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Effect of Plant Growth Hormones and Liquid Fertilizer on Rooting and Tuberization of Yam (*Dioscorea rotundata* Poir.) Vine Cuttings

Dibi Konan Evrard Brice[1]*, Kouakou Amani Michel[1], Amari Ler-Ogn Dadé Georges Elisée[2], Brouth Lorng Jean Bernard[2], Dossou-Aminon Innocent[3], Essis Brice Sidoine[1], N'zue Boni[1], Dick Acka Emmanuel[2]

[1]Root and Tuber Crops Program, Food Crops Research Station, National Centre for Agronomic Research-CNRA, Bouake, Côte d'Ivoire
[2]Laboratory of Plant Physiology, Biosciences Training and Research Unit, Felix Houphouët-Boigny University, Abidjan, Côte d'Ivoire
[3]Faculty of Science and Technology of Dassa, University of Abomey-Calavi, Abomey-Calavi, Benin
Email: *dibikonan@yahoo.fr

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Abstract

Vine cutting is an effective solution to solve the problem of seed availability in yam cultivation. This study was conducted to improve the recovery and rooting rate of vine cuttings of *Dioscorea rotundata*. Two-node cuttings from five (5)-month-old hybrid plants were grown in liquid media consisting of phytohormones (AIA_3 and GA_3) and liquid fertilizer (NPK 8-8-8) at different concentrations. Observations were made weekly from the 21st day after transplanting and focused on the survival rate of the cuttings, the number of roots emitted and the number of minitubers initiated. The results obtained showed a significant effect of the different growing media on the survival rate, rooting and production of minitubers. The best survival rates were obtained for cuttings grown in NPK (8-8-8) at 0.25% (100%) and AIA_3 at 25 ppm (93.3%). The highest averages root number was recorded with growing media containing 0.25% NPK 8-8-8 (20.3) and 25 ppm AIA_3 (17.7). Growing media with 0.25% NPK (8-8-8) and 25 ppm AIA_3 provided the highest average numbers of minitubers initiated, respectively 5 and 4.6. Growing medium containing 0.25% NPK 8-8-8 has been identified as the one that allows better roots emission and minitubers production by yam vines cuttings.

Keywords

Yam, Vine Cutting, Yam Seed, Growing Medium, *Dioscorea rotundata*

1. Introduction

Yam (*Dioscorea spp*.) of the *Dioscoreaceae* family, is a tuber crop with high nutritional, economic and socio-cultural importance in the tropical world and especially in West Africa where more than 90% of world production is recorded [1] [2] [3]. In this region of Africa, yam trade accounts for about 32% of farmers' income [4]. It is a financial source for a significant portion of small producers, especially women, who are mainly involved in production, processing and marketing [5].

In Côte d'Ivoire, yam is the leading food crop with an estimated production of more than 7.148 million tons in 2017 [4]. It is the staple food for more than 56% of the Ivorian rural population [6]. It is consumed in several forms: boiled, crushed, stewed, roasted and fried. Two species contribute mainly to production: *Dioscorea rotundata*, a species native to West Africa and *Dioscorea alata* native to Southeast Asia and introduced into Africa during the 16th century [7] [8] [9].

Yam tubers are intended for two types of use. They can be directly consumed or used as planting material [10]. Yam is mainly vegetatively propagated using whole tubers or different portions of tubers [11] [12]. This vegetative propagation technique has the disadvantage that a significant portion of the harvest is saved as seed for new cultivation [10] [13]. This reduces the proportion of production available for food. On average, it is estimated that 25% to 50% of the yam harvest is converted back into seed [12] [14] [15] [16].

The availability and cost of yam seeds have thus been identified as a major limiting factor for the expansion of yam cultivation. Indeed, yam seeds are not only expensive, but also scarce [17]. They represent 40% to 60% of the total variable cost of yam production and are also bulky [18] [19] [20]. These constraints are attributed to the relatively low multiplication rate of yams, which varies from 4 to 8, as opposed to 300 for cereals [21] [22].

In addition, the increase in demographic and land tenure pressure in Côte d'Ivoire is leading to a very high demand for yam seeds [23]. It is, therefore, necessary to reduce the pressure due to the demand for seed on ware yams and to solve the seed shortage caused by the consumption of tubers. Thus, other methods of yam propagation that do not require the use of tubers or a large quantity of tubers are necessary.

Yam vine cuttings to obtain seeds are a promising alternative [12]. This technique has been tested with some success with *D. alata* and *D. rotundata*. Survival rates of 30% to 80% and average numbers of minitubers of 0.5 to 2 have been recorded [12] [22] [24]. However, the survival rate, rooting and production of minitubers remain generally low and unstable for *D. rotundata*, the most popular and commercialized species in Africa. These rates have varied from 40% to 80% on low soil or carbonized rice husk environments and are not under control [25] [26]. The aeroponics method that gives better results [11] requires the use of advanced equipment that everyone cannot afford. However, a simple nursery phase in a liquid nutrient medium could significantly increase the survival rates of cuttings [27]. To improve the rooting of yam vine cuttings, some works with varying results have been carried out using auxins or synthetic hormones [28] [29], natural hormones [30] [31] and inorganic fertilizer [32].

The objective of this study is to develop a simple and effective technique for *D. rotundata* yams vine cuttings. Specifically, the effect of two types of phytohormones (Indole-3-Acetic Acid and Gibberellic Acid) and a liquid fertilizer (NPK 8-8-8) on the survival rate, rooting and tuberization of vine cuttings are tested.

