, the relationship among the parameters evaluated showed that there were positive and significantly correlation between the number of plant emergence and plant stands at harvest ($r = 1.00$), the number of tubers ($r = 0.94$), and a significant negative correlation with the percentage of tubers above the seed category ($r = -0.81$) (Table 8). The stands at harvest had a positive and significant correlation with number of tubers at harvest

($r = 0.94$), tuber weight at harvest ($r = 0.9$), and a negative and significant correlation with percentage of harvested tubers above the seed category ($r = -0.81$). There was a negative and significant correlation between the tuber weight at harvest and the harvested tubers within the seed category ($r = -0.94$) and a positive significant correlation with the tubers above the seed category ($r = 0.94$), while the relationship between the seed category and tubers above the seed category was significant and negative ($r = -1.00$). However, in 2014, the percentage of plants emerged and the percentage of plants remaining at harvest were positively correlated ($r = 0.92$) (Table 9). The relationship between the percentage of plant stands at harvest and the number of tubers harvested ($r = 0.92$) and the tuber weight ($r = 0.92$) was significant and strongly correlated, respectively. Also, the relationship between the number of tubers harvested and the tuber weight was significant and strongly correlated ($r = 0.82$).

Table 8. Correlation among the agronomic and yield parameters of *Dioscorea rotundata* and *Dioscorea alata* yam species evaluated in 2013 planting season.

	Plant Emergence (%)	Number of Plant Stands at Harvest (%)	NOT @ Harvest	Tuber Weight (t ha ⁻¹)	STH (%)	STHHTSC (%)	STHLTSC (%)
Plant emergence (%)	1.00						
Number of plant stands at harvest (%)	1.00 *	1.00					
NOT @ harvest	1.00 **	0.94 **	1.00				
Tuber weight t ha ⁻¹	0.81	0.94 **	0.81	1.00			
STH (%)	-0.63	-0.7	-0.6	-0.94 **	1.00		
STHHTSC (%)	0.74	0.73	0.73	0.90 **	-1.00 **	1.00	
STHLTSC (%)	-0.81 **	-0.81 **	-0.73	-0.81	0.53	-0.73	1.00

NOT @ harvest: number of tubers harvested at harvest. STH: seed tubers harvested (%), STHHTSC: proportion of seed tubers heavier than seed category (%), and STHLTSC: proportion of seed tubers lighter than seed category (%). Significance is shown as *— $p < 0.05$; **— $p < 0.01$.

Table 9. Correlation among the agronomic and yield parameters of *Dioscorea rotundata* and *Dioscorea alata* yam species evaluated in 2014 planting season.

	Plant Emergence (%)	Number of Plant Stands at Harvest (%)	NOT @ Harvest	Yield (t ha ⁻¹)	STH (%)	STHHTSC (%)	STHLTSC (%)
Plant emergence (%)	1.00						
Number of plant stands at harvest (%)	0.92 **	1.00					
NOT @ harvest	0.83	0.92 **	1.00				
Tuber weight t ha ⁻¹	0.83	0.92 **	0.82 **	1.00			
STH (%)	-0.13	-0.11	-0.33	-0.54	1.00		
STHHTSC (%)	0.40	0.40	0.33	0.70	-0.70	1.00	
STHLTSC (%)	-0.34	-0.34	0.11	-0.11	-0.6	-0.23	1.00

NOT @ harvest: number of tubers harvested at harvest. STH: seed tubers harvested (%), STHHTSC: proportion of seed tubers heavier than seed category (%), and STHLTSC: proportion of seed tubers lighter than seed category (%). Significance is shown as **— $p < 0.01$.

4. Discussion

The miniset technology holds promise in addressing the significant deficit of seed yam, which exceeds 80%, contributing to low production and yield [10]. Variability in sprouting ability among the varieties tested using the miniset technique suggests low adoption rates, as Ayankanmi et al. [17] and Okoro [15] reported. In the trials conducted for this study, all breeder lines used demonstrated over 70% sprouting even with small setts as

low as 10 g. At the same time, farmer genotypes (landraces) exhibited poor performance in both sprouting and yield. Improving sprout performance with small setts can help conserve planting material under the miniset technique.

Although increasing the sett weight led to yield increases, the yield did not proportionately increase with SW. A threshold exists beyond which further increases in SW lead to wastage of planting material. Several studies, including Aighewi et al. [8], Emokaro and Law-Ogbomo [19], confirm the relationship between SW and yield. Information on varietal responses to this technique, including different seed weights produced per variety and SW, is valuable for farmers in addressing low productivity and adoption challenges associated with the initial transfer of YMT to farmers.

Furthermore, inherent traits may also contribute to observed differences among varieties. Alieu et al. [21] linked improved and landrace varieties yields to phenotypic traits. Genotypes with desirable traits, such as early plant emergence, field establishment, early tuber initiation, and short tuber dormancy periods, were significant contributors to yam's tuber yield. Using 100–400 g tubers to generate minitubers could contribute to successful miniset sprouting, as observed in these trials, with minitubers exhibiting over 50% periderm cover. Akoroda et al. [22] corroborated this observation, noting that smaller tubers with more periderm tend to sprout more than larger ones. Despite using smaller yam tubers treated with chemicals, sprouting depended on SW and variety, with breeder lines outperforming landraces. Thus, introducing breeder lines to farmers could enhance productivity. The relationship between yield and yield-related parameters regarding SW and variety aligns with previous findings [8].

