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Performance Of Irish Potato Varieties Under Aeroponic Conditions In Rwanda

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Abstract

Productivity of Irish potato (Solanum tuberosum) is constrained primarily by use of low quality seeds in Rwanda. Many field multiplication generations of vegetatively propagated basic seed result in build-up of seed-borne diseases and subsequent dissemination to new fields. Using soil-less media is an alternative to reduce soil borne disease infections in production of vegetatively propagated planting materials. The objective of this study was to determine the adaptability and optimum plant density of potato varieties under aeroponics production system. Two commercial potato varieties (Kinigi and Kigega) were evaluated in an aeroponics greenhouse at 14, 17 and 21 plants per m^2 using a split-plot design with four replications at RAB-Musanze station in 2010/2011. Plant densities were assigned to main-plots and varieties were in the sub-plots. Nitrogen, P, P, Ca, Mg and other micronutrients were supplied to plants by way of a mist nebulizer in an enclosed environment. Analyses of variance showed highly significant ($p<0.01$) differences between the two varieties for plant height, number of nodes at nine and eleven weeks after transplanting, days to maturity and tubers per plant. Plant density and variety × density interaction effects were not significant ($p>0.05$) for any of these parameters. Plants in Kinigi variety were about 50% taller at 3, 5, 7 and 9 weeks after transplanting; developed 2.5 more nodes per plant, matured 49 days earlier, and produced 29 more mini-tubers than Kigega. The data showed that (i) Kinigi variety was more adapted and productive in the aeroponics environment than Kigega. (ii) plant population density had no significant influence on productivity of the two varieties in the system, and (iii) response under aeroponics conditions is cultivar dependent in potato and requires testing more varieties to select the most adapted for production in the system.

Key words: *Potato seed, cultivars, mini-tubers, aeroponics*

INTRODUCTION

Food crops dominate Rwandan agriculture and potato (*Solanum tuberosum*) is very important for income generation and national food security (REMA, 2009). Annual consumption of potato is very high at 125 kg per person per year and it is the country's second most important source of energy after cassava (RIU, 2010). Though Irish potato is very important in Rwanda, average yields still remain low, ranging between 5.0 and 20.0 t/ha in farmers' fields compared to potential yields of 30.0 t/ha (Frans, 2002). Among the causes of the sub-optimal yields are late blight and bacterial wilt diseases, and seed degeneration caused by viruses and mycoplasmas (Frans, 2002).

Potato is one of the best examples of the yield-depressing effect of seed-borne pathogens in crop species (Chiarappa, 1992). There is no cure once a plant or tuber is infected by bacterial wilt, viral diseases or some other potato diseases (Peter et al., 2007). The only efficient control measure is prevention of initial infection using healthy potato seed and crop rotation. Using healthy and quality seed is essential for growing an optimal potato crop (Parveen et al., 2010).

Provision of healthy, improved potato seed to growers in Rwanda entails initial mini-tuber production in research stations and subsequent field multiplications by specialized seed growers to obtain adequate healthy seeds (Idrissa et al., 2006). Though, the promotion of specialized seed multipliers is essential to obtain quality planting materials, yield losses still occur as seeds lose their quality through many open-field multiplication generations. Commercial potato seeds are obtained after six generations of multiplication and with each multiplication, the seed becomes increasingly infected, and good cultural practices including seed treatment are not effective for controlling organisms carried inside the tuber (Richard et al., 1974). This problem justifies the urgent need to reduce field multiplication cycles in order to ensure disease-free seeds in potato.

One plausible solution to this problem is to adopt a soil-less seed production system. Aeroponics is one of such systems that can be used to produce potato mini-tubers. Aeroponics can be used to produce higher yields, up to 10-times higher than the conventional method as well as reduce the rate of soil-based disease infections (Otazu, 2010). In aeroponics, plant roots grow in the air, tuber contact with soil-borne pathogens is avoided, and production per plant increases considerably (CIP, 2010). This system will help shift from six generations of multiplication in open fields to only three generations. However,

potato cultivars respond differently to aeroponics and proper plant populations need to be determined for each cultivar (Otazu, 2010). This study was conducted to assess the adaptability of important potato varieties in Rwanda to the aeroponics system and determine the optimum plant density for each variety.

