Field Performance of Seed Yam (*Dioscorea rotundata* Poir) Derived from Tissue Culture and Aeroponics Seedlings

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**Abstract**

A major constraint to yam production in Ghana has been lack of quality seed. Tissue culture and aeroponics seedlings were explored for the rapid production of disease-free and high quality seed yam in large quantities. This preliminary study was conducted in a forest agro ecological zone in Ghana to assess the field performance of the growth and yield of seed yams generated from tissue culture and aeroponics seedlings. Four hundred tissue culture seedlings of TDr 95/19177 were planted in April 2015. The survival percentage from the seedlings reduced from 100% at planting to 42% at 159 days after planting (DAP). At harvest, 6 months after planting (MAP), the tubers were sorted into four different groups based on their sizes. Four hundred and eleven (411) numbers of tubers with a total tuber yield of 13.99 t/ha were harvested. Group 1 (0.33 kg) recorded the highest total tuber yield of 7.83 t/ha followed by group 2 (0.17 kg) 3.99 t/ha, group 3 (0.07) 1.69 t/ha and group 4 (0.02) 0.48 t/ha respectively. In March 2017, both TDr 95/19177 and Mankrong pona aeroponics yam seedlings were planted on the field. The number of survived seedlings reduced from 100% at planting to 38% and 45% for TDr 95/19177 and Mankrong pona respectively after 65 DAP. Harvesting the tubers at 8 months after planting (MAP) instead of 6 MAP, did not result in any major change in the harvested tuber number and yield. TDr 95/19177 yielded 48.12 t/ha and 50.75 t/ha from 429 and 413 numbers of tubers harvested respectively after 6 and 8 MAP. Mankrong pona yielded 41.67 t/ha and 22.67 t/ha from 19 and 11 number of tubers harvested respectively after 6 and 8 MAP. The average weight per tuber and total tuber yield were higher in plants derived from aeroponics compared to that from the tissue culture at the same time of harvest. The results suggested that both tissue culture and aeroponics system are useful means to ensure reliable source of clean seed yam for enhanced yam production. There is however the need for further studies on the factors that influence their establishment on the field.

**Keywords:** Seed Yam; *Dioscorea rotundata*; Tissue Culture; Aeroponics Seedlings; Ghana

**Introduction**

Yam plays an important role in the livelihoods of people in the yam growing regions of the yam belt in West Africa. It forms the dominant crop in these areas and serves as an important source of income to the people [1]. The crop is generally cultivated from farmers’ saved seed yams from previous harvests. This traditional way of cultivating yam usually leads to significantly low yields as a result of a build-up of pests and diseases accumulated through recycling of infested seed yams [2]. Tuber yield weight of 20 - 30% is lost annually at harvest as a result of pests and diseases of seed yam [3].

The use of healthy seed yams is therefore essential for high and sustainable yam production and storability. Healthy and quality seed yam is however scarce as a result of the low propagation ratio of the crop. Yam farmers therefore resort to the use of diseased and pest infested seed yam resulting in the production of small and poor quality ware yams.

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Modern techniques such as tissue culture and aeroponics system for rapid production of disease-free and high quality seed yam in large quantities are being explored for yam propagation [4]. Tissue culture is the growth of small pieces of plant tissue in a nutrient medium under sterile conditions in a glass or plastic vessels to generate whole plant [5]. The production cycles can be planned as it is carried out in a controlled laboratory environment which is not susceptible to changing weather conditions [6]. Aeroponics is the method of growing plants in a soilless culture where their roots are kept in a dark environment saturated with aerosol of nutrient solution [7].

Little information is, however, available on the field performance of yam established from tissue culture and aeroponics seedlings despite the potential advantages of the technologies in ensuring mass production of disease-free seedlings.

Objective of the Study

The objective of this study was to assess the field performance of seed yam generated from tissue culture and single nodes established from aeroponics.

Materials and Methods

Study area

The studies were conducted on a research field of the Council for Scientific and Industrial Research (CSIR)-Crops Research Institute (CRI) at Fumesua, Kumasi-Ghana from April 2015 to December 2015 (using tissue culture seedlings) and March 2017 to December 2017 (using aeroponics seedlings) respectively. Fumesua is located on latitude 06°41′N and longitude 01°28′W in the humid forest agro-ecological zone of Ghana. The area is characterized by a bimodal rainfall pattern with the major season spanning from March to mid-August with a peak in June and a minor season from September to November which peaks in October. The annual rainfall of the area ranges between 1190 - 1650 mm with an average of 1345 mm/year, while the mean annual temperature is between 22 - 31°C. The soil type at the study site is a Ferric Acrisol, Asuansi series with a slope of 2 - 6% [8].

