


Response of Selected Species of Yam (*Dioscorea* spp.) Vine Cuttings to Different Growing Media

Sootino Salaevalu Samau Taungakava^{1,2*}, Leslie Toralba Ubaub¹, Sanjay Anand¹,
Falaniko Faumuina Amosa¹

¹School of Agriculture, Geography, Environment, Ocean and Natural Sciences, Samoa Campus, The University of the South Pacific, Apia, Samoa

²Department of Science, Faculty of Science, The National University of Samoa, Apia, Samoa

Email: *sootinosamau@gmail.com

How to cite this paper: Taungakava, S.S.S., Ubaub, L.T., Anand, S. and Amosa, F.F. (2025) Response of Selected Species of Yam (*Dioscorea* spp.) Vine Cuttings to Different Growing Media. *Agricultural Sciences*, 16, 1257-1289.

<https://doi.org/10.4236/as.2025.1611073>

Received: March 20, 2025

Accepted: November 25, 2025

Published: November 28, 2025

Copyright © 2025 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Yam, *Dioscorea* spp., is an important staple food in tropical regions including the Pacific. The traditional propagation technique using the whole or part of the seed tubers limits the farmers' capacity to produce more yams. Vine-cutting method is an effective way to solve the problem of seed tuber shortage in yam cultivation. This study was conducted to evaluate the root, shoot, and tuberization potent of vine cuttings of three local yam cultivars namely, "palai uea", "palai maol", and "palai afelika" which were coded as DN1, DN2, and DR, respectively. These cultivars belonged to the two local yam species, *D. nummularia* and *D. rotundata* grown in different growing media combinations of carbonized sawdust (CS) and sterilized topsoil (TS) as follows: 100CS:0TS, 75CS:25TS, 50CS:50TS, 25CS:75TS, and 0CS:100TS. Observations and data collection for the number and length of roots and new shoots, survival rate, and the number of minitubers initiated were first made 28 days (4 weeks) after planting (AP) the vine cuttings, followed by weekly observations and collection for a period of five weeks. There was a very significant interaction effect between the different growing media and yam cultivars on the root length (p-0.001) of vine cuttings from the three cultivars (DN1, DN2, and DR) grown in different media under nursery conditions. There was also a significant interaction effect between the different growing media and cultivars on tuber length (p-0.048) of rooted vine cuttings grown under field conditions. The combination of 50CS:50TS was the best-growing media for cultivar DN1 that favours the production of higher average root number (4.80 ± 1.48), root length (5.32 ± 2.25), and the number of shoots (1.35 ± 0.38). Cultivar DN2 responded well to the combination of 25CS:75TS where it produced the highest number of roots (5.70 ± 1.01), root length (11.19 ± 7.13), number of shoots (2.25 ± 0.82) and shoot length (11.19 ± 7.13). The combination of 75CS:25TS

was the best for cultivar DR, which produced a higher average number of roots (6.25 ± 1.89) and shoots (6.25 ± 1.89). However, the combination of 25CS:75TS was more suitable for producing longer roots (10.38 ± 1.89) and shoot lengths (9.84 ± 2.79) and the number of minitubers (1.25 ± 0.25). The survival rate of vine cuttings grown in different growing media under nursery conditions ranged from 39% to 61%. Nevertheless, the survival rate for vine cuttings grown under field conditions was from 25% - 75%. The findings indicate that specific CS:TS ratios optimize growth for each cultivar under nursery conditions and that this method is a viable technique to increase the availability of yam planting materials in Samoa.

Keywords

Vine Cutting, Growing Media, Yam Cultivar, Minituber

1. Introduction

The yam plant is an angiosperm of the family *Dioscoreaceae* within the order *Dioscoreales* genus *Dioscorea*. The yam plant produces consumable bulbils and tubers of economic importance [1] [2] in many parts of the world. In the tropical region, it is important as a crop for both sustenance and revenue generation, particularly in West Africa along with the major yam-growing regions including Asia, South America, and several island countries in the Pacific namely Samoa, Tonga, Vanuatu, and Fiji the main producers and exporters of yam [3].

The *Dioscorea* yam species abound in hundreds as wild and domesticated types. Vital among these types is the *D. rotundata*—the White Guinea yam, mainly in the areas of highest yam production such as West and Central Africa where it is a native species, similar to the *D. cayenensis*, the Yellow yam. On the other hand, the Water yam *D. alata*, which was first introduced in Asia and is the second most planted species, is also a widely dispersed species worldwide [3].

Across the Pacific, the two most significant species of yam are the water yam (*D. alata*) and the potato yam (*D. esculenta*). Both species originated in Southeast Asia but were introduced to the Western Pacific by early voyagers where it spread as far as Hawaii [4]. In Tonga, there are only six species of yam found, of which three are in danger of extinction. *D. alata* (“Ufi”) is both the most grown and most widely found throughout Tonga. Tongans would regard *D. alata* species of yam as the dominant species, in the same way Africans would refer to the species *D. cayenensis*, or *D. rotundata* as their main species of yam [5].

Dioscorea nummularia, known locally as “Ufi Palai”, is grown perennially and has tubers with hard textures. It was not often included in the cropping area, but was grown and left underneath huge trees for some years, and can be harvested at multiple times. This species is also endangered and was more commonly grown on “Eua Island” [6]. Profuse *Dioscorea rotundata* (Tongan name “Lose”), “*Palai afelika*” in Samoan is a newly introduced species in the kingdom that has captured

much attention in the last few years.

1.1. Cultural and Economic Importance of Yam in the Pacific

Throughout the South Pacific, yam is highly reputed for its socio-cultural significance, as a vital source of good nutrition, and for its contribution to ensuring food security in the island nations. For instance, in the Federated States of Micronesia, Fiji, Vanuatu, Tonga, Samoa and Papua New Guinea, the *D. alata* species is held as a prestigious food [7].

1.2. Research Problem Statement

The usual traditional practice for yam farmers involves getting small seed tubers of about 200 g to 500 g from every harvest to plant in the next planting season [8]. This limits farmers' capacity to produce more yams. The seed tubers are costly, and the cost somehow accounts for about as much as 50% of the total variable costs. Furthermore, yams are bulky and have lengthy dormancy periods. In comparison to other crops such as cereals with a 1:300 field ratio rate, yam has a lower multiplication rate (less than 1:10) [9]. This problem is common among yam farmers across the Pacific region. Farmers heavily depend on tubers reserved during past harvests, and most of them buy planting materials to partially meet their needs.

One of the promising yam propagation methods that could help overcome these limitations is using vine cuttings. An increase in the production of planting materials from using vine cuttings will consequently ensure that the harvested tubers that results will be sufficient for both household consumption and for selling. Obtaining good quality planting materials is very costly among farmers, and using vine cuttings will be a great alternative in sustaining a high yam cultivation rate throughout the farming season. This study investigated the responses of three cultivars from two species of yam (*D. rotundata* and *D. nummularia*) bred from vine cuttings to differing proportions of carbonized sawdust and sterilized topsoil growing media. This approach was built on the ideas suggested by previous similar research conducted at the USP Campus in Samoa and by the International Institute of Tropical Agriculture (IITA). The main argument is the utilization of affordable and accessible local growing media to local yam farmers to minimize production costs and use other techniques of yam breeding, such as vine cuttings to produce planting materials.

Using and promoting vine cuttings as substitutes for planting material [2] was a success in some places like Nigeria. The use of tubers is still the dominant method of breeding for most low-scale farmers worldwide, including the Pacific region. There are very few works devoted to exploring the vine cuttings and the best growing media in the region, therefore, this study is proposed.

1.3. Implication of the Study

The study will impact the yam growers in Tonga, Samoa, and the rest of the Pacific region. Since the vine cutting method is a first for most island countries, results

and recommendations can enrich the farmers' pool of knowledge and empower them through future research. Furthermore, the results will motivate them to continue growing yam despite the shortage of planting materials being a major problem. The study contributes to and supports sustainable agricultural development thus ensuring food security for island nations that grow and market yams. This research could serve as the foundation for future research in the use of vine cuttings in yam farming in the Pacific.

2. Literature Review

2.1. Yam Propagation Methods

2.1.1. Traditional Propagation Methods

According to Okoli and Akoroda [10], traditional methods of yam propagation often involved the planting of entire tubers or cut pieces weighing 200 g or more and using corms. A good number of edible tubers are put aside as planting materials every year, leading to a scarcity of planting materials that, on their own, constitute about 50% of farming costs [11].

The old system utilizes tubers as planting materials, is insufficient and costly. High farming costs are due to using seed yam tubers, which make up about 30% of the total harvest and up to 63% of the total variable costs for every season of cultivation. The multiplication rate in the field when using the traditional system is also quite low (1:5 to 1:10) in comparison to some cereals (1:300). Low-value seed yam with pests (nematodes) and pathogens (viruses) also lead to low yield of poor quality [12].

2.1.2. The Mini-Sett Technology

Mini-sett technology is an easy and time-saving method developed at the International Institute of Tropical Agriculture (IITA) to boost yam production. This method has been piloted in some West African countries and is now widely practiced among yam growers worldwide. The mini-sett technique makes use of the whole tuber rather than using just the head portion. Therefore, the ratio of one "head" to be used as planting material from one tuber changes to many mini-setts per tuber (from 10 to 20 pieces). This enables the availability of a high amount of planting materials annually. The technology is a most useful method for the speedy multiplication of seed yams needed for increased and sustainable yam production [13].

2.1.3. Milking

Milking is used by some farmers to propagate their yams. In this method, tubers are harvested carefully when they have grown about two-thirds throughout the growing season to avoid damage to the root system. This provides early yam for home consumption and excess to be sold at the local market. The existing corm regenerates fresh small tubers for the plant to continue growing until the next harvest [14]. The young tubers are harvested, ensuring that the plant is left intact. The milked plants are left to grow until the end of the duration of the yam-grow-

ing season. The yams obtained by milking are among the earliest harvested during the rainy season when there is always a shortage of food [14].

2.1.4. Use of Aerial Tubers

Another proposed alternative to seed tuber production is the use of aerial tubers requires more investigation, though they are hardly produced in *D. rotundata* unless encouraged by stem girdling [15]. However, plants nurtured from sexual seeds and the subsequent tubers produced, are small by comparison, in contrast to those raised from tubers, probably due to the small number of reserved carbohydrates in the botanical seeds [16].

2.1.5. Seeds

Synthetic seed technology is also useful for the propagation of vegetatively propagated plants whose true seeds are not used or readily available for multiplication such as yams and potatoes [17]. Micropagation laboratory developments may utilize the possibility of using synthetic seeds to time production if the development of the plant could be properly directed toward proliferation and rooting. However, the conversion aspect may limit the practical use of synthetic seed technology [18].

