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IMPROVING MINITUBER PRODUCTION FROM TISSUE-CULTURED POTATO PLANTLETS WITH AEROPONIC TECHNOLOGY IN UGANDA

Rogers Kakuhenzire[1*], Deo Tibanyendera[2], Imelda Night Kashaija[3], Berga Lemaga[4], George Kimoone[2], Vasiter Eunice Kesiime[2], Victor Otazu[5], Oscar Ortiz[5], and Ian Barker[6]

[1]International Potato Centre-SSA (Kampala), P. O. Box 22247, Kampala, Uganda

[2]Kachwekano ZARDI, P.O. Box 421, Kabale, Uganda

[3]National Agricultural Research Organization, P.O. Box 295, Entebbe, Uganda

[4]International Potato Center-SSA (Addis Ababa), P.O. Box 5689 Addis Ababa, Ethiopia

[5]International Potato Center, Apartado 1558, Lima 12, Peru

[6]International Potato Centre-SSA (Nairobi), P.O. 2571-00603, Nairobi, Kenya

*Corresponding author

ABSTRACT

Seed accounts for a significant proportion of potato production cost and its quality cannot be compromised for profitable potato production. Potato is conventionally vegetatively propagated, has a low multiplication rate and requires many generations to bulk the requisite seed quantity often in open fields. During seed bulking, the crop is prone to degeneration leading to successive loss in yield as a result of viral, bacterial and fungal infections. To reduce this, there should be few open field seed bulking generations before the stock is used for ware potato production. Rapid bulking of seed potato has not been possible due to its inherent low multiplication rate. However, this can be partly overcome by tissue culture, micro-propagation and deployment of novel technologies such as aeroponics to produce mini-tubers. Consequently, aeroponic technology for rapid production of nuclear seed was tested in Uganda for adaption in different seasons and with different varieties to produce potato mini-tubers. Production of mini-tubers was affected by cropping seasons and potato varieties. Generally, however, the performance of local potato varieties in aeroponics is promising. More mini-tubers per plantlet were produced at low than high plantlet density, while more mini-tubers per unit area were produced at high than low plantlet density. Preliminary results indicated that aeroponics on average produces 8.5 times more mini-tubers than the conventional soil substrates. The technology has shown a high potential to break the seed potato bottle-neck in Uganda.

Keywords: rapid multiplication, rhizotron, seed potato degeneration

1. INTRODUCTION

Bulking large quantities of quality planting material in a short time has always been a limitation in providing planting stock of potato and other vegetatively propagated crops because of low multiplication rates. The low multiplication rate of potato and restricted number of open field seed bulking to curb degeneration leads inadequate supply of quality seed potato particularly in developing countries. This renders quality seed scarce and prohibitively expensive for poor farmers in Uganda and most other developing countries. To enhance the multiplication rate of potato, various technologies have been developed and tried over time [1-3]. Rapid seed potato multiplication technologies can be as simple as use of stem cuttings or as complex and capital intensive as tissue culture [2, 4]. Single plant selections where large, disease-indexed tubers are planted at wide spacing has been used to enhance the number of progeny tubers that can be harvested from each planted mother tuber [2]. However, the technology requires large open fields and several field multiplication cycles, often exposing the stocks to degeneration. This notwithstanding, the multiplication rate is not radically enhanced.

In rapid multiplication technique using stem cuttings, young shoots are harvested from virus-tested mother plants, rooted and transplanted in open fields or net houses to produce nuclear seed stocks. Each mother plant may yield 30-100 stem-shoot cuttings. Each successfully rooted, transplanted and field established cutting may produce 2-5 tubers. However, this technology is labour intensive and tends to have a low field survival. Rooted stem cutting transplants are often grown in open fields where they are prone to infection with degenerative infections [1]. Alternatively, leaf-bud cuttings may be used to produce micro-tubers. However, they generally have a long dormancy and are prone to high storage losses due to shrinkage [3,5].

The potato multiplication rate can be enhanced by micro-propagation which has become an integral component of seed potato production systems in most developing countries since 1980's [4,5]. Nuclear seed tubers can be produced by in-vitro induction of micro-tubers or transplanting rooted in-vitro plantlets in porous media to produce mini-tubers [6]. Many micro-tubers may be produced per in-vitro plantlet but, they tend to have a longer dormancy period than normal tubers. They also require to be planted in green or net houses. Micro-tubers also suffer from high storage losses or may not be suitable for certain agro-climates [5]. The vitality of seed tubers from micro-propagated potato plants can be enhanced by production of mini-tubers. Mini-tubers are large, less delicate and can be directly planted in open fields or net houses depending on the degeneration rate of an agro-ecology [7]. However, the number of mini-tubers produced per plantlet hardly exceeds ten [6,8]. The number of mini-tubers produced per plantlet can be enhanced by repeated tuber harvesting where potato plants are carefully lifted from the soil and

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Volume:03, Issue:05 "September-October 2017"

replanted after removing tubers above a critical size [6]. This technique, however is labour intensive, disrupts plant growth, may cause early plant senescence often resulting in few tubers per plantlet than expected.