Tissue culture planting materials, cultural practices and statistical analysis

Four hundred (400) pre-basic seedlings of TDr 95/19177 were obtained from the biotechnology division of the CSIR-Crops Research Institute. The seedlings were virus indexed and certified as virus free material before being used in the experiment. The in-vitro generated seedlings were hardened in the screen house and maintained under screen house conditions for eight weeks prior to establishment on the field. The field was ploughed and harrowed after which ridges spaced 1m apart were constructed. The seedlings were planted on ridges at a spacing of 0.4m in between rows on an 8.5m x 20m plot. The seedlings were shaded with palm fronds to protect them from direct sunlight and direct impact of the rain. The seedlings were also irrigated as and when necessary. The field was fertilized with 6 t/ha poultry manure before planting and 45-45-60 N-P₂O₅-K₂O kg inorganic fertilizer at 8 weeks after planting (WAP). The field was sprayed with Roundup (360g/Glyphosate) at 2 l/ha before planting and subsequently hand weeded to control weeds. Stand counts were done every two weeks to determine the crop survival rate on the field. The tubers were harvested after six months after planting (MAP) and sorted into four (4) different groups based on their sizes (Plate 1). Microsoft office excel 2010 was used to analyze all the data collected from the studies.

Aeroponics planting materials, cultural practices and statistical analysis

The pre-basic aeroponics seedlings, obtained from the biotechnology unit of the CSIR- Crops Research Institute were generated from single nodes of aeroponics plants, virus indexed and certified as virus free planting material. The single nodes were planted in topsoil in micro propagation trays and maintained under screen house conditions for 6 weeks when seedlings developed from the single nodes before they were transferred to the field. Seven hundred seedlings of TDr 95/19177 and one hundred *Mankrong pona* varieties were planted on ridges at a spacing of 0.3m in between plants and 1m apart on a 32m x 7.5m plot. The seedlings were irrigated as and when...
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necessary and staked at the vegetative stage. The field was fertilized with 6 t/ha poultry manure before planting and 45-45-60 N-P₂O₅-K₂O kg inorganic fertilizer at 8 weeks after planting (WAP). The field was sprayed with Roundup (360g/Glyphosate) at 2l/ha before planting and subsequently hand weeded to control weeds. Stand counts were done every two weeks to determine the crop survival rate on the field. The tubers were harvested twice at six and eight months after planting and sorted into four (4) different groups based on their sizes at harvest: Ware yam (≥ 1 kg), Seed A (999 - 500g), Seed B (499 - 100g) and Micro tubers (≤ 100g) [9] (Plate 2). Microsoft office excel 2010 was used to analyse all the data collected from the studies.

Plate 1: Harvested tissue culture tubers.

Plate 2: Harvested aeroponics yam tubers.

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Results

Tissue culture and aeroponics seedlings survival rate

The percentage number of survived seedlings for the tissue culture seedlings, reduced from 100% at planting to 42% at 159 days after planting (Figure 1). Regarding the aeroponics seedlings, the percentage number of survived TDr 95/19177 seedlings reduced from 100% at planting to 38% at 65 days after planting (Figure 2). The seedlings from Mankrong pona also reduced from 100% at planting to 45% at 65 days after planting (Figure 3).

Figure 1: Survival percentage of tissue culture seedlings on the field.

Figure 2: Survival percentage of TDr 95/19177 yam seedlings on the field (%).
Tissue culture and aeroponics tuber yields

Four hundred and eleven (411) numbers of tubers with a total tuber yield of 13.99 t/ha were harvested from the tissue culture seedlings (Table 1). Group 1 recorded the highest total tuber yield of 7.83 t/ha followed by group 2 (3.99 t/ha), group 3 (1.69 t/ha) and group 4 (0.48 t/ha) respectively.

<table>
<thead>
<tr>
<th>Groups Number</th>
<th>Number of tubers harvested</th>
<th>Average weight per tuber (kg)</th>
<th>Total tuber yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27</td>
<td>0.33</td>
<td>7.83</td>
</tr>
<tr>
<td>2</td>
<td>69</td>
<td>0.17</td>
<td>3.99</td>
</tr>
<tr>
<td>3</td>
<td>140</td>
<td>0.07</td>
<td>1.69</td>
</tr>
<tr>
<td>4</td>
<td>175</td>
<td>0.02</td>
<td>0.48</td>
</tr>
<tr>
<td>Total</td>
<td>411</td>
<td></td>
<td>13.99</td>
</tr>
</tbody>
</table>

Table 1: Number of tubers, average weight per tuber and total tuber yield of tissue culture derived seed yams at harvest.