The findings of this research showed that growing TDa 00/00194 386 (*D. alata*) using a 30 g sett weight produced the highest percentage of tubers above the seed class in 2013 and 2014 planting seasons, respectively, while Ojuyawo (*D. rotundata*) cut at a 10 g sett weight and TDr 89/02665 (*D. rotundata*) cut at a 20 g sett weight produced the highest percentage of seed yam class. Tubers weighing 100–300 g, reaching 500 g, are considered seed yam, while tubers weighing above 500 g are considered ware yam [23]. It is the seed yam category that is the expected output from the yam miniset technique. Some farmers have resorted to using tubers weighing 50–100 g due to the low sprouting characteristics of popular landraces [10]. However, recurring use of local varieties over several decades, with accompanying viral and nematode loads, may contribute to their poor performance [24]. A general overview of plant emergence at the different timelines indicates that *D. alata* performed better than *D. rotundata*. The improved lines of both species were also found to have performed better than the landraces. On the other hand, plant emergence values from the 30 g sett weight and 50 g sett weight of a particular variety were much higher than the value obtained from the 10 g sett weight.

Overall, the performances of yam varieties based on the proportion of seed yam tubers (SYTs) and other tuber sizes suggest that *D. rotundata* performs better for SYT production than *D. alata*. Among both varieties, landraces outperformed improved lines for SYT production. Additionally, the 10 g sett weight and 30 g sett weight appear more favorable for SYT production than the 50 g sett weight, with the 30 g sett weight exhibiting the best performance. These findings suggest that *D. alata* varieties may be more suitable for ware yam production than SYT production, while *D. rotundata* has better tendency to produce seed yam. The findings above support the findings of Aighewi et al. [23] who compared the use of the whole tuber and the miniset of *D. rotundata* in tuber production. The positively strong correlation between plant emergence (sprouts) and the percentage of plant stands at harvest in both 2013 and 2014 planting seasons suggests the good agronomic practices and maintenance invested on the experimental farm leading to the low mortality rate, and this translated to a good harvest as the higher stands at harvest translates to a higher number

of tubers harvested and in tuber weight. However, the tuber weight is strongly correlated with yams above the seed weight category (100 to 300 g), and there was a strong negative correlation between the seed category and the ware yam tubers, meaning the heavier the tubers you harvest, the less the seed class will be obtained for planting purposes. This is important as it is useful in educating the farmers on the sett weight to plant depending on the yield target since the bigger the sett weight planted, the more ware yam (tuber sizes above 1000 g) will be harvested, and the smaller the set weight planted, the more likelihood of harvesting seed category for sale or distribution; this supports the findings of Iseki and Matsumoto [25]. In 2013, the strong negative correlation between the proportion of harvested tubers less than the seed category and plant emergence and plant stands at harvest is a direct reflection of a healthy tuber sett planted, which followed the normal biological growth cycle and eventual yield [26], because delayed emergence could be a result of an unhealthy tuber sett, which will result in a low yield [27]. Also, a negative and significant relationship between tuber weight and seed tubers harvested shows that the higher the number of tubers harvested, the more they will be classified into the ware yam category.

5. Conclusions

The findings of this research accept the null hypothesis that an increase in the planting sett weight of yam tubers leads to the production of ware yam sizes, while the use of a smaller sett weight in planting leads to the production of more seed yam classes, which are needed in subsequent planting seasons and circumvent the constraint of seed yam scarcity. Also, the *D. alata* genotypes produced more ware yam, while the *D. rotundata* genotypes produced more of the seed yam. It is thus recommended that farmers interested in producing seed yam should use a miniset weight of 10 g or 30 g, while those interested in producing ware yam tubers for direct consumption should use a 50 g sett weight in planting.

The implication of this study is that farmers can decide from the onset to planting on the SW to use in yam cultivation relative to the class of tubers he/she intends to produce. As a result, farmers intending to produce seed yam class will not waste their yam tubers by planting tubers bigger than 30 g.

Future Perspective

It has been established in the findings of this research that the minimum and maximum tuber weight for seed tuber production were 10 g and 30 g, respectively; we thus advocate that further research on yam miniset should focus on the use of range from 10 g to 30 g in cutting the tubers to avoid tuber wastages. As part of the work conducted on yam breeding at the International Institute of Tropical Agriculture (IITA), the Breeding and Extension Units of IITA will organize more on-farm demonstration trainings and trials to facilitate the technological adoption by the local farmers who are faced with the scarcity of seed yams every year leading to the high cost of seed yam purchase for planting.

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Abbreviations

The following abbreviations are used in this manuscript:

AYMT	Adapted yam miniset technology
SYT	Seed yam tubers
MAP	Months after planting
YMT	Yam miniset technology
SW	Set weight
IITA	International Institute of Tropical Agriculture
STH	Seed tubers harvested
STHHTLC	Proportion of seed tubers heavier than seed category
STHLTSC	Proportion of seed tubers lighter than seed category

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