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A LOW COST LIQUID NURSERY FOR PRODUCTION OF ROOTED STEM CUTTINGS AS PLANTING MATERIALS FOR HYDROPONIC POTATO PRODUCTION

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ABSTRACT

Researchers around the world have dedicated a great deal of effort to improve the vigour and quality of seed potatoes to maximize production efficiency and increase crop yield. Plantlets produced by planting G_0 mini tubers in sand trays and stem cuttings rooted in solid nurseries are used as standard planting materials for hydroponic systems. With the objective of increasing the quality of planting materials and lower the cost of production, liquid nursery system was introduced into G_0 seed potato production flow. A completely randomized, sixteen times replicated trial was carried out in a poly-tunnel and a greenhouse at RARDC, Bandarawela with biological and economic analysis. Nursery stage plantlets were evaluated in glass house up to transplanting and growth and yield performances of plantlets were evaluated inside the poly tunnel. The results revealed that, root and shoot development of plantlets in liquid nursery was significantly higher than that of other methods at the stage of transplanting. There was no significant difference among nursery methods in seed yield and quality. Cost reduction per propagule by using liquid nursery is 85% compared to sand nursery method . It has two fold economic advantages than other two conventional methods tested. It is revealed that, liquid nursery is very useful to produce large number of vigorous and high quality planting materials of potato in limited space at low price, which is more advantageous for G_0 mini tuber production programmes.

Key words: liquid nursery, potato, rooted stem cuttings, G_0 mini tuber, hydroponic

INTRODUCTION

Supply of high quality seed potatoes at an affordable price is a pre requisite of the Sri Lankan potato industry today. Therefore, good quality, disease free seed tuber production is an important need to optimize the seed tuber production. Rapid multiplication technique is one of the flexible methods used worldwide to produce first generation tubers (G_0) which are free from pests and diseases. It produces seed potato tubers free from seed borne diseases (Roca *et al.*, 1978). *In vitro* mother plant production, primary and secondary mother plant production, production of rooted stem cuttings (RSC) and production of mini tubers and pre basic seeds are the main consecutive steps of rapid multiplication technique. Various hydroponic techniques and geoponic techniques are used to produce mini tubers and pre basic seeds. Mini-tubers are small tubers of 5 – 25 mm in diameter and a range in weight between 0.1 – 10 g and sometime higher (Ostroshy 2006).

In majority of the occasions, planting materials for mini tuber multiplication is done by germinating previously produced mini tubers in sand nurseries (Mazeen *et al.*, 2008). Furthermore, rooted stem cutting produced in solid media nurseries are used occasionally. It is essential to use sterilized sand and solid media to avoid contaminations in both instances. Because of vegetative propagation, viruses and viroid can be accumulated in tubers (Muthoni *et al.*, 2013). Root system of plantlets obtained from sand and solid nurseries are cleaned to remove soil and other solid particles and supported by a piece of gauze to facilitate nutrient uptake at the initial stage before placing them in hydroponic systems. Hence, cost also increases as several steps are involved in the production process and furthermore, roots can be damaged during the process.

Stem cuttings can be easily rooted in a liquid media. It results in a good root system and vigorous growth. The root system of stem cuttings rooted in a liquid nursery needs no pre care practices as conventional practices. Therefore it is economically and biologically beneficial to plants than conventional methods. With the objective of introducing liquid media nursery system to the seed production process, an experiment was conducted using a hydroponic seed producing method to evaluate the growth and yield advantages of plantlets produced in a liquid nursery.

MATERIALS AND METHODS

Experiments were carried out in a glass house for two weeks at nursery stage and seed producing stage inside poly-tunnel from September to November in 2014 at Regional Agriculture Research and Development Centre (RARDC), Bandarawela. Poly tunnel for the experiment was laid out in a Complete Randomize Design with 10 replicates with 5 experimental units for each replicate. Plantlets from different nurseries were transplanted in a simplified hydroponic seed producing system which uses nutrient film technique. G_0 Seed tubers and stem cuttings (SC) of secondary mother plants of potato variety Granola were used. Three different nursery management techniques for planting material production were used as treatments (Plate 1). They are, (I) rooted sprouts from whole G_0 tubers (small tubers of 5-20 mm diameter) grown in a sand tray (G_0 sand nursery), (II) stem cuttings (from secondary mother plants raised in a glass house) rooted in liquid (SC liquid nursery) and (III) stem cuttings rooted in solid media nurseries (SC solid nursery).