2. Materials and Methods

2.1. Study Site

The work was carried out at the Food Crops Research Station (SRCV) of the National Center for Agronomic Research (CNRA) located in Bouake in central Côte d'Ivoire (7˚46' north latitude, 5˚06' west longitude and 376 m of altitude). The climate in the study area is tropical, humid and bimodal with two rainy seasons (March-June and September-October) and two dry seasons (November February and July-August). The average annual rainfall is between 700 and 1100 mm [33].

2.2. Plant Material

The plant material consisted of vine cuttings of yam hybrids of the species *Dioscorea rotundata*. The plants are derived from the germination of seeds obtained from intraspecific crossbreeding at the Food Crops Research Station (SRCV).

2.3. Study Establishment

The experiment was carried out in a room in 250 ml glass jars placed on a workbench. The jars containing the growing media were arranged in a complete randomized block system with 3 replicates and 37 treatments. The treatments consist of the different liquid growing media tested (**Table 1**). They are represented by 3 jars containing a medium and constituting the elementary plot. Five (5) cuttings were transplanted per jar, for a total of 15 cuttings per medium (treatment) and per repetition.

The jars were placed in the room under a 12-hour photoperiod at a temperature between 24˚C and 28˚C and a relative humidity between 60% and 62%.

2.4. Growing Media

Hormonal solutions of Indole-3-Acetic Acid (AIA_3) and Gibberellic Acid (GA_3) were each prepared at the initial concentration of 100 ppm. Daughter solutions of different concentrations: 25; 50 and 75 ppm for AIA_3 and 2.5; 5 and 7.5 ppm for GA_3 were obtained after diluting the stock solutions in distilled water.

Three doses of a liquid fertilizer NPK (8-8-8) at 0.25; 0.50% and 0.75% were obtained by diluting 2.5; 5 and 7.5 ml of the fertilizer product in a final volume of 1l distilled water.

Table 1. Growing media and their composition.

Growing media		Composition
Simple growing media (AIA_3; GA_3; NPK 8-8-8)	A1	25 ppm AIA_3
	A2	50 ppm AIA_3
	A3	75ppm AIA_3
	G1	2.5 ppm GA_3
	G2	5 ppm GA_3
	G3	7.5 ppm GA_3
	D1	0.25% NPK (8-8-8)
	D2	0.5% NPK (8-8-8)
	D3	0.75% NPK (8-8-8)
Composed growing media (AIA_3 + GA_3 + NPK (8-8-8))	B1	25 AIA_3 + 2.5 GA_3 + 0.25 NPK
	B2	25 AIA_3 + 2.5 GA_3 + 0.5 NPK
	B3	25 AIA_3 + 2.5 GA_3 + 0.75 NPK
	B4	25 AIA_3 + 5 GA_3 + 0.25 NPK
	B5	25 AIA_3 + 5 GA_3 + 0.5 NPK
	B6	25 AIA_3 + 5 GA_3 + 0.75 NPK
	B7	25 AIA_3 + 7.5 GA_3 + 0.25 NPK
	B8	25 AIA_3 + 7.5 GA_3 + 0.5 NPK
	B9	25 AIA_3 + 7.5 GA_3 + 0.75 NPK
	B10	50 AIA_3 + 2.5 GA_3 + 0.25 NPK
	B11	50 AIA_3 + 2.5 GA_3 + 0.5 NPK
	B12	50 AIA_3 + 2.5 GA_3 + 0.75 NPK
	B13	50 AIA_3 + 5 GA_3 + 0.25 NPK
	B14	50 AIA_3 + 5 GA_3 + 0.5 NPK
	B15	50 AIA_3 + 5 GA_3 + 0.75 NPK
	B16	50 AIA_3 + 7.5 GA_3 + 0.25 NPK
	B17	50 AIA_3 + 7.5 GA_3 + 0.5 NPK
	B18	50 AIA_3 + 7.5 GA_3 + 0.75 NPK
	B19	75 AIA_3 + 2.5 GA_3 + 0.25 NPK
	B20	75 AIA_3 + 2.5 GA_3 + 0.5 NPK
	B21	75 AIA_3 + 2.5 GA_3 + 0.75 NPK
	B22	75 AIA_3 + 5 GA_3 + 0.25 NPK
	B23	75 AIA_3 + 5 GA_3 + 0.5 NPK
	B24	75 AIA_3 + 5 GA_3 + 0.75 NPK
	B25	75 AIA_3 + 7.5 GA_3 + 0.25 NPK
	B26	75 AIA_3 + 7.5 GA_3 + 0.5 NPK
	B27	75 AIA_3 + 7.5 GA_3 + 0.75 NPK
	Control	Water

Hormonal solutions (25; 50 and 75 ppm AIA_3; 2.5; 5 and 7.5 ppm GA_3) and doses of NPK 8-8-8 (0.25%; 0.50% and 0.75%) were put separately in jars to form different simple growing media. Growing media composed of mixtures of the different concentrations of hormonal solutions with the doses of liquid fertilizer, have also been developed. Each jar contained 125 ml of the final growing medium solution (**Table 1**).

2.5. Sampling, Preparation and Transplanting of Cuttings

Vine cuttings with two nodes were collected with scissors from five (5) month old yam hybrids of *D. rotundata* growing in a screen house. They were soaked in water during transportation to the growing room to avoid dehydration. Seventy five percent (75%) of the cuttings were stripped of their leaves to reduce leaf transpiration. One of the leaves at the top was left in place to allow breathing and photosynthetic activity [34]. The transplanting was carried out by plunging the basal part (basal node) of the cuttings into the different growing media contained in the glass jars.