2.1.6. Tissue Culture

Reports on the use of *in vitro* tuberization exist in *D. abyssinica* [16]; *D. floribunda* [19]; *D. alata* [18]; [20]; [21]; *D. bulbifera*; [22]; [23]; *D. rotundata* and *D. cayenensis* [24]; and *Dioscorea opposita* [25]; with differing degrees of success. Micro tubers produced from *in vitro* plantlets are proposed for conservation and propagation purposes, for they have a longer shelf life due to dormancy, and are much harder and less bulky compared to plantlets. However, there has been varying success, with very few reports on micro-tuber dormancy. In addition, there are no documented studies on post-sprout management and the efficiency of micro-tubers relative to other systems in the areas of ease of handling, cost, and savings on time and space. These research gaps act as limiting factors in the practical application of micro-tubers in conservation and yam propagation [26].

2.1.7. Vine Cutting Method of Yam Propagation

Vine cutting technology is a method used in yam farming that has garnered much attention nowadays with regard to its importance in the field of yam breeding. The technique can be performed faster using simple procedures. It is noted as a successful way to rapidly increase a limited quantity of planting materials and produce healthy planting materials. Propagating food yams using stem cuttings is seen as a step aside from the usual traditional propagation method where whole tubers and tuber pieces are used for planting [26]. The first report on the use of vine cutting involved non-edible yams [27] and from then on, it has been widely cited in food yams [15]. The method involves taking cuttings of one to three nodes with leaves, from thriving vines, and planting them in other available media. When these cuttings are well-rooted, they are transferred into nursery beds for careful nurturing for 120 days. They will be able to produce minitubers during

this stage. These mini tubers are then used as the planting material in the next cropping season [3]. However, the rate of rooting or establishment of the vine cuttings may differ across the species, also with physiological factors related to plant growth [28]. Based on Njoku's pioneering work [26], increased interest in vine cuttings as appropriate materials for plant propagation was generated. Additionally, the method offers hopes of a different planting material than the tuber that produces an energy food source for humans [15]. Moreover, producing seed tubers through vine cuttings raises the duplication level of clones beyond possible levels through the conventional use of tuber pieces [29].

2.1.8. Advantages of Vine Cuttings

The use of vine cutting as a propagation method for yam seed tubers production is faster, cheaper, and produces clean planting material. This new propagation system for yam developed by International Institute of Tropical Agriculture (IITA) uses vine cuttings grown on carbonized rice husks combined with in vitro or tissue culture micro propagation techniques [30]. The use of vine cuttings as a planting material gives a higher multiplication rate that is about 20 - 50 times more than the traditional system. It also significantly lowers the risk of nematode infestation and promotes faster multiplication and better and uniform crop quality. Although viruses are difficult to eliminate, this technique produced relatively clean tubers in comparison with those from other propagation methods used in the open field.

3. Experiment 1

Evaluation of the three locally available yam cultivars vine cuttings grown in different growing media combinations of carbonised sawdust and topsoil under nursery conditions as shown in **Table 1**.

3.1. Materials and Methods

The experiment was conducted at the University of the South Pacific-Samoa Campus utilizing land area behind the staff-housing complex located in the village of Moamoa, Samoa. The experimental area has a yearly mean rainfall of 31.6 mm and average monthly temperatures of about 27.5°C.

Three yam cultivars namely "*palai uea*" (DN1) and "*palai maoi*" (DN2) both are *D. nummularia* and "*palai afelika*" (DR), a *D. rotundata* were used in this study. Root, shoot, and tuberization potentials of the vine cuttings of the three cultivars were evaluated as affected by different growing media as well as their survival rate under nursery and field conditions.

3.1.1. Growing of Yam for Parent Materials

Clean, disease-free, and mature tubers of "*palai uea*", "*palai maoi*", and "*palai afelika*" from local farmers were selected, collected, and brought to the laboratory. Tubers were processed into minisets to be planted in the field. A total of 90 minisets, 30 for each variety. The average tuber weight was between 30 - 40 grams.

The chosen tubers were cut into mini-setts with weights ranging from 25 - 30 grams. The minisetts were then pre-treated with fungicide by placing and shaking them inside plastic bags containing the recommended rate of fungicide solution and sand. Treated minisetts for each variety were placed inside each polythene bag already filled with sterile topsoil to stimulate pre-sprouting.

3.1.2. Planting of Sprouted Minisetts

The sprouted setts (**Figure 1**) were planted in the field with a spacing of 100 cm within rows and 100 cm between rows. A month after planting, each plant was allowed to climb on wire frameworks established along each plot to provide support (**Figure 1**). These plants served as the source of the vine cuttings for the experiments.



Figure 1. Sprouting minisetts of the three cultivars.



(a) *Dioscorea nummelaria*

(b) *Dioscorea rotundata*

Figure 2. Parent plants where the vine cuttings were taken from after 4 months of planting.

3.1.3. Collection of Vine Cuttings

Four-month-old parents of the three yam cultivars that were growing vigorously and healthily were selected for the vine collection (**Figure 2**). This is when the main stems produce lateral branches. Lateral branches or side shoots were used so as not to disturb the growth of the main plant. Side shoots with more than three nodes were selected from the mother plants. Extra care was taken to avoid damaging the main stem. The lateral branches selected were removed from the main plants using sharp sterilized scissors and secateurs. The vines were excised early in the morning between 6:00 am and 9:00 am. For each cutting, the main part of the stem that is not too hard nor too soft was identified. This part of the stem was

cut at a $\angle 45$ angle. The collected vines of each cultivar were placed in large plastic bags immediately after collection, labelled, and taken to the nursery for further processing before planting.

3.1.4. Growing Media Preparation

Five different growing media combinations of carbonized sawdust (CS) and topsoil (TS) were prepared which served as the different treatments for Experiment 1 (**Figure 3**). Growth media combinations were as follows: 100CS:0TS, 75CS:25TS, 50CS:50TS, 25CS:75TS, and 0CS:100TS (**Table 1**) and (**Table 2**). Carbonized sawdust was prepared by heating the sawdust acquired from the market at 300°C - 350°C with a residence time of 1 hour and 30 minutes. While topsoil was collected from the field and sterilized using an oven. Both materials were cooled down then they were used to fill the PB2 polybags for planting the vine cuttings.



Figure 3. Mixing sterilized top soil and carbonised sawdust.

3.1.5. Preparation and Planting of Vine Cuttings

Vines were cut into 12 - 15 cm long, each bearing a pair of mature leaves and two nodes. The end of every vine was dipped into a fungicide (Mancozeb) solution. After treatment, the treated end of each vine was inserted into PB2 polybags filled with the appropriate growing media, and the medium was gently pressed around the vine cutting. The entire leafless portion of the vine was slantly buried under 2 - 3 cm of the growth medium leaving just the leafy tip above the medium and firm around. A watering can was used to distribute water to every cutting after planting (**Figure 4**, **Figure 5**).



Figure 4. (a) Planting vine cuttings in the nursery (b) Sprouting vine cutting ready for field transplanting.



Figure 5. Transplanting of fully-grown yam from vine cuttings grown in the different growing media in the nursery to the field.

Table 1. Experimental layout.

Block 1	Block 2	Block 3	Block 4	Carbonized Sawdust (CS) and Topsoil (TS) Ratio
1	2	3	4	1-100:0 DN1
2	3	4	5	2-100:0 DN2
3	4	5	6	3-100:0 DR
4	5	6	7	4-75:25 DN1
5	6	7	8	5-75:25 DN2
6	7	8	9	6-75:25 DR
7	8	9	10	7-50:50 DN1
8	9	10	11	8-50:50 DN2
9	10	11	12	9-50:50 DR
10	11	12	13	10-25:75 DN1
11	12	13	14	11-25:75 DN2
12	13	14	15	12-25:75 DR
13	14	15	1	13-0:100 DN1
14	15	1	2	14-0:100 DN2
15	1	2	3	15-0:100 DR

Table 2. The ratio of the Carbonized Sawdust and Topsoil in the PB2 polybags planted with three (3) yam cultivars.

Media combination (Factor A)		Yam cultivar (Factor B)
Carbonized sawdust	Topsoil	
100	0	DN1
100	0	DN2
100	0	DR
75	25	DN1
75	25	DN2
75	25	DR

Continued

50	50	DN1
50	50	DN2
50	50	DR
25	75	DN1
25	75	DN2
25	75	DR
0	100	DN1
0	100	DN2
0	100	DR

Legend: DN1—“*palai uea*”; DN2 —“*palai maol*”; DR—“*palai afelika*”.

3.1.6. Care and Management Inside the Nursery

Irrigation

Vine cuttings were gently and thoroughly irrigated shortly after planting them in the growing medium and were sprayed at regular intervals to keep moisture inside the growing medium.

Weeding

Weeds were hand-pulled from the growing media once a week as soon as they started appearing.

Pest and Disease management

There was no significant visual presence of pests or diseases in the bags. However, a few identified scale insects were handpicked where necessary.

Data Collection

Destructive sampling method was used to obtain data for each of the parameters evaluated after 28 days from planting. The number of roots for each plant sampled was counted and the length for every root was measured using a ruler and recorded in the data collection book. Furthermore, the number of shoots was counted, and the length was also measured using a ruler. One plant from each treatment was randomly selected and carefully uprooted to collect the data (Table 3 and Figure 6 & Figure 7). The procedure was repeated for all plant samples. There were five harvests carried out for the whole duration of each trial conducted in both nursery and under field experiments.

Table 3. Data collected from the three (2) experiments.

Experiment	Data sets
1 and 2	Number and length of roots
	Number and length of shoots
	Number of tubers
	Survivalability rate
3 (Growing media)	Number of lateral shoots
	Fresh and dried weight of shoots
	Number, length, and diameter of tubers
	Fresh and dry weight of tubers
	Survivalability rate

Observations and measurements of planted vine cuttings were made weekly from the 28th day after planting in the nursery. They focused on the survival rate of vine cuttings, the number of roots emitted, the length of roots, the number of mini tubers initiated, and the number and length of new shoots.

3.1.7. Statistical Analysis

The data obtained from Experiments 1 and 2 (field experiments on different growing media) were subjected to a two-way Analysis of Variance (ANOVA) and the Least Significant Difference (LSD) to determine if there is any significant interaction effect on the dependent variables, at $P \leq 0.05$ level of significance was used to compare the differences of means between the treatments and cultivars using the SPSS program for statistical analysis.

