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Bridging the gap in quality and quantity of seed potatoes through farmer managed screen houses in Uganda

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Quality seed potato is a key factor in enhancing potato yields in Uganda. Available disease-free seed potato accounts for less than 5% of the whole potato seed market demand in Uganda leaving 95% as seed availability gap. This study was conducted to explore the potential of using farmer managed screen houses to alleviate the seed potato availability gap that exists in Uganda. Six screen houses of 7 m × 14 m each with capacity of 1620 plants were set up, three (3) screen houses in Bukimbiri, one (1) in Kisoro, one (1) in Hamurwa and one (1) in Maziba sites. All the sites were managed by trained six famers. Sterilized soil was used to reduce the incidence of pathogens and to ensure that clean mini-tubers were produced. Seed production was done in 2015 for two consecutive seasons (A and B). From the 6 screen houses, a total of 107,638 clean mini-tubers were generated across the sites for both seasons. At multiplication ratio of 1: 9 the generated mini-tubers have the potential of generating 968,742 tubers. This would reduce on existing seed gap for the next season. It was noted during the study that mini-tuber production, vigour and rate of growth varied significantly (P<0.001) across the varieties with 'Rwangume' achieving the highest yield in terms of tuber number per plant and height, compared to other 4 varieties (Kiningi, Rwashaki, Kachpot 1 and Victoria). This study showed that production of disease free mini-tuber at farmer level is possible using screen house technology and has a potential of reducing the seed availability gap through production of quality seed that can be accessed by other farmers.

Key words: Seed potato, seed gap, farmer screen houses.

INTRODUCTION

The potato (*Solanum tuberosum* L.) is the third most important food crop in the world after rice and wheat in terms of human consumption (CIP, 2014, Gastelo et al., 2014). More than a billion people worldwide eat potato,

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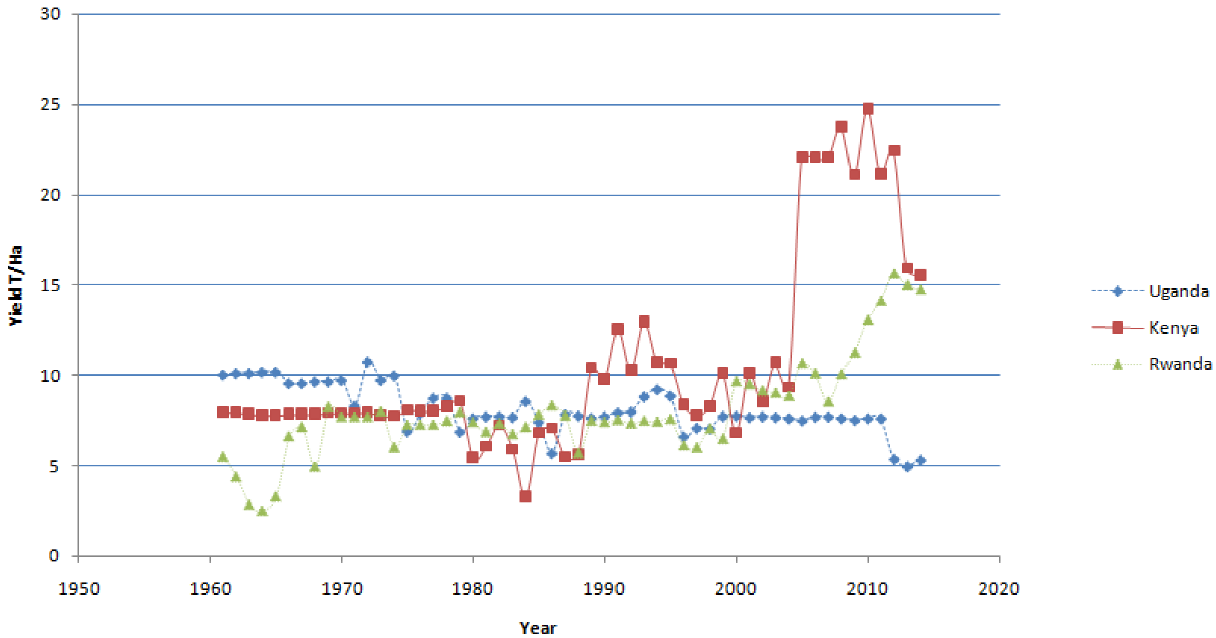

