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Construction And Evaluation Of Modular Aeroponics System For Small Scale Seed Yam Production

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Abstract

Yam stores relatively longer than most root crops and this attribute have gained it recognition as a food security crop in Nigeria. However, inadequate access and high cost of seed yams have prevented farmers from intensive sustainable production. New technologies to increase and make available quality seed yams to farmers can boost yam production, increase food security and improve farmers livelihoods. In this regard, construction and evaluation of modular aeroponics system for small scale seed yam production was carried out. The objective is to design and construct small modular aeroponics system for the production of seed yam also to evaluate the feasibility of generating seed yams from modular aeroponics system. Results of the technical evaluation of the modular aeroponics systems showed that all the installed components worked perfectly according to their specifications. The results of directly planted vines were impressive as plants and vines suspended in air continued growing normally with the development of new roots and shoots. Within 10 days, more than 50% of the vines produced roots and in week 3 after planting, 85–100% of the direct vine cuttings produced roots on the modular aeroponics system. Agronomic evaluation of vines planted on the modular aeroponics systems showed a progressive growth in all the parameters measured indicating the functionality of the system. The study demonstrates the potentials of modular aeroponics systems in the production of clean materials for small-medium scale seed yam production venture.

Keywords: construction, evaluation, modular, aeroponcis system, small scale, yam, production, Lafia, Nasarawa State.

Introduction

Yams (*Dioscorea spp.*) are among the most important staple foods in the world, especially in some parts of the tropics and subtropics. It belongs to the family Dioscoreaceae (genus Dioscorea). Yams are native to tropical regions throughout the world. They are cultivated for their edible tubers, which in some species can grow up to about 2.4 m long and weigh up to 45 kg (Okigbo and Ogbonnya, 2006). Yam is largely carbohydrate and is one of the cheaper sources of the nutrient to humans (FAO 2010). Yams are major sources of nutrients (carbohydrates, phosphorus, calcium) and vitamins such, iron and vitamins such as thiamine, riboflavin, and vitamins B and C (Coursey, 1967). Yam is one of the most important dietary sources of energy produced within the tropics and plays a major role as a food and trade commodity in Nigeria. This attribute has gained it recognition as a food security crop in Nigeria. There are a lot of challenges with yam production in Nigeria, chief among them being unavailability and high cost of seed yams. Growing yams in Nigeria is labor intensive and land demanding because of its over reliance on traditional production techniques. Furthermore, farmers rely on traditional method of milking for seed generation. The size of ware yam harvested usually depends on the size of sett used in its cultivation. Farmers therefore prefer using whole setts, however big or small for planting. To generate such whole setts, farmers use a technique known as “milking”. This process involves early harvesting of ware yams to pave way for a second tuber that can be used as seed only in early maturing varieties. After “milking”, if the second tuber regrowth is not met with favorable weather conditions, the farmers cannot get enough seed to use in the next season’s planting, thus having to leave a substantial part of the ware yam as seed for planting. The slow technology for seed yam production is one of three obstacles which stand in the way of cost reduction and expansion in yam production; others are the high labor requirement and problems of pests and diseases.