2.6. Data Collection

Observations and measurements were made weekly from the 21st day after transplanting. They focused on the survival rate of vine cuttings, the number of roots emitted (primary and secondary roots) and the number of minitubers initiated.

2.7. Statistical Analysis

The one-factor analysis of variance was performed using STATISTICA version 7.1 software. The Newman-Keuls mean comparison test was applied at the 5% threshold in cases significant effects were observed between treatments.

3. Results

The results recorded concern the survival rate and the number of roots and minitubers initiated by vine cuttings in the different growing media (**Figure 1**).

3.1. Effects of Different Growing Media on the Survival Rate of Cuttings

For media containing AIA_3 (**Figure 2**), the highest survival rate value was 93.3%. It was recorded with the growing medium containing the lowest concentration of AIA_3 (A1 = 25 ppm). This rate is significantly different ($p = 0.00$) from those recorded with media with concentrations (A2 and A3) of 0; 50 and 75 ppm AIA_3. For these concentrations, the exercise rates are 40%, 73.3% and 60% respectively. No significant differences were noted between media at 50 and 75 ppm AIA_3.

The highest average survival rate for GA_3-based media was 60% (**Figure 3**). It was obtained with the lowest concentration (G1) which is 2.5 ppm. This survival rate is about the double and significantly different ($p = 0.00$) from those of cuttings grown in media (G2 and G3) containing 5 and 7.5 ppm GA_3 as well as in the control medium containing only water (C).

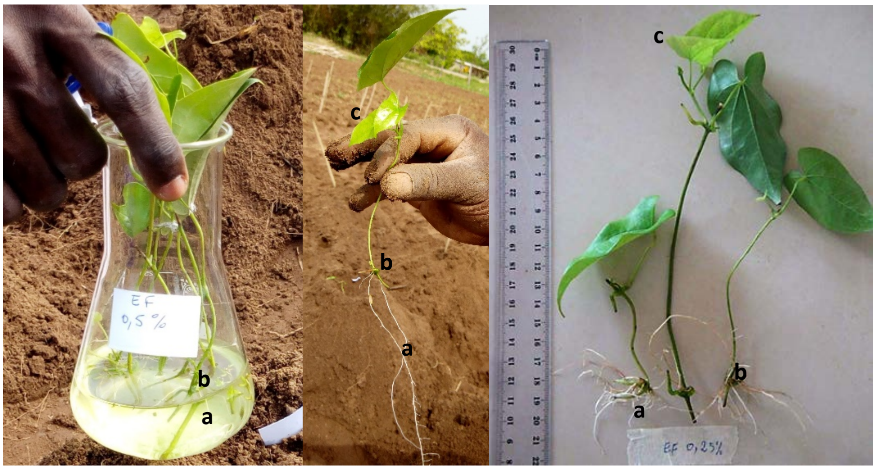

Figure 1. Vine cuttings growing in a liquid media in a jar with roots and minitubers initiated. a: Roots; b: minituber initiated; c: new leaf generated.

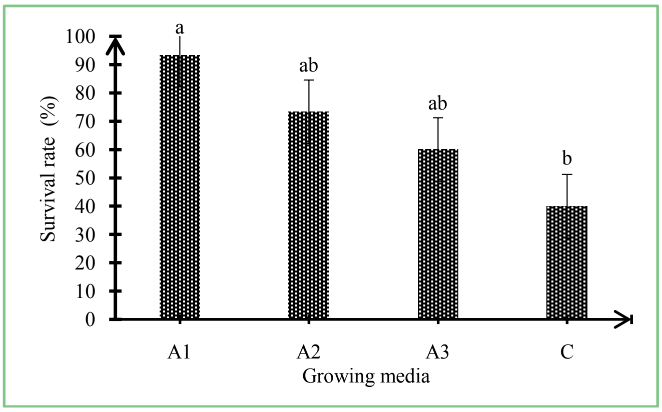

Figure 2. Survival rate of vine cuttings in growing media containing different concentrations of indole-3-acetic acid (AIA_3). A1: 25 ppm; A2: 50 ppm; A3: 75 ppm; C: Control (water).

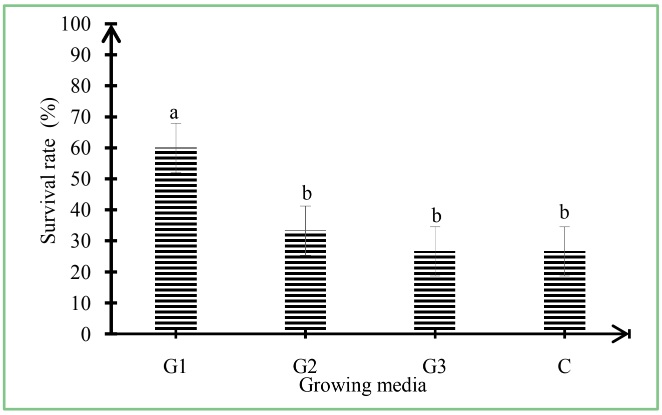

Figure 3. Survival rate of vine cuttings in growing media containing different concentrations of gibberellic acid (GA_3). G1: 2.5 ppm; G2: 5 ppm; G3: 7.5 ppm; C: Control (water).

For media containing liquid fertilizer NPK 8-8-8 (**Figure 4**), a significant effect ($p = 0.01$) was also observed between them. The lowest dose of liquid fertilizer (D1) of 0.25% resulted in a 100% survival rate. With media D2 and D3 containing 0.5% and 0.75% respectively, the survival rates were lower (60%).