A B C

Plate 1. Different nurseries used to produce RSC in the study

Note: A=Rooted sprouts from whole G_0 tubers grown in a sand tray; B=Stem cutting rooted in Liquid nursery; C=Stem cutting rooted in solid nursery.

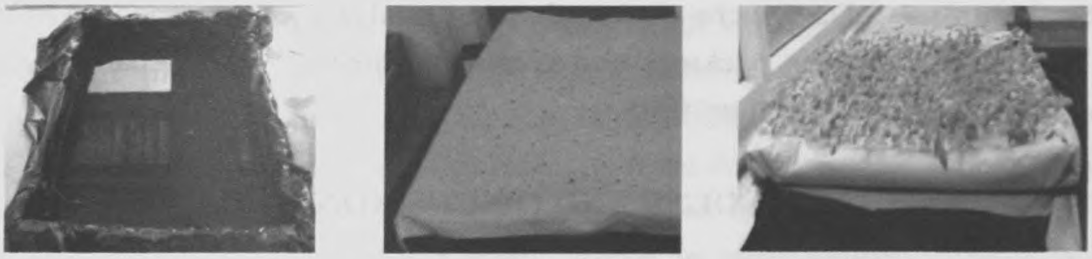
Preparation of nursery

Solid media: Cattle manure, coir dust and soil (1:1:1) were used as nursery media. Soil and dried cattle manure was sieved and they were thoroughly mixed with washed coir dust. Then the mixture was filled in small net bags and stacked inside a barrel for steam sterilization. More than four hours were required for full sterilization. Then they were filled in nursery trays and watered up to field capacity before establishing stem cuttings. To induce rooting, trays were covered with transparent polythene as propagators for a week. Then polythene was removed and kept for another week to acclimatize the plants before transplanting.

Liquid media: Black polythene lined plastic crate was filled with Albert solution (1.5 g of Albert's mixture dissolved in one litre of water). A metal net (mesh size

2.5 cm^2) was placed on the tray and covered with two layers of black and white polythene, one to over the other. Inner black polythenes provide the dark root environment while, white polythene reflects the light and heat at outside. Small incisions (0.5" x 0.5") were made in the polythene layer in 2"x2" distance. Stem cuttings obtained from secondary mother plants were inserted into the incisions (newly introduced method for rooting of stem cuttings). Plants were maintained for two weeks until they reached 15 cm height (Plate 2).

Sand nursery: G_0 seeds were planted (2''x 1'' spacing) in 16" x 23'' plastic trays filled with cleaned and sterilized two inches thickness sand layer. Sand was washed and steamed prior to filling into the tray. This is the most popular nursery preparation method used to produce seedlings for hydroponic systems. Plants were maintained for two weeks until they reached 15 cm height.



(a) (b) (c)

Plate 2. Preparation steps of liquid nursery.

Note: A=Lining of plastic crate with black polythene; B=Small incisions made on the top covered polythene layers; C=Stem cuttings establishment

Transplanting: Transplanting was done two weeks after the nursery period. Plantlets from tubers and stem cuttings rooted in solid media were uprooted from the nursery with minimum damages to the root system and mother tuber was separated. Root systems of plantlets obtained from solid media nurseries were washed with clean water to remove sand and soil particles and dipped in a fungicide solution (Thiophanate–methyl 50% + 500g / l SC). A small piece of gauze (2" x1") was wrapped over the root system of less rooted plants to facilitate nutrient absorption to the plants at early stages. They were established in the hydroponic system. Plantlets obtained from the liquid nursery were directly established in the hydroponic system without any aftercare treatments such as washing, treating with fungicides and gauze wrapping.

Measurements: Shoot and root length of transplanted plantlets were measured in weekly intervals. After seven weeks, number of leaves per plant and nodal distance were measured and plants were destructively sampled to record volume and dry weight of shoot, root, leaves and stolon. Average leaf area was measured by using graph papers and dry weights of leaves were obtained. At harvesting, number of tubers per plant, tuber diameter, tuber weight and specific gravity of tubers were recorded.

Costs for preparing and maintaining each type of nursery was calculated considering all cost components such as material cost, labour cost, maintenance cost etc. Income was computed by considering average seed yield and price of a tuber. Space requirement for nursery systems were calculated by tray sizes and number of plants accommodated in each tray. Temperature and relative humidity was measured inside the poly tunnel throughout the experimental period.

Statistical analysis: Data were analyzed using analysis of variance (ANOVA) using SAS 9.1 computer package and treatment means were separated using Duncan multiple range test at $p< 0.05$.