With the aeroponics seedlings, ninety eight (98) plants of TDr 95/19177 were harvested at both 6 and 8 MAP on a 32.4 m² plot (Table 2). Four hundred and twenty nine (429) and 413 tubers were harvested from those numbers of plants at 6 and 8 MAP respectively. The total tuber yields were 48.12 t/ha and 50.75 t/ha respectively at 6 and 8 MAP. Reductions in total tuber yield were recorded for tuber range of 499 - 100g and ≤ 100g when harvested at 8 MAP compared to 6 MAP.

Ten (10) plants of Mankrong pona were also harvested from the aeroponics seedlings at both 6 and 8 MAP on a 32.4 m² plot (Table 3). Nineteen (19) and eleven (11) numbers of tubers were harvested from the 10 plants at 6 and 8 MAP respectively. Harvesting the tubers at 8 MAP instead of 6 MAP resulted in reduction in the numbers and total tuber yields.

Figure 3: Survival percentage of Mankrong pona yam seedlings on the field (%).
Table 2: Yield parameters of TDr 95/19177 aeroponics tubers at six and eight months after planting.

<table>
<thead>
<tr>
<th>Tuber Range</th>
<th>Number of plants harvested</th>
<th>Number of tubers harvested</th>
<th>Average weight per tuber (kg)</th>
<th>Total tuber yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 1 kg</td>
<td>98</td>
<td>18</td>
<td>1.70</td>
<td>10.54</td>
</tr>
<tr>
<td>999 - 500g</td>
<td></td>
<td>61</td>
<td>0.80</td>
<td>16.49</td>
</tr>
<tr>
<td>499 - 100g</td>
<td></td>
<td>169</td>
<td>0.30</td>
<td>18.03</td>
</tr>
<tr>
<td>≤ 100g</td>
<td></td>
<td>181</td>
<td>0.05</td>
<td>3.06</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>429</td>
<td></td>
<td>48.12</td>
</tr>
<tr>
<td>8 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 1 kg</td>
<td>98</td>
<td>33</td>
<td>1.60</td>
<td>17.93</td>
</tr>
<tr>
<td>999 - 500g</td>
<td></td>
<td>82</td>
<td>0.60</td>
<td>17.52</td>
</tr>
<tr>
<td>499 - 100g</td>
<td></td>
<td>152</td>
<td>0.30</td>
<td>13.26</td>
</tr>
<tr>
<td>≤ 100g</td>
<td></td>
<td>146</td>
<td>0.04</td>
<td>2.04</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>413</td>
<td></td>
<td>50.75</td>
</tr>
</tbody>
</table>

Table 3: Yield parameters of Mankrong pona aeroponics tubers at six and eight months after planting.

<table>
<thead>
<tr>
<th>Tuber Range</th>
<th>Number of plants harvested</th>
<th>Number of tubers harvested</th>
<th>Average weight per tuber (kg)</th>
<th>Total tuber yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 1 kg</td>
<td>10</td>
<td>4</td>
<td>1.40</td>
<td>18.33</td>
</tr>
<tr>
<td>999 - 500g</td>
<td></td>
<td>8</td>
<td>0.60</td>
<td>16.67</td>
</tr>
<tr>
<td>499 - 100g</td>
<td></td>
<td>7</td>
<td>0.30</td>
<td>6.67</td>
</tr>
<tr>
<td>≤ 100g</td>
<td></td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>19</td>
<td></td>
<td>41.67</td>
</tr>
<tr>
<td>8 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 1 kg</td>
<td>10</td>
<td>1</td>
<td>2.40</td>
<td>8.00</td>
</tr>
<tr>
<td>999 - 500g</td>
<td></td>
<td>7</td>
<td>0.50</td>
<td>12.07</td>
</tr>
<tr>
<td>499 - 100g</td>
<td></td>
<td>3</td>
<td>0.30</td>
<td>2.67</td>
</tr>
<tr>
<td>≤ 100g</td>
<td></td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>11</td>
<td></td>
<td>22.67</td>
</tr>
</tbody>
</table>

The total tuber yields of 41.67 t/ha at 6 MAP were reduced by 46% when harvested at 8 MAP.

