

Performance of different potato genotypes under aeroponics system

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Abstract

Potato yields in developing countries are below potential yield because potato production is mainly constrained by lack of quality seed. Lack of potato seed systems to provide farmers with quality clean and certified potato seed has led majority of farmers save their own seed. Such potato seed is characterized by systemic viral and bacterial diseases that are transmitted from generation to generation and this leads to low crop yields. The study was aimed at exploring the use of tissue culture and aeroponics techniques in the production of quality potato seed. Potato plantlets were produced in the tissue culture laboratory at Bvumbwe Research Station, 15° 41' 0" South, 35° 8' 0" East in Thyolo district of Malawi and then transferred to an aeroponics facility at Njuli Estate, 15° 41' 0" South, 35° 8' 0" East in Chiradzulu district of Malawi. The four potato genotypes did not differ on plant growth performance, but responded differently to aeroponics system in terms of mini tuber yield and stolon numbers. Genotypes CIP381381.20 and CIP381381.13 showed superiority among the other tested genotypes in terms of tuber number per plant. Genotype CIP381381.20 produced significantly higher number of stolons than the rest. In this study, on an average 30 tubers were produced per plant under aeroponics system which is six times more than the conventional (use of soil-based substrate) seed potato production system under screen house conditions (5 tubers per plant) under Malawian conditions.

Key words: Aeroponics, tissue culture, potato genotypes, potato seed, potato, *Solanum tuberosum*

Introduction

The yields of potato (*Solanum tuberosum*) crop in developing countries are declining as a result of inappropriate cultural practices, use of poor quality seed, and poor pest and disease management strategies (CIP, 2008). In Malawi, potato production is mainly constrained by lack of good quality seed (Jayasinghe, 2003). There are no potato seed multiplication programs in many developing countries to provide small-scale farmers with clean potato seed. Most of the potatoes are sold for consumption and those reserved for seed are the low quality small tubers. Majority of farmers save their own seed, often from un-marketed tubers or virtually without conscious selection. This method of seed sourcing leads to rapid degeneration mainly due to systemic viral and bacterial diseases that are transmitted from generation to generation resulting to subsequent low crop yields (Jayasinghe, 2003; Badoni and Chauhan, 2010). This implies that every year, excessive grower's time, labour and space are spent on less efficient seed production technique. In addition, significant numbers of young plants are lost to viruses, bacteria, fungi and insect pests.

Application of aeroponics in tuber crops like potatoes complements tissue culture technology. The tissue culture system provides seed potato tubers free from pathogens (Wang and Ching, 1982; Mahmood, 2006). The use of pathogen free potato seed derived from tissue culture has proved to save time lost by growers because of the higher percentage of clean, viable and mature plants produced (Colin, 1988). The aeroponics permits to achieve

a high multiplication ratio in a growing season (Ritter *et al.*, 2001; Otazu, 2010). Aeroponics growing is also considered as safe and ecologically friendly for producing natural, healthy plants and crops (Farran *et al.*, 2006). The disease free environment under aeroponics is a result of plants being enclosed in sterile polystyrene chamber and spraying of sterile pulse (Ritter *et al.*, 2001; Clawson, 2012). While aeroponics has been found to be a good technique for multiplying seed for other crops there is little information on how currently developed potato genotypes would respond to multiplication rate under aeroponics. The objective of this study was to evaluate the performance of different *in vitro* produced potato genotype plantlets under aeroponics system by determining plant growth and yield of different potato genotypes under aeroponics systems.

Materials and methods

Explants and experimental design: Plant materials for the experiment were the four International Potato Centre (CIP) potato genotypes CIP393382.44, CIP381381.13, CIP381381.20 and CIP395015.6 from Lima, Peru. These four potato genotypes were certified as disease free plantlets using ELISA test by the supplier and were micro-propagated using nodal cutting technique for multiplication in the plant tissue culture laboratory at Bvumbwe Research Station 15° 41' 0" South, 35° 8' 0" East in Thyolo district of Malawi in March, 2009. The culture media was prepared using Murashige and Skoog basal salts (Murashige and Skoog, 1962) supplemented with 3 % sucrose and 0.001 mg/L gibberellic acid. Agar 8 g/L was used as a gelling agent.