Figure 1. Potato tuber yield (T/ha) in Uganda vis-à-vis other East African countries. Source: FAOSTAT (2014).

and global total crop production exceeds 300 million metric tons (FAOSTAT, 2014). The world average potato production is about 17 t ha^{-1}, while direct consumption as human food is 31.3 kg per capita (kg/year) (FAOSTAT, 2014). Worldwide, Asia and Europe are the world's major potato producing regions, accounting for more than 80% of world production while Africa is the least, accounting for about 5%. 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} (FAOSTAT, 2014). In Africa, the top ten potato producers in descending order are Egypt, Malawi, South Africa, Algeria, Morocco, Rwanda, Nigeria, Kenya, Uganda, and Angola (Muthoni et al., 2011). Potato yields in Uganda have stagnated between 5 and 7.5 t/ha at farmers level while on-station, yields go as high as 20T/HA (Figure 1) (FAOSTAT, 2014).

Lack of quality basic seed potato by farmers is widely recognized as a key constraint to potato production in Uganda and other East African countries (Aheisibwe et al., 2015). In potato production, the quality of seed potatoes planted is an important determinant of the final yield and quality (Lanteri and Quagliotti, 1997). If farmer saved seed potatoes are used for several cropping cycles, without renewing the seed lot from a reliable source, seed-borne diseases cause severe yield and quality losses (Gildemacher et al., 2009). The potential demand for seed potatoes is estimated at 239,328 tones (Aheisibwe et al., 2015). However, availability of disease-free seed potato is less than 5% of the whole potato seed market demand in Uganda which is normally produced by Kachwekano Zonal Agricultural Research and Development Institute (KAZARDI) (KAZARDI, 2014). (Figures 2 and 3).

Kachwekano Zonal Agricultural Research and Development Institute (KAZARDI) has been spearheading the country’s seed potato production using *in vitro* derived mini-tubers for multiplication to basic level in Uganda. Despite these significant advancement good quality seed remains a scarce commodity (Aheisibwe et al., 2015) and other approaches of farmer managed quality production systems are hence needed to bridge the seed gap (Kinyua et al., 2008). International Potato Centre recommends the use of tissue culture and mini-tubers production through aeroponics technology and use of screen houses as approaches that can quickly multiply quality seed potatoes (Farran and Mingo-Castel, 2006; Gildemacher et al., 2009).

Efforts to bridge the seed availability gap were initiated in a collaborative arrangement between International Fertilizer Development Centre (IFDC) and National Agricultural Research organization (NARO) to empower the smallholder potato farmers to be self-sufficient in good quality mini-tuber seed production using *in vitro* plantlets that are grown in screen houses for generation of mini-tubers. . This strategy was sought that it would have significant impact in reducing the seed availability gap and complementing the efforts put forward by the national potato program. In addition, the health of the seed produced through this process is assured since the seed is generated under sterile soils and is further supported by testing for latent bacterial wilt infection (Chindi et al., 2014). The production of mini-tubers at farm level would reduce the number of field multiplication