MATERIALS AND METHODS

Tissue culture plantlets of two commercial potato cultivars provided by the Rwanda Agricultural Board (RAB) were evaluated under three plant densities in an aeroponics greenhouse at RAB Musanze Station from September 2010 to January 2011. The experiment was laid out as a split-plot in a randomized complete block design with plant densities (14, 17 and 21 plants m^{-2}) in the main-plots and varieties (Kigega and Kinigi) in sub-plots with four replications. Boxes were constructed to optimize the greenhouse space and six boxes of 4.8 × 1.2 m dimension each were used. Each box was divided into two main-plots of 2.4 m × 1.2 m and four sub-plots of 1.2 m × 1.2 m each.

Wooden and styrofoam sheets were used to make the frame of the aeroponics box infrastructure with four windows at each side to facilitate harvesting. All boxes had a slope towards a collection tank to allow excess nutrient solution to drain into by gravity. Black plastic sheets were used for lining holes and covering the windows as double curtains to exclude light to the root system of the plants. Internal curtains were used to prevent the nebulized nutrient solution from drifting out of the aeroponics system. The top styrofoam covers of 1.2 m × 1.2 m each were holed according to fixed plant spacing and lined with PVC pipes. The aeroponic system including the different materials such as sponge, shading net, thermometer, tanks, pump, ruler, timers and power connecting wires used in the system are illustrated in Figures 1 and 2. In-vitro plantlets were first grown in sterilized sand trays for root development before they were transplanted in the aeroponics system to protect plants from different adverse biotic and abiotic factors.

The underground plant parts were enclosed in a dark chamber and supplied with a nutrient solution by way of a mist device (Otazu, 2010). The salts and minerals consisted of 252 g of potassium nitrate, 246 g of magnesium sulfate, 68 g of potassium phosphate, 118 g of calcium nitrate, and 6 g of fetrilon combi and were dissolved in 10 liters of water to make the stock solution (Table 1). To make the nutrient solution ready for use, 2.0 l of the stock

solution was added to 98.0 l of water for 100 l of preparation. The nutrient solution was supplied to plant root system by a 15 minute automatic timer pump. Plants were lowered whenever necessary to allow better formation of stolons in each plant. To avoid contamination, hands were disinfected using alcohol solution before any operation in which plants parts were touched, such as transplanting, plant lowering, leaf cutting and harvesting.

Data were recorded at two week-intervals beginning from the third week after transplanting on two morphological parameters - plant height and number of node plant per plant in each sub-plot. Temperature inside the aeroponics greenhouse was recorded three times a day, at 07:30, 13:00 and 17:00 hours from transplanting up to end of harvest using a thermometer. When tubers attained the size of 25 mm in diameter, they were harvested by hand through the access windows and counted. Harvesting was at 7 day intervals for both varieties. Days to maturity was measured as number of days from transplanting to the first harvest.

Data were analyzed using GenStat Discovery Edition 3 (Genstat, 2003) statistical software to compute analyses of variance for each parameter measured. Means comparisons were done using the least significant difference (LSD) at the 0.05 level of probability to determine significant differences among treatments.

RESULTS

Conditions in the aeroponics greenhouse were monitored in order to maintain favorable growing environment and to intervene when necessary. Day temperatures inside the greenhouse were 28^0 C and were higher in the first two months (September & October) and decreased considerably to 20.5^0 C from November (Table 2). The black shading net on top of the roof of the greenhouse was kept when high temperatures were recorded to allow a better luminosity and cooler environment inside the aeroponics greenhouse. The shading net was removed when low temperatures were recorded. Night temperatures were slightly above the recommended maximum of 10^0 C to 15^0 C and day temperatures of around 20^0 C when tuberization began (Otazu, 2010).