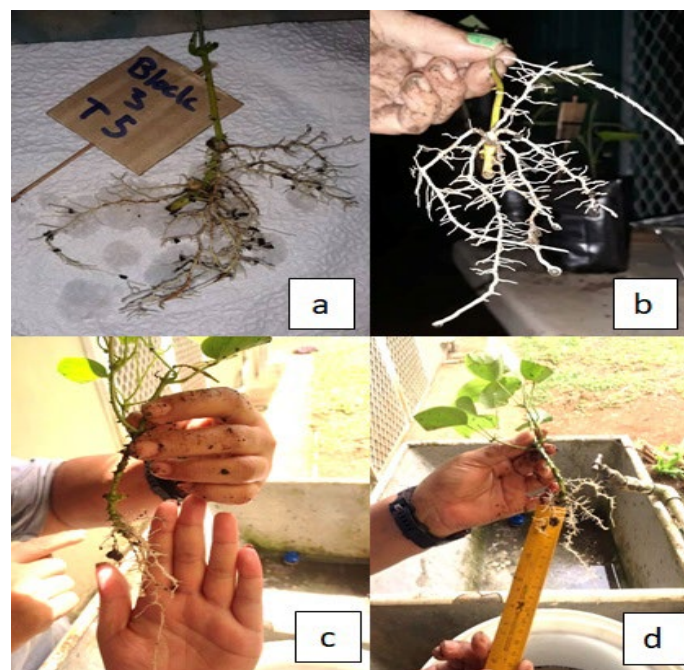


Figure 6. Destructive sampling to count (a & b) and measure (c & d) using a ruler.



Figure 7. Minitubers initiated by yam vine cuttings grown in different media in the nursery.



Figure 8. Tubers of different cultivars harvested from rooted yam cuttings (a) DN1; (b) DN2; (c) DR.

4. Results

There was a very significant interaction effect of the growing media and yam cultivar on the root length of the three yam cultivars grown under nursery conditions (**Table 4**). In addition, there was no significant effect of the interaction of the growing media and the cultivars on the remaining parameters. The highest average root length among treatments was found in 25CS:75TS in DN2 (12.4 cm) and it is comparable with those in treatments 50CS:50TS (11.2 cm) and 0CS:100TS in DN2 (11.2 cm), 25CS:75TS (10.4 cm) and 0CS:100TS (10.3 cm) all from cultivar DR. The lowest average root length (1.3 cm) among the treatments was found in the treatment combination of 100CS:0TS in cultivar DR, which is comparable to those in the 100CS:0TS treatment group for both DN2 and DN1 with 1.4 cm and 1.7 cm, respectively.

Table 4. Interaction effect of growing media and yam cultivar on the average number of roots, root length, number of shoots, shoot length, and no. of tubers of yam vine cuttings grown in different media under nursery conditions.

Treatments	No.of roots ^{ns}	Root length (cm)**	No.of shoots ^{ns}	Shoot length (cm) ^{ns}	No.of tubers ^{ns}
100CS:0TS DN1	1.7	1.4 ^e	1.1	3.4	1.0
75CS:25TS DN1	3.7	4.6 ^d	1.3	2.0	1.0
50CS:50TS DN1	4.4	5.3 ^d	1.4	3.4	1.0
25CS:75TS DN1	4.2	3.8 ^{de}	1.3	7.6	1.0
0CS:100TS DN1	2.7	4.4 ^d	1.2	4.6	1.0
100CS:0TS DN2	2.3	1.7 ^e	0.9	1.6	1.0
75CS:25TS DN2	4.9	6.3 ^{cd}	1.7	5.9	1.3
50CS:50TS DN2	5.0	11.2 ^{ab}	2.2	8.5	1.3
25CS:75TS DN2	5.2	12.4 ^a	2.3	11.2	1.0
0CS:100TS DN2	4.4	11.2 ^{ab}	1.5	9.6	1.5
100CS:0TS DR	3.3	1.3 ^e	1.2	1.1	1.0
75CS:25TS DR	5.6	6.2 ^d	2.3	7.7	1.0
50CS:50TS DR	4.8	8.9 ^{bc}	1.9	8.9	1.3
25CS:75TS DR	4.3	10.4 ^{ab}	1.9	9.8	1.3
0CS:100TS DR	3.0	10.3 ^{ab}	1.6	7.3	1.0
CV (%)	37.0	61.2	38.8	66.5	27.5
P value	0.323	0.001	0.217	0.153	0.434

**—Very significant, ^{ns}—Not Significant. The means followed by the same letter in a column are not statistically different from one another at $P \leq 0.05$ level of significance using the Least Significant Difference (LSD).

Cultivar DN1 showed a highly significant difference ($p=0.001$) while cultivars DN2 ($p=0.047$) and DR ($p=0.021$) both showed significant difference in the number of roots (**Table 5**). The highest number of roots obtained by cultivar DN1 was in the 50CS:50TS treatment combination (4.80 ± 1.14), which is comparable with those grown in 25CS:75TS and 75CS:25TS treatment combinations. The latter combinations recorded an average root number of 4.55 ± 0.90 and 3.90 ± 0.77 , respectively. These were comparable with 0CS:100TS combinations that obtained 2.70 ± 0.87 average roots, which are also comparable with 100CS:0TS combinations with 1.55 ± 0.70 . Cultivar DN2 obtained a higher average number of roots in the 25CS:75TS combinations with 5.70 ± 1.01 , which is comparable with 50CS:50TS, 75CS:25TS and 0CS:100TS with an average number of roots of 5.45 ± 2.24 , 5.40 ± 1.36 , and 4.75 ± 1.91 , respectively. Like DN1, the growing media with 100CS:0TS obtained the lowest average number of roots (2.20 ± 1.36).

Meanwhile, the 6.25 ± 1.89 average number of roots, the overall highest for all three cultivars was recorded in cultivar DR from the 75CS:25TS combinations. This is followed by 50CS:50TS with 5.25 ± 1.11 , then 25CS:75TS with 4.65 ± 0.75 , both are comparable with 75CS:25TS. The 100CS:0TS combinations obtained 3.50 ± 0.52 , which is comparable with 50CS:50TS and 25CS:75TS. The lowest average number of roots was obtained by 0CS:100TS combinations (3.15 ± 0.57), which is comparable with 100CS:0TS.

Table 5. Average number of roots produced by each of the three cultivars (DN1, DN2 and DR) grown in different media combinations under nursery conditions.

Treatments	Cultivar		
	DN1***	DN2*	DR*
100:0	1.55 ± 0.70^c	2.20 ± 1.36^b	3.50 ± 0.52^{bc}
75:25	3.90 ± 0.77^{ab}	5.40 ± 1.36^a	6.25 ± 1.89^a
50:50	4.80 ± 1.14^a	5.45 ± 2.24^a	5.25 ± 1.11^{ab}
25:75	4.55 ± 0.90^{ab}	5.70 ± 1.01^a	4.65 ± 0.75^{abc}
0:100	2.70 ± 0.87^{bc}	4.75 ± 1.91^a	3.15 ± 0.57^c
p-value	0.001	0.047	0.021
LSD	1.34	2.46	1.91
CV (%)	25.45	34.75	27.74

The means followed by the same letter in a column are not statistically different from one another at $P \leq 0.05$ level of significance using the Least Significant Difference (LSD), * significant, ** very significant, *** highly significant.

Cultivars DN2 and DR showed highly significant differences ($p < 0.0001$) while cultivar DN1 ($p=0.039$) showed a significant difference in their average root lengths (**Table 6**). The highest average root length by cultivar DN1 was in the 50CS:50TS combination (5.32 ± 2.25), which is comparable with those grown in 75CS:27TS and 0CS:100TS that recorded an average root length of 4.60 ± 1.25 and 4.4 ± 2.3

respectively. The ones in 25CS:75TS are comparable to 100CS:0TS obtained 1.38 ± 0.39 average root length.

Cultivar DN2 obtained a higher average root length, the highest overall recorded in 25CS:75TS treatment combination with 12.36 ± 2.80 , which is comparable with those grown in 50CS:50TS, 100CS:0TS, and 0CS:100TS that recorded an average root length of 11.2 ± 2.91 , 11.15 ± 0.68 and 11.15 ± 0.70 respectively. The growing media with 75CS:25TS obtained the lowest average root length (6.27 ± 1.84) for cultivar DN2.

Meanwhile, 10.38 ± 1.89 average root length was the highest recorded in cultivar DR from 25CS:75TS treatment combination. This is followed by 0CS:100TS with 10.30 ± 2.65 , then 50CS:50TS with 8.86 ± 1.58 , both are comparable with 25CS:75TS. Like DN1, the growing media combination with 100CS:0TS obtained the lowest average root length of 1.34 ± 0.14 for cultivar DR.

Table 6. Average root length of the three cultivars (DN1, DN2 and DR) grown in different growing media combinations under nursery conditions.

Treatment	Cultivar		
	DN1*	DN2***	DR***
100:0	1.38 ± 0.39^b	11.15 ± 0.68^a	1.34 ± 0.14^c
75:25	4.60 ± 1.25^a	6.27 ± 1.84^b	6.18 ± 1.13^b
50:50	5.32 ± 2.25^a	11.2 ± 2.91^a	8.86 ± 1.58^a
25:75	3.83 ± 1.29^{ab}	12.36 ± 2.80^a	10.38 ± 1.89^a
0:100	4.4 ± 2.3^a	11.15 ± 0.70^a	10.30 ± 2.65^a
p-value	0.039	<0.0001	<0.0001
LSD	2.5	3.06	2.56
CV (%)	42.46	23.79	22.9

The means followed by the same letter in a column are not statistically different from one another at $P \leq 0.05$ level of significance using the Least Significant Difference (LSD), * Significant, ** very significant, *** highly significant.

Cultivars DN2 and DR both showed significant differences (DN2; $p=0.03$, DR; $p=0.02$) while DN1 showed no significant difference ($p=0.73$) in the average number of shoots produced by vine cuttings grown in different growing media combinations (Table 7). The highest number of shoots by cultivar DN1 was in the 50CS:50TS combination with 1.35 ± 0.38 . This was followed by a 25CS:75TS combination with 1.30 ± 0.26 , and the lowest average number of shoots was in the 100CS:0TS with 1.05 ± 0.10 . Cultivar DN2 obtained the highest (2.25 ± 0.82) average number of shoots in the 25CS:75TS combination. This is followed by a 50CS:50TS combination with an average of 2.15 ± 0.85 , which is comparable to a 25CS:75TS combination. Both of these combinations are comparable with those in combination 75CS:25TS and combination 0CS:100TS which obtained an average number of shoots of 1.65 ± 0.44 and 1.45 ± 0.34 respectively. Like DN1, com-

bination 100CS:0TS obtained the lowest average number of shoots (0.85 ± 0.19) which is comparable to combinations 75CS:25TS (1.65 ± 0.44) and combination 0CS:100TS with 1.45 ± 0.34 . Meanwhile, the highest average number of shoots recorded for DR was 6.25 ± 1.89 from the combination 75CS:25TS. However, the growing media combinations 50CS:50TS and 25CS:75TS produced the following average number of shoots, 5.25 ± 1.11 and 4.65 ± 0.75 , which are comparable to 75CS:25TS. Additionally, the combination 0CS:100TS obtained an average number of shoots of 3.5 ± 1.52 , which is comparable to combinations 50CS:50TS, 25CS:75TS, and 0CS:100TS. Unlike DN1 and DN2, the combination 0CS:100TS obtained the lowest number of shoots (3.15 ± 0.57) for DR. This is comparable with combination 100CS:0TS and 25CS:75TS.