The pH of the medium was adjusted to 5.8 using 1 N NaOH or 0.1 M HCL. The *in vitro* produced plantlets were used at Njuli Estate, 15° 41' 0" South, 35° 8' 0" East in Chiradzulu district of Malawi for production of mini-tubers during the cool season period between May and September, 2009 under green house conditions. The average temperature during this period was below 25°C and experiment was laid out in a Randomized Complete Block Design with three replications.

Production of planting material: *In vitro* rooted plantlets generated in the tissue culture laboratory at Bvumbwe Research Station were utilized as the starting materials for the experiment. Plantlets were transferred into a screen house and kept in test tubes for two days and then transplanted in steam-sterilized sand on the third day to allow them to develop longer roots and to acclimatize for 21 days. During the acclimatization period, plants were watered with tap water without nutrients supply for two days and then with half the recommended rate of nutrient solution for seven days and thereafter with full rate of nutrient solution (Table 1).

Table 1. Nutrient solution used in an aeroponics system

Chemical	Amount in 1 L of water
Ammonium nitrate	0.35 g
Potassium nitrate	0.54 g
Calcium Triple Super phosphate	0.61 g
Fetrilon Combi	0.012 g
Magnesium Sulphate	0.44 g

Production of mini-tubers under aeroponics: Aeroponics production was carried out in a two-level walk-in growth chamber of 7 m long, 1 m wide and 1 m high, 400 L nutrient tank, a spraying unit and a control panel with an automatic timer. The growth chamber had a removable top cover having 2 cm diameter holes into which the rooted *in vitro* plantlets were inserted. When transplanting the rooted *in vitro* plantlets into the aeroponics boxes, they were wrapped with a thin sponge around the plant neck and fitted into the holes containing Styrofoam covered with a black plastic to avoid light penetration. The planting holes were spaced at 25 cm between plants and 25 cm between rows, corresponding to a transplant density of 20 plantlets per m². The spraying unit was placed at the bottom of the growth chamber.

The inlet of this unit was connected to the water pump through a solenoid valve and the outlet to the nutrient solution tank to collect drop-out of the solution. The nozzles of the spray unit were fixed 60 cm equidistant apart to direct the nutrient solution towards the root zone at required time intervals. The timers which were connected to the pressure switch and solenoid valve were programmed to spray nutrient solution for 15 minutes and break for 15 minutes during the day time (8 am to 6 pm) and spray for 15 minutes and break for 60 minutes during the night times (6 pm to 8 am) throughout plant growth from May to September, 2009.

Data collection: Data collection was done on plant growth parameters *viz.*, plant survival, number of days to tuberization, number of days to maturity, number of harvests, root length, stolon length and stolon number. Percentage plant survival at harvest was determined by counting total number of plants that survived from the day of transplanting into the aeroponics boxes to the final day of harvesting, and expressed as a percentage of total number that was transplanted. Harvesting of mini-tubers started when the mini tubers showed maturity. The skin of the mature mini-tuber was thick and easy to skin off (Fig. 1). The number of days to tuberization and maturity was determined by counting the number of days from transplanting day to tuber formation and maturity, respectively. Number of harvests was obtained by counting the number of times each treatment was harvested. The primary root length and stolon length was collected at final harvest by measuring from the point of root insertion on a stem to the root tip. The number of stolons was determined by counting stolons developed on stem. The data collection was also done on yield performance parameters which include number of mini-tubers per plant, weight of tubers and size of tubers. Number of mini-tubers per plant was obtained by averaging tubers obtained from net plot per treatment. Weight of tubers was determined by weighing all tubers collected from a net plot and then dividing the result by the total number of tubers weighed. A mini-tuber size was determined by randomly selecting tubers per treatment and measuring the tuber length and width. Other important parameters like disease incidence and temperature were also recorded. Late blight scores were taken 30, 70 and 90 days after transplanting. The late blight score of 0-100 % was used to assess the late blight attack on the crop foliage. Temperature data was collected twice in a day, at 9 am and 2 pm using thermometer.

