International Scholars Journals

International Journal of Agricultural Extension and Rural Development ISSN 2756-3642 Vol. 8 (9), pp. 001-006, September, 2020. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Up-scaling production of certified potato seed tubers in Kenya: Potential of aeroponics technology

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Accepted 28 April, 2020

Unavailability of certified seed tubers is a major constraint to potato production in Kenya. This compels most farmers to use planting materials from informal sources such as previous harvests, local markets and neighbours. Kenya Agricultural Research Institute (KARI), Tigoni has the national mandate to produce basic seed tubers but can only supply much less than 1% of the national seed requirements. In order to improve on the situation, aeroponics technique was introduced to enhance production of prebasic seeds from tissue culture plantlets. The aeroponics unit is still in experimental stages and is being evaluated for productivity and profitability. Some results show that aeroponics can increase production of prebasic minitubers. However, the aeroponic technology needs further and complete evaluation in terms of productivity, profitability and sustainability.

Key words: Aeroponics, certified seed, Kenya Agricultural Research Institute (KARI), Tigoni, minitubers, potatoes.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a crop of major economic importance worldwide (Tsegaw, 2005; FAO, 2008). On a global scale, potato is the fourth most cultivated food crop after wheat, rice, and maize (FAO, 2008). Potato is also the most important tuber crop ranking first in volume produced among root and tuber crops, with an annual production of approximately 300 million tonnes grown on about 19 million hectares (FAO, 2008), it is followed by cassava, sweet potato, and yam (FAO, 2004, 2008).

The world average potato production is about 17 t ha^{-1}, while direct consumption as human food is 31.3 kg per capita (kg yr^{-1}) (FAO, 1995, 2008). Worldwide, there are wide regional disparities in potato production (FAO, 2008). Asia and Europe are the world's major potato pro-ducing regions, accounting for more than 80% of world production while Africa is the least, accounting for about 5% (Table 1). North America is the clear leader in productivity at more than 40 t ha^{-1}, followed by Europe at 17.4 t ha^{-1} while Africa lags at about 10 t ha^{-1} (FAO, 2004; FAO, 2008). In Africa, the top ten potato producers in descending order are Egypt, Malawi, South Africa, Algeria, Morocco, Rwanda, Nigeria, Kenya, Uganda, and Angola (FAO, 2008). In Kenya, potato is the second most important food crop after maize (MoA/GTZ, 1998; CIP, 2006; MoA, 2008). It is grown by about 500 000 farmers, cultivating 120,000 hectares per season with an annual production of about 1 million tonnes in two growing seasons (MoA, 2008). National potato production ranges from 4.4 tha^{-1} to 15 tha^{-1} with an average of about 6.7 tha^{-1} although yields of 40 tha^{-1} are attainable under research conditions (Lung'aho et al., 1997; MoA, 2008). The low yields are attributed to production constraints such as low soil fertility, diseases such as bacterial wilt and late blight as well as high cost of inputs mainly certified seed tubers.

Certified potato seeds are produced only by Kenya Agricultural Research Institute (KARI), Tigoni, whose physical capacity is limited (Kaguongo et al., 2008).

Consequently, KARI can only produce 1% of the national certified seed requirement (Ayieko and Tschirley, 2006). Due to limited supply, the certified potato seeds are highly priced and the cost of seeds account for 42%

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Table 1. Potato production by regions in 2007.

Region	Harvested area (,000 ha)	Production (,000 tons)	Productivity (t ha^{-1})
Africa	1,542	16,707	10.8
Asia/Oceania	8,733	137,344	15.7
Europe	7,474	130,224	17.4
Latin America	964	15,683	16.3
North America	616	25,345	41.2
World	19,328	325,302	16.8

Source: FAO, 2008.

Table 2. Amount of basic seed produced from KARI Tigoni and its subcentres from 2006 to 2009 (kg).