Table 7. Average number of shoots produced by cultivars DN1, DN2, and DR grown in different growing media combinations under nursery conditions.

Treatment	Cultivar		
	DN1 ^{ns}	DN2*	DR*
100:0	1.05 ± 0.10	0.85 ± 0.19^b	3.5 ± 1.52^{bc}
75:25	1.25 ± 0.38	1.65 ± 0.44^{ab}	6.25 ± 1.89^a
50:50	1.35 ± 0.38	2.15 ± 0.85^a	5.25 ± 1.11^{ab}
25:75	1.30 ± 0.26	2.25 ± 0.82^a	4.65 ± 0.75^{abc}
0:100	1.20 ± 0.40	1.45 ± 0.34^{ab}	3.15 ± 0.57^c
p-value	0.73	0.03	0.02
LSD	0.49	0.89	1.9
CV (%)	26.3	35.49	27.74

The means followed by the same letter in a column are not statistically different from one another at $P \leq 0.05$ level of significance using the Least Significant Difference (LSD), * significant, ^{ns} not significant.

Cultivar DR showed a very significant difference ($p=0.001$) while cultivars DN1 ($p=0.03$) and DN2 ($p=0.02$) both showed significant differences in the average shoot length (**Table 8**). The highest average shoot length by cultivar DN1 was in the 25CS:75TS combination (7.60 ± 2.53) which is comparable with those in the 0CS:100TS combination that recorded an average shoot length of 4.59 ± 3.65 . Furthermore, the combinations 100CS:0TS, 75CS:25TS, and 50CS:50TS recorded average shoot lengths of 3.42 ± 0.97 , 2.02 ± 0.89 , and 3.38 ± 1.66 , respectively. These were comparable with the 0CS:100TS combination, which obtained a 4.59 ± 3.65 average shoot length. However, the lowest average shoot length (2.02 ± 0.89) was obtained by the combination 75CS:25TS, which is comparable to the combinations 100CS:0TS, 50CS:50TS, and 0CS:100TS.

Cultivar DN2 obtained a higher average shoot length; the highest was recorded in 25CS:75TS combinations with 11.19 ± 7.13 , which is comparable with 50CS:50TS, 0CS:100TS, and 75CS:25TS with an average shoot length of $8.46 \pm$

2.34, 9.59 ± 3.48 and 5.90 ± 1.45 , respectively. The growing media combination with 100CS:0TS obtained the lowest average shoot length of 5.90 ± 1.45 , which is comparable to combination, 75CS:25TS with an average shoot length of 5.90 ± 1.45 . The highest shoot length obtained by cultivar DR was in the 25CS:75TS combination (9.84 ± 2.79), which is comparable with those grown in 75CS:25TS, 50CS:50TS and 0CS:100TS combinations, which recorded an average shoot length of 7.65 ± 1.20 , 8.88 ± 2.52 and 6.86 ± 3.69 , respectively. The lowest average shoot length (1.13 ± 0.24) recorded for cultivar DR was in the 100CS:0TS combination, which is similar to DN2 where the lowest average shoot length was obtained by the 100CS:0TS combination.

Table 8. Average shoot length of vine cuttings of cultivars DN1, DN2, and DR grown in different growing media combinations under nursery conditions.

Treatment	Cultivar		
	DN1*	DN2*	DR**
100:0	3.42 ± 0.97^b	1.63 ± 1.16^b	1.13 ± 0.24^b
75:25	2.02 ± 0.89^b	5.90 ± 1.45^{ab}	7.65 ± 1.20^a
50:50	3.38 ± 1.66^b	8.46 ± 2.34^a	8.88 ± 2.52^a
25:75	7.60 ± 2.53^a	11.19 ± 7.13^a	9.84 ± 2.79^a
0:100	4.59 ± 3.65^{ab}	9.59 ± 3.48^a	6.86 ± 3.69^a
p-value	0.03	0.02	0.001
LSD	3.31	5.71	3.65
CV (%)	52.33	51.53	35.2

The means followed by the same letter in a column are not statistically different from one another at $P \leq 0.05$ level of significance using the Least Significant Difference (LSD). * significant, ** very significant, *** highly significant.

Table 9. Average number of tubers produced by vine cuttings of cultivars DN1, DN2, and DR grown in different growing media combinations under nursery conditions.

Treatment	Cultivar		
	DN1 ^{ns}	DN2 ^{ns}	DR ^{ns}
100:0	0.90 ± 0.26	0.90 ± 0.26	0.85 ± 0.19
75:25	0.19 ± 0.19	1.35 ± 0.30	1.00 ± 0.28
50:50	1.00 ± 0.28	1.15 ± 0.34	1.20 ± 0.43
25:75	0.95 ± 0.19	1.30 ± 0.12	1.25 ± 0.25
0:100	0.90 ± 0.26	1.4 ± 0.52	1.05 ± 0.25
p-value	0.97	0.25	0.35
LSD	0.36	0.5	0.44
cv (%)	25.47	27.27	27.4

^{ns}—Not significant.

There was no significant difference in the average number of tubers produced by the three cultivars (DN1, DN2 and DR) (**Table 9**). However, numerical values showed that DN1 from 50CS:50TS treatment group recorded the highest average number of tubers of 1.00 ± 0.28 , followed by 25CS:75TS (0.95 ± 0.19), 0CS:100TS (0.90 ± 0.26), 100CS:0TS (0.90 ± 0.26), and the lowest was from 75CS:25TS (0.19 ± 0.19). While DN2, vine cuttings from 0CS:100TS recorded the highest average number of tubers, which is 1.4 ± 0.52 , and the lowest was observed in 100CS:0TS (0.90 ± 0.26). Vine cuttings from 25CS:75TS in cultivar DR recorded the highest average number of tubers, which is 1.25 ± 0.25 while the lowest was in cultivar DN1, where combination 100CS:0TS gave the lowest (0.85 ± 0.19) average number of tubers.

Shoot and tuber characteristics from fully-grown yams from vine cuttings of the three locally available yam cultivars (DN1, DN2 and DR) grown in different media combinations under field conditions.

The successfully grown yam plants from vine cuttings under nursery conditions were transplanted in the field (**Figure 5**) to evaluate the growth performance and survival rate of the planting materials under field conditions.

Table 10. Interaction effect of growing media and yam cultivar on the number of lateral shoots, number of tubers, tuber length, tuber diameter, fresh shoot weight, dry shoot weight, fresh tuber weight, and dry tuber weight on rooted vine cuttings grown under field conditions.

Treatment combinations	No. lateral shoots ^{ns}	No. of tubers ^{ns}	Tuber length (cm) [*]	Tuber diameter (cm) ^{ns}	Fresh shoot weight (g) ^{ns}	Dried shoot weight (g) ^{ns}	Fresh tuber weight (g) ^{ns}	Dried tuber weight (g) ^{ns}
100CS:0TS DN1	4.5	1.5	4.5 ^b	3.0	3.8	1.3	30.5	8.3
75CS:25TS DN1	2.8	2.8	4.5 ^b	2.3	4.5	1.4	28	7.1
50CS:50TS DN1	3.4	1.8	5.0 ^{ab}	2.3	19	3.9	31.5	7.8
25CS:75TS DN1	4.3	2.0	7.5 ^a	2.6	3.8	1.0	32.3	8.5
0CS:100TS DN1	4.2	1.8	5.3 ^{ab}	3.0	3.3	1.1	36.3	8.9
100CS:0TS DN2	3.2	1.3	6.3 ^{ab}	3.0	7.3	2.1	43	10.8
75CS:25TS DN2	2.7	2.0	5.0 ^{ab}	2.8	8.0	2.2	38.3	9.8
50CS:50TS DN2	5.8	2.5	4.0 ^b	2.1	4.5	1.4	28.8	7.6
25CS:75TS DN2	4.9	2.0	3.8 ^b	2.3	3.8	1.2	20.8	5.9
0CS:100TS DN2	5.3	1.8	3.8 ^b	2.8	3.3	0.9	24.8	6.2
100CS:0TS DR	4.2	1.5	4.0 ^b	3.0	4.3	1.3	30.8	8.2
75CS:25TS DR	3.6	3.0	4.0 ^b	2.5	5.0	1.5	28.8	7.6
50CS:50TS DR	3.3	1.8	5.8 ^{ab}	2.8	21.8	4.4	33.5	8.4
25CS:75TS DR	4.1	2.8	3.8 ^b	2.5	3.5	1.1	30.8	7.4
0CS:100TS DR	4.5	1.5	5.0 ^{ab}	2.8	3.8	1.1	34.8	8.7
CV (%)	43.3	59.1	41.5	24.8	194.0	140.7	46.3	40.5
P Value	0.512	0.788	0.048	0.806	0.783	0.799	0.628	0.599

^{*}Significant, ^{ns}—Not Significant. The means followed by the same letter in a column are not statistically different from one another at $P \leq 0.05$ level of significance using the Least Significant Difference (LSD).

There was a significant ($p=0.048$) interaction effect of the yam cultivars and growing media on tuber length only (**Table 10**). There was no significant interaction effect on the number of lateral shoots, number of tubers, tuber diameter, fresh shoot weight, dried shoot weight, fresh tuber weight, and dried tuber weight.

Growth performance was based on the shoots and tubers of the growing yam plants while the number of plants that survived throughout the duration of the experiment were counted for the survival rate. There were no significant differences in the average number of shoots produced by the three cultivars grown (**Table 11**). However, numerical values showed that DN1 from the 100CS; 0TS recorded the highest average number of shoots of 4.45 ± 1.06 , followed by the 25CS; 75TS (4.25 ± 2.33), 0CS:100TS (4.15 ± 1.50), 50CS:50TS (3.40 ± 0.67) and the lowest was from the 75CS:25TS (2.80 ± 0.59). While cultivar DN2, planting materials from the 50CS:50TS recorded the highest average number of shoots, which is 5.80 ± 2.97 , and the lowest was observed in 75CS:25TS (2.70 ± 0.58). Like cultivar DN1, planting materials from 100CS:0TS in cultivar DR gained the highest average number of shoots, which is 4.75 ± 0.85 while the lowest was from the 50CS:50TS (3.25 ± 1.01).

Table 11. Average number of shoots produced by the rooted vine cuttings of cultivars DN1, DN2, and DR grown in different growing media combinations in the nursery and later grown under field conditions.

Treatments	Cultivar		
	DN1 ^{ns}	DN2 ^{ns}	DR ^{ns}
100:0	4.45 ± 1.06	3.15 ± 1.04	4.75 ± 0.85
75:25	2.80 ± 0.59	2.70 ± 0.58	3.60 ± 1.69
50:50	3.40 ± 0.67	5.80 ± 2.97	3.25 ± 1.01
25:75	4.25 ± 2.33	4.85 ± 1.90	4.05 ± 0.30
0:100	4.15 ± 1.50	5.3 ± 3.41	4.5 ± 1.67
p-value	0.44	0.26	0.43
LSD	2.09	3.4	1.84
cv (%)	36.43	51.76	30.36

^{ns}—Not significant.