Potato mini-tuber production from micro-propagated plantlets permits faster multiplication and bulking of seed potato than other conventional methods and reduces the number of generations of open field bulking [9]. However, there is need to improve the multiplication rates further especially in tropical highlands in developing countries where previous seed potato production technologies have not significantly improved the quantity of quality seed at affordable prices for resource limited farmers.

In the last 20 years, non-solid or soil-free technologies have been developed and tested for potato cultivation to increase the multiplication rate without compromising seed tuber quality and plant growth through repeated mini-tuber harvesting. Such technologies include hydroponics [11, 12], nutrient film technique (NFT) [12], and aeroponics [9, 10]. Hydroponics and NFT have not been widely adopted in potato because they offered little improvement in mini-tuber production per plantlet partly because the stolons lack mechanical resistance, resulting in poor tuberisation ([6, 12]. Additionally, potato roots, stolons and tubers are continuously submerged in nutrient solution resulting in rotting, early plant senescence with consequent low multiplication rates [10]. The disadvantages of hydroponics and NFT can be overcome by draining the root eco-zone without denying the plants moisture and nutrient supply with potential to exert mechanical pressure that would stimulate tuber formation [10]. Aeroponics offer opportunities to overcome low multiplication rate in potato, renders potato plants to easy repeated mini-tuber harvesting with less plant disturbance. In potato grown aeroponically, all the nutrient solution is drained back to the reservoir tanks until the next cycle of misting. The technology also requires little or no greenhouse air conditioning in agro-ecologies where it has been tried [14].

Aeroponics is a method of growing crops, particularly vegetables in an air-nutrient solution mixture environment without soil or any other porous medium. Plant roots are grown suspended in a dark tunnel that is a closed or semi-closed environment where they are intermittently sprayed with a solution rich in plant nutrients [8, 14]. The development of feeding roots and stolons is greatly enhanced due to improved aeration of the root zone in presence of adequate moisture and nutrient supply [9, 14]. In potato, aeroponics has been adapted and used to produce large quantities of mini-tubers through vigorous growth of roots, stolons, extended vegetative growth and sequential harvesting of mini-tubers as they attain a suitable size [14]. Aeroponics offers opportunities to improve potato plantlet mini-tuber productivity and reduce production cost for the same number of tuber units produced in other conventional soil-based or soil-less culture systems. This would greatly increase the quantity of mini-tubers, reduce the number of

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

field generations, decrease seed degeneration and revitalize potato yields. Aeroponics will probably reduce the cost of seed potato due to increased supply of starter seed in countries where this technology will be adapted and adopted. Consequently, aeroponics is being tested for adaptation and eventual adoption in Uganda, Rwanda, Kenya and Ethiopia where seed is a serious bottle-neck to potato production ([15, 16]. Results from two potato crop cycles for aeroponics adaptation in Uganda are presented and discussed herein.

2. MATERIALS AND METHODS

A greenhouse experiment was carried out to test and adapt aeroponics technology for production of potato mini-tubers at Kachwekano Agricultural Research and Development Institute (KAZARDI) in Kabale, south western Uganda. The first aeroponically grown potato was established in September 2009 and it stayed vegetative until February 2010. The second crop was planted in March 2010 and removed in August 2010.

To establish potato aeroponics experiment, virus-indexed, in-vitro plantlets were transplanted in steam-sterilized sand for acclimatization and root development for three weeks. During the first seven days, the plantlets were irrigated with a nutrient solution at half strength of what is normally used for aeroponics-grown potato. Thereafter, the plantlets were irrigated every two days with full strength aeroponic nutrient solution for two weeks. Fully developed, rooted, hardened and uniform plantlets were removed from sand, roots washed with clean rain water to remove sand, rinsed in distilled water and then quickly transplanted in specially constructed aeroponic boxes or rhizotrons ([14].