The average survival rates of cuttings are significantly different in growing media composed of combinations of hormonal solutions (AIA_3 and GA_3) and liquid fertilizer NPK 8-8-8 (**Table 2**). Growing media B2 (25 ppm AIA_3 + 5 ppm GA_3 + 0.5% NPK), B11 (50 ppm AIA_3 + 2.5 ppm GA_3 + 0.5% NPK 8-8-8) and B22 (75 ppm AIA_3 + 5 ppm GA_3 + 0.25% NPK 8-8-8) showed the highest survival rates of 66.6%; 62.4% and 60.0% respectively.

3.2. Effects of Different Growing Media on Root Emission of Cuttings

The average number of roots assessed 21 days after transplanting the cuttings was higher (11.7) with the medium containing the lowest dose of AIA_3 (**Figure 5**) which was 25 ppm (A1). At this date, treatments A2 (50 ppm AIA_3), A3 (75 ppm AIA_3) and the control (C = without auxin) have induced 6, 4 and 3.3 roots per cuttings respectively. Subsequently, root numbers increased in all media. The values recorded 35 days after transplanting the cuttings were 17.7, 14, 10.3 and 6.7 respectively for growing media A1, A2, A3 and the control.

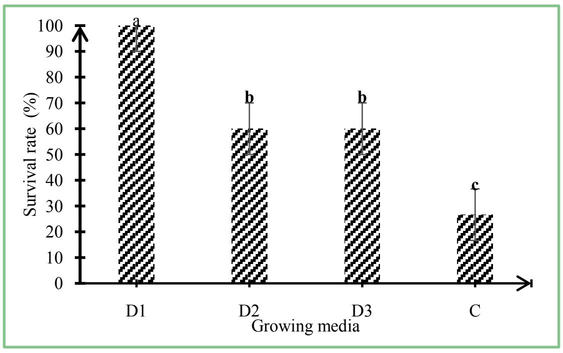

Figure 4. Survival rate of vine cuttings in growing media containing different concentrations of liquid fertilizer (NPK 8-8-8). D1: 0.25%; D2: 0.5%; D3: 0.75%; C: Control (water).

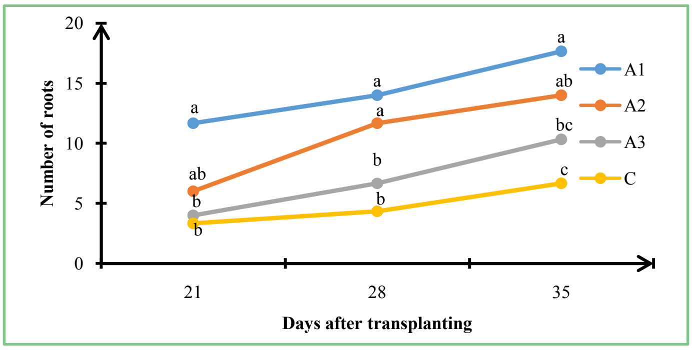

Figure 5. Root emission of vine cuttings in growing media containing different concentrations of indole-3-acetic acid (AIA_3). A1: 25 ppm; A2: 50 ppm; A3: 75 ppm; C: Control (water).

Table 2. Survival rates means of vine cuttings in growing media consisting of mixtures of hormonal solutions (AIA_3 and GA_3) and liquid fertilizer (NPK 8-8-8).

Growing media	Composition	Survival rates means (%)
B1	25 AIA_3 + 2.5 GA_3 + 0.25 NPK	0.0e
B2	25 AIA_3 + 2.5 GA_3 + 0.5 NPK	66.6a
B3	25 AIA_3 + 2.5 GA_3 + 0.75 NPK	40.0b
B4	25 AIA_3 + 5 GA_3 + 0.25 NPK	33.3b
B5	25 AIA_3 + 5 GA_3 + 0.5 NPK	26.6bcde
B6	25 AIA_3 + 5 GA_3 + 0.75 NPK	26.6bcde
B7	25 AIA_3 + 7.5 GA_3 + 0.25 NPK	26.6bcde
B8	25 AIA_3 + 7.5 GA_3 + 0.5 NPK	40.0b
B9	25 AIA_3 + 7.5 GA_3 + 0.75 NPK	20.0bcde
B10	50 AIA_3 + 2.5 GA_3 + 0.25 NPK	10.0cde
B11	50 AIA_3 + 2.5 GA_3 + 0.5 NPK	62.4a
B12	50 AIA_3 + 2.5 GA_3 + 0.75 NPK	20.0bcde
B13	50 AIA_3 + 5 GA_3 + 0.25 NPK	26.6bcde
B14	50 AIA_3 + 5 GA_3 + 0.5 NPK	20.0bcde
B15	50 AIA_3 + 5 GA_3 + 0.75 NPK	6.6cde
B16	50 AIA3 + 7.5 GA3 + 0.25 NPK	20.0bcde
B17	50 AIA_3 + 7.5 GA_3 + 0.5 NPK	14.0bcde
B18	50 AIA_3 + 7.5 GA_3 + 0.75 NPK	0.0e
B19	75 AIA_3 + 2.5 GA_3 + 0.25 NPK	13.3bcde
B20	75 AIA_3 + 2.5 GA_3 + 0.5 NPK	20.0bcde
B21	75 AIA_3 + 2.5 GA_3 + 0.75 NPK	20.0bcde
B22	75 AIA_3 + 5 GA_3 + 0.25 NPK	60.0a
B23	75 AIA_3 + 5 GA_3 + 0.5 NPK	26.6bcde
B24	75 AIA_3 + 5 GA_3 + 0.75 NPK	20.0bcde
B25	75 AIA_3 + 7.5 GA_3 + 0.25 NPK	20.0bcde
B26	75 AIA_3 + 7.5 GA_3 + 0.5 NPK	20.0bcde
B27	75 AIA_3 + 7.5 GA_3 + 0.75 NPK	20.0bcde
Control	Water	26.6bcde
P-value		0.00

Survival rates means followed by the same letter in a column are not significantly different at a probability threshold of 5%, according to the Newman-Keuls mean comparison test.