There was no significant difference in the average fresh weight of the shoot in the three cultivars. (**Table 12**). Nevertheless, numerical values showed that DN1 grown in the 50CS:50TS recorded the highest average fresh of shoots of 19.00 ± 30.71 , followed by the 75CS:25TS (4.50 ± 3.00), 100CS:0TS (3.75 ± 2.99), 25CS:75TS (3.75 ± 2.63), and the lowest was from the 0CS:100TS (3.25 ± 2.50). While cultivar DN2, planting materials from the 75CS:25TS recorded the highest average fresh weight of shoots which is 8.00 ± 5.72 , and the lowest was observed in 0CS:100TS (2.70 ± 0.58) as shown in DN1. Like cultivar DN1, planting materials from the 50CS:50TS in cultivar DR gained the highest average fresh weight of

shoots of 21.75 ± 38.88 while the lowest was from the 25CS:75TS (3.50 ± 3.79).

Table 12. Average fresh weight of shoots of the three cultivars (DN1, DN2, and DR) grown in different growing media combinations in the nursery and later grown under field conditions.

Treatment	Cultivar		
	DN1 ^{ns}	DN2 ^{ns}	DR ^{ns}
100:0	3.75 ± 2.99	7.25 ± 6.65	4.25 ± 2.97
75:25	4.50 ± 3.00	8.00 ± 5.72	5.00 ± 2.45
50:50	19.00 ± 30.71	4.50 ± 1.91	21.75 ± 38.88
25:75	3.75 ± 2.63	3.75 ± 2.87	3.50 ± 3.79
0:100	3.25 ± 2.50	3.25 ± 1.26	6.25 ± 8.54
p-value	0.46	0.43	0.59
cv (%)	203.8	79.3	220.43

^{ns}—Not significant.

There were no significant differences in the average dry weight of shoots of the three cultivars (Table 13). However, cultivar DN1 from the 50CS:50TS treatment group recorded the highest average shoot dry weight of 3.88 ± 5.52 , followed by the 75CS:25TS (1.35 ± 0.85), 100CS:0TS (1.30 ± 0.85), 0CS:100TS (1.09 ± 0.64), and the lowest was from the 25CS:75TS (0.99 ± 0.69). For cultivar DN2, planting materials from the 75CS:25TS recorded the highest average dry weight of shoots, which is 2.20 ± 1.12 , and the lowest was observed in the 0CS:100TS (0.94 ± 0.45). Like cultivar DN1, planting materials from the 50CS:50TS in cultivar DR gained the highest average dry weight of shoots, which is 4.45 ± 7.35 while the lowest was also from the 25CS:75TS (1.08 ± 1.11) like in cultivar DN1.

Table 13. Average dry weight of shoots of the three cultivars (DN1, DN2, and DR) grown in different growing media combinations in the nursery and later grown under field conditions.

Treatment	Cultivar		
	DN1 ^{ns}	DN2 ^{ns}	DR ^{ns}
100:0	1.30 ± 0.85	2.10 ± 1.55	1.10 ± 0.55
75:25	1.35 ± 0.85	2.20 ± 1.12	1.46 ± 0.59
50:50	3.88 ± 5.52	1.39 ± 0.52	4.45 ± 7.35
25:75	0.99 ± 0.69	1.19 ± 0.82	1.08 ± 1.11
0:100	1.09 ± 0.64	0.94 ± 0.45	1.11 ± 1.06
p-value	0.49	0.31	0.59
cv (%)	148.89	62.86	179.19

^{ns}—Not significant.

There were no significant differences in the average number of tubers produced by the cultivars DN1, DN2, and DR (**Table 14**), however, numerical values showed that DN1 from the 75CS:25TS recorded the highest average number of tubers of 2.75 ± 2.22 , followed by the 25CS:75TS, 2.0 ± 1.41 , 0CS:100TS (1.75 ± 0.96), 50CS:50TS (1.75 ± 0.96) and the lowest was from the 100CS:0TS (1.5 ± 0.58). While cultivar DN2, planting materials from the 50CS:50TS recorded the highest average number of tubers which is 2.5 ± 1.29 , and the lowest was observed in the 100CS:0TS (1.25 ± 0.50). Like cultivar DN1, planting materials from the 75CS:25TS in cultivar DR gained the highest average number of tubers which is 3.00 ± 0.82 while the lowest was recorded in both 100CS:0TS (1.50 ± 0.58) like in cultivar DN1 and cultivar DN2 and 0CS:100TS (1.50 ± 0.58).

Several tuber characteristics of the yam plants from the three cultivars were measured and recorded to allow further observation of the growth performance of the three cultivars. These include tuber diameter, tuber length, and fresh and dry weight.

Table 14. Average number of tubers produced by the three cultivars (DN1, DN2 and DR) grown in different growing media under field conditions.

Treatment	Cultivar		
	DN1 ^{ns}	DN2 ^{ns}	DR ^{ns}
100:0	1.5 ± 0.58	1.25 ± 0.50	1.50 ± 0.58
75:25	2.75 ± 2.22	2.00 ± 0.82	3.00 ± 0.82
50:50	1.75 ± 0.96	2.5 ± 1.29	1.75 ± 0.96
25:75	2.0 ± 1.41	2.00 ± 1.15	2.75 ± 2.06
0:100	1.75 ± 0.96	1.75 ± 1.50	1.50 ± 0.58
p-value	0.73	0.62	0.23
cv (%)	69.12	58.45	54.29

^{ns}—Not significant.

Table 15. Average tuber diameter of the three yam cultivars (DN1, DN2, and DR) grown in different growing media combinations in the nursery and later grown under field conditions.

Treatment	Cultivar		
	DN1 ^{ns}	DN2 ^{ns}	DR ^{ns}
100:0	3.0 ± 0.00	3.00 ± 0.00	3.00 ± 0.00
75:25	2.75 ± 0.50	2.75 ± 0.50	2.50 ± 0.58
50:50	2.25 ± 0.96	2.05 ± 0.74	3.00 ± 0.82
25:75	2.55 ± 0.90	2.25 ± 0.50	2.25 ± 0.50
0:100	3.0 ± 0.00	2.75 ± 1.50	2.75 ± 0.50
p-value	0.42	0.47	0.28
cv (%)	23.2	31.7	20.29

^{ns}—Not significant.

There were no significant differences across the three cultivars in tuber diameter (**Table 15**). Looking at the numerical value, it showed that DN1 from the 0CS:100TS recorded the highest average tuber diameter of 3.0 ± 0.00 , followed by the 100CS:0TS (3.0 ± 0.00), 75CS:25TS (2.75 ± 0.50), 25CS:75TS (2.55 ± 0.90) and the lowest was from the 50CS:50TS (2.25 ± 0.96). For cultivar DN2, planting materials from the 100CS:0TS recorded the highest average tuber diameter, which is 2.5 ± 1.29 , and like DN1, the lowest was observed in 50CS:50TS (2.05 ± 0.74). Unlike cultivars DN1 and DN2, planting materials from the 50CS:50TS for cultivar DR gained the highest average tuber diameter, which is 3.00 ± 0.82 , while 25CS:75TS treatment group recorded the lowest (2.25 ± 0.50) average tuber diameter.

There were no significant differences in the average tuber length produced by the cultivars DN1, DN2, and DR (**Table 16**). However, based on numerical values, DN1 from the 25CS:75TS has recorded the highest average tuber length of 2.25 ± 0.50 , followed by the 0CS:100TS (5.25 ± 0.96), 50CS:50TS (5.00 ± 1.83), 75CS:25TS (4.50 ± 0.58) and the lowest was from the 100CS:0TS (4.5 ± 1.29) (**Figure 8**). For cultivar DN2, planting materials from the 100CS:0TS recorded the highest average tuber length, which is 6.25 ± 2.06 , and the lowest was observed in the 0CS:100TS (3.25 ± 0.96). Cultivar DR recorded the highest average tuber length of 5.75 ± 1.71 from planting materials in the 50CS:50TS, while the lowest was obtained in the 25CS:75TS treatment group with an average tuber length of 3.75 ± 0.96 .

Table 16. Average tuber length of the yam cultivars DN1, DN2, and DR grown in different growing media in the nursery and later grown under field conditions.

Treatment	Cultivar		
	DN1 ^{ns}	DN2 ^{ns}	DR ^{ns}
100:0	4.5 ± 1.29	6.25 ± 2.06	4.00 ± 0.82
75:25	4.50 ± 0.58	5.00 ± 2.58	4.00 ± 0.82
50:50	5.00 ± 1.83	4.00 ± 1.41	5.75 ± 1.71
25:75	7.50 ± 5.07	3.75 ± 0.95	3.75 ± 0.96
0:100	5.25 ± 0.96	3.25 ± 0.96	5.00 ± 1.41
p-value	0.45	0.16	0.15
cv (%)	47.22	38.6	26.6

^{ns}—Not significant.

There was no significant difference in the average tuber fresh weight produced by the cultivars DN1, DN2, and DR (**Table 17**). However, based on given numerical values, DN1 from the 0CS:100TS recorded the highest average of 34.50 ± 9.00 , followed by the 50CS:50TS (33.00 ± 8.12), 100CS:0TS (29.25 ± 17.46), 75CS:25TS (28.50 ± 15.59) and the lowest was from the 25CS:75TS (25.50 ± 15.55). For cultivar DN2, planting materials from the 100CS:0TS recorded the highest average tuber fresh weight, which is 43.75 ± 15.95 and unlike DN1, the lowest was observed

in the 0CS:100TS (21.75 ± 7.14). Like cultivar DN2, planting materials from the 100CS:0TS in cultivar DR gained the highest average tuber fresh weight, which is 34.25 ± 9.43 , while the lowest was recorded in 25CS:75TS treatment group (27.75 ± 28.88) like in cultivar DN1.

Table 17. Average tuber fresh weight of the yam cultivars DN1, DN2, and DR grown in different growing media combinations in the nursery and later raised under field conditions.

Treatment	Cultivar		
	DN1 ^{ns}	DN2 ^{ns}	DR ^{ns}
100:0	29.25 ± 17.46	43.75 ± 15.95	34.25 ± 9.43
75:25	28.50 ± 15.59	36.25 ± 13.57	33.25 ± 14.34
50:50	33.00 ± 8.12	29.00 ± 13.78	30.50 ± 10.21
25:75	25.50 ± 15.55	26.00 ± 7.30	27.75 ± 28.88
0:100	34.50 ± 9.00	21.75 ± 7.14	31 ± 17.76
p-value	0.89	0.14	0.99
cv (%)	45.39	38.61	56.13

^{ns}—Not significant.

Table 18. Average tuber dry weight of the yam cultivars DN1, DN2, and DR grown in different growing media combinations in the nursery and later grown under field conditions.