2.1 Composition of nutrient solution for aeroponic potato

The nutrient solution for aeroponic-grown potato consists of both macro and micro elements. The macro-nutrient stock solution consists of 110.0 g l^{-1} of potassium nitrate, 36.0 g l^{-1} of Calcium triple supper phosphate, 70.0 g l^{-1} ammonium nitrate and 220.0 g l^{-1} magnesium sulphate. A stock solution of micro-nutrients consists of 17.0 g l^{-1} of iron EDTA, 1.4 g l^{-1} of boric acid, 3.0 g l^{-1} manganese sulphate, 0.6 g l^{-1} of zinc II sulphate, 0.2 g l^{-1} copper II sulphate and 0.2 g l^{-1} molybidic acid. Four and one litres of stock solution of macro- and micro-nutrient stock solutions, respectively were added to 995 l of clean rain water in the nutrient tank to make a final aeroponics plant nutrient solution. The nutrient solution was checked regularly for p^H and electric conductivity (EC). The electric conductivity should not exceed 2.0 mili-seimens cm^{-1} lest the plants will suffer from phytotoxicity. Similarly, the p^H of the nutrient solution should range between 6.8 and 7.3 for the nutrients to be freely available to aeroponically grown potato ([14]. The nutrient solution was renewed approximately every 7-14 days either when it got exhausted or had fallen below critical chemical properties.

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

2.2 Adapting local potato cultivars to aeroponics technology

Three potato varieties; Kachpot1 (CIP 393382.44), Victoria (CIP 381381.20) and Uganda 11 syn. Rutuku (CIP 720097) were tested at 24 and 36 plantlets per square metre. In 2009 only Kachpot1 was used while in 2010 all the three cultivars were tested. The plant densities were determined by making holes in the top covers of the rhizotrons either at 25 cm by 25 cm or 20 cm by 20 cm to offer 24 and 36 plantlets per square metre, respectively. This first experiment was planted in September 2009 and harvesting was completed in February 2010. In the 2010 the experiment was planted in March and harvesting was completed in August 2010. In the green house, 12 rhizotrons were available and each variety by plantlet density treatment combination occupied one rhizotron. The experiment was arranged in a completely randomized design with two repetitions. For each treatment combination, two rhizotrons were used. The rhizotrons were 4.8 m long, 1.2 wide and 1.2 m long. Each rhizotron had a separate nutrient supply pipe from the main nutrient delivery pipe fitted with eight fine-mist nebulizers, each able to discharge 12.5 ml $sec.^{-1}$ of nutrient solution.

2.3 Setting potato plantlets in aeroponic boxes

The stem section, between the roots and first lower leaves of a potato plantlet, was rolled in black sponge and inserted in a ¾-inch diameter PVC pipe previously fitted in the top covers of the rhizotrons. This ensured that the plantlets were firm with roots freely hanging inside the rhizotron. The black sponge reduced light penetration into the box. The set plantlets were fed with a nutrient solution for two minutes every 10 minutes through the pipes fitted with nebulizers hanging beneath the top cover of the rhizotrons. This was controlled by a digital irrigation timer, Galcon® (Kfar Blum, Israel) through a solenoid switch that shuts the outlet valves in the main nutrient supply pipe from the nutrient tanks after the misting cycle. After every timed misting cycle, the solenoid switch automatically closes the outlet valve but while the pumps are still working. Pressure build-up in the main supply pipe before outlet valve automatically turns off the electric pump through a hydro-pneumatic pressure control. The nutrient solution from the rhizotrons flows back to the nutrient tank through a plumbing system connected at the base of each box by gravity since they are placed inclined at about 2.5^{O} or 30 cm in 7 m (4% slope) to allow free nutrient flow back to the tanks.

The rhizotrons were checked regularly for nutrient and light leakage and to ensure that the all the plantlet roots evenly received the nutrient mists and got exposed to light, respectively. As the root system developed, the plantlets were periodically lowered by pushing them through the PVC pipe until the supporting sponge dropped out the PVC pipe to ensure unimpeded stolon development and prevent formation of tubers within the supporting pipe. After removing the sponge, each hole-carrying a plantlet was covered with a piece of black plastic to stop light penetration into the box and prevent foliage formation by stolons which would interfere with tuberization. Between 20 and 30 days after transplanting when the potato plantlets were about 35 cm tall and unable to keep upright and subsequently, support nets were installed at 30 cm interval on wooden extensions on the rhizotrons. As the plantlets grew and accumulated foliage, the lower and older leaves were clipped with sterile scissors or blades to reduce overcrowding and self-shading.

Tuber bulking in aeroponic potato began at about 60 days after transplanting and harvesting started 7-15 days later depending on the variety. Sizeable mini-tuber, were harvested at weekly intervals until the plants started senescing and could not support further mini-tuber formation and bulking. Tuber harvesting lasted thirteen weeks in both crop sets. The aeroponic potato was protected from foliar late blight and early blight attack by spraying twice with each of Agro-zeb 80 WP (mancozeb). Wettable sulphur (Thiovit Jet 80) was used to control powdery mildew and mites.