RESULTS AND DISCUSSION

Average relative humidity and temprature inside the poly-tunnel during the cropping period was 63% and 26 ^{0}C, respectively. Fairly high temperatures and low humidity levels were observed during the experimental period compared to conventional potato growing seasons.

Growth performances of nurseries

Root length of plants in liquid nursery was significantly higher than that of other methods at the stage of transplanting (Table 1). Well-developed root system always facilitates water and nutrient absorption. Therefore, vegetative growth was comparatively higher in plants obtained from liquid nursery. Plant establishment and growth depends on a good root system to make immediate contact with the potting media for successful establishment (Kularathna and Ariyarathna, 2008).

Higher root length is an advantage for the establishment in hydroponic systems like deep flow or nutrient film. There is no need to support the roots with gauze to keep contact with the solution at initial stage as in other practices. There was no significant difference of the root length of the plants from the solid nursery with liquid nursery at latter stage due to quick adapting and development of roots for the new environment than planting of G_0 in sand nurseries.

Table 1. Root lengths of plants from different nurseries.

Treatment	1 wap	2 wap	4 wap	6 wap	8 wap	10 wap
G_0 Sand nursery	11.6 b	13.7 b	20.8 b	28.9 b	35.7 b	33.5 b
SC liquid nursery	16.2a	17.0 a	28.3 a	34.3 a	42.7 a	40.3 a
SC Solid nursery	9.2 b	12.4 b	19.9 b	37.6 a	40.9 a	39.1 a
CV%	21.4	21.53	16.04	12.38	13.88	14.18

Note: CV= coefficient of variance; Mean in each column followed by the same letters are not significantly different (p=0.05). *wap*=weeks after transplanting

As shown in Table 2, significantly high average root dry weight was recorded in plantlets obtained from liquid nursery (p=0.0001). Average root volume, stolen volume and stolen lengths of plantlets obtained from liquid nursery were not significantly different with plantlets from conventional methods. It means stem cuttings rooted in liquid nursery has the same ability to produce good plants and yield. Survival rate is significantly higher in sand nursery compared to the stem cutting nurseries. It is due to the initial strong support by the mother tuber. Planting media and other environmental factors such as temperature and moisture can have a direct effect on establishment of rooted stem cuttings and their growth (Kularathna and Ariyarathna, 2008). Plant should have good root system to make immediate contact with the potting media for successful establishment (Kularathna and Ariyarathna, 2008).

There is a significantly higher shoot length observed in plantlets obtained from the liquid nursery at 1^{st} week of transplanting (Table 3). It clearly shows vigorous growth at the nursery. From first to 7^{th} week after transplanting, significant differences of shoot length was observed in liquid nursery. Maximum shoot length of plants in liquid nursery throughout the vegetative growth could be a result of well-developed, vigorous root system at nursery stage (Table 1.) Both solid and sand nursery meet different root environment after transplanting in hydroponic system. Hence, such plants showed low vegetative growth at initial stage than plants from liquid nursery. Removing of mother tuber, washing roots to remove the media at transplanting of sand nursery may cause sudden nutrient loss to plantlets. Therefore, plants experienced a slight stress on nutrient uptake for few weeks (Struic and Wiresma, 1999).

Table 2. Root and stolon characteristics of plants after 7 week after transplanting and survival rate after 4th week.

Treatment	Survival rate (%)	Average root dry weigh (g)	Average root volume (ml)	Average stolen volume (ml)	Average stolen length (cm)
G_0 Sand nursery	95 a	0.46 c	9.00 b	6.50 a	15.0 a
SC liquid nursery	90 b	1.22 a	12.52 a	6.66 a	17.0 a
SC Solid nursery	90 b	0.84 b	12.50 a	6.00 a	13.0 a
CV %	14.5	21.58	21.94	23.54	19.07

Note: CV= coefficient of variance; Mean in each column followed by the same letters are not significantly different (p=0.05).

Significantly higher number of leaves and average total leaf area were observed in liquid nursery (Table 3). Internodal lengths were significantly higher in liquid and solid nursery than in sand nursery. Higher internodal length is a result of vigorous vegetative growth of stem cuttings of potato. It helps to develop good canopy architecture. High leaf area and good canopy architecture provide better ability for photosynthesis. Throughout the season, canopy diameters of the plants obtained from the liquid nursery were significantly higher. But from 1week to 10 weeks after planting there were no significant difference of canopy diameter between sand and the solid nurseries (Figure 1). Considering the growth performances of plantlets obtained from stem cuttings showed good performance than with using tubers. Potato plant has flexibility in organ development and therefore it could be utilized for alternative method of propagation (Kularathna and Ariyarathna, 2008). Therefore, multiplication of rooted stem cuttings in up country wet zone was comparatively lower than that of the up country intermediate zone (Kularathna and Ariyarathna, 2008).