Treatment	Cultivar		
	DN1 ^{ns}	DN2 ^{ns}	DR ^{ns}
100:0	8.28 ± 3.74	10.84 ± 3.74	8.21 ± 3.18
75:25	7.14 ± 3.35	9.78 ± 2.88	7.59 ± 3.92
50:50	7.83 ± 3.19	7.57 ± 4.37	8.39 ± 2.45
25:75	6.07 ± 3.62	5.90 ± 1.44	6.41 ± 6.80
0:100	8.91 ± 2.76	4.48 ± 2.80	8.65 ± 2.41
p-value	0.79	0.07	0.94
cv (%)	43.84	41.51	52.09

^{ns}—Not significant.

All three cultivars showed no significant difference; DN1 (p-0.75), DN2 (p-0.07), and DR (p-0.94) in the average tuber dry weight (**Table 18**). Cultivar DN1 from the 0CS:100TS treatment group recorded the highest average tuber dry weight of 8.91 ± 2.76 , followed by the 100CS:0TS was 8.28 ± 3.74 , 50CS:50TS was 8.28 ± 3.74 , and 75CS:25TS was 7.14 ± 3.35 . The lowest was from the 25CS:75TS (6.07 ± 3.62). Meanwhile, the highest tuber dry weight obtained by cultivar DN2 was in the 100CS:0TS (10.84 ± 3.74), which is comparable with those grown in the 75CS:25TS and 50CS:50TS combinations, which recorded an average of 7.57 ± 4.37 and 7.57 ± 4.37 , respectively. These were comparable with the 25CS:75TS,

which obtained an average tuber dry weight of 5.90 ± 1.44 and is comparable with the 0CS:100TS with 4.48 ± 2.80 . Like the DN1 cultivar DR from the 0CS:100TS recorded the highest tuber dry weight with 8.65 ± 2.41 . Additionally, planting materials from the 25CS:75TS recorded the lowest average tuber dry weight of 6.41 ± 6.80 .

The means followed by the same letter in a column are not statistically different from one another at $P \leq 0.05$ level of significance using the Least Significant Difference (LSD).

Survival rate of vine cuttings of the three locally available yam cultivars grown in different media under nursery and field conditions.

Under the nursery conditions, cultivar DN1 obtained the highest survival rate in both the 100CS:0TS and 75CS:25TS combinations (46%) while it was only 39% in the 50CS:50TS, 25CS:75TS, and 0CS:100TS combinations (**Table 19**). The cultivar DN2 grown in the 75CS:25TS combination obtained the highest survival rate of 61% followed by the 0CS:100TS combination (53%) and the lowest survival rate was at 50% in the 100CS:0TS, 50CS:50TS, and 25CS:75TS combinations. The cultivar DR obtained only a 57% survival rate at the 75CS:25TS, 50CS:50TS, and 0CS:100TS combinations, a 53% in the 25CS:75TS, and a 50% in the 100CS:0TS combinations. Under field conditions, a 75% survival rate was obtained by cultivars DN1, and DR from the 25CS:75TS while cultivar DN2 obtained 75% in the 75CS:25TS combination. A 50% survival rate was obtained by cultivar DN1 in the 75CS:25TS, 50CS:50TS and 0CS:100TS combinations while in 100CS:0TS was only 25%. While the rest of the vine cuttings grown in the other four growing media combinations obtained a 50% survival rate. Cultivar DR on the other hand, recorded a 50% survival rate in the 50CS:50TS and 0CS:100TS, and the lowest was 25% in both the 100CS:0TS and 75CS:25TS combinations.

Table 19. Survival rate (%) of the three yam cultivars (DN1, DN2 and DR) grown in different growing media combinations under nursery and field conditions.

Cultivar	Growing media	Percent survival (%)	
		Nursery	Field
DN1	100CS:0TS	46	25
	75CS:25TS	46	50
	50CS:50TS	39	50
	25CS:75TS	39	75
	0CS:100TS	39	50
DN2	100CS:0TS	50	50
	75CS:25TS	61	75
	50CS:50TS	50	50
	25CS:75TS	50	50
	0CS:100TS	53	50

Continued

	100CS:0TS	50	25
	75CS:25TS	57	25
DR	50CS:50TS	57	50
	25CS:75TS	53	75
	0CS:100TS	57	50

5. Discussion

The outcomes of this research have provided insights into the use of vine cuttings as a potential alternative in producing minitubers that can be used as planting materials. The study investigated the viability of the yam vine-cutting method grown in different growing media as a potential source of planting materials for yam production particularly for the yam species *D. rotundata* and *D. nummularia*.

The experiment involving three cultivars from the two local yam species (*D. nummularia* and *D. rotundata*) coded as DN1, DN2, and DR grown in different growing media containing different ratios of carbonized sawdust (CS) and sterilized topsoil (TS) produced some promising results. Three yam cultivars were able to produce a significant number of roots, shoots, and minitubers when grown under nursery conditions but not in the field. In addition, the study showed that cultivars DN1, DN2, and DR were able to produce minitubers when grown under nursery conditions. In line with the hypothesis of this study, the three yam cultivars showed different responses to the different growing media containing varying ratios of carbonized sawdust and sterilized topsoil. Of the five parameters observed, results showed that all three cultivars, DN1, DN2, and DR growing under nursery conditions were highly responsive to the different growing media combinations with varying degrees of significance to each of the parameters recorded. The 50CS:50TS growing media combination seemed to be the most suitable for cultivar DN1 under nursery conditions. It provided suitable conditions for root production and plant growth. In response, vine cuttings of cultivar DN1 generated a higher number of roots (4.80 ± 1.14), produced longer roots (5.32 ± 2.25), a higher number of shoots (1.35 ± 0.38) as well as initiated a higher number of minitubers (1.00 ± 0.28). Nonetheless, combination 25CS:75TS was the most favourable in producing longer shoot lengths for cultivar DN1 under nursery conditions.

Cultivar DN2 showed a positive response to the growing media combination 25CS:75TS by generating a higher number of roots (4.85 ± 1.90), producing longer root length (11.19 ± 7.13), producing a higher number of shoots (2.25 ± 0.82) and longer shoot length (11.19 ± 7.13). Nevertheless, the growing media combination 0CS:100TS gave the highest average number of tuber (1.4 ± 0.52).

Meanwhile, cultivar DR showed favourable responses to the growing media combination of 75CS:25TS by producing a higher number of roots (6.25 ± 1.89) and a higher number of shoots. However, the growing media combination 25CS:75TS

was more suitable for producing longer roots, and longer shoot lengths as well as initiating a higher number of minitubers for cultivar DR.

It was noted that the 100CS: 0TS combination, or 100 percent carbonized sawdust, was not a suitable growing media for all three cultivars, DN1, DN2, and DR under nursery conditions. This implies that even though carbonised sawdust helped improve soil physicochemical properties of the growing medium, it must be mixed with topsoil to provide suitable conditions for root initiation and plant development.

The responses of cultivars DN1, DN2, and DR to the selected suitable growing media combinations imply that the addition of carbonised sawdust helped improve the physicochemical properties of the growing media. These include improving bulk density, and increasing P concentration and carbon content, which is beneficial to microorganisms enhancing nutrient availability and leading to better plant growth. Carbonizing sawdust, also known as biochar production, can be a useful component of soil that plants can thrive in. Biochar is increasingly being used as a soil amendment that contributes a lot to improving soil growing conditions favourable to plants [31]. This is in line with the findings of Jeffery *et al.* [32] who reported that carbonizing sawdust changes its chemical and physical properties, making it more stable and less prone to nitrogen depletion. Additionally, the high carbon content in carbonized sawdust (biochar) can help sequester carbon in the soil and improve soil structure, while the porous nature of biochar can enhance water-holding capacity, nutrient retention, and microbial activity in the soil [32]. According to Atkinson *et al.* [31] and Hesham [33], carbonised sawdust was found to be capable of improving the fertility level of the soil and reducing the impacts of climate change. Biochar absorbs moisture and keeps nutrients in the soil, thus decreasing the amount of mineral fertilizer needed and protecting plants from the effects of drought stress [34]. However, the properties of the biochar material produced by the pyrolysis process are different based on the biomass and the temperature used during preparation [35]. [36] found that the addition of plant waste biochars greatly improved the aggregate properties of sandy soil, while other studies showed that applications of herbaceous and wood biochars did not affect the aggregate stability of sandy or fine sandy soils. Biochar made from sawdust feedstock has been reported to assist plant growth by improving soil physicochemical properties mostly enhancing nutrient retention by up to 59%, and nutrient content of the plant, which, was also observed in the sawdust-amended soil of the study done by [37], which enhanced nutrient concentration in soil. Unpublished results from an experiment conducted at the University of the South Pacific in Samoa Campus that tested different growing media including carbonised sawdust alone and sterilized topsoil concluded that both media are good for raising vine-propagated yams. However, plants raised on carbonised sawdust would require longer nursery time and careful management. This study found that the three yam cultivars, DN1, DN2, and DR responded differently to each growing media combination used, with each cultivar favouring a particular grow-

ing media combination when raised under nursery conditions. That is, DN1 performed better in the 50CS:50TS combination, while DN2 showed a higher response to the growing media combination 25CS:75TS. Nevertheless, the combination 75CS:25TS favours the production of a higher average number of roots and shoots by cultivar DR while growing media combination 25CS:75TS was more suitable for producing longer roots, longer shoots, and more tubers by cuttings of the same cultivar, DR. There is a possibility for future research to focus on testing these growing media combinations on the same cultivars to confirm these findings recorded in this current study. Also, to explore different materials for biochar and the addition of AMF.

Results from a pot experiment conducted by [37] to evaluate the effects of carbonized rice hulls (CRH) and arbuscular mycorrhizal (AM) fungi inoculation on potting media on chemical properties, growth, N and P uptake of *Paraserianthes falcataria* showed that charcoal application could greatly decrease soil pH in potting media. It also increases soil OC, total N, extractable P, and exchangeable K compared to unamended pots. The results of their experiment demonstrated the ability of CRH and AMF to influence soil chemical properties. Moreover, CRH is a sterile, highly porous, low bulk-density material made up of a recalcitrant form of carbon, which is more resistant to microbial decomposition [37].

The three cultivars used in this study are responsive to the growing media containing different combinations of carbonised sawdust and sterilised topsoil each favouring a particular combination of carbonised sawdust and sterilised topsoil. The most important part of the technique is to take cuttings at a very early stage in the growth of the plant when cuttings are most likely to succeed. Old and damaged or very young cuttings should also be avoided, for they are unlikely to root and shoot. Response to propagation technique also depends on varieties and their inbuilt characteristics, hence if varieties are not responsive, it will be very difficult for the cutting to produce roots [37]. The differences in the cultivar's responses in this study to the growing media could be attributed to cultivar characteristics. In other words, each cultivar possesses its own inbuilt characteristics that govern and control its growth and development as well as its responses to other factors affecting growth and production.