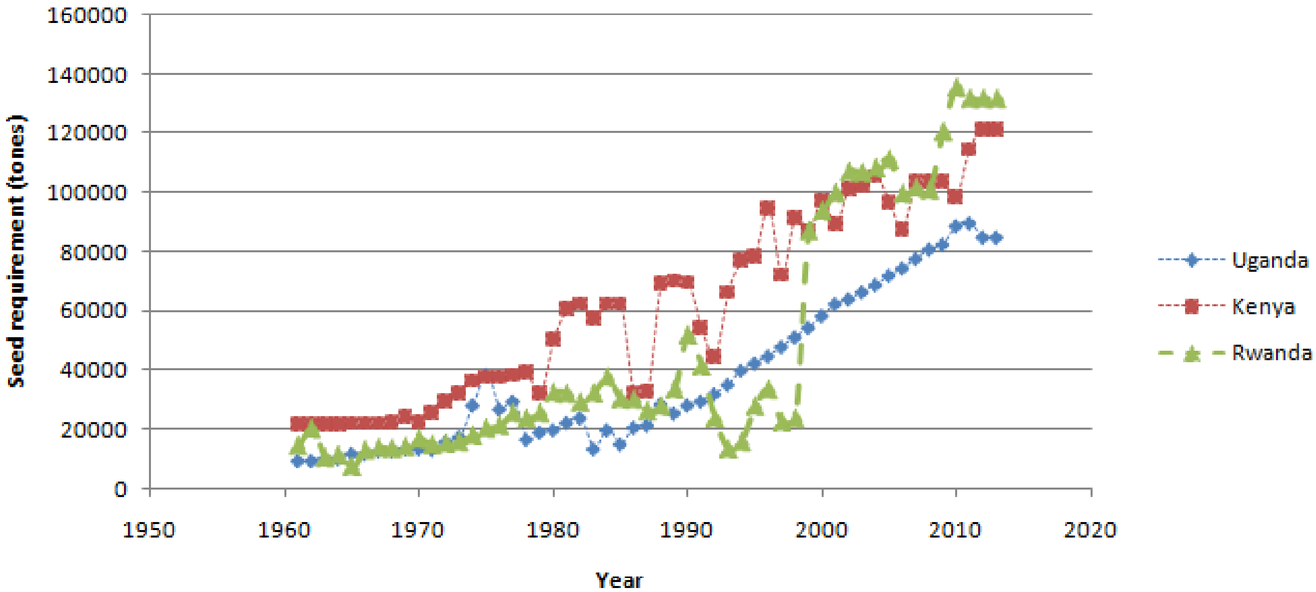

Figure 2. Seed supply requirements from 1960 2013: Source: FAOSTAT, 2014.

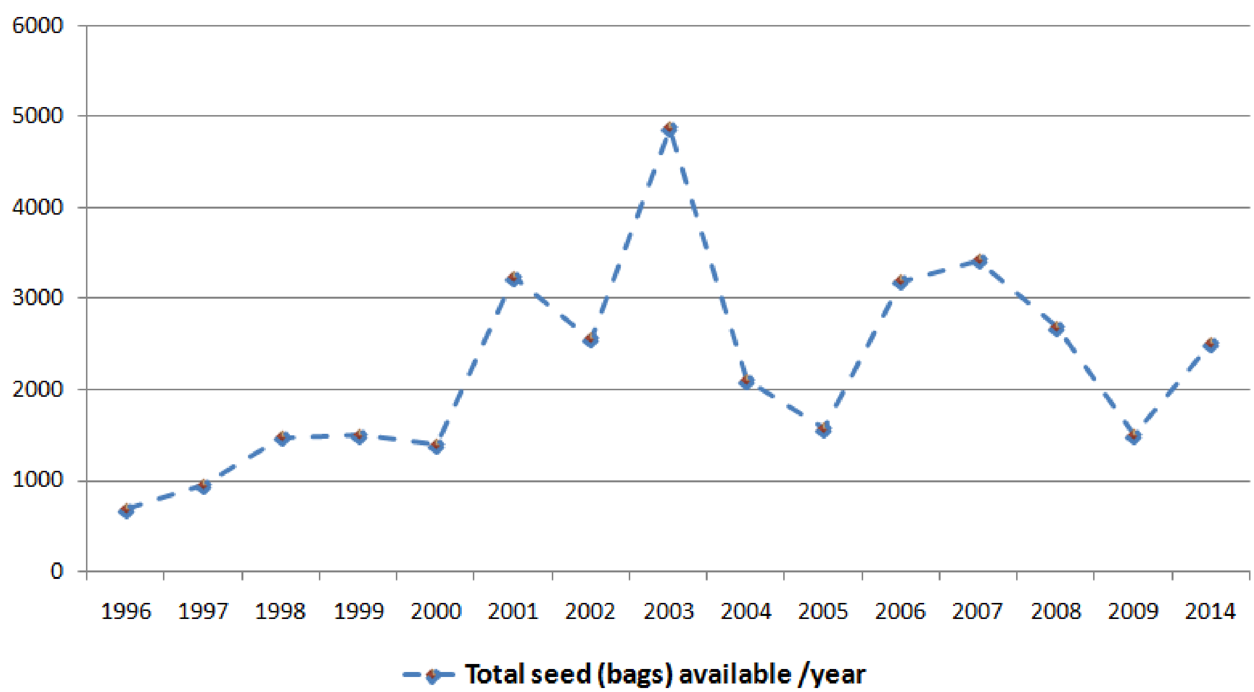

Figure 3. Total quality seed (100kg bags) supplied per year from national potato program and seed multipliers. Source: KAZARDI (2014).