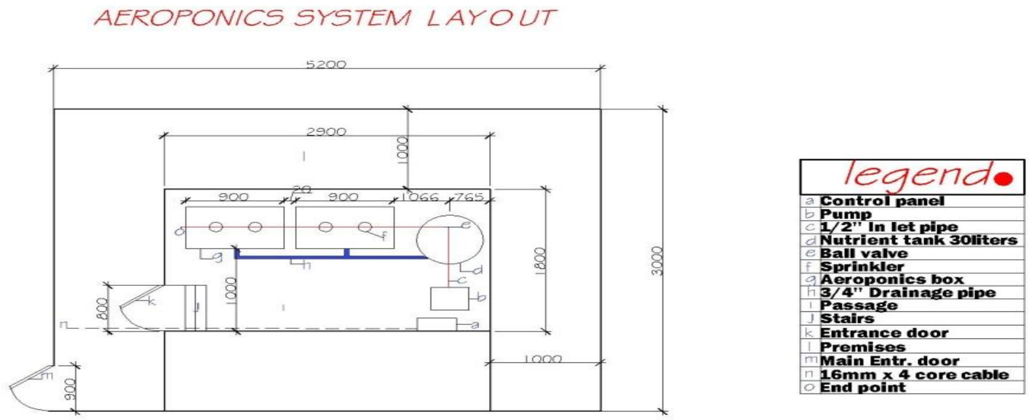
New technologies for growing foods that are not overly dependent on soils and water are becoming not only a distinct advantage, but a necessity. The modular aeroponics technology has been demonstrated in several ways to be a significantly more water- and energy-efficient means for food production. Hence, the modular aeroponics technology is being adapted for use in this research to propagate seed yam. In modular aeroponics, plants are grown in an air or mist environment without engaging soils or any soil aggregate or soil medium (Kalu and Erhabor, 1992). The modular aeroponics gives room for easy access to plant roots since it is not planted in any aggregate media. The growth chamber and fertigation system employed in the modular aeroponics also give room for complete regulation of the root zone setting, including temperature, humidity, pH, nutrient concentration, mist application frequency and duration. Plants grown using aeroponics often show signs of accelerated growth and early maturity (Nugali et al., 2005). These abilities have made the technology a popular research tool for studying root growth and nutrient uptake. Aeroponically generated seed yams can improve the seed multiplication ratio of yams and thus make available more seed yams on the market. It can also reduce disease incidence of seed yams which results in yield losses. If successfully used in the propagation of seed yams, can significantly increase the incomes of farmers, improve access to quality seed yams all year round (by making it more accessible and affordable to small-scale farmers) and reduce the production costs of yams. This would improve farmers’ livelihood and also enhance food security. The objective of the study is to design and construct small modular aeroponics system for the production of seed yam. Also evaluate the feasibility of generating seed yams from modular aeroponics system. Yams can be reproduced sexually from true botanical seeds, aerial tubers, underground tubers and vine cuttings. Propagation by botanical seeds is dominant in Lafia only researcher carryout propagation by botanical seeds, aerial tubers underground tubers and vine cuttings, for breeding purpose (NADP 2016). Propagation through vines, which in previous years was only done by researchers, is also gaining attention with yam farmers in Lafia. The most common form of propagation is by underground tubers either planted as whole setts or minisetts. In Lafia, the traditional methods of seed yam still remain dominant. Several rapid multiplication techniques for seed yam production have been developed globally. These include the mini-sett technology, the vine multiplication technique, tissue culture multiplication and aeroponics

The International Union of Soil Sciences Working Group on Soilless Culture defines aeroponics “as a system where roots are continuously or discontinuously grown in an environment saturated with fine drops (a mist or aerosol) of nutrient solution” (Nugali et al. 2005). Went (1957) named the air growing process in spray culture as “aeroponics”. Simply put, aeroponics is a method of growing plants in a soilless environment with very little water (Carter 1942). Basically, it is growing without earth. The box is an enclosed area known as root chambers. The purpose of this area is twofold: it protects the roots from light and holds the nutrient/water solution that feeds them. In addition to the greenhouse, a powerhouse is constructed with tanks for the nutrient solution. A pump pushes the nutrient solution through a piping system and out of a series of nozzles inside the box that atomize the solution and spray a fine fog directly onto the roots. The way nutrients and water are delivered also demonstrates the efficiency of aeroponics. The nutrient solution used on plants requires only a little water. In the enclosed system, whatever doesn’t get absorbed by the roots falls back down and returns to the nutrient tank by gravity and gets cycled through again. For this purpose, the box should have a slope towards the return piping system to the tanks. The feeding pump is set to an automatic timer through an electric control panel and delivers this high-powered nutrient solution at regular intervals. In enclosed systems, water use is even further diminished. Atomizing nozzles ensure the most effective delivery of nutrients, since they turn the water into a fine mist. Plants absorb nutrients through their roots by osmosis, a selective absorption of compounds through cell walls. Roots can absorb nutrients more easily because they are delivered via the mist. The following are some advantages of modular aeroponics system, the growing is ecologically friendly and safe. Roots and crops from modular aeroponics production are free of soils and soil-borne organisms or diseases and contaminants. Plant growth and development cycles are accelerated resulting in early maturity and harvest. Aeroponically cultivated crops are consistent in its phytochemical properties as a result of stability of nutrient concentrations used in fertigation. Elimination of water and nutrient competition in aeroponics gives room to higher planting densities and thus increased yields. Efficient use of water and nutrients due to reutilizing ability of the nutrient solutions used. Elimination of soil fertility and degradation issues in crop production. Production can be done independent of climatic conditions thus ensuring a continuous production cycle and availability of fresh produce close to consumer and market. Aeroponics technology provides the opportunity to produce where demand is thereby reducing freight and transaction cost. The modular aeroponics depends on power systems like timers and pumps which controls most of the production activities. Failure or breakdown of the system can spell disaster for the plants or the whole system. Technology and technical knowledge demand of the system is also very high. Aeroponics plants also need close care, attention and support and will succumb to diseases and crop failure if not frequently monitored. In addition to these, the following are some disadvantages of modular aeroponics cultivation of tuber crops (Mbanaso et al., 2011):