The analysis of variance showed highly ($p<0.01$) significant differences between the two varieties for plant height and number of nodes per plant, both measured at 3, 5, 7, 9, 11 and 13 weeks after transplanting (Tables 3 & 4). Highly significant ($p<0.01$) differences were also observed among the varieties

for days to maturity and mini-tubers produced per plant (Tables 3 & 4). No significant density or density × variety interaction effect was observed for any of the traits measured (Tables 3 & 4).

Plants in Kinigi variety were generally taller than those of Kigega and averaged about 50 % taller at 3, 5, 7 and 9 weeks after transplanting (Table 5). Kigega generally showed retarded growth throughout the growth period under the aeroponics condition. Consequently, Kinigi was earlier in maturity, taking only 77 days after transplanting to maturity compared to 126 days for Kigega (Table 5). On the average, plants in Kinigi had 2.5 more nodes per plant than Kigega, yielded 36 mini-tubers per plant compared to 7 in Kigega (Table 5).

DISCUSSIONS AND CONCLUSION

The two varieties were evaluated under 14 to 21 plants m^{-2} but neither the plant density nor the density × variety interaction effect was significant for any of the parameters measured. The non-significance of density × variety interaction effects indicated that both varieties exhibited similar response to increasing plant populations in the aeroponics environment. The lack of significant response to increasing plant populations suggested that the densities used in the study were moderate and did not permit strong competition for light in the system. Higher plant densities need to be considered in future studies.

Increased vegetative cycle was observed in Kigega variety whereas it was shortened in Kinigi in aeroponics. Under field conditions, both varieties mature in 120 days after transplanting and not 126 days for Kigega and 77 days for Kinigi as observed in the study. Farran et al. (2006) also observed increased vegetative cycle and plant height in Zorba variety and attributed this to unlimited nitrogen supply to plants in the aeroponics system. The significant differences for plant heights between the two varieties were attributed to a more positive growth response of Kinigi than Kigega to the aeroponics conditions. This was attributed to genetic differences between the two varieties. However, no significant differences were observed between the two varieties for number of nodes per plant in the early growth stages, indicating that stem elongation was more severely restricted in Kigega variety under aeroponics conditions. Farran et al. (2006) attributed this inhibition to a weak capacity for utilizing the low light intensity in the aeroponics greenhouse.

The significant differences observed between the two varieties for number of nodes per plant at nine and eleven weeks after transplanting were attributed to better adaptation of Kinigi variety, developing more nodes under the low irradiation recorded from November (Table 2). Kigega was delayed by 49 days to the first harvest compared to Kinigi. This showed delayed tuberization in Kigega, although, both varieties are reported to have similar vegetative cycles of 100 to 120 days (ISAR, 2003). This very long delay was attributed to poor adaptation to the aeroponics conditions.

Kinigi yielded about five times more mini-tubers compared to Kigega. However, Kigega is reported to be more productive than Kinigi under field conditions (ISAR, 2003). This confirmed that Kigega was less adapted to the aeroponics conditions than Kinigi due to genetic differences. Similar;y, Otazu (2010) reported that response to aeroponics system is cultivar dependent and should be determined for each genotype.

The data showed that Kinigi variety was more adapted and productive in the aeroponics environment than Kigega. Response under aeroponics is cultivar dependent and requires testing more varieties to select the most adapted for production in this system.

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Table 1: Salts and minerals used as nutrient sources in the evaluation of two potato varieties in the aeroponics greenhouse at RAB Musanze.

Salt or fertilizer	Formulae	Molecular weight
Calcium Nitrate	$(CaN03)2.4H_20$	118g
Potassium Phosphate	KH_2P0_4	68g
Potassium Nitrate	$KN0_3$	252g
Magnesium Sulfate	$MgS0_4$	246g
Fetrilon combi		6g

Fetrilon combi is a commercial foliar micronutrient powder that has the following formulation: 9% MgO, 3% S, 4% Fe, 4% Mn, 1.5%Cu, 1.5% Zn, 0.5% B, and 0.1% Mo (Otazu, 2010).