cycles needed to generate enough seed for distribution and would lower the degree of transmission of seed-borne diseases (Mbiyu et al., 2012). Therefore, the objective of this study was to explore the potential of generating quality seed potatoes using farm managed screen houses.

MATERIALS AND METHODS

Generation of tissue culture potato plantlets

Potato *in vitro* plantlets for planting in screen houses were generated in tissue culture laboratory at KAZARDI and availed for planting to the farmers. Tissue culture plantlets were micro

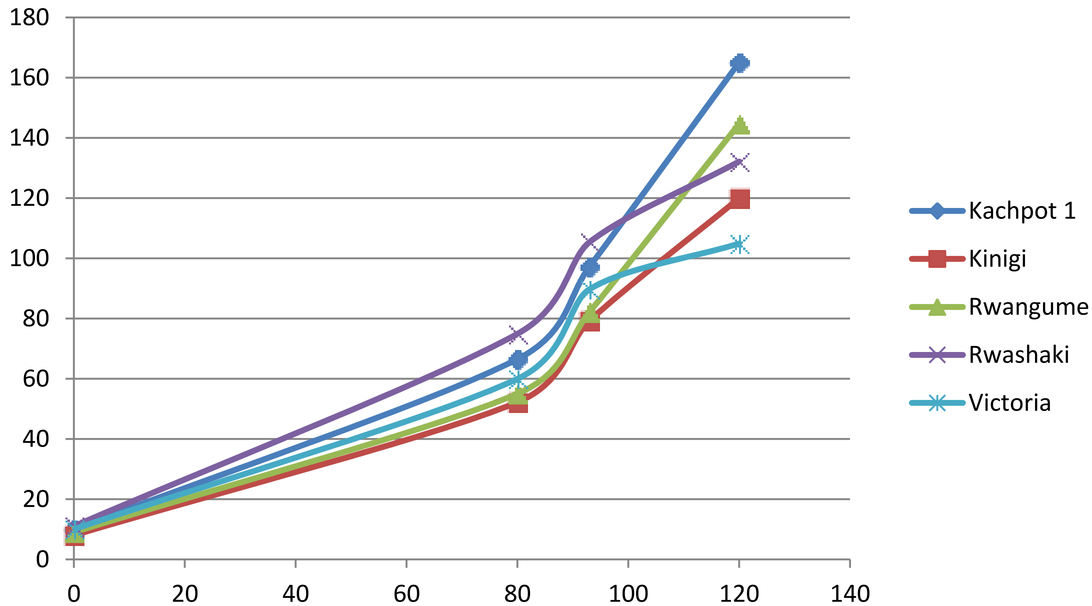

Figure 4. Growth in height (cm) performance of different potato varieties at Kisoro town farmer screen house.

propagated using a modified protocol on MS media according to Fite et al. (2013).

Construction of screen houses and sitting of the screen houses

Six screen houses of dimension 7 meters wide × 14 m long each with capacity of 1620 potato plantlets were built in partnership with the IFDC and farmers for production of quality seed potato. Four (4) screen houses were established in Kisoro district (3 in Bukimbiri sub county and 1 in Kisoro town) while 2 were constructed in Kabale district (1 in Hamurwa and 1 in Maziba sub county). Water tanks of capacity 2000 L were installed at each site to enable constant supply of water for irrigation to the plants.