Season / Place	2006 Long rains	2006/2007 Short rains	2007 Long rains	2007/2008 Short rains	2008 Long rains	2008/2009 Short rains	2009 Long rains
Njambini sub station	5550	6250	4050	3000	6250	1500	16250
Marindas substation	14450	0	23650	0	8650	0	5050
Marimba substation	2050	2650	2650	4150	2650	3000	7500
Tigoni	13450	16500	20000	20000	16250	12600	9000
Total	35500	25400	50350	27150	33800	17100	37800

Source: KARI (2007).

of the total production costs (Kaguongo et al ., 2008). Consequently, farmers depend on seed from informal sources which include farm-saved (self supply), local markets and neighbours (Kaguongo et al ., 2008). Self-supply is the major source of potato seed tubers for most farmers (Kaguongo et al ., 2008). This informal system leads to use of poor quality seeds and often accelerates the spread of seed-borne diseases (Ng'ang'a et al., 2003).

This paper reviews the certified potato seed production system in Kenya, the problems it faces, and the potential of aeroponic technology to improve on it.

PRODUCTION OF CERTIFIED POTATO SEED TUBERS IN KENYA

Conventionally, certified potato seed tuber production starts with *in vitro* plantlets from meristematic tissue in the tissue culture laboratory (KARI, 2007). The plantlets are multiplied and after hardening-off, they are planted in potted sand media in a screen house to produce pre-basic minituber seeds (generation 0). The prebasic minitubers are then multiplied for three generations in the field to produce generation 1, 2 and 3 basic seeds. The generation 3 basic seeds are planted for one generation at KARI, Tigoni and its substations, contracted certified seed farmers' fields as well as Agricultural Development Corporation (ADC) farms to produce certified seeds (KARI, 2007). Production of prebasic minituber seeds from *in vitro* plantlets is slow and this leads to a bottle-neck in certified seeds production chain (Muthoni et al., 2010). The multiplication rate is 6 to 8 minituber seeds/ plant (KARI, 2007). Table 2 shows amount of generation 3 basic seeds produced from KARI, Tigoni for the last seven years. Figure 1 shows a schematic system of seed potato production from pre-basic to basic as done at KARI, Tigoni

COMPARISON BETWEEN AEROPONICS TECHNOLOGY AND CONVENTIONAL METHODS

In a bid to compare the productivity of aeroponics technology and conventional methods, two most popular potato varieties *Tigoni* and *Asante* were evaluated for minituber production. The experiment was conducted between March 2009 and December 2009 (first season) while the second season was between March 2010 and December 2010.