There was no significant difference among nursery methods in seed yield, number of tubers per plant, weight per tuber, diameter per tuber and specific gravity of tubers in the experiment (Table 4). It shows the possibility of using liquid nursery to produce planting materials for any hydroponic system. The nonsignificance in specific gravity revealed that there was no effect of the higher amount of nitrogen supplied by the liquid nursery at nursery stage. Increased nitrogen causes marked and highly significant reduction in the dry matter content of the tubers. In all cases, the lowest specific gravity was found with increasing nitrogen (240 pounds/acre). This appears to be a reflection of the delay in maturity due to high nitrogen (Timm *et al.*, 1960). Evaluating the growth and yield performances of plantlets obtained from different nursery methods, it is revealed that the liquid nursery method can produce planting materials for mini tuber and pre basic seed production. However, it is necessary to do a cost benefit analysis to identify its economic advantage.

Table 3. Shoot length, mean leaf number, internodal length and total leaf area of plants from different nurseries after transplanting.

Treatment	Shoot lengths(cm)		Number of leaves/ plant	Average Inter nodal length(cm)	Average total leaf area per plant (cm^2)
	1 wap	7 wap			
G_0 Sand nursery	21.5 b	51.9 b	22.5 b	3.2 b	1,729c
SC liquid nursery	27.9a	67.5 a	36.22 a	4.2 ab	5,373a
SC Solid nursery	16.0 c	52.8 b	36.5 a	4.4 a	3,805 b
CV%	16.78	16.46	20.2	19.13	19.08

Note: CV= coefficient of variance; Mean in each column followed by the same letters are not significantly different (p=0.05). *wap*=weeks after transplanting.

Costs for nurseries and space requirements

Highest total cost accounted for sand nursery and lowest was for the liquid nursery (Table 5). The highest cost of sand nursery system was recorded because of the high cost of G_0 seed tubers. Mini-tubers are more economical and preferred by farmers due to its high quality. This is not sufficient to cater to the high demand for seed potatoes. (Nissanka, 2011)

Since the number of tubers per plant was not significant, stem cuttings rooted in liquid and solid nurseries were cost effective than sand nursery. Data revealed that cost benefit ratio is very high in use of liquid nursery. Cost reduction per propagule by using liquid nursery is 85% compared to sand nursery method. It has two fold economic advantage than other two conventional methods tested.

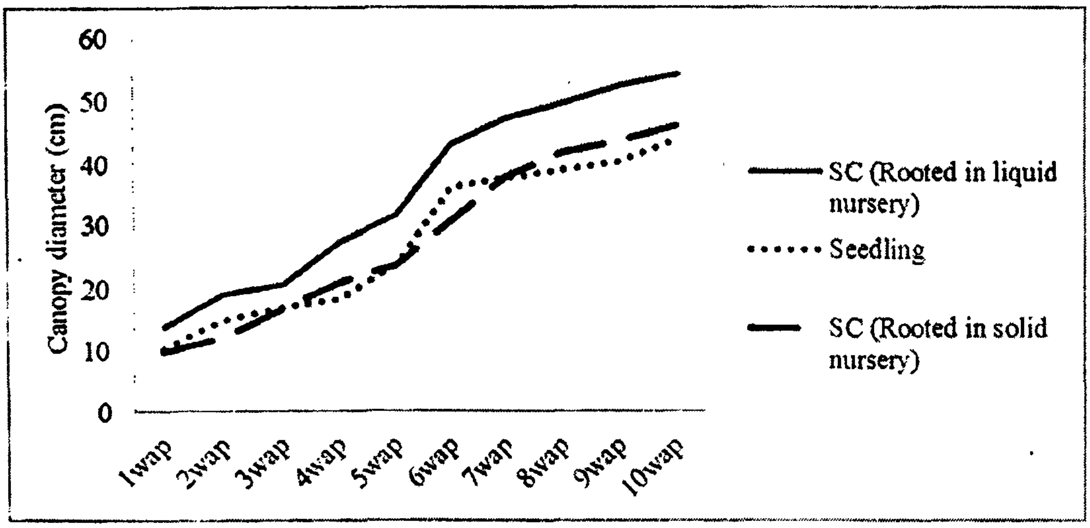


Figure 1: Canopy diameter of different nurseries.