Even though total darkness is a demand in aeroponics systems, it cannot be maintained entirely because of the tendency to monitor the root environment. Some production operations (e.g. staking of plants and manual harvesting) of the system are labor intensive. Initial capital cost investment into modular aeroponics technology for crop production is relatively high. The aeroponic system has three major components (Lung'aho et al. (2010). The first is the chamber environment. This is the physical environment of the screen house, such as temperature and humidity, which needs to be monitored and controlled. The second part is the control block/unit (Lung'aho et al. (2010). This part is responsible for monitoring and affecting the growth chamber environment through fertigation systems, sensors, heaters, etc. The third part of the system is the plant holding and growth system consisting of the growth chamber and plant holding tray. This part of the system provides support to the plant and gives access to the plant roots. In aeroponics systems, there are a number of factors that must be carefully monitored and some that must be controlled. According to the International Committee for Controlled Environments (ICCE), the minimum measuring and reporting guidelines are: watering schedule, temperature, atmospheric moisture, radiation, carbon dioxide, air velocity, electrical conductivity, pH, nutrition and growth chamber dimensions (Lung'aho et al. 2010). Producing large quantities of high quality mini-tubers at low cost is essential for an economically viable supply of seed yam. Evaluating the modular aeroponics system for its ability to produce mini-tubers at a low cost is an essential part of this research and evaluate the system for its ability to economically produce mini-tubers of yam.

Materials And Methods

The study was conducted at the Faculty of Agriculture Teaching and research farm Nasarawa State University keffi, Shabu –Lafia Campus, Nasarawa State. The location situated at latitude $08^{0}33$ N, longitude 08º 32E, with mean elevation of 181.53m above sea level (Jayeoba 2013). The soil is an oxisol. It is deep porous brownish red and made up of Kaolinite clay derived from sandy deposits of sand stone origin. The area characterized by a sub –humid tropical climate with wet climate and dry season. The annual rainfall distribution is about 113mm, the mean annual

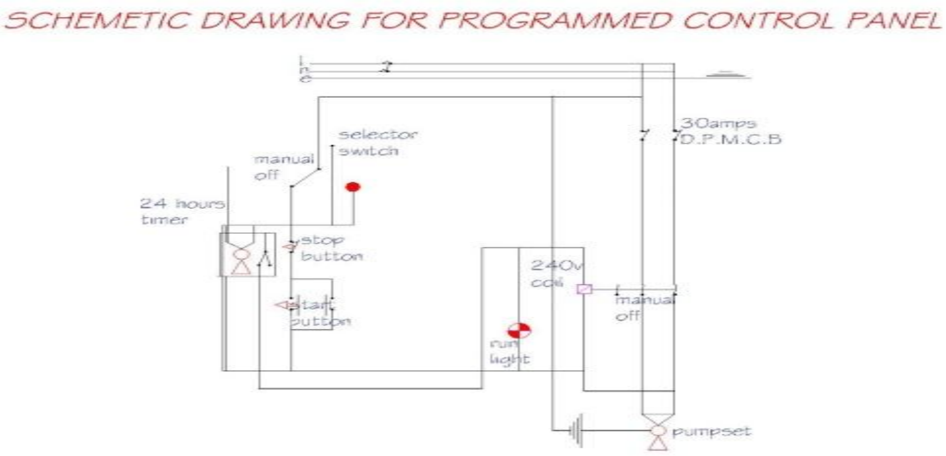


Detailed layout of modular aeroponics system in faculty of agriculture,shabu-Lafia.