The growing medium with the lowest concentration of gibberellin G1 (2.5 ppm of GA_3) and the control medium without this hormone induced the highest mean root numbers (**Figure 6**). For these media, the values increased from 5.3 and 4 respectively on the 21st day after transplanting the cuttings to 6.3 on the 35th day. In other respects, the lowest average numbers of roots emitted by yam cuttings were recorded in the case of G2 (5 ppm of GA_3) and G3 (7.5 ppm of

GA_3) treatments. For the latter media, the values ranged from 2.7 to 4 and 1.3 to 3 roots on average from day 21 to day 35 after transplanting.

Between the 21st and 35th days after transplanting the cuttings, the average number of roots formed varied from 12 to 20.3 in medium D1 (0.25% NPK) and from 9.3 to 17.7 on average in medium D2 (0.5% NPK) and D3 (0.75% NPK). The average number of roots of cuttings in water (control) increased from 4 to 6.3 (Figure 7).

For the combination of the 3 products, 21 days after transplanting, yam vine cuttings emitted a greater number of roots in B2 medium (25 ppm AIA_3 + 2.5 ppm GA_3 + 0.5% NPK 8-8-8) than in other combined media (Table 3). However, on average 7.5 and 6.5 roots were emitted by the cuttings respectively in the media B11 (50 ppm AIA_3 + 2.5 ppm GA_3 + 0.5% NPK 8-8-8) and B22 (75 ppm AIA_3 + 5 ppm GA_3 + 0.25% NPK 8-8-8). On the thirty-fifth day after transplanting, the highest numbers of roots emitted by cuttings were 16.5 in B2 medium (25 ppm AIA_3 + 2.5 ppm GA_3 + 0.5% NPK 8-8-8) and 9.5 in B3 medium (25 ppm AIA_3 + 2.5 ppm GA_3 + 0.75% NPK 8-8-8) and B22 (75 ppm AIA_3 + 5 ppm GA_3 + 0.25% NPK 8-8-8).

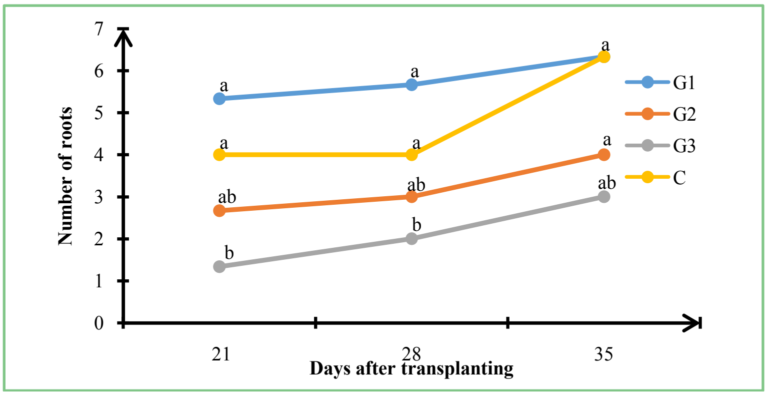

Figure 6. Root emission of vine cuttings in growing media containing different concentrations of gibberellic acid (GA_3). G1: 2.5 ppm; G2: 5 ppm; G3: 7.5 ppm; C: Control (water).

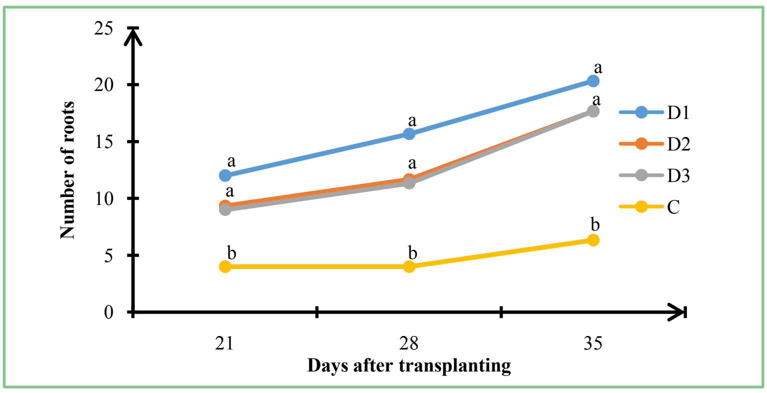

Figure 7. Root emission of vine cuttings in growing media containing different concentrations of liquid fertilizer (NPK 8-8-8). D1: 0.25%; D2: 0.5%; D3: 0.75%; C: Control (water).

Table 3. Roots numbers means observed on yam vine cuttings at different dates after transplanting into growing media consisting of mixtures of hormonal solutions (AIA_3 and GA_3) and liquid fertilizer (NPK 8-8-8).

