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Early generation seed starter materials and approaches to seed production: Challenge for improving the potato seed system in Uganda

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Abstract

Quality seed is one of the key inputs for increasing potato (*Solanum tuberosum L.*) productivity; however, its limited availability is widely recognized as a major constraint to potato production. In Uganda, certified seed production meets approximately 1.5% of effective demand implying most farmers use home-saved seed. This practice encourages the buildup of degenerative seed-borne diseases which ultimately affect productivity. Consequently, a study was conducted to determine the productivity of different seed potato production starting stock: tissue culture plantlets (TC) and rooted apical cuttings. Fifty plants of two potato varieties, NAROPOT1 and NAROPOT4, and for each starter material were evaluated both in the field and screen house for two seasons at Kachwekano and Karengyere research stations. Data were collected on the number of tubers per plant and tuber weight. Highly significant differences were observed for the type of starter materials and varieties for the number of tubers per plant ($p \leq 0.001$) from both the screen house and field environments. More tubers per plant were obtained from TC for both varieties and the highest recorded was (24.5) for NAROPOT4 and (15.5) for NAROPOT1 in the screen house. Tuber weight was higher from rooted apical cuttings for both varieties NAROPOT1 (153.3 g) and NAROPOT4 (167.7 g). The correlation between the number of tubers per plant and weight was highly significant at $p \leq 0.001$. Tissue culture raised plants were more productive in terms of tuber, and numbers are more important in seed production than weight and mini-tuber production can be done by farmers under affordable conditions.

1 | INTRODUCTION

Potato (*Solanum tuberosum L.*) is a major food and cash crop, mainly grown by small-scale farmers in the highland regions of many African countries. The use of quality seed is an important factor in increasing potato productivity and its inadequacy greatly limits production (Aheisibwe et al., 2015). In Uganda, limited amounts of certified seed are produced meeting about 1.5% of the effective demand. This then implies that most farmers use home-saved seed, which greatly affects productivity and encourages the buildup of degenerative seed-borne diseases (Fuglie, 2007; Hirpa et al., 2010; Haverkort et al., 2012; Namugga et al., 2017). In Uganda, potato yields have been low and estimated at 7.5 t/ha compared to

Abbreviations: RACs, rooted apical cuttings; TC, tissue culture plantlets; TNT, total number of tubers; TWT, total weight of tubers.

40–60 t/ha achievable under improved management practices (UBOS, 2020). Numerous factors are ascribed to this low productivity and these include socioeconomic constraints, such as poorly adapted and adopted varieties and abiotic and biotic stresses. Some of these factors are intensified by the low farmer incomes (FAO, 2008). Declining soil fertility, inadequate moisture supply, drought, and erratic and sometimes violent rainfall greatly limit potato production (Gildemacher et al., 2009). Major disease affecting potatoes is late blight caused by *Phytophthora infestans* (Mont.) de Bary, bacterial wilt (BW) (*Ralstonia solanacearum*) (Yabuuchi et al., 1995), and viruses (Muhinyuza et al., 2012). However, insufficient quantities of quality seed are a key limiting factor because seed accounts for about 40%–50% of the total cost of production and can improve productivity by 15%–25% (Gildemacher et al., 2009; Roy, 2014; Chindi et al., 2017). With this, continuous generation of quality seed is paramount to increase yields, reduce pest and disease pressure, and maximize profitability among farming communities.

Various approaches have been used to enhance seed quality and quantity over years in Uganda like the use of stem cuttings and clonal tubers from tissue culture plantlets (TC, also called in vitro plants; personal observation). This is always followed by three to four seasons of field multiplication, which is time consuming and in some cases with compromised seed quality. Aeroponics, a plant culture technique in which mechanically supported plant roots are either continuously or periodically misted with nutrient solution, has also been used. Tissue culture or rooted apical cuttings (RACs) may be used as starter materials and aeroponics promotes availability of healthy seed potatoes.