temperature is 27˚c with minimum and maximum temperature of 24.8˚c and 33˚c respectively. The requirement of this aspect was to design fully functional, low-cost modular aeroponic growth system that is pressurized with misters (power-dependent).

Results And Discussion

The power-dependent or pressurized aeroponic system (PAS) utilized electrical power in its operations. It utilized a high-pressure pump which was used to atomize the water through small orifice misters to create water droplets of about 50 microns or less in diameter. Fertigation was automatically timed using irrigation timers at twenty minutes on and ten minutes off.



Layout of control panel component of automatic timer

Results And Discussion

The construction the modular aeroponics system composed of 2 boxes for seed yam production and site size of 5.2 m × 3 m. The layout of the boxes, 0.5 m in length and 0.4 m wide, with 0.3 m space between two adjacent boxes. The tops of the boxes are covered with Styrofoam, 0.4 m thick, corresponding to 2 tables/box perforated at 10 cm × 10 cm, giving 15 planting holes/table (100 cm2/plant). One of the boxes was perforated at a density of 10 cm × 10 cm to test the higher density of 30 holes/table (100 cm2/plant). The significance of this agronomic evaluation was to determine the functionality of the modular aeroponics system to be used as a propagation medium for yam mini-tuber production. Following the procedure assembling of the complete modular areoponics system as presented below.

The growth chamber houses the roots of the plants and serves as the enclosing medium for nutrient delivery and drainage. Growth chambers are made opaque to avoid the penetration of light into the root chamber, thus mimicking some soil properties. The growth chamber houses the roots of the plants and serves as the enclosing medium for nutrient delivery and drainage.

The drainage system was designed to specification to accommodate the proper pipe network, sprinkler and pumping system respectively. The drainage system also considers the slope of the chamber for effective recycling of the nutrient media which is powered by the electrical system.

Growth response to two varieties of yam TDr 95/18544 and TDa 2014 was planted in modular aeroponics system are presented in Figures 1-4. The steady growth trend of all the measured parameters indicates the system's ability to support growth and development of the vines planted. It was also indicative of the functionality of the constructed modular aeroponics system.

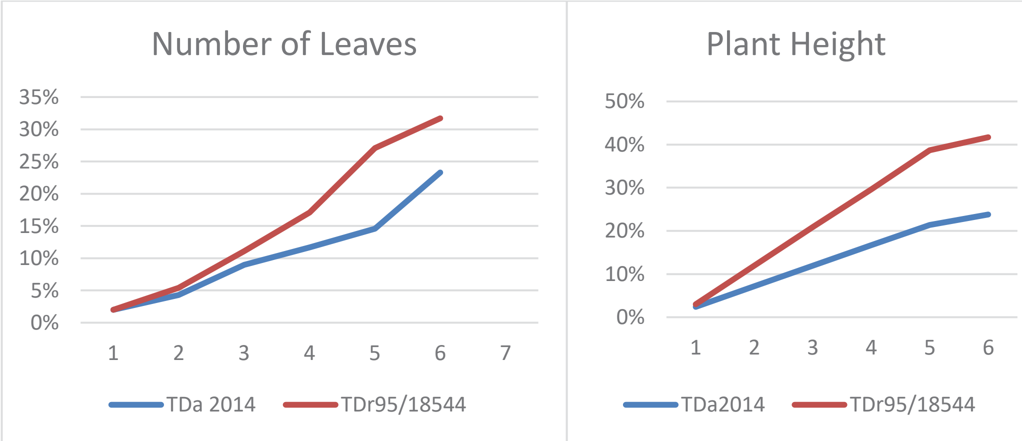


Figure 1 and 2: Number of leaves of yam vine grown in modular aeroponics system and Number of plant height of yam vine grown in modular aeroponics system.