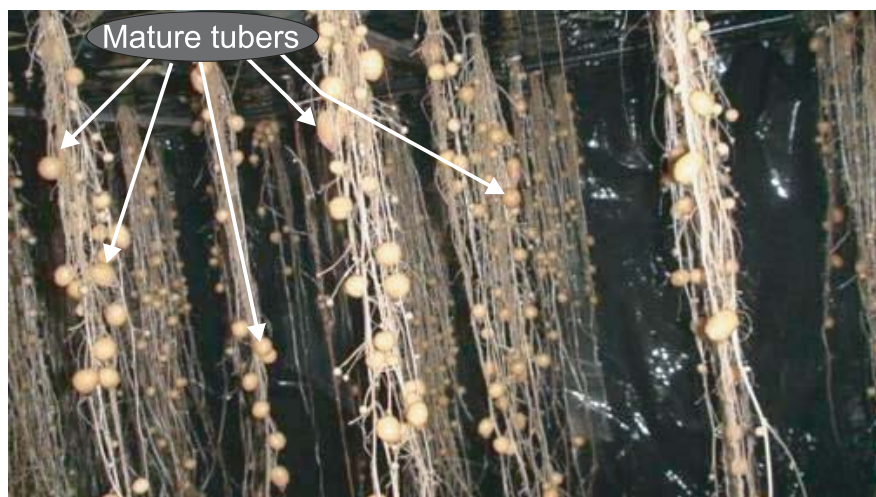


Fig. 1. Mature mini-tubers, 50 days after transplanting in an aeroponics structure

Data analysis and statistical model: The statistical package SAS System using General Linear Model procedure was used to analyze the data.

Results

Plant growth of different potato genotypes under aeroponics systems: There was no significant difference among the genotypes in terms of plant survival rate under aeroponics conditions until harvest. Significant ($P < 0.0001$) differences were observed among the potato genotypes tested on the number of days that the plants took to start forming tubers. All genotypes started forming mini tubers almost at the same time except CIP393382.44 (21.00±0) which started early and the rest of the genotypes started after 28 days. Significant ($P < 0.01$) differences were observed on days to maturity among the genotypes. Genotype CIP393382.44 matured earlier (50.6±1.80 days) than the rest with CIP381381.13 (63.3±1.80 days), CIP395015.6 (56±1.80 days) and CIP381381.20 (58.7±1.80 days). There was also a significant ($P < 0.0001$) difference on the number of harvests performed in each genotype. The genotypes CIP395015.6 (6±0.17 harvests), CIP393382.44 (6±0.17 harvests) and CIP381381.20 (5.7±0.17 harvests) had significantly higher number of harvests than CIP381381.13 (4±0.17 harvests) (Table 2).

There was no significant variation on length of stolon and length of root among the genotypes. Significant ($P < 0.001$) variation was only observed on number of stolon produced per plant. The genotype CIP381381.20 produced more stolons (45±3.57 stolons) than the other genotypes while genotype CIP393382.44 produced the least number of stolons (11±3.57 stolons) (Table 3).

Yield of different potato genotypes under aeroponics systems:

There was a significant ($P < 0.05$) variation in number of mini-tubers produced per plant among the four genotypes. Genotype

Table 2. Number of days to tuberization, maturity and number of harvests done among genotypes under aeroponics system

Genotype	Survival % in aeroponics	Days to tuberization	Days to maturity	Number of harvests done
CIP381381.13	99.67±0.24	28.00±0	63.30±1.80	4.00±0.17
CIP395015.6	100.00±0.24	28.00±0	56.00±1.80	6.00±0.17
CIP393382.44	99.33±0.24	21.00±0	50.60±1.80	6.00±0.17
CIP381381.20	100.00±0.24	28.00±0	58.70±1.80	5.7±0.17
Mean	99.75	26.30	57.17	5.42
F _{prob}	0.2192	0.0001	0.0069	0.0001

Table 3. Root length, stolon length, and stolon numbers per plant of the different potato genotypes under aeroponics system

Genotype	Root length (cm)	Stolon length (cm)	No. of stolon/plant
CIP381381.13	74.58±11.57	90.33±19.89	20±3.57
CIP395015.6	78.78±11.57	160.67±19.89	12±3.57
CIP393382.44	79.67±11.57	138.33±19.89	11±3.57
CIP381381.20	70.67±11.57	89.33±19.89	45±3.57
Mean	75.92	119.67	22.00
F _{prob}	0.9405	0.0832	0.0004