The average weight per tuber was higher in the aeroponics compared to that from the tissue culture. The highest average weight per tuber from the tissue culture in Group 1 (0.33 kg) corresponded to that in the aeroponics tuber range of 499 - 100g from the same yam variety at the same time of harvest (TDr 95/19177 at 6 MAP). The highest average weight per tuber from the aeroponics of 1.7 kg was 81% higher than that from the tissue culture (0.33 kg). The total tuber yield from the same tuber range for the aeroponics (18.03 t/ha) was also 57% higher compared to that from the tissue culture (7.83).

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Discussion

Survival rate of seedlings on the field

The decline in the survival rate in both tissue culture and aeroponics seedlings may be due to the heat shock the seedlings suffered on transferring to the field particularly when rainfall was poor at the time of transplanting which necessitated the irrigation of plants. The limited rainfall experienced during the early part of the crop development may have contributed to the water stress and ultimately poor survival rate (Table 4).

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall (mm)</th>
<th>Temp (°C)</th>
<th>Solar radiation (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Jan</td>
<td>0.17</td>
<td>26.10</td>
<td>26.65</td>
</tr>
<tr>
<td>Feb</td>
<td>21.58</td>
<td>27.66</td>
<td>28.25</td>
</tr>
<tr>
<td>Mar</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Apr</td>
<td>20.82</td>
<td>27.06</td>
<td>27.52</td>
</tr>
<tr>
<td>May</td>
<td>133.43</td>
<td>26.20</td>
<td>26.67</td>
</tr>
<tr>
<td>Jun</td>
<td>147.20</td>
<td>24.96</td>
<td>25.34</td>
</tr>
<tr>
<td>Jul</td>
<td>54.74</td>
<td>24.26</td>
<td>24.60</td>
</tr>
<tr>
<td>Aug</td>
<td>188.19</td>
<td>23.82</td>
<td>24.16</td>
</tr>
<tr>
<td>Sep</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Oct</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nov</td>
<td>33.17</td>
<td>25.19</td>
<td>25.67</td>
</tr>
<tr>
<td>Dec</td>
<td>43.50</td>
<td>25.46</td>
<td>25.95</td>
</tr>
</tbody>
</table>

Table 4: Monthly rainfall (mm), Temperature (°C) and solar radiation (W/m²) recorded at the study area for 2017.

Source: CSIR-Crops Research Institute weather station.

The transfer of the seedlings from the screen house with low irradiance and high humidity to natural environment with high irradiance and low humidity negatively affected the seedlings survival [10]. In-vitro generated plants are known to develop leaves with poor or no development of cuticular wax, impaired stomatal mechanism, low photosynthetic pigments, biochemicals e.g. carbohydrates, proteins, proline and phenols, poor photosynthetic activity, poor vascular development and connections [10].

The other reasons for the decline may also be due to pests and diseases infestation and infection on the field and water stress. Soil pathogens such as Fusarium solani, Fusarium moniliforme, Aspergillus flavus, Aspergillus niger and Rhizopus and nematodes species for example are known to cause significant damage to yam seedlings. According to [11] and [12], the season for transplanting seedlings to the field also have influence on the survival rate and growth of the seedlings. They observed that seedlings transferred from July to August showed higher survival rate with sprouting of more new shoots than other months. There is therefore, the need for further research to understand the factors that influence the field establishment of both tissue culture and aeroponics seedlings.

Tuber yields

The high total tuber yield observed in Group 1 compared to the others was as a result of the higher average weight of the tubers harvested in that group. This corroborates the findings of [13] who found that the average tuber weight had equal effects on total tuber yield.
The reduction in harvested tuber numbers and yield at 8 MAP compared to 6 MAP means that it’s more economical to harvest the tubers at 6 MAP. This however needs to be further investigated. The relatively higher tuber yields from the aeroponics seedlings compared to the tissue culture, has also been confirmed by reports from International Potato Centre [14] on their work on sweet potatoes. Also, according to [14], aeroponics system improves root growth, survival rate, growth rate and maturation time of crops.

Conclusion

The potential of tissue culture and aeroponics system as high propagation ratio techniques for reliable seed yam production has been demonstrated. The aeroponics seedlings however performed better in terms of higher average tuber weight and yield compared to the tissue culture generated seedlings. Further studies are however needed on factors such as rainfall, heat shock, soil pests and diseases and time of planting that influence the establishment of both tissue culture and aeroponics seedlings on the field.

Bibliography


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