MATERIALS AND METHODS

Aeroponics

The aeroponics unit at KARI, Tigoni was constructed in 2009. The

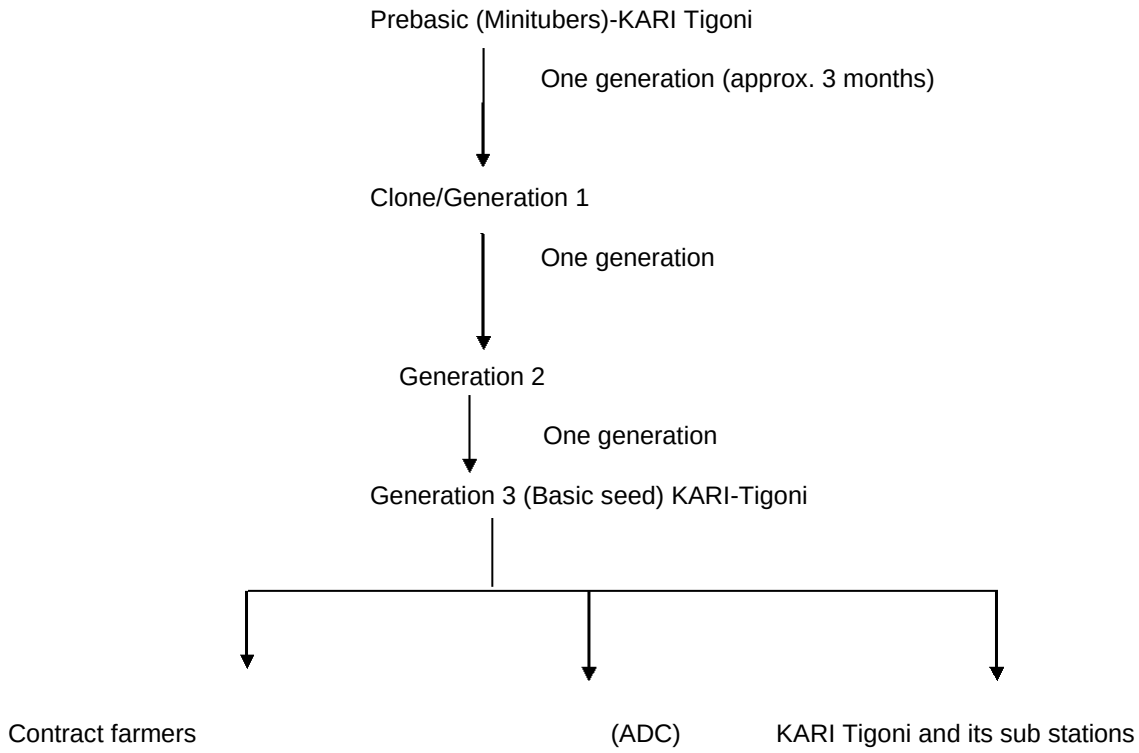

Figure 1. Schematic system of seed potato production from pre-basic to basic.
Source: KARI (2007).

Table 3. Composition of 500 liters nutrient solution.

Nutrient	Quantity (g)
KNO_3	2.2
NH_4NO_3	1.4
Ca superphosphate	0.8
$MgSO_4$	0.8
Fe(EDTA) Fe 6%	0.036
Micro(Fetrilon)	0.048
pH	6.5

Source: Farran and Mingo-Castel (2006).

unit consisted of a screen house measuring 30 m × 6 m. It was a metallic structure with translucent asbestos roof and the sides were made of white muslin shading net to lower the temperature inside. Inside the screen house were the growth chambers. Each chamber could accommodate 180 plants.

Each growth chamber consisted of a styrofoam box measuring 6 m × 1.8 m × 1.5 m. The sides were cut to ease minituber harvesting and monitoring of the fertigation system. The cut sides were covered with a black polythene paper which could be lifted to check the tuber growth. The fertigation system consisted of an underground plastic tank in which the nutrient solution was held. The nutrient solution was transmitted into growth chambers using pipes.

The fertigation system was controlled by a timer and mists of nutrient solution were sprayed onto the dangling potato roots for 5 min after every 15 min. The nutrient solution was collected at the bottom of the boxes and pumped back into the tank. This system was powered by electricity, but a solar-powered generator was used in case of electricity failure. The composition of the nutrient stock solution used is given in Table 3. Each growth chamber represented a replication and each potato variety was grown in three such chambers giving a total of three replications for each potato variety. The experiment was laid out in a completely randomized design replicated three times.

Crop management

The plantlets from tissue culture laboratory were transplanted into growth boxes when they attained 5 cm tall with root length of about 2.5 cm and with 2 to 3 leaves. Small holes were made on the lids of the growth chambers and the plantlets were fitted into the holes at the crown with the roots hanging inside the box. The plantlets were held firmly in an upright position with the help of masking tape, this also ensured no light got inside the growth chamber. The lowest leaf of the plant was cut off every two weeks for the next two months. This allowed the plants to be pushed deep down into the growth chamber to promote stolon development.

The black polythene paper on the sides of the growth chamber was lifted to allow minituber harvesting. The minitubers were harvested when they attained a minimum of 8 g. This corresponded to a tuber diameter of 0.5 cm. This was done continuously to promote

Table 4. Average number of minitubers per replicate from aeroponics in the first season.

Minituber size	1	2	3	Total
Asante	7404	1856	470	9730
Tigoni	15298	3858	1146	20302

Minituber size (diameter): 1 = 0.5 to 1.5 cm, 2 = 1.51 to 2.5 cm, 3 = 2.51 to 3.5 cm.

Table 5. Average number of minitubers per replicate from aeroponics in the second season.

Minituber size	1	2	3	Total
Asante	7521	1820	521	9862
Tigoni	16620	4246	1059	21925

Minituber size (diameter): 1 = 0.5 to 1.5 cm, 2 = 1.51 to 2.5 cm, 3 = 2.51 to 3.5 cm.

Table 6. Average number of minitubers per replicate from pots in the first season.

Minituber size	1	2	3	Total
Tigoni	1155	761	164	2080
Asante	926	299	165	1390

Minituber size (diameter): 1 = 0.5 to 1.5 cm, 2 = 1.51 to 2.5 cm, 3 = 2.51 to 3.5 cm.

Table 7. Average number of minitubers per replicate from pots in the second season.