Table 4. Number of tubers, weight of tubers and tuber size of different potato genotypes under aeroponics system

Genotype	Tubers per plant	Tuber weight (g)	Tuber size		
			Weight (g/tuber)	Length (mm)	Width (mm)
CIP381381.13	38±5.27	227±72.1	6.02±1.24	28.77±2.36	18.93±2.21
CIP395015.6	27±5.27	197±72.1	7.02±1.24	28.23±2.36	17.87±2.21
CIP393382.44	14±5.27	137±72.1	9.49±1.24	24.13±2.36	19.15±2.21
CIP381381.20	41±5.27	296±72.1	7.59±1.24	22.90±2.36	15.47±2.21
Mean	30.00	214.0	7.53	26.01	17.85
F _{prob}	0.0297	0.155	0.3161	0.2755	0.6413

CIP381381.20 produced relatively more mini-tubers per plant (41±5.27 tubers) compared to the other genotypes CIP381381.13 (38±5.27 tubers per plant), CIP395015.6 (27±5.27 tubers/plant) and CIP393382.44 (14±5.27 tubers per plant). No significant difference was observed in weight among the genotypes (Table 4). The mini-tuber size of potato in terms of weight, length of a tuber and width of a tuber did not significantly vary among the genotypes tested (Table 4). Fig. 2 shows potato tuber size from four tested potato genotypes.

Diseases: There were no symptoms of late blight on crop foliage throughout the growing period with an average score of 0 %.

Temperature: In this study, the average daily temperature during growing period of May to September 2009 under aeroponics at Njuli Estate, Chiradzulu, Malawi ranged from 19 to 21°C in the afternoon and 16 to 18 °C in the morning (Fig. 3).

Discussion

In this study, all tested genotypes have shown very high plant survival rate with no variation among themselves. This high plant survival rate under aeroponics could be because plants in aeroponics system are totally suspended in the air, giving the plant stem and root systems access to 100 % of the available



Fig. 2. Mini-tubers of the four different potato genotypes produced in aeroponics systems.

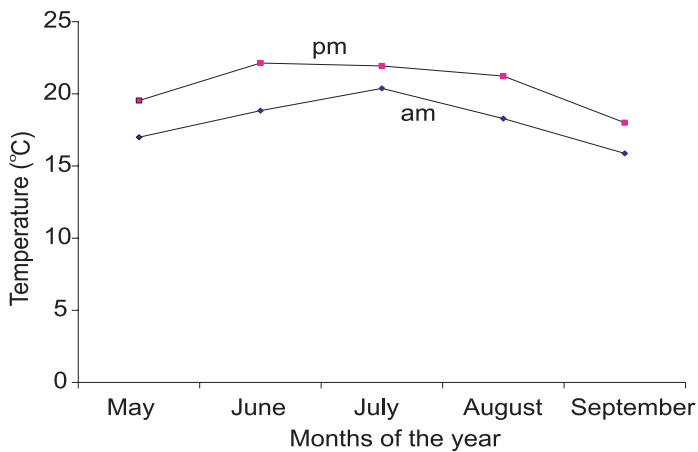


Fig. 3. Day temperature during growing period of May to September, 2009 under aeroponics system at Njuli Estate, Chiradzulu, Malawi.

oxygen. In addition, plants have 100 % access to the carbon dioxide concentrations for photosynthesis (Ritter *et al.*, 2001; Sun *et al.*, 2004). The results obtained under aeroponics concur with those obtained by Tsoka *et al.* (2012) who also reported non-significant difference in plant survival rate among genotypes under aeroponics system.

Genotype CIP393382.44 matured earlier than the rest with an average of 50 days after transplanting and genotype CIP381381.13 was the last maturing at 63 days after transplanting. This variation indicates that tuberization and maturity were influenced by genetic responses of genotypes. Similar observations were made by Mateus-Rodriguez *et al.* (2012) and Tsoka *et al.* (2012) when potato genotypes were grown in aeroponics system under variable environments.