Crop management and data collection

The six farmers that hosted the screen houses were trained in mini-tuber production focusing on handling of tissue culture potato plantlets, soil sterilization, screen house maintenance, establishment and management of potato crop in screen house, and post-harvest handling (storage and management) of mini-tubers by scientists from Kachwekano ZARDI. Following the training, the *invitro* plantlets of different varieties ('Kiningi', 'Rwangume', 'Rwashaki', 'Victoria' and Kachpot 1) were given to farmers and left to be managed by the farmers in the screen houses. Plantlets (64 *Invitro* plantlets) were put in each planting box containing mixed sterile soils (loam and sand soil in ration of 3: 1) and supplemented with inorganic fertilizer NPK (17:17:17) Each box served as a replicate for the variety and four boxes were used per variety in each screen house allocation of varieties to planting boxes was done randomly The plants were managed following standard agronomic practices. Data were collected on growth vigour, using a scale of 1-9 (Rykaczewska, 2013), the height of the plants and mini-tuber yield per variety and tuber number per plant was collected for 2 seasons of 2015 (A AND B).

Data analysis

Statistical methods

Analysis of variance was performed on growth vigour, height of the plant and mini-tuber number using Genstart computer package 11 edition. Mean comparisons were conducted using Fisher's Least Significant Difference (LSD~=0.05). The sources of variability used in the statistical model were treatment (variety), the blocks (replicates) and the experimental error.

RESULTS AND DISCUSSION

Performance of different potato varieties under farmer managed screen houses

The growth rate of the five different varieties was noted to be low in the first 50 days after transplanting in the screen house for all the test sites and later peaked with peak growth rate observed at 80 days after transplanting (Figures 4 to 7). Slow growth rate at the start was due to the fact that the plantlets was introduced from the tissue culture laboratory to the screen house, hence was undergoing physiological adjustment in acclimatizing to the new environment in the screen house. Varieties planted in Bukimbiri sites (1, 2 and 3) were noted to have shorter height in range of 65 to 96 cm for the period of 109 to 114 days after transplanting while in Kisoro town and Maziba sites, the test varieties were taller with maximum height noted to range from 100 to 192 cm (Figure 4 to 7) observed from 108 to 120 days after transplanting. The potato plant vigour of the test varieties also varied within the varieties and across the sites.

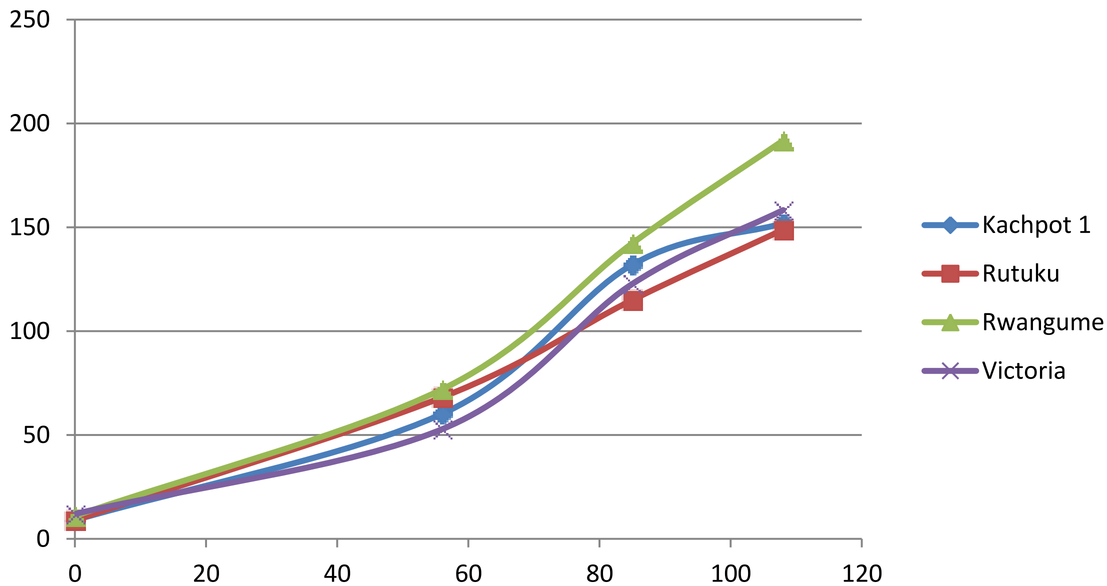

Figure 5. Growth in height (cm) performance of different potato varieties at Maziba farmer screen house.