Growing media	Compositions	Number of roots		
		Days after transplanting		
		21	28	35
B1	25 AIA_3 + 2.5 GA_3 + 0.25 NPK	0.0c	0.0c	0.0c
B2	25 AIA_3 + 2.5 GA_3 + 0.5 NPK	9.5a	13a	16.5a
B3	25 AIA_3 + 2.5 GA_3 + 0.75 NPK	4.5abc	7ab	9.5ab
B4	25 AIA_3 + 5 GA_3 + 0.25 NPK	0.5c	0.5c	1.0c
B5	25 AIA_3 + 5 GA_3 + 0.5 NPK	0.0c	2.0bc	2.0bc
B6	25 AIA_3 + 5 GA_3 + 0.75 NPK	4.0abc	5.5ab	9.5ab
B7	25 AIA_3 + 7.5 GA_3 + 0.25 NPK	0.0c	0.5c	0.5c
B8	25 AIA_3 + 7.5 GA_3 + 0.5 NPK	0.0c	0.0c	0.0c
B9	25 AIA_3 + 7.5 GA_3 + 0.75 NPK	1.5bc	3.5abc	5abc
B10	50 AIA_3 + 2.5 GA_3 + 0.25 NPK	0.0c	2.5abc	2.5bc
B11	50 AIA_3 + 2.5 GA_3 + 0.5 NPK	7.5ab	8.5ab	9.0ab
B12	50 AIA_3 + 2.5 GA_3 + 0.75 NPK	0.5c	1.0bc	1.5c
B13	50 AIA_3 + 5 GA_3 + 0.25 NPK	1.0bc	5.5abc	6.5ab
B14	50 AIA_3 + 5 GA_3 + 0.5 NPK	4.0abc	4.0abc	5.0abc
B15	50 AIA_3 + 5 GA_3 + 0.75 NPK	0.0c	0.0c	0.0c
B16	50 AIA_3 + 7.5 GA_3 + 0.25 NPK	0.0c	0.0c	0.0c
B17	50 AIA_3 + 7.5 GA_3 + 0.5 NPK	6.0ab	6.5ab	6.5ab
B18	50 AIA_3 + 7.5 GA_3 + 0.75 NPK	0.0c	0.0c	0.0c
B19	75 AIA_3 + 2.5 GA_3 + 0.25 NPK	0.0c	0.0c	0.0c
B20	75 AIA_3 + 2.5 GA_3 + 0.5 NPK	1.5bc	2.5bc	4.0abc
B21	75 AIA_3 + 2.5 GA_3 + 0.75 NPK	0.0c	5.5abc	5.5abc
B22	75 AIA_3 + 5 GA_3 + 0.25 NPK	6.5ab	9.0a	9.5ab
B23	75 AIA_3 + 5 GA_3 + 0.5 NPK	0.5c	0.5c	0.5c
B24	75 AIA_3 + 5 GA_3 + 0.75 NPK	2.0bc	2.5bc	3.5bc
B25	75 AIA_3 + 7.5 GA_3 + 0.25 NPK	0.0c	2bc	2.0bc
B26	75 AIA_3 + 7.5 GA_3 + 0.5 NPK	0.0c	0.5c	0.5bc
B27	75 AIA_3 + 7.5 GA_3 + 0.75 NPK	2.5bc	4.5abc	7.0ab
Control	Water	5.5abc	6ab	7.5ab
P-value		0.00		

Roots numbers means followed by the same letter in a column are not significantly different at a probability threshold of 5%, according to the Newman-Keuls mean comparison test.

3.3. Effects of Different Growing Media on the Number of Minitubers Initiated

Cuttings transplanted into growing media containing 25 and 50 ppm of AIA_3 initiated on average 4.6 and 3.6 minitubers respectively (Table 4). These numbers of minitubers are the double of those initiated in growing media containing 75 ppm AIA_3 and in the control medium.

On media containing GA_3, there was no significant difference for the production of minitubers (Table 5). Indeed, cuttings grown in media containing 2.5 and 5 ppm of GA_3 produced an average of one (01) minitubert. Cuttings grown in the medium containing 7.5 ppm GA_3 and in the control medium did not produce any minituber.

The average numbers of minitubers produced by the cuttings are significantly different between growing media containing different doses of liquid fertilizer (Table 6). The largest numbers of minitubers were produced in media D1 at 0.25% NPK (5.0 ± 0.0) and D3 at 0.75% NPK (4.0 ± 1.1). Cuttings grown in medium D2 containing 0.5% NPK produced an average of 3.3 ± 0.3 minitubers. The cuttings did not produce any minitubers in the water control medium.

A significant difference ($p = 0.00$) is noted between the different growing media containing a mixture of the three (3) types of elements (Table 7). The average number of minitubers (3.0 ± 0.0) obtained in B2 medium (25 ppm AIA_3 + 2.5 ppm GA_3 + 0.5% NPK 8-8-8) was the highest. The cuttings transplanted into the B6 medium (25 ppm AIA_3 + 5 ppm GA_3 + 0.75% NPK 8-8-8), had an average number of minitubers of 2.0 ± 0.5. The other combinations of media produced one or no minitubers.

Table 4. Number of minitubers initiated by vine cuttings in growing media containing different concentrations of indole-3-acetic acid (AIA_3).

Growing media	Compositions	Number of minitubers initiated
A1	25 ppm AIA_3	4.6 ± 0.3a
A2	50 ppm AIA_3	3.6 ± 0.6a
A3	75 ppm AIA_3	1,6 ± 0.3b
Control	water	0.0 ± 0.0b
P-value		0.00

Minitubers numbers means followed by the same letter in a column are not significantly different at a probability threshold of 5%, according to the Newman-Keuls mean comparison test.