Removal of tubers by repeated harvesting in this study appeared to contribute to more tuber formation and higher number of harvests. The results obtained agree with Ritter *et al.* (2001), Otazu (2010) and Karuga (2012) who reported that aeroponics provides room for sequential harvests as well as extended harvesting period per plant. An average of five harvests were realised over a period of three months in this study. Repeated harvest has been reported to have helped in breaking apical dominance that has resulted into promotion of lateral tuber formation inside the aeroponics chamber (Otazu, 2007; Mateus-Rodriguez *et al.*, 2012) thereby extending harvesting period. Aeroponics system optimizes root aeration (Ritter *et al.*, 2001; Farran and Mingo-Castel, 2006) and facilitates good monitoring of nutrients uptake (Barak *et al.*, 1996). The non-significant variation on the length of the root per plant among the genotypes under aeroponics in this study can be attributed to uniform distribution of nutrient solution and optimum aeration under the aeroponics chamber that ensured a corresponding uniform growth in roots.

Variations on number of stolon produced per plant implies that stolon number vary with genotypes. The first step in the formation of tubers is stolon formation (Xu *et al.*, 1998). Stolons provide a structure where tuberization occurs and this is why genotype CIP 381381.20 that had the highest number of stolons correlated with the higher number of tubers per plant. Similar observations were also made by Tsoka *et al.* (2012) when genotypes were subjected to different plantlet propagation methods.

The significant differences in the number of mini-tubers among the genotypes were attributable to the genotypic differences. The significant difference in number of tubers among the four tested genotypes supports Scherwinski-Pereira *et al.* (2009) and Tsoka *et al.* (2012) findings who reported significant differences when cultivars were subjected to different production systems and propagation methods respectively. In this study, the results showed that an average of 30 tubers can be produced per plant under aeroponics system. The mean tuber numbers obtained under aeroponics in this study is higher than the use of soil based substrate as they would only yield average of 8 tubers per plant (Hussey and Stacey, 1981). These results also suggest that genotypes CIP381381.20 and CIP381381.13 are superior genotypes among the tested genotypes in terms of number of mini-tubers produced per plant under aeroponics system. These results supports Lung'aho *et al.* (1998) findings who observed that genotypes CIP381381.13 and CIP381381.20 exhibited superior performance in yield when tested across a wide range of field environmental conditions, variable by altitude, rainfall, soil type, and season of cultivation. Özkaynak *et al.* (2005) and Mateus-Rodriguez *et al.* (2012) also observed that final mini tuber production is dependent of the cultivar used, hence, to achieve high yield under aeroponics system there is need to use the genotypes that are known to respond well to the aeroponics.

One of the advantages of aeroponics system is that seed users can harvest the small tubers at any size they like, from 5 to 30 g (CTA, 2008). The average tuber size of 7.53 g obtained in this experiment was within the recommended seed size. The smaller size tubers obtained was a result of continuous differentiation and formation of new tubers which in turn diverts energy from increasing the tuber size to formation of more small new tubers (Scherwinski-Pereira *et al.*, 2009).

There were no diseases observed in aeroponics screen house throughout the growing period. This is because the plants were grown under controlled environment (Cocoponics, 2011). These results also agree with Clawson (2012) who reported that the disease free environment under aeroponics is a result of plants being enclosed in sterile polystyrene chamber and spraying of sterile pulse. This shows that plant tissue culture and aeroponics systems could be complementary in production of high quality seed potato tubers. Micro propagation aids in pathogen elimination and rapid multiplication of the plantlet while aeroponics can be applied in rapid tuberization to produce high quality seed tubers that can further be multiplied under field conditions. Seed materials that are re-infected in the field can be re-cleaned in the tissue culture laboratory and repeat the seed tuber production under aeroponics system.

Temperature plays a vital role in seed tuber yield, as increase in temperature at a time of tuberisation reduces the seed tuber yield. High temperature (day/night: 32°C/20°C) stresses during tuberisation cause yield reduction of over 50 % (Harvey *et al.*, 1992; Rykaczewska, 2009; Mateus-Rodriguez *et al.*, 2012). The mini-tuber yield in this study was not affected by temperature since the mean temperature was below 25°C. This shows that timing in terms of when to produce seed potato tubers under aeroponics has to be taken into consideration. Tuberisation should coincide with cooler months in tropical and sub-tropical areas.

This study shows that potato genotypes responded differently to aeroponics system in terms of plant growth and mini tuber yield. In addition, plant tissue culture and aeroponics systems could be complementary in production of high quality seed potato tubers.

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