2.4 Data collection

Plant growth was monitored every week by measuring plant height and root length of two randomly selected and tagged plantlets per rhizotron from the middle two rows until the end of flowering and beginning of tuber setting. Mini-tuber harvesting started from 67-75 days after transplanting and continued for 13 weeks in both crop cycles. The mini-tubers from each partition per rhizotron were harvested separately, counted and weighed. The mini-tubers per harvesting date were bulked and kept at high humidity by covering them with black polythene in a box lined with manila paper for one week. This initial storage condition allowed gradual acclimatization of the mini-tubers to low humidity environment, reduced water loss, cured the tubers and prevented excessive shrinkage. Subsequently, mini-tubers for three consecutive weeks were later bulked and kept together to have as uniform sprouting as possible.

2.5 Data analysis

Only data for mini-tuber yield was processed and statistically analyzed for the purpose of this article. The effects of experimental treatments were tested with analysis of variance. Significant main effects and their interaction were compared with Fisher's protected least significant difference test at 5% probability. Genstat (6.2 Ed.) statistical computer package was used for the relevant statistical analysis procedures. Periodic trends in mini-tuber yield and yield components were examined with graphics generated in MS Excel.

3.0 RESULTS

3.1 Variety and plantlet spacing effects

The number of mini-tubers harvested per plantlet was significantly ($P \leq 0.01$) influenced by plantlet density in both September 2009- and March 2010- planted experiments. In the March 20210 trial, where more than one variety was used, the effects potato variety were highly significant ($P \leq 0.001$) across the measure variables (Table 1). All measured variables were not significantly ($P \leq 0.05$) affected by interaction between plantlet density and potato variety (Table 1). The number of mini-tuber harvested per square metre was significantly ($P \leq 0.05$) influenced by plantlet density (plantlets m^{-2}) in a trial planted in September 2009 but not the one of March 2010 (Table 1).

Table 1: Analysis of variance for effect of plantlet density and potato variety in aeroponics system on mini-tuber yield per square metre, number of tubers per plant and average mini-tuber weight (g) at Kachwekano, September 2009 and August 2010

Crop cycle	Source of variation	d.f.	Number of mini-tubers plant^{-1}	Number of mini-tubers m^{-2} week^{-1}	Total mini-tubers weight (Kg m^{-2})	Mean tuber weight (g)
Sep. 2009	Spacing (S)	1	1916.7***	225661**	1.394^{ns}	0.477^{ns}
	Error	42	34.0	29067	0.589	0.138
Mar. 2010	Variety (V)	2	745.5***	42887**	22.53**	3.380***
	Spacing (S)	1	216.8***	5862*	10.85^{ns}	0.219^{ns}
	V x S	2	8.92	48846^{ns}	0.721	0.176
	Error	16	12.42	120767	2.519	0.252

*, ** and *** represents significance at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$. ns indicates mean squares are not significant at $P \leq 0.05$

Mini-tuber production during the September 2009 trial showed that significantly ($P \leq 0.05$) more mini-tubers m^{-2} were produced at 36 than at 24 plantlets m^{-2} (Table 2). Plantlet density did not significantly ($P \leq 0.05$) affect the total weight (Kg) of mini-tubers harvested m^{-2} and average mini-tuber weight (g) (Table 2). Notably, the number of mini-tubers produced per plantlet was significantly ($P \leq 0.05$) higher at 24 than 36 plantlets m^{-2} (Table 2).

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

Table 2: Mini-tuber yield and yield components in aeroponic culture during September 2009 to February 2010 experiment at Kachwekano ZARDI, Kabale, Uganda

Mini-tuber yield components	Plantlet density (m^{-2})		$LDS_{0.05}$
	24	36	
Number of mini-tubers m^{-2}	1,242	1,386	104
Number of mini-tubers per plant	51.8	38.5	3.6
Total mini-tuber weight (Kg m^{-2})	5.36	5.71	0.47
Average mini-tuber weight (g)	4.3	4.1	3.2

Similar results due to plantlet density effects were obtained when the experiment was repeated with different potato varieties. However, in this trial, the effects of varieties were evident. Significantly ($P \leq 0.05$) more tubers per plantlet were harvested from variety Uganda 11 than Kachpot1 and Victoria, while the two varieties did not significantly ($P \leq 0.05$) differ from each other (Table 3).