Table 5. Number of minitubers initiated by vine cuttings in growing media containing different concentrations of gibberellic acid (GA_3).

Growing media	Compositions	Number of minitubers initiated
G1	2.5 ppm GA_3	1.0 ± 0.0a
G2	5 ppm GA_3	1.0 ± 0.0a
G3	7.5 ppm GA_3	0.0 ± 0.0a
Control	water	0.0 ± 0.0a
P-value		0.1

Minitubers numbers means followed by the same letter in a column are not significantly different at a probability threshold of 5%, according to the Newman-Keuls mean comparison test.

Table 6. Number of minitubers initiated by vine cuttings in growing media containing different concentrations of liquid fertilizer (NPK 8-8-8).

Growing media	Compositions	Number of minitubers initiated
D1	0.25% NPK	5.0 ± 0.0a
D2	0.5% NPK	3.3 ± 0.3ab
D3	0.75% NPK	4.0 ± 1.1a
Control	water	0.0 ± 0.0b
P-value		0.01

Minitubers numbers means followed by the same letter in a column are not significantly different at a probability threshold of 5%, according to the Newman-Keuls mean comparison test.

Table 7. Number of minitubers initiated by vine cuttings in growing media consisting of mixtures of hormonal solutions (AIA_3 and GA_3) and liquid fertilizer (NPK 8-8-8).

Growing media	Compositions	Number of minitubers initiated
B1	25 AIA_3 + 2.5 GA_3 + 0.25 NPK	0.0 ± 0.0b
B2	25 AIA_3 + 2.5 GA_3 + 0.5 NPK	3.0 ± 0.0a
B3	25 AIA_3 + 2.5 GA_3 + 0.75 NPK	1.3 ± 1.3ab
B4	25 AIA_3 + 5 GA_3 + 0.25 NPK	0.0 ± 0.0b
B5	25 AIA_3 + 5 GA_3 + 0.5 NPK	0.0 ± 0.0b
B6	25 AIA_3 + 5 GA_3 + 0.75 NPK	2.0 ± 0.5ab
B7	25 AIA_3 + 7.5 GA_3 + 0.25 NPK	0.0 ± 0.0b
B8	25 AIA_3 + 7.5 GA_3 + 0.5 NPK	1.3 ± 1.3ab
B9	25 AIA_3 + 7.5 GA_3 + 0.75 NPK	03 ± 0.3b
B10	50 AIA_3 + 2.5 GA_3 + 0.25 NPK	0.0 ± 0.0b
B11	50 AIA_3 + 2.5 GA_3 + 0.5 NPK	1.6 ± 0.8ab
B12	50 AIA_3 + 2.5 GA_3 + 0.75 NPK	0.0 ± 0.0b
B13	50 AIA_3 + 5 GA_3 + 0.25 NPK	1.0 ± 0.0ab
B14	50 AIA_3 + 5 GA_3 + 0.5 NPK	1.0 + 0.0ab
B15	50 AIA_3 + 5 GA_3 + 0.75 NPK	0.3 ± 0.3b
B16	50 AIA_3 + 7.5 GA_3 + 0.25 NPK	0.5 ± 0.5b
B17	50 AIA_3 + 7.5 GA_3 + 0.5 NPK	0.3 ± 0.3b
B18	50 AIA_3 + 7.5 GA_3 + 0.75 NPK	0.0 ± 0.0b
B19	75 AIA_3 + 2.5 GA_3 + 0.25 NPK	0.6 ± 0.3ab
B20	75 AIA_3 + 2.5 GA_3 + 0.5 NPK	0.6 ± 0.3b
B21	75 AIA_3 + 2.5 GA_3 + 0.75 NPK	0.6 ± 0.3b
B22	75 AIA_3 + 5 GA_3 + 0.25 NPK	1.3 ± 0.6ab
B23	75 AIA_3 + 5 GA_3 + 0.5 NPK	0.0 ± 0.0b
B24	75 AIA_3 + 5 GA_3 + 0.75 NPK	1.0 ± 0.0ab
B25	75 AIA_3 + 7.5 GA_3 + 0.25 NPK	1.0 ± 0.0ab
B26	75 AIA_3 + 7.5 GA_3 + 0.5 NPK	0.3 ± 0.3ab
B27	75 AIA_3 + 7.5 GA_3 + 0.75 NPK	1.0 ± 0.0ab
Control	water	0.0 ± 0.0b
P-value		0.003

Minitubers numbers means followed by the same letter in a column are not significantly different at a probability threshold of 5%, according to the Newman-Keuls mean comparison test.