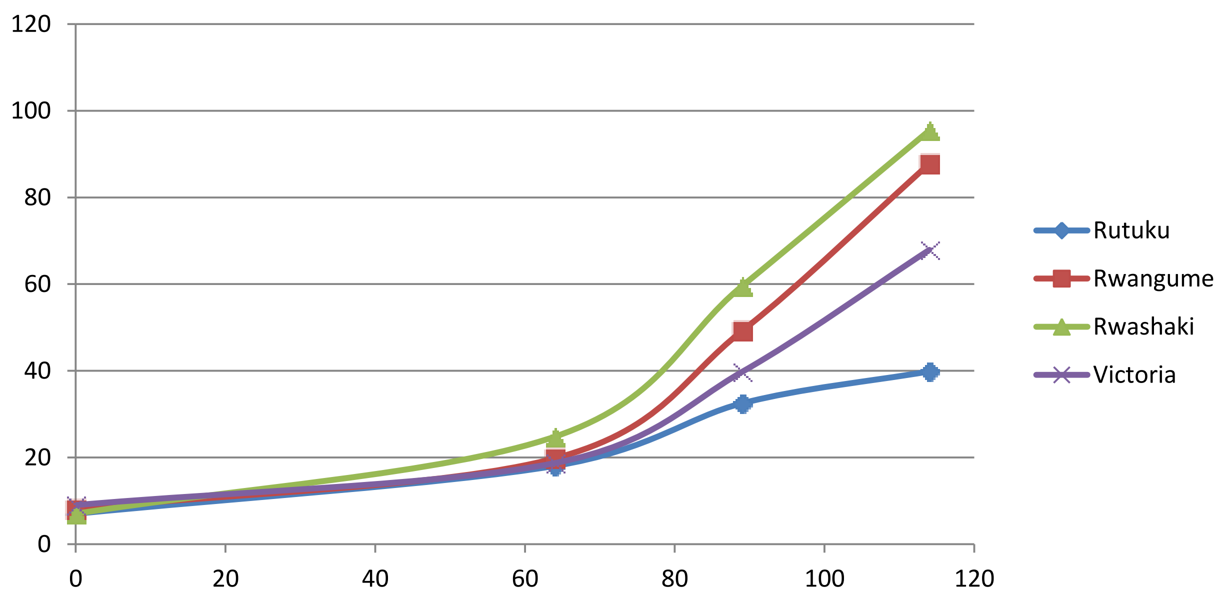

Figure 6. Growth in height (cm) performance of different potato varieties at Bukimbiri site 1 farmer screen house.

Plants at Kisoro town site were the most vigorous, followed by Bukibiri-2, Maziba, Bukimbiri-3. The plant vigour of the varieties varied across the sites. Kiningi was most vigorous at Kisoro town screen house compared to other varieties. Kachpot 1 was least vigorous compared to all the varieties tested. The vigour of potato is dependent on the physiological potential during establishment, emergence and development of plants. The plant vigour in this study was seen as an important aspect since it determines the materials future productivity that is conditioned genetically, physiologically and ecologically (Oliveira, 2015). The growth performance of the potato plants was seen to influence the production capacity and overall potato mini-tube yields. The plant vigour and stem length (height) varied significantly different ($P<0.05$) (Tables 1 and 2). This was largely dependent on genotype, phenological age and environmental conditions especially temperature during the growth stages of potato. This is similar to the work done by Oliveira (2015) and also supported by Lanteri