Minituber size	1	2	3	Total
Tigoni	1123	832	112	2067
Asante	912	322	153	1387

Minituber size (diameter): 1 = 0.5 to 1.5 cm, 2 = 1.51 to 2.5 cm, 3 = 2.51 to 3.5 cm.

promote tuber initiation. The first harvest was done five weeks after transplanting while subsequent harvesting was done weekly for the next 18 weeks. During each harvest, all the 180 plants in a growth chamber were harvested to give total replicate yield. The average replicate total yields for each variety were then calculated. The minitubers were then sorted out into three sizes based on diameter: Size 1 had a diameter of 0.5 to 1.5 cm, size 2 had diameter of 1.51 to 2.5 cm while size 3 had diameter of 2.51 to 3.5 cm. Harvested tubers were left to cure in wooden trays for 4 weeks before cold storage.

Conventional method

The experiment was laid out in a completely randomized design replicated three times. Each replication consisted of 180 pots. The plantlets from tissue culture laboratory were transplanted into pots when they were about 5 cm tall with root length of about 2.5 cm and with 2 to 3 leaves. Each plantlet was translated into its own pot. The pots were half filled with sterilised soil and put into screenhouse. The plants were watered regularly as need arose. Eight weeks after transplanting, all the plants were harvested. During each harvest, all the 180 plants in a replicate were harvested to give total replicate yield. The average replicate total yields for each variety were then calculated. The minitubers were then sorted out into three sizes based on diameter: Size 1 had a diameter of 0.5 to 1.5 cm, size 2 had diameter of 1.51 to 2.5 cm while size 3 had diameter of 2.51 to 3.5 cm. Harvested tubers were left to cure in wooden trays for 4 weeks before cold storage.

RESULTS AND DISCUSSION

Variety *Tigoni* produced more minitubers than *Asante* in both seasons for both aeroponics and conventional methods (Tables 4, 5, 6, and 7). For aeroponics, variety *Tigoni* produced an average total yield of 20,302 mini-tubers during the first season which translated to about 112 minitubers per plant (Table 4). In the second season, it produced 21,925 minitubers which translated to 122 tubers per plant (Table 5). By comparison, variety *Asante* produced an average total of 9,730 minitubers during the first season which translated to 54 minitubers per plant

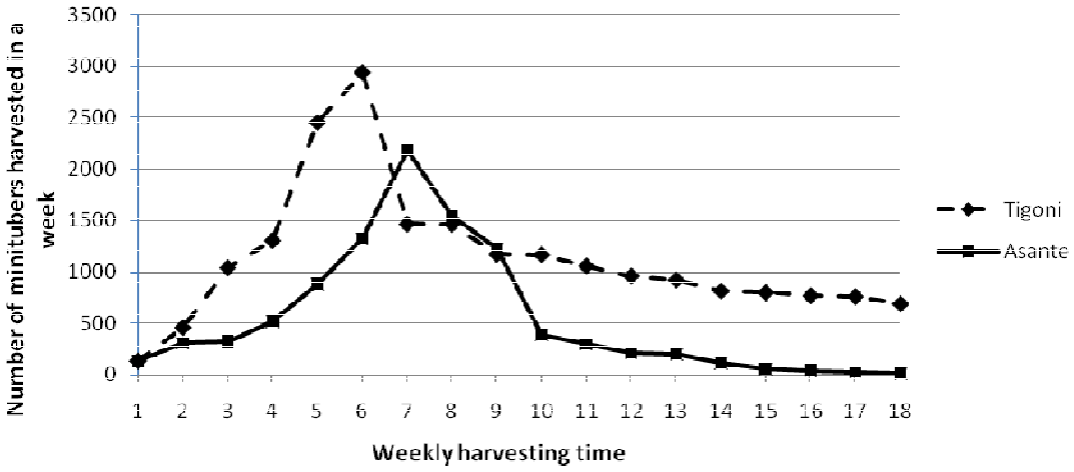

Figure 2. Average number of total minitubers harvested from each replication over a period of 18 weeks during the first season.