The other component of the tested growing media was topsoil, which has important functions in plant growth and development. Topsoil supplies a balance of valuable plant nutrients. It provides a suitable seedbed for the germination of seeds and the establishment of a rooting system for the crop. It supports a vast community of beneficial microorganisms that play a vital role in the decomposition of plant residues and the recycling of nutrients. This implies that carbonized sawdust mixed with sterilized topsoil could promote root growth and enhance shoot growth and development of the vine cuttings under nursery conditions.

Yams from vine cuttings of the three cultivars DN1, DN2, and DR transplanted from the nursery were successfully grown in the field. This facilitates the evaluation of the growth performance and survival rate of the planting materials as in-

fluenced by field conditions. Results on the growth performance of these plants based mainly on shoots and tuber characteristics revealed that cultivars DN1, DN2, and DR grown in different growing media containing different ratios of carbonized sawdust and sterilized topsoil in the nursery showed similar responses when grown under field conditions. The outcomes from the field experiment indicated that vine cuttings initially grown in 100% carbonized sawdust in the nursery generated a higher number of shoots in the field relative to vine cutting in other treatment combinations. It also produced tubers with bigger diameters and heavy fresh weights for all three yam cultivars (DN1, DN2, and DR). Furthermore, cultivar DR also produced longer tuber length, larger tuber diameter as well as heavier tuber dry weight when grown in the field. These results indicated that yam plants transplanted to the field were able to utilise the essential resources such as water and nutrients available in the soil environment in the field. This enabled them to perform the photosynthesis process more effectively to provide photosynthate to support the growing yam plants.

Unlike in the nursery, where carbonised sawdust used alone as a growing media results in a poor response by cultivars DN1, DN2, and DR to the growing media conditions. The responses of all three cultivars to the different growing media combinations were similar when taken to the field. Cultivars DN1, DN2, and DR grown in the different media combinations when transplanted in the field have all shown positive responses as expressed in the number of shoots, shoot fresh and dry weight, tuber length, tuber diameter, tuber fresh and dry weight. For instance, the 50CS:50TS combination is suitable for all three cultivars in producing a higher number of shoots (DN2), and higher shoot fresh and dry weight (DN1 and DR). Meanwhile, 0CS:100TS was favourable in producing higher tuber fresh and dry weight of cultivars DN1 and DR, while it was suitable in producing longer tuber length for cultivar DR.

The insignificant results in the field for all parameters recorded for the three yam cultivars tested could be attributed to the fact that the fully grown vine cuttings transplanted to the field were all able to have access to available resources in the soil environment. After their recovery from transplanting shock at the early stages of field transplanting, shortly after a few days, they were able to make use of water and nutrients available in the soil through root absorption to keep them growing. Leaves performed photosynthesis to provide photosynthates to support the growing yam plants and assisted with tuber formation. This implies that all these yam plants from cultivar DN1, DN2, and DR grown in the field were not restricted to utilizing the resources provided by the growing media while in the nursery. They took advantage of what the soil provided that supported further growth and development that enabled them to produce tubers that were harvested at the end of the field experiment. All yam plants grown in the field were exposed to similar soil factors such as water and nutrients as well as external factors such as temperature, humidity, and sunlight that could affect their growth and production performance in the field. Therefore, the seedling media is no longer a relevant

factor once rooted vine cuttings were transplanted and adjusted to field conditions. However, the yam planting materials with good growth performance in the nursery can survive in the field, but they may not perform better as they were in the nursery since the results in the field were not significant. Nonetheless, the good establishment of roots and shoots under nursery conditions is essential for better growth and yield performance in the field. Furthermore, shoot development and tuber production rely on the quality and physiological activity of the roots. The association of roots and shoots is an important factor in keeping these plants growing and developing until tubers are formed [38]. This result indicates that the use of vine cuttings to produce minitubers that can be used to provide yam planting materials from the three cultivars is possible. Further research into the use of vine-cutting technology focusing on how field conditions can be managed to allow vine cuttings to reach their full potential and produce better yields, will confirm these findings. The differences in the responses of vine cuttings of the three cultivars may be attributed to the physiology and biochemistry of the yam cultivars being utilized as supported by [39].

Other contributing factors to the different responses by the three cultivars may be related to the genetic characteristics of each cultivar along with environmental factors' effect. [30] observed the formation of mini tubers when studying the effect of auxins on root development in yam (*D. rotundata*) vine. In this study, the formation or production of mini tubers ranged from 1.2 to 2.1 per vine with an average size of 1.9 cm in height, 1.3 cm in width (long), 0.9 cm in width (short), and weight of 2.7 g as shown in **Figure 8**. The same study also recorded that the ease of mini tuber formation on cutting appears to be genotype-dependent. The highest survival rate in growing media combinations in the nursery for all three cultivars was 61% (DN2 grown in 75CS:25TS), while the lowest was 39% (DN1 in 50CS:50TS and 0CS:100TS). In the field, the highest percentage for survival rate was 75% (DN1 and DR from 25CS:75TS and 75CS:25TS for DN2) and the lowest was 25% (DR in 100CS:0TS and 75CS:25TS).

The higher survival rate under field conditions indicates that the vine cuttings from the nursery having well-developed root systems were able to utilize nutrients and water available from the soil in which they grow in addition to what was provided by the growing media combination. By doing so, they were also able to take advantage of the sunlight to make photo assimilate which was transferred into making tubers as well as producing more vegetative growth. Unlike when the plants were grown in the nursery, these fully grown yam plants were able to produce more shoots and more leaves to absorb more sunlight to enhance the production of photo assimilate that support plant growth and development enabling them to survive in the field. While in the nursery, the vine cuttings needed to produce and develop strong root systems to make the most of the resources produced by the growing media they were planted in. Moreover, these plants under nursery conditions were restricted to what was provided by the growing media as well as received less sunlight, which means less photosynthesis and therefore, less photo

assimilate production. Furthermore, the nutrient supply for those plants in the nursery is limited to what was provided by the growing media combination they were planted in as no supplementary feed was provided. This implies that the three yam cultivars have the potential to be propagated from vine cuttings, which grow and survive in the field after they were raised in the nursery to enable them to produce strong root systems that can help them make use of the resources in the soil after transplanting to the field. In a study on the production of mini-tubers from vine cuttings of white yam (*D. rotundata*), among the seven cultivars of *D. rotundata* evaluated, the percentage survival was between 31.0% and 77.1%. The average percentage of vine survival of the seven cultivars was 56.7% with a deviation of 16.6. It was observed that the survival rates of two cultivars were below 50%, while the survival rates of the remaining five cultivars were above average (50%) [40]. The vine cuttings grown in different media combinations utilized nutrients provided by the carbonized sawdust sterilized topsoil, and water, which was supplied manually to them daily. Their ability to make use of these resources determined their potential to produce more roots, shoots, and initiating minitubers.

This research can contribute to the limited information about the production of yam in the PICs. This will provide options on the propagation methods of planting materials for the farmers to enhance their knowledge of yam production. This propagation method is easy to administer and farmers do not require expensive equipment to make it work since the growing media used in this research are accessible to farmers. Furthermore, the results of this study will serve as a benchmark for more research to optimize propagation methods of yam in the region.

6. Conclusions

The propagation of yams by vine cuttings can be an alternative method of producing useful planting materials to help solve the problem of planting material shortages faced by yam farmers. However, for this technology to be successful, vine cuttings must be raised in suitable growing media to allow for better root growth and development to support the growing vines. In this study, vine cuttings of three yam cultivars, DN1, DN2, and DR from the two local yam species, *D. rotundata* and *D. nummularia* were grown in growing media containing different ratios of carbonized sawdust and sterilized topsoil. The growing media combinations were 100CS:0TS, 75CS:25TS, 50CS:50TS, 25CS:0TS, and 0CS:100TS grown under nursery conditions and subsequently transplanted to the field. The growing media combination of 50Carbonised Sawdust (CS):50TopSoil (TS) was the most suitable growing media for cultivar DN1 under nursery conditions as it generated a higher number of roots and longer root length. It also produced higher shoot numbers as well as a higher average number of minitubers. Cultivar DN2 seemed to respond well to the growing media combination of 25CS:75TS by producing a higher number of roots, and longer root length, as well as producing a higher average number of shoots and longer shoot length, while combination 0CS:100 fa-

vours the production of tuber for DN2. The growing media combination of 75CS:25TS favours the production of a higher number of roots and shoots for cultivar DR. On the other hand, the combination of 25CS:75TS was more suitable for producing longer roots, and longer shoots as well as initiating more minitubers for cultivar DR.

The fully grown yam plants from the vine cuttings from the three cultivars, DN1, DN2, and DR showed similar responses when grown under field conditions.

The survivability of the three cultivars grown in different media combinations under nursery conditions ranged from 39% (DN1) to 61% (DN2), while the cultivars under field conditions ranged from 25% (DN and DR) to 75% (DN1, DN2, and DR). Results showed that the use of carbonized sawdust in the growing media combination enhanced the rooting of cuttings making them stronger and surviving field conditions. The use of natural products such as sawdust can be adopted by farmers, which are accessible and cheaper for yam farmers for sustainable yam production.

Therefore, results confirmed the potential of producing tubers from vine cuttings, which can be used as planting materials to produce more crops of yams in a year. Since both the mother plant and the cut vines can produce tubers, the vine cutting method can be profitable. The success of this approach depends on the use of suitable growing media like carbonized sawdust combined with topsoil that allows better root growth and development producing strong fully grown yam plants from vine cuttings. Furthermore, the three yam cultivars DN1, DN2, and DR from the locally available yam species are suitable for use in the vine cutting method.

7. Recommendations

Farmers should be encouraged to use vine cuttings as a potential method of yam propagation and use carbonized sawdust in combination with topsoil to promote root and shoot growth of the vines to produce tubers to provide another source of planting materials to increase their yam production. Based on the results of this study, the growing media combinations of 50CS:50TS are recommended for cultivar DN1, while the combinations of 25CS:75TS for cultivar DN2, and the combinations of 75CS:25TS for cultivar DR.

It is recommended that at the early stages of using the vine propagation method, especially under nursery conditions, care must be exercised when preparing the growing media, planting the cuttings, and watering. Vine cuttings can spend a longer period in the nursery to ensure that the cuttings are well established before they can be transplanted to the field.

Farmers can also explore the use of other materials for biochar from locally available materials and the use of organic materials such as compost as their rooting media. Research on the addition of effective microorganisms to biochar is also recommended to optimize the production of yam using the vine cuttings method. Though vine cutting is not yet practiced in commercial plantings, it has a future.