Table 4. Yield performances of planting materials produced in different nurseries.

Treatment	Number of tubers per plant	Mean weight per tuber (g)	Diameter per tuber (cm)	Specific gravity
G_0 Sand nursery	22 a	2.7 a	2.38 a	1.04 a
SC liquid nursery	24 a	2.85 a	2.5 a	1.00 a
SC Solid nursery	21 a	2.7 a	2.65 a	0.97 a
CV%	5.44	6.804	3.984	14.3

Note: CV= coefficient of variance; Mean in each column followed by the same letters are not significantly different (p=0.05).

Another benefit of using plantlets obtained from liquid nursery at transplanting is, no need to wash the roots to remove adhered solid particles of media and it reduces the root damages. Using plantlets obtained from liquid nursery can eliminate the costly, time consuming and labour intensive activities such as wrapping of gauze, and washing of roots in plantlet establishment to the system. Establishment and maintenance cost can be reduced by 47% by using liquid nurseries. Less risk of infection by different pathogens, high rate of multiplication and higher number of mini-tubers per unit area are reported as advantages of the soil-less system (hydroponic system) for mini-tuber production compared to mini-tuber production in the solid media such as peat (Rolot, and Seutin, 1999; Ostroshy, 2006).

Table 5. Different cost components to prepare nursery with 100 plants and space reqirement for nurseries inside the net house.

Treatment	Cost per propagule (Rs.)	Income (Rs.)	Establishment and maintenance cost (Rs.)	Cost/ benefit ratio per plant	Per plant space requirement (cm^2)
G_0 Sand nursery	6.58	132.00	95.00	1.3	23.0
SC liquid nursery	0.97	144.00	50.00	2.8	9.2
SC Solid nursery	2.70	126.00	95.00	1.3	17.4

Greenhouse space is very much important because of the high installation cost. Using liquid nursery, it is possible to produce large number of planting materials in limited space, hence increases the production capacity of the greenhouse. In conventional methods, it is unable to accommodate large number of tubers due to many difficulties in uprooting for transplanting. High density planting results in root entangles. But it does not occur in liquid nurseries. So high density planting can be done with the liquid nurseries, and can increase the density by 60% than sand nursery method.

CONCLUSIONS

Liquid nurseries are the most appropriate method to produce large number of vigorous, high quality planting materials of potato at lower price in limited space. It is twofold economically advantageous than conventional methods and more advantageous in G_0 mini-tuber production programmes.

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REFERENCES

Kularathna, R.J.K.N and D. Ariyarathna. 2008. Evaluation of propagule types of potato for pre basic seed production. Proceedings of International potato symposium Department of Agriculture, Sri Lanka: 59-69.

Mazeen,A.C.M., M.M. Nugaliyadda, M.A.G.C.N. Premarathna and R.S.R.M.A.D. Rathnayak. 2008. Growth and yield performance of potato (*Solanum tuberosum*) Pre basic seeds produced through repeated harvesting method using different soil less cultivation system. Proceedings of International potato symposium. Department of Agriculture, Sri Lanka: 111-117.

Muthoni, J., H. Shimelis and R. Rob Melis. 2013. Alleviating potato seed tuber shortage in developing countries. Journal of potential of true potato seeds. AJCS 7(12):1946-1954.

Nissanka, N.A.K.A.L., M.M. Nugaliyadde and U.R. Sangakkara. 2011. Potential of mini-tuber production of four potato cultivars in a hydroponics system. Proceedings of Peradeniya University research sessions, Sri Lanka 16.

Ostroshy, M. 2006. Utilization of tissue culture techniques in a seed potato tuber production scheme. Journal of General introduction to tissue culture, 3: 21-33.

Roca, W.M., M.R. Espinoza and J.F. Bryan. 1978. A tissue culture method for rapid propagation of plants. Journal on Annual Meeting of Potato, 59: 691-701.

Rolot., J.L. and H. Seutin. 1999. Soilless production of potato mini-tubers using a hydroponic technique. Journal of Potato Research 42, 14-16.

Struik P.C and S.G. Wiresma. 1999. Seed potato technology. .Wagenin GEN Press, 65: 3. 383

Timm H., D.D.T. Lyons, J.C. Bishop, J.C .Schweers, V,H. and J.R. Stockton .1960.Potato quality lowered in field tests with High Nitrogen Fertilization. California Agriculture, 123: 10-11.