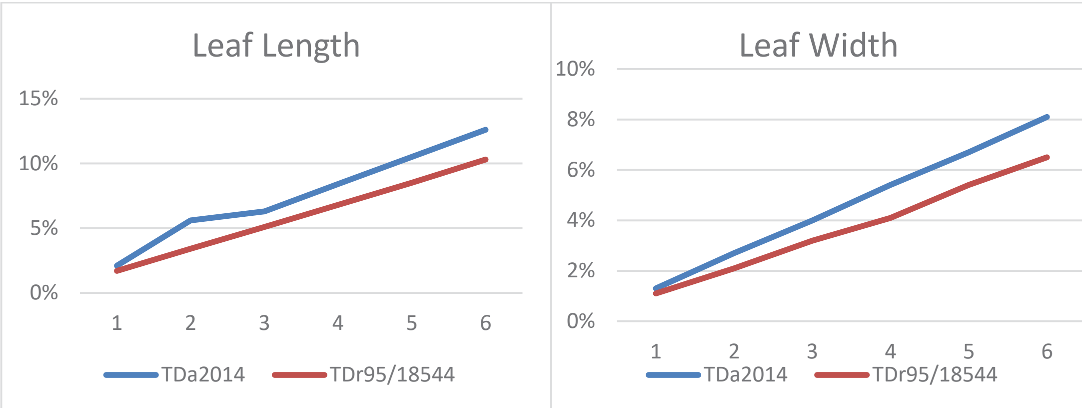


Figure 3 and 4: Leaf Length of yam vine grown in modular aeroponics system and Leaf width of yam vine grown in modular aeroponics system.

The results of directly planted vines were impressive as plants and vines suspended in air continued growing normally with the development of new roots and shoots. Within 10 days, more than 50% of the vines produced roots and in week 3 after planting, 85–100% of the direct vine cuttings produced roots on the aeroponics system.

Conclusion And Recommendations

The modular aeroponics system was developed to enhance and optimize the rapid multiplication of seed yams. A well designed modular aeroponics system should be efficient in water/nutrient distribution, water and energy use. The modular system can also be adapted for use with other crops to boost food production and security even in the face of climate change, population growth and limited access to farm lands. In designing and setting up the systems, all items were procured and bought locally. The system, thus, has far proven to be better in terms of financial capabilities and comparable in terms of production to the power-dependent system.

The potential benefits herein discussed such as rapid rooting and tuberisation, high multiplication ratios and economically sound production gives these systems the potential to revolutionaries' seed yam production in the Lafia.

Aeroponics can be recommended to producer organizations, national seed production programs, private companies, individual farmers or other institutions with interest in seed production. However, before such recommendations are made, it is important to take notice of the following discussions for future research.

Research on the technical and agronomic aspects of the modular aeroponics system, particularly when focused on intensification of the production edge beyond the current multiplication ratios (Growing media and fertilizer doses, age of explants at time of cutting vines, plantlet density, crop duration as well as development of some special cultivation techniques and use of biofertilizers) should also be conducted. The research could be based on customized management by variety (i.e. timings of fertigation, duration of each fertigation incidence), intensive management to hasten multiple tuberisation and shoot biomass, and improved control of the growing environment (temperature and humidity control). Consideration should be made that mini-tuber production represents only one critical stage in the seed yam production network. Production of the mini-tubers would therefore have to be scheduled to meet the season's seed yam production calendar.

Healthy planting materials should always be used in the initial propagation of mini-tubers to always ensure healthy harvests. Thus, further research to devise ways of cultivating explants for generating disease-free vine cuttings should be conducted. To use the modular aeroponics technology for the first time, it is recommended to combine the modular aeroponics technology with other conventional methods to prevent losses that can arise from unforeseen eventual collapse of the modular aeroponics system. Policies that can enhance rapid dissemination of these technologies should be put in place to enhance speedy dissemination and adoption of the modular aeroponics technologies for rapid multiplication of seed yams in Lafia.

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