4. Discussion

Among all the growing media tested, the best survival rates of *Dioscorea rotundata* vine cuttings were obtained in media containing 0.25% NPK 8-8-8 (100%), 25 ppm AIA_3 (93.3%), 25 ppm AIA_3 + 5 ppm GA_3 + 0.5% NPK (66.6%) and 2.5 ppm GA_3 (60%). It appears that the survival rates in media containing 0.25% NPK 8-8-8 and 25 ppm AIA_3 respectively are higher than those obtained by Igwilo (2003) [35] and Dibi *et al.* (2014) [25] on solid media consisting of coarse construction sand and carbonized rice husks. Indeed, these authors reported survival rates of 71% and 68% respectively. In addition, AIA_3 favoured root development in *D. rotundata* vine cuttings. Indole-3 acetic acid (AIA_3) is an auxin which is a plant growth hormone essential for plant development. Also known as cuttings hormone, auxin acts at a high concentration (between 10-8 and 10-3 $g \cdot L^{-1}$) on rhizogenesis, promoting the appearance of roots on cuttings [36]. The liquid growing medium containing mineral elements such as nitrogen (N), phosphorus (P) and potassium (K) at a rate of 0.25% favored the survival of vine cuttings of *Dioscorea rotundata*. In fact, the positive action of mineral elements on the development of yam vine cuttings has been reported by several authors. According to Otoo *et al.* (2016) [22], in general, improving the nutritional status of mother plants through nutrient supplementation (NPK 15-25-8) before cutting vines has improved survival rates by more than 16% and ensures good subsequent development of minitubers. It has also been found that spraying urea on vine cuttings of *Dioscorea alata* facilitates rooting, increases the size of the minitubers and increases the number of roots per cut; but the survival rate decreases with increasing urea concentration [32]. The average survival rate of vine cuttings in the growing medium containing 2.5 ppm GA_3 (60%) is similar to that obtained by Behera *et al.* (2009) [32]. These authors obtained survival rates of 60.02% for *Dioscorea alata* vine cuttings when dipped in a solution containing 10 ppm GA_3 followed by NPK (100-100-100) on a solid medium consisting of a mixture of sand and cow dung.

The rooting is an essential parameter in the management of cuttings. It is observed 15 days to 3 weeks on average after transplanting vine cuttings of the species *D. rotundata* and *D. cayenensis* [37]. This is confirmed by Ayankanmi *et al.* (2010) [38] who found the formation of roots of vine cuttings from two clones of *D. rotundata* three weeks after transplanting onto a medium containing sand. In addition, Igwilo (2003) [35] reported that after 14 days, cuttings of the Obiaoturugo variety (*D. rotundata*) showed a high rooting rate. In our study, the highest mean root number was recorded with growing media containing 0.25% NPK 8-8-8 (20.3), 25 ppm AIA_3 (17.7) and mixed media 25 ppm AIA_3 + 5 ppm GA_3 + 0.5% NPK (16.5). These environments favored the increase in the number of roots from the 21st day to the 35th day. These average numbers of roots of cuttings are similar to those obtained by other authors. Work by Acha *et al.* (2004) [28] showed that auxin (AIA_3) induced an increase in the number of roots of vine cuttings of 10 cultivars of *D. rotundata* from 15 to 30 days after transplanting. It induces the formation of new roots by overcoming root apical dominance resulting from the cytokinin effect [39]. Behera *et al.* (2009) [32] showed that treatment with 2% urea increased the number of roots per cut (38.16%) on the 20th day after transplanting. The results obtained in our study corroborate those of Igwilo (2003) [35]. According to these authors, the use of a hormonal solution composed by 50 ppm AIA_3, 5 ppm GA_3 and 10 ppm Benzyladenin increases the number of roots per vine cuttings of *D. rotundata*. However, the average number of roots of cuttings in GA_3-based growing media would be lower than that of the control because the concentrations of GA_3 used would appear low to induce an increase in the number or growth of roots. However, the root numbers obtained with 2.5 ppm gibberellic acid are higher than those obtained by Behera *et al.* (2009) [32] who found that with 1 ppm GA_3, the root number per cut can be improved.

The average numbers of minitubers initiated by vine cuttings in the different growing media at 25 ppm AIA_3, 0.25% NPK 8-8-8 and the medium containing 25 ppm AIA_3 + 5 ppm GA_3 + 0.5% NPK 8-8-8 are 4.6 ± 0.3 ; 5.0 ± 0.0 and 3.3 ± 0.0 respectively. These numbers of minitubers obtained are higher than those reported by Dibi *et al.* (2014) [25] which were 1.03 ± 0.3 and 1.73 ± 0.86. Ayankanmi *et al.* (2010) [38] also obtained poorer results on a rice husk-based growing medium with 0.6 and 0.7 per cut. These differences could be due to the types of media used. The nutrient richness of the medium, its texture and structure influence the formation and development of minitubers [22]. In this study, liquid media were fortified with growth hormones and nutrients, while most authors used solid media based on soil and carbonized rice husks. GA_3 growing media produced very little or no minitubers. No significant differences were observed between the numbers of minitubers initiated by cuttings in GA_3. Our results are in line with those of Kefi *et al.* (1995) [40] who reported that gibberellic acid inhibits tuberization in yams. This is confirmed by Behera *et al.* (2009) [32] who found no significant difference between the numbers of minitubers initiated by vine cuttings treated with different concentrations of gibberellic acid.

The nature and age of the mother plants of the cuttings used could also explain the differences in results observed from one experimenter to another [24]. In this study, vine cuttings were collected from seedlings of 5-month-old grown in a screen house. Other authors have used vitro-plants as mother plants or yam plants grown in the field, whose age varied from 2 to 5 months [22] [35] [38].

5. Conclusion

The growing media used in this work produced average survival rates of *Dioscorea rotundata* vine cuttings between 60% and 100% and average root numbers between 5.3 and 17.7. Growing medium containing 0.25% NPK 8-8-8 has been identified as the one that allows better survival rate, root emission and minituber production by yam vine cuttings. As this nutrient compound is cheaper and more accessible, it is possible to improve the survival rate and rooting of vine cuttings that will allow the production of yam seeds without the use of tubers. However, for the standardization of this technic for yam vine cuttings, further studies will have to be carried out, including the definition of the stage and conditions for transplanting vine cuttings from the nursery room to the field.

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Conflicts of Interest

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

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