Good management practices for rooting leafy vine cuttings are recommended to obtain good yield. Further research to determine the number of nodes needed for optimum survival and good yield should also be considered. But with proper timing and good management practices, more tubers can be obtained from vine cuttings in one season. Consequently, healthy seed tuber production is possible if initial vine cuttings used for field planting are obtained from healthy mother plants.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Ayensu, E.S. and Coursey, D.G. (1972) Guinea Yams the Botany, Ethnobotany, Use and Possible Future of Yams in West Africa. *Economic Botany*, **26**, 301-318. <https://doi.org/10.1007/bf02860700>
- [2] Lebot, V. (2020) Tropical Root and Tuber Crops: Cassava, Sweet Potato, Yams and Aroids. CAB International.
- [3] Shiwachi, H., Kikuno, H. and Asiedu, R. (2005) Mini-Tuber Production Using Yam (*Dioscorea rotundata*) Vines. *Tropical Science*, **45**, 163-169. <https://doi.org/10.1002/ts.22>
- [4] Kenyon, L., Lebas, B.S.M. and Seal, S.E. (2008) Yams (*Dioscorea* spp.) from the South Pacific Islands Contain Many Novel Badnaviruses: Implications for International Movement of Yam Germplasm. *Archives of Virology*, **153**, 877-889. <https://doi.org/10.1007/s00705-008-0062-5>
- [5] Lawrence, J.B. (2006) Socio-Economic Determinants of the Adoption of Yam Mini-Sett Technology in the Middle Belt Region of Nigeria. *Journal of Agricultural Science. Canadian for Science and Education*, **4**, 217-218.
- [6] Pole, F.S. (2004) Tonga Biodiversity Stocktaking. Technical Report, Taulua Press, 11-19.
- [7] Bourke, R.M. and Allen, B. (2009) Village Food Production Systems. In: Bourke, R.M. and Harwood, T., Eds., *Food and Agriculture in Papua New Guinea*, ANU Press, 193-269. <https://doi.org/10.22459/fapng.08.2009.03>
- [8] FAO (2013) Food and Agricultural Organization. FAOSTATDATA. https://www.apps.fao.org/cgi-bin/nph_db.pl
- [9] Aighewi, B.A., Asiedu, R., Maroya, N. and Balogun, M. (2015) Improved Propagation Methods to Raise the Productivity of Yam (*Dioscorea rotundata* Poir.). *Food Security*, **7**, 823-834. <https://doi.org/10.1007/s12571-015-0481-6>
- [10] Maroya, N., Balogun, M. and Asiedu, R. (2014) Seed Yam Production in Aeroponics Systems: A Novel Technology. YIIFSW. A Working Paper, International Institute of Tropical Agriculture, 9.
- [11] Balogun, M., Maroya, N., Taiwo, J., Ossai, C., Ajayi, A., Kumar, P.L., Pelemo, O., Aighewi, B. and Asiedu, R. (2017) Clean Breeder Seed Yam Tuber Production Using Temporary Immersion Bioreactors. IITA, 66.
- [12] Okoli, O.O. and Akoroda, M.O. (1995) Providing Seed Tubers for the Production of Food Yams. *African Journal of Root and Tuber Crops*, **1**, 1-6.
- [13] Nweke, F.I., Okorji, E.C., Njoku, J.E. and Kling, D.J. (1994) Expenditure Elasticity of

- Demand for Major Food Items in Southeast Nigeria. *Tropical Agriculture (Trinidad)*, **71**, 229-234.
- [14] Akoroda, M.O. and Hahn, S.K. (1995) Yams in Nigeria: Status and Trends. *African Journal of Root and Tuber Crops*, **1**, 38-41.
- [15] Kikuno, H., Matsumoto, R., Shiwachi, H., Toyohara, H. and Asiedu, R. (2007) Comparative Effects of Explants Sources and Age of Plant on Rooting, Shooting and Tuber Formation of Vine Cuttings from Yams (*Dioscorea* spp.). *Japan Journal of Tropical Agriculture*, **51**, 71-72.
- [16] Okonkwo, S.N.C. (1985) The Botany of the Yam Plant and Its Exploitation in Enhanced Productivity of the Crop. In: Osuji, G., Ed., *Advances in Yam Research: The Biochemistry and Technology of the Yam Tuber*, Biochemical Society of Nigeria and Anambra State University of Technology, 3-29.
- [17] Kumar, U. (1998) Synthetic Seeds for Commercial Crop Production. Agrobios, 160.
- [18] Standardi, A. and Piccioni, E. (1998) Recent Perspectives on Synthetic Seed Technology Using Nonembryogenic *in Vitro*-Derived Explants. *International Journal of Plant Sciences*, **159**, 968-978. <https://doi.org/10.1086/314087>
- [19] Sengupta, J., Mitra, G.C. and Sharma, A.K. (1984) Organogenesis and Tuberization in Cultures of *Dioscorea Floribunda*. *Plant Cell, Tissue and Organ Culture*, **3**, 325-331. <https://doi.org/10.1007/bf00043084>
- [20] Ammirato, P.V. (1982) Growth and Morphogenesis in Cultures of the Monocot Yam, *Dioscorea*. *Proceedings of the 5th International Congress of Plant Tissue and Cell Culture*, Tokyo, 11-16 July 1982, 169-170.
- [21] Alhassan, A.Y. and Mantell, S.H. (1991) Manipulation of Cultural Factors to Increase Microtuber Size and Frequency in Shoot Cultures of Food Yam *Dioscorea alata* L. cv. Orienta Libson. *Proceedings of the 9th Symposium of the International Society for Tropical Root Crops*, Accra, 20-26 October 1991, 342-348.
- [22] Forsyth, C. and van Staden, J. (1984) Tuberization of *Dioscorea bulbifera* Stem Nodes in Culture. *Journal of Plant Physiology*, **115**, 79-83. [https://doi.org/10.1016/s0176-1617\(84\)80053-x](https://doi.org/10.1016/s0176-1617(84)80053-x)
- [23] Mantell, S.H. (1987) Development of Microtuber Production Systems for Yam to Enable Direct Field Planting of Micro Propagated Clone Sections. In: *Summaries of the Final Reports of Research Projects of 1st Programme, 1983-86, of Science and Technology for Development: Tropical and Subtropical Agriculture*, CTA, Analytical, 187-192.
- [24] Ng, S.Y.C. and Mantell, S.H. (1996) Final Report of ODA Project R4886 (H) on Technologies for Germplasm Conservation and Distribution of Pathogen-Free *Dioscorea* Yams to National Root Crop Research Programs. Wye College/IITA/SARI, 73.
- [25] Mantell, S.H. and Hugo, S.A. (1989) Effects of Photoperiod, Mineral Medium Strength, Inorganic Ammonium, Sucrose and Cytokinin on Root, Shoot and Microtuber Development in Shoot Cultures of *Dioscorea alata* L. and *D. bulbifera* L. Yams. *Plant Cell, Tissue and Organ Culture*, **16**, 23-37. <https://doi.org/10.1007/bf00044069>
- [26] Njoku, E. (1963) The Propagation of Yams (*Dioscorea* spp.) by Vine Cutting. *Journal of West African Science Association*, **8**, 29-32.
- [27] Correll, D.S., Schubert, B.G., Gentry, H.S. and Hawley, W.O. (1955) The Search for Plant Precursors of Cortisone. *Economic Botany*, **9**, 307-375. <https://doi.org/10.1007/bf02985309>
- [28] Hartman, H.T., Kester, D.E. and Davies, F.T. (1990) *Plant Propagation: Principles and Practices*. 5th Edition, Regents Prentice Hall, 113.

- [29] Agele, S.O., Ayankanmi, T.G. and Kikuno, H. (2010) Effects of Synthetic Hormone Substitutes and Genotypes on Rooting and Mini Tuber Production of Vines Cuttings Obtained from White Yam (*Dioscorea rotundata*, Poir). *African Journal of Biotechnology*, **9**, 4714-4724.
- [30] Acha, I.A., Shiwachi, H., Asiedu, R. and Akoroda, M.O. (2004) Effect of Auxins on Root Development in Yam (*Dioscorea rotundata*) Vine. *Tropical Science*, **44**, 80-84. <https://doi.org/10.1002/ts.140>
- [31] Rollon, R.J.C., Almendras, F.A.S. and Ferraren, D.O. (2017) Effects of Biochar Application on Potting Media Chemical Properties, Arbuscular Mycorrhizal Fungi Spore Density, Growth and Nutrient Uptake of Sorghum (*Sorghum vulgare* L.). *AAB Bio-Flux*, **9**, 199-135.
- [32] Jeffery, S., Abalos, D., Prodana, M., Bastos, A.C., van Groenigen, J.W., Hungate, B.A., *et al.* (2017) Biochar Boosts Tropical but Not Temperate Crop Yields. *Environmental Research Letters*, **12**, Article ID: 053001. <https://doi.org/10.1088/1748-9326/aa67bd>
- [33] Ibrahim, H.M., Al-Wabel, M.I., Usman, A.R.A. and Al-Omran, A. (2013) Effect of Conocarpus Biochar Application on the Hydraulic Properties of a Sandy Loam Soil. *Soil Science*, **178**, 165-173. <https://doi.org/10.1097/ss.0b013e3182979eac>
- [34] Laghari, M., Naidu, R., Xiao, B., Hu, Z., Mirjat, M.S., Hu, M., *et al.* (2016) Recent Developments in Biochar as an Effective Tool for Agricultural Soil Management: A Review. *Journal of the Science of Food and Agriculture*, **96**, 4840-4849. <https://doi.org/10.1002/jsfa.7753>
- [35] Singh, B.P., Cowie, A.L. and Smernik, R.J. (2012) Biochar Carbon Stability in a Clayey Soil as a Function of Feedstock and Pyrolysis Temperature. *Environmental Science & Technology*, **46**, 11770-11778. <https://doi.org/10.1021/es302545b>
- [36] Yadav, N.K., Kumar, V., Sharma, K.R., Choudhary, R.S., Butter, T.S., Singh, G., Kumar, M. and Kumar, R. (2018) Biochar and Their Impacts on Soil Properties and Crop Productivity: A Review. *Journal of Pharmacognosy and Phytochemistry*, **7**, 49-54.
- [37] Reuben, J., Rollon, C., Rutchel, A. and Batac, S.M. (2018) Effects of Carbonised Rice Hull and Arbuscular Mycorrhizal Fungi Application on Potting Media Chemical Properties Growth and Nutrient Uptake of Falcata (*Paraserianthes falcataria* L.). *International Journal of Agronomy and Agricultural Research*, **13**, 93-101.
- [38] Atkinson, J.A., Hawkesford, M.J., Whalley, W.R., Zhou, H. and Mooney, S.J. (2019) Soil Strength Influences Wheat Root Interactions with Soil Macropores. *Plant, Cell & Environment*, **43**, 235-245. <https://doi.org/10.1111/pce.13659>
- [39] Kabeya, M. (2006) Production of Mini Tubers from Vine Cuttings of Yam (*Dioscorea rotundata*, Poir). M.Sc. Thesis, Department of Botany and Microbiology, University Ipadan, 41-47.
- [40] Kabeya, O.J.M. and Shiwachi, H. (2007) Production of Mini-Tubers from Vine Cuttings of *Dioscorea rotundata* (White Yam). *Journal of Applied Horticulture*, **9**, 167-172. <https://doi.org/10.37855/jah.2007.v09i02.37>