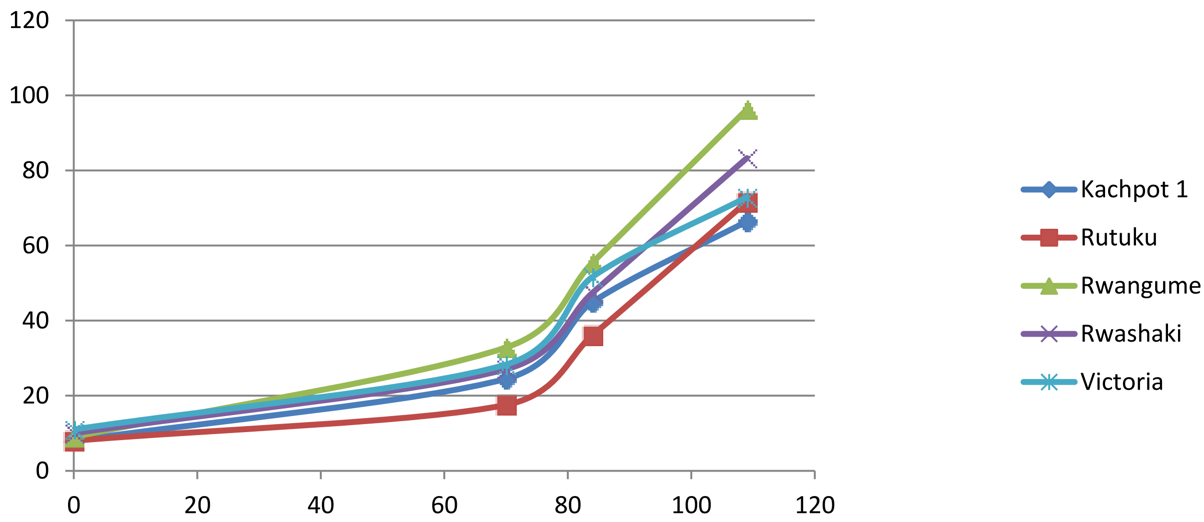

Figure 7. Growth in height (cm) performance of different potato varieties at Bukimbiri site 2 farmer screen house.

Table 1. Potato growth vigor performance of different varieties ranked based on Kruskal Wallis model.

Variety	Size	Mean rank
Kachpot 1	200	728.8
Kinigi	60	1017.2
Rutuku	388	767.76
Rwangume	358	885.19
Rwashaki	179	904.87
Victoria	449	784.5

Degrees of freedom = 5; Chi-square probability < 0.001.

Table 2. Potato growth vigor performance as influenced by farmer screen house site.

Location	Size	Mean rank
Hamurwa	120	689.89
Bukimbiri-1	240	516.59
Bukimbiri-2	336	967.93
Bukimbiri-3	298	731.62
Maziba	340	788.9
Kisoro town	300	1058.51

Degrees of freedom = 5; Chi-square probability < 0.001.

and Quagliotti (1997). The temperature or thermal-time accumulated by the potato during the growing period is known to influence the plant performance. These factors explain the variability observed in respect to potato plant vigour and height under different farmer managed since the different screen houses were established in different districts.

The study also showed a positive relation between growth vigour and overall tuber yield/plant (Figure 8). Variety Rwagume yielded highest with 13 tubers per plant followed by Victoria (9 tubers /plant), Rutuku (7 tubers/plant) and Kachpot 1 (5 tubers/plant). Average yield per plant across the sites ranged from 5 to 15 tuber per plant with Bukimbiri-2 being the highest (15 tubers/plant). A total of 107,638 tubers were produced during 2015 A and B season across the six sites with an average yield of 10 tubers per plant (Tables 3 and 4) The generated tubers upon one cycle of field multiplication by the farmers at a rate of 1:9 would generate significant number of seed tubers (968,742 tubers) that can reduce on the existing seed gap in Uganda. However, to achieve this it would depend on growing season since tuber yield is dependent of genotype and growing condition (Struik and Wiersema, 1999).

Seed quality assurance

The mini-tubers harvested in 2015A and B seasons were indexed for the presence of bacterial wilt pathogen (*Ralstonia solanacearum*) using NCM-ELISA method and results showed that all the collected mini-tuber samples from the screen house were negative for the bacterial wilt pathogen which is always a major concern in seed production as put forward by Kinyua et al. (2001). This indicated that seed produced using this method is completely clean and satisfies the quality standards for certification. The supply of this seed to other farmers would reduce on the gap in quality and quantity of seed potatoes in the Uganda.