Examination of mini-tuber yield per unit area per week based on rhizotron-cover showed that var. Uganda 11 produced significantly ($P \leq 0.05$) more mini-tubers m^{-2} $week^{-1}$ than vars. Kachpot1 and Victoria (Table 4). Similarly, more tubers per week were harvested at high than a low plantlet density (Table 4). Data also showed that var. Kachpot1 and Uganda 11 had significantly ($P \leq 0.05$) larger and heavier tubers than Victoria (Fig. 1). Describing potato plantlet productivity in absolute terms without examining trends in accumulation of min-tubers over time with sequential harvesting is not adequate for optimizing utilization of labour especially for mini-tuber harvesting. Figure 2 shows that more mini-tubers were harvested m^{-2} for the September 2009 trial, between the 4^{th} and 11^{th} week of harvesting with significant ($P \leq 0.05$) difference between 24 and 36 plantlets m^{-2}.

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

Table 3: Effect of variety and plantlet density (plantlets m^{-2}) on number of mini-tubers per plantlet from potato in aeroponics at Kachwekano ZARDI, Kabale, Uganda in March – August 2010

Potato variety	Number of mini-tubers per plantlet		
	Plantlets m^{-2}		Average
	24	36	
Kachpot1	22.0	16.4	19.2
Uganga 11	41.5	32.0	36.8
Victoria	23.2	18.0	20.6
Average	**28.9**	**22.1**	**25.5**

$LDS_{0.05}$ values between potato varieties and plantlets m^{-2} are 4.0 and 3.2, respectively.

Tabe 4: Effect of potato variety on number of mini-tuber yield per square metre per week from aeroponics at Kachwekano ZARDI, Kabale, Uganda in March–August 2010

Potato variety	Number of mini-tuber per square metre per week		
	Number of plants m^{-2}		**Average**
	24	**36**	
Kackpot1	41.0	45.5	43.3
Victoria	43.6	50.4	47.0
Uganda 11	76.8	88.2	82.5
Average	**53.8**	**61.3**	**57.6**

$LDS_{0.05}$ between plant densities and potato varieties are 5.8 and 6.1, respectively

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

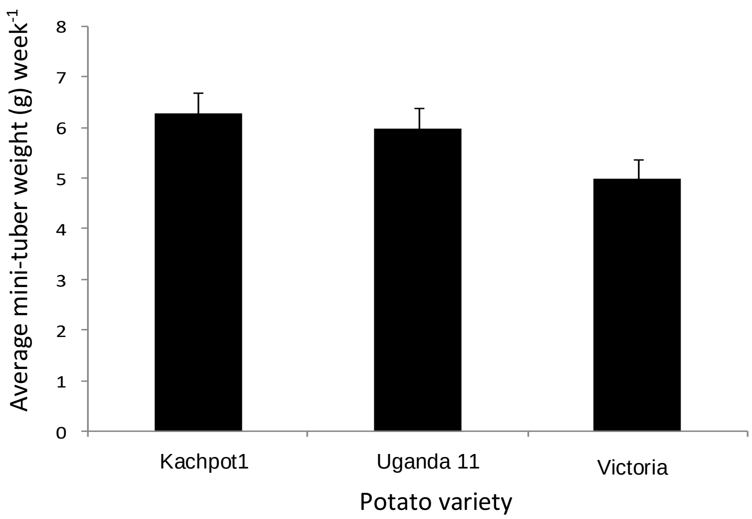

Fig. 1: Effect of potato variety and plantlet density (m^{-2}) on average mini-tuber weight (g) per week from aeroponic system at Kachwekano ZARDI, Kabale, Uganda in March–August 2010

During March 2010 experiment, peak mini-tuber harvesting per square metre was obtained between the 4th and 11th week of harvesting for both vars. Kachpot1 and Victoria and, 3rd to 12th week for var. Uganda 11 (Fig. 3). Sequential harvesting in var. Uganda 11 was delayed by one week after harvesting had commenced in var. Kachpot1 and Victoria (Fig. 3). There was generally significant ($P \leq 0.05$) difference in tubers harvested per unit area per week at 24 and 36 plantlet m^{-2} in var. Uganda 11 than vars. Kachpot1 and Victoria (Fig. 3).