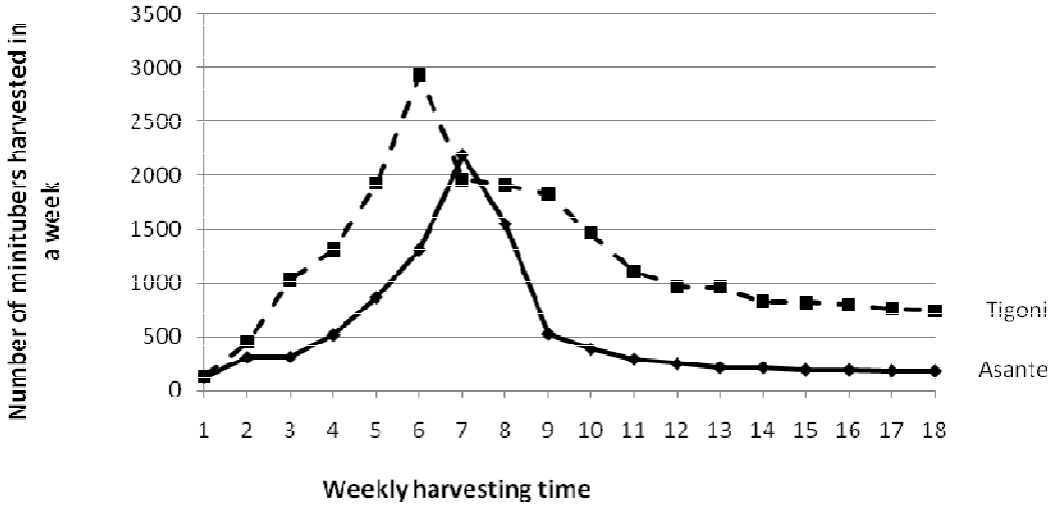

Figure 3. Average number of total minitubers harvested from each replication over a period of 18 weeks during the second season.

per plant (Table 4). During the second season, it yielded 9,862 minitubers which translated to 55 minitubers per plant (Table 5). This high multiplication rate was most likely due to longer harvesting period (Figures 2 and 3), which was made possible by the non-destructive harvesting method.

For the conventional pot method, variety *Tigoni* produced 2080 minitubers in the first season which translated into 12 minitubers per plant (Table 6). In the second season, it yielded 2067 minitubers which translated into 11 minitubers per plant (Table 7). By comparison, variety *Asante* produced an average total of 1,390 minitubers during the first season which translated to 8 minitubers per plant (Table 6). During the second season, it yielded 1,387 minitubers which translated to 8 minitubers per plant (Table 7).

For variety *Tigoni,* the minituber multiplication rate was 9.76 times higher for the aeroponics technology than the conventional pot method in the first season, in the second season, the minituber multiplication rate for aeroponics technology was 10.6 times higher than the conventional pot method. For variety *Asante,* the minituber multiplication rate was 7 times higher for the aeroponics technology than the conventional pot method in both

seasons.

Previous study have indicated a multiplication rate 14 to 18 times higher for aeroponics technology than the conventional methods for variety *Tigoni* while for variety *Asante*, the multiplication rate was 7 to 9 times higher for aeroponics than the conventional pot method (CIP, 2010). In the same study, 67 minitubers/ plant were obtained from potato variety *Yungay*, 70 minitubers/ plant from variety *Canchán INIA*, and 69 minitubers/ plant from variety *Perricholi* when using aeroponic technique. These potato varieties produced an average of 5 to 10 minitubers per plant using conventional pot method (CIP, 2010).

In terms of minituber size distribution, the small size (diameter 0.5 to 1.51 cm) had the highest number of minitubers harvested in both seasons for both varieties (Tables 4 and 5). The largest size (diameter 2.51 to 3.5 cm) had the least number of minitubers (Tables 4 and 5). This has the advantage in that the small minitubers can be planted on a far much larger area than the large minitubers given the same mass.

CONCLUSIONS AND RECOMMENDATIONS

Aeroponics technology produced far more minituber than the conventional pot method. The aeroponics technology might offer some solution to the perennial problem of shortage of certified potato seeds in Kenya. However, the system needs further and complete evaluation in terms of productivity, profitability and sustainability. In addition, a comparative cost analysis is required between aeroponics and conventional methods in terms of unit cost per tuber.

ACKNOWLEDGEMENTS

The authors acknowledge International Potato Center (CIP) for putting up the aeroponics unit where the study was conducted, and for all the technical assistance without which the study could not have been conducted. The authors also acknowledge the technical staff at KARI, Tigoni who worked tirelessly in the aeroponics unit. The authors also acknowledge the assistance of the management KARI, Tigoni for facilitating the study.

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