Table 2: Average temperatures recorded inside the greenhouse in the evaluation of two potato varieties in the aeroponics greenhouse at RAB Musanze.

Months	Night temperature (^{0} C)	Day Temperature(^{0} C)
Mid-September 2010	23.3	29.9
October	18.2	26.1
November	16.7	20.5
December	16.6	20.6
January	16.8	20.4

Table 3: Mean squares and significance levels from the analysis of variance for plant height and days to maturity in two potato varieties evaluated under three plant densities in the aeroponics greenhouse at RAB-Musanze in 2010/11.

Source of variation	d.f	Plant height (3WAP)	Plant height (5WAP)	Plant height (7WAP)	Plant height (9WAP)	Plant height (11WAP)	Plant height (13WAP)	Days to maturity
Rep	3	10.12	139.29	269.5	53.13	59.68	6.97	181.3
Density (D)	2	4.0327	101.57	125.85	198.17	156.5	188.6	130.7
Residual	6	0.9131	34.33	28.16	72.88	197.1	172.06	173.3
Variety (V)	1	106.2183**	3775.04**	11539.13**	10479.26**	6919.01**	2720.01**	14602.7**
D×V	2	0.7208	11.2	12.42	28.25	3.08	7.61	130.7
Residual	9	0.7667	11.01	28.12	31.92	27	49.36	176

**: Highly significant difference at $p<0.01$, WAP: Weeks after transplanting

Table 4: Mean squares and significance levels from the analysis of variance for number of nodes and number of tubers per plant of two potato varieties evaluated under aeroponics conditions at RAB-Kinigi station in 2010/11.

Source of variation	d.f	Node number (3 WAP)	Node number (5 WAP)	Node number (7 WAP)	Node number (9 WAP)	Node number (11WAP)	Node number (13 WAP)	Tubers per plant (number)
Rep	3	1.4514	6.448	6.073	2.619	1.51	0.601	18.65
Density (D)	2	2.5547	6.448	9.867	3.96	4.367	2.753	108.96
Residual	6	0.3915	1.031	1.107	0.784	1.576	1.603	25.14
Variety (V)	1	4.5938	13.5	9.375	38.229**	33.844**	7.042	5029.19**
D×V	2	0.1016	1.969	2.133	1.68	0.711	1.628	24.35
Residual	9	0.4323	1.569	1.936	1.433	1.769	1.307	11.77

**: Highly significant difference at $p<0.01$, WAP: Weeks after transplanting

Table 3: Means of plant height, node number, mini-tuber traits and days to maturity in two potato varieties evaluated under three plant densities in the aeroponics greenhouse at RAB-Musanze in 2010/11.

	Plant height (cm)						Node number		Days to maturity	Tubers per plant (number)
Varieties	3 WAP	5 WAP	7 WAP	9 WAP	11 WAP	13 WAP	9 WAP	11 WAP		
KIGEGA	4.7	22.8	42.0	69.1	89.9	110.1	25.3	28.9	126.3	7.0
KINIGI	8.9	47.9	85.8	110.9	123.8	131.4	27.8	31.3	77.0	35.9
Mean	6.8	35.3	63.9	90.0	106.9	120.7	26.7	30.1	101.7	21.4
LSD (0.05)	0.8	3.1	4.9	5.2	17.4	6.49	1.1	1.2	12.3	3.2
% CV	12.9	9.4	8.3	6.3	4.9	5.8	4.5	4.4	13.0	16.0

WAP: Weeks after transplanting

Figure 10: (a) Wooden frame filled with styrofoam panels in boxes, and (b) External tank and pump installation in the aeroponics greenhouse.

Figure 11: (a) Vegetative development, and (b) Stolons and mini-tubers development of two potato varieties evaluated in the aeroponics greenhouse at RAB-Musanze in 2010/11