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

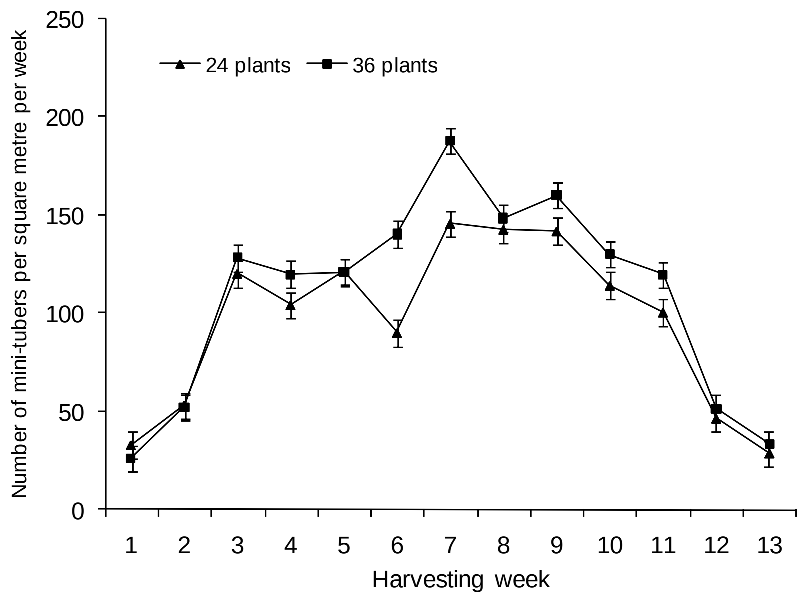

Fig. 2: Effect of plantlet density in aeroponics system on number of potato mini-tuber yield per square metre per week at Kachwekano ZARDI, Kabale, Uganda in 2009

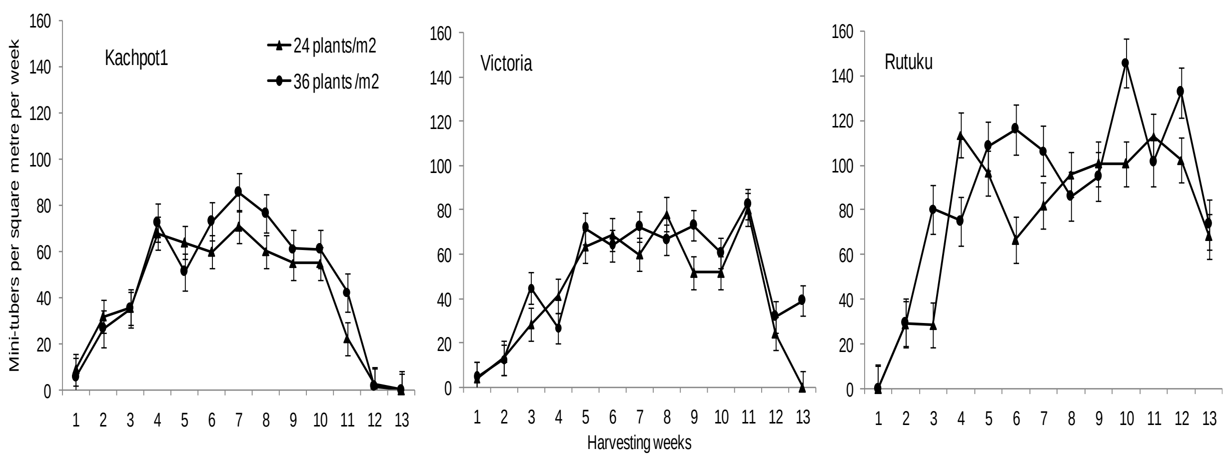

Fig. 3: Variation in number of mini-tubers harvested per square metre per week in aeroponic system at Kachwekano ZARDI, Kabale, Uganda in March 2010A

3.2 Precision in harvesting uniformly-sized tubers

The efficiency of any rapid seed potato multiplication technology is measured from its productivity per plantlet or per unit area than in gross tuber weight. Aiming at large tubers is

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Volume:03, Issue:05 "September-October 2017"

likely to result in few mini-tubers per plantlet or unit area. However, picking very small tubers in order have more numbers may increase mini-tuber loss through shrinkage during storage. In the crop planted in September 2009, the average mini-tuber weight per week ranged between 2.2 and 5.8g over the harvesting period. The overall average mini-tuber weight was 4.2 g with little variation in average mini-tuber weight (Fig. 4A). In the crop planted in March 2010 there was high deviation of weekly average mini-tuber weight (g) (Fig. 4B-D). Significantly ($P \leq 0.05$) larger or heavier tubers were generally harvested at the beginning of the harvesting period and small or light ones at the end (Fig. 4B and D) except for var. Uganda 11 (Fig. 4C).