Conclusion

Multiplication of potato mini-tubers using screen houses

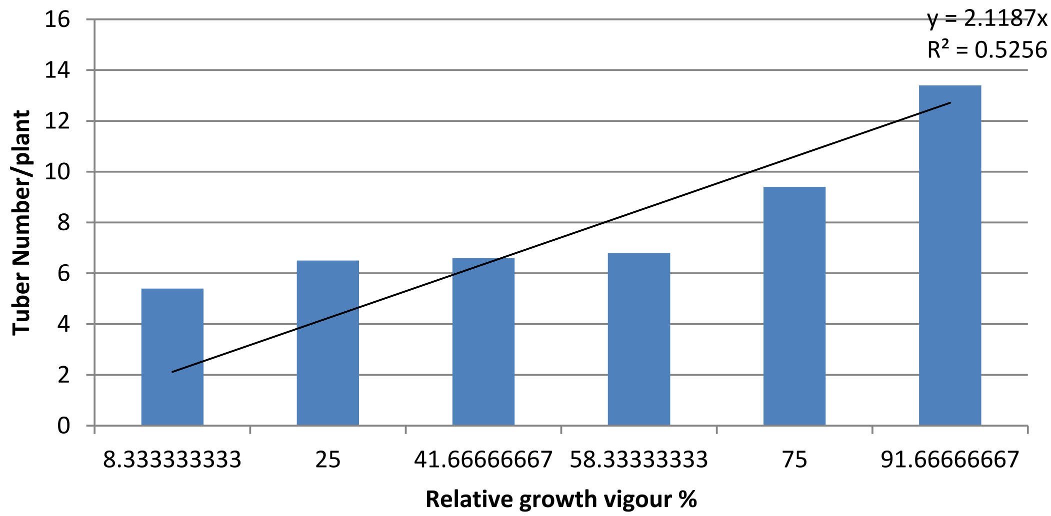

Figure 8. Probability plot of tuber number as influenced by growth vigour.

Table 3. Mini-tuber yield number per variety across different sites and seasons.

Screen house	Variety						
	Kachpot 1	Kinigi	Rutuku	Rwangume	Rwashaki	Victoria	Grand total
Season 2015A mean			**9142**	**6861**		**11580**	**27883**
Hamurwa			691	4715		2351	7757
Bukimbiri-2			4782	2146		4103	11031
Maziba			3969			5126	9095
Season 2015B mean	**3849**	**1758**	**5722**	**42995**	**7171**	**18260**	**79755**
Hamurwa	1170		451	1979		346	3946
Bukimbiri-1			938	10813	2111	5069	18931
Bukimbiri-2	831		1681	9785		7011	19308
Bukimbiri-3	732		1961	7685	3399	2319	16096
Maziba	752		691	3511		2556	7510
Kisoro Town	364	1758		9222	1661	959	13964
Grand mean	**3849**	**1758**	**11195**	**49856**	**7171**	**29840**	**107638**
F.Pr				<0.001			
LSD				**102.1**			

Table 4. Mini-tuber yield per plant for different varieties across different sites and seasons.

Screen house X season	Varieties						
	Kachpot 1	Kinigi	Rutuku	Rwangume	Rwashaki	Victoria	Grand mean
2015A mean			**6.7**	**10.9**		**7.7**	**7.9**
Hamurwa			7.2	10.4		5.6	7.8
Bukimbiri-2			7.1	12.7		8.0	8.1
Maziba			6.2			9.4	7.8
2015B mean	**5.4**	**6.5**	**6.8**	**14.0**	**6.6**	**10.9**	**10.4**
Hamurwa	4.9		4.8	5.5		3.1	4.9
Bukimbiri-1			6.1	19.3	7.0	16.0	14.2
Bukimbiri-2	8.8		9.2	18.6		15.7	15.4
Bukimbiri-3	6.3		7.9	19.7	6.9	11.4	11.3

Table 4. Contd.

Screen house X season	Varieties						
	Kachpot 1	**Kinigi**	**Rutuku**	**Rwangume**	**Rwashaki**	**Victoria**	**Grand mean**
Kisoro Town	3.7	6.5		12.9	5.6	7.9	9.2
Grand mean	**5.4**	**6.5**	**6.8**	**13.4**	**6.6**	**9.4**	**9.6**
F.pr	<0.001						
LSD	1.978						

has demonstrated a potential of alleviating the gap in seed quality and quantity seed potato that will contribute on reducing the seed availability gap in Uganda. This study has shown that seed production using screen house technology is possible at farm level.

Conflicts of Interests

The authors have not declared any conflict of interests.

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