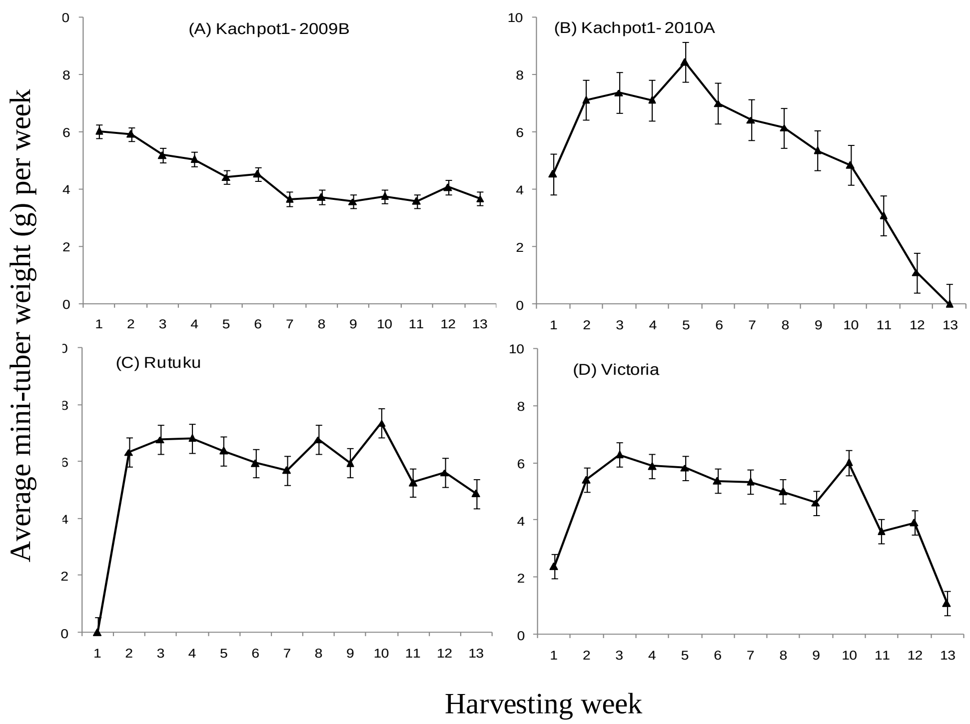

Fig. 4: Variation in average mini-tuber weight (g) in sequentially harvested aeroponics-grown potato at Kachwekano ZARDI, Uganda in 2009 and 2010

3.3 Comparison of mini-tuber plantlet productivity in soil substrate and aeroponics

Comparing soil substrate and aeroponics mini-tuber plantlet productivity showed that 8.5 times more mini-tubers were produced in aeroponics than soil substrate (Table 4). Considering that two crop cycles in green house conditions are possible per year in the highlands of south western Uganda aeroponics than soil substrates may hold the future for improving basic seed potato supply in this country.

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

Table 5: Average annual mini-tuber production in soil substrate and aeroponics at Kachwekano ZARDI, Kabale, Uganda in 2007-2009 and 2009-2010, respectively

Variety	Number of mini-tubers		Aeroponics:soil productivity ratio
	Soil substrate*	Aeroponics**	
Victoria	8,862	40,774	4.6
Kachpot1	875	45,493	52.0
Uganda 11	1,247	6,653	5.3
Total	10,983	92,920	8.5

*and ** are average mini-tuber production of three years on 100 m^2 in soil media and one year production on 70 m^2 of aeroponic boxes, respectively.

4. DISCUSSION

Preliminary data from piloting and adapting aeroponics revealed that the technology has a promising future to revolutionarise seed potato production in Uganda, although there is need to conduct more investigations to optimize it. The significant effect of plantlet density on number of mini-tubers harvested per square metre of rhizotron cover in 2009 but not in 2010 crop indicated the need for more seasons to test these plantlet densities to generate more consistent data in order to make robust recommendations. More mini-tubers m^{-2} were harvested at a high than low plantlet density probably due to more stolons per unit volume of rhizotron than at a low plantlet density. However, a high stolon number per unit volume of rhizotron would probably reduced the number of mini-tubers per plantlet. Consequently, more mini-tubers were harvested per plantlet at a low than high plantlet density. This may be related to reduce intra-plant competition resulting in more stolons and therefore more mini-tubers per plantlet. When potato plantlets are not limiting therefore, a high plantlet density would be more desirable in order to maximize mini-tuber production per unit volume of rhizotron space. If plantlets are limiting, a low plantlet density (wide spacing) should be used in order to maximize the number of mini-tubers per plantlet although this will probably reduce the number of mini-tubers per unit volume of rhizotron.

Observations indicated that var. Victoria has a slow bulking rate than Kachpot1 and Uganda 11. Over the same harvesting period per week, var. Victoria generally produced smaller tubers than var. Kachpot1 and Uganda 11 when allowed a same growing period. Verities Kachpot1 and Victoria did not significantly differ from each other in the number of mini-tuber produced per plantlet and per square metre because mini-tubers of the later variety were not allowed to bulk to the size of cvs. Kachpot1 or Uganda 11. This means that, Kachpot1 produced larger mini-tubers per week than var. Victoria, over the same period of bulking before the tubers were picked. This

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

also implies, if small tubers are harvested in var. Kachpot1 and Uganda 11 as var. Victoria, the former cultivar would produce more mini-tubers than the later. The mini-tubers of var. Kachpot1 were probably allowed to grow unnecessarily large in seven days since harvesting was done at weekly intervals possibly limiting development of more tubers and reducing potential productivity of Kachpot1. Unless small mini-tubers are found to be disadvantageous in storage, sprouting and field establishment, then the size of tubers to be harvested could be reduced to improve mini-tuber productivity per plantlet.

The similarity in average mini-tuber weight (g) at the 24 and 36 plantlets m^{-2} was largely because the size of mini-tubers to be harvested was controlled as much as possible where mini-tubers that had attained a particular sized were picked. Consequently, the average mini-tuber weight over the harvesting period is not expected to change if only tubers that attain a specific size are harvested. However, the mini-tuber size may differ at the beginning or end of harvesting period or due to potato variety differences if harvesting is set on fixed interval. As a result, the difference in average tuber weight (g) by variety per harvesting week is expected due to inherent variety differences in bulking. The observed variation in mini-tuber weight in the same variety over harvesting period may be due to changing the harvesting team on successive weeks or failure of the individuals in the team to adhere to harvesting instructions or lack of precision is estimating the sizes mini-tubers to be picked. If the size of the tubers to be harvested is standardized, the curve representing average mini-tuber weight over the harvesting period should be parallel to the x-axis over the harvesting period to a great extent. The trend in mini-tuber harvesting indicated that peak yields occurs between the 4^{th} and 11^{th} week, therefore, manpower deployment for mini-tuber harvesting should be concentrated to this time to optimize labour utilization.

The mini-tubers from aeroponic potato trial planted in March 2010 were 1.32 times heavier than those harvested from the September 2009 planted crop. This means larger or heavier tubers were harvested in aeroponic potato planted in March 2010 probably reducing the number of mini-tubers that would have potentially developed in this crop. This being a pilot study, the threshold size for mini-tubers to be harvested per week that would successfully sprout and vigorously grow in the field is not established yet. Consequently, the mini-tubers that were produced in the first aeroponic potato are being evaluated in the field by investigating the effect of mini-tuber size on field establishment and performance. This study will rationalize the mini-tuber size to be harvested that would feasibly sprout and grow normally in the field. This will in turn optimize the number that can be feasibly produced from aeroponic-potato per plantlet or unit area during a full potato growth cycle.

ISSN: 2455-6939

Volume:03, Issue:05 "September-October 2017"

5. CONCLUSION AND RECOMMENDATIONS

The study demonstrated that aeroponics technology for production of potato mini-tubers has potential to improve the supply of basic seed in Uganda and probably elsewhere the technology can be adopted. Aeroponics produced more mini-tubers per plantlet or per unit area than the conventional soil substrate. In aeroponics, more mini-tubers per plantlet were produced at a low than high plantlet density however, the low plantlet density reduced the number produced per unit area of rhizotron. Therefore, if the plantlets are limiting, they should be planted at a low density or wide spacing in aeroponics in order to maximize mini-tuber production per plantlet. If number of in-vitro plantlets is adequate, they should be transplanted at high density to maximize mini-tuber production per unit area. The difference in performance of different varieties in aeroponics was evident where, var. Uganda 11, a long cycle variety produced more mini-tubers per plantlet than vars. Victoria and Kachpot1 which are rather early-maturing potato varieties.

Aeroponics is a promising technology for breaking the seed potato bottleneck in tropical highlands however, it still has challenges. It is dependent on electric power to pump and circulate the nutrient solution. Electric power supply in Uganda and probably other developing countries is unreliable. There is a possible loss of aeroponically grown plants in the event of extended or total power failure. This however can be occasionally overcome by installing a thermal electric power generator but this is more expensive than the usual national grid power supply and may increase the cost of mini-tuber production. Power fluctuations can also damage the electric and electronic equipment used to run the aeroponic misting system predisposing the technology to failure and loss. The performance of the technology is sometimes affected by adverse weather, particularly high temperature inversion. This can be overcome by air conditioning or adding wrapped ice in nutrient tanks. However, this may not be sustainable or is likely to increase the cost of mini-tuber production with consequent expensive basic seed.

It is vital to optimize critical factors in order to maximize mini-tuber production through aeroponics. Such factors include diversifying the source and quality planting materials for aeroponics, standardizing duration of misting cycle to minimize electric power consumption, investigating potato root disease management in rhizotrons, studying the effect of water quality on aeroponic mini-tuber production, storage management of aeroponically produced mini-tubers, investigating diversification of power sources to run aeroponics to make it more sustainable including use of solar and wind energy. Finally, there is need to understand the economics of mini-tuber production with aeroponics. These notwithstanding, aeroponics is promising as a future basic component of seed potato production systems in tropical highlands with access to stable and inexpensive electric power supply.

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Volume:03, Issue:05 "September-October 2017"

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