Recent advances in enhancing the availability of quality seed potatoes are the use of TC and RACs. Plant tissue culture is a specialized technology used for plant propagation and operates on the principle of growing disease-free plant tissues under sterile conditions on an artificial plant growth medium. The technology permits a faster rate of multiplication and decreases the number of field generations, thus preserving seed quality (Sharma & Pandey, 2013). In vitro generated plantlets are hardened first and then transplanted into the field for mini-tuber production (Tadesse et al., 2001). On the other hand, an apical cutting is a rooted transplant produced from TC. A cutting is similar to a nursery-grown seedling except that it is produced through vegetative means and does not originate from a seed. Cuttings are also clean and free of diseases. RACs are the easiest and cheapest means of propagating potatoes as they have faster regeneration potential and are true to type. RACs have the ability to regenerate rapidly with great potential for the conservation and production of potato seeds (Tsoka et al., 2012). This study was undertaken to assess the productivity of different seed potato production starting stocks and their viability in addressing the challenge of early generation seed. RACs and TC of selected potato varieties were compared.

Core Ideas

- Tissue culture plantlets produced more tubers per plant than rooted apical cuttings.
- More tuber weight per plant was obtained from rooted apical cuttings compared to in vitro plants.
- There was differential performance of varieties with the test starter materials.
- Varietal response with two types of starter materials in the screen house was comparable to that from the field conditions.
- Given the higher productivity of in vitro from this study, direct planting is recommended to farmers with ability to manage this level of seed in the screen house, field, or both.

2 | MATERIALS AND METHODS

2.1 | Planting materials

The study involved two starter planting stock materials: TC and RACs of two potato varieties of NAROPOT1 and NAROPOT4.

2.2 | Study sites

Screen house studies were conducted at Karengyere research station. Field experiments were carried out for two seasons at Kachwekano and Karengyere research stations of the National Agricultural Research Organisation (NARO). Kachwekano is located in southwestern Uganda, 01° 16′ S 29° 57 ′E at 2200 m above sea level (masl). The soil type is isomeric typic Palehumult (Kakuhenzire et al., 2013). Karegyere research station is located at 01° 13.2′ S, 29° 47.8′ E in southwestern Uganda at an altitude of 2450 masl. Both sites have a bimodal rainfall pattern separated by a dry spell ranging from 30 to 60 days.

2.3 | Plantlet and cuttings management

Fifty in vitro plantlets of each variety for screen house experiments were planted directly into the soil media in planting trays. Plantlets for field experiments were hardened by planting them into boxes and transplanted after 3 weeks. Cuttings were produced from TC in the screen house by taking

FIGURE 1 Potato tissue culture plantlets and rooted apical cuttings.

TABLE 1 Analysis of variance for number of tubers per plant and tuber weight in the screen house.

		TNT	TWT (g)
Source of variation	**df**	**MS**	**MS**
Season	1	14.8	195,395.0***
Starter material	1	855.6***	136,054.0***
Variety	1	1853.3***	19,515.0**
Starter material variety	1	60.1	3052.0
Residual	395	24.4	3480.0
Total	399	31.1	4332.5

Abbreviations: df, degrees of freedom; MS, Murashige and Skoog; TNT, total number of tubers; TWT, total weight of tubers.
***$p \leq 0.001$; **$p \leq 0.01$.

single- or double-node cuts from lateral shoots and after rooting, planted in the field (Figure 1). At planting, 50 plants of both hardened TC and RACs for the two varieties were planted in the field in slightly raised beds to produce high numbers of seed tubers at a spacing of 30 cm × 70 cm. All recommended management practices were observed in the screen house and the field. Data were collected on the number and weight of tubers per plant (in grams) and analyzed using GenStat 17th edition (Sharma et al., 2014) software package.

3 | RESULTS

3.1 | Analysis of variance

The combined analysis of variance for the total number of tubers (TNT) per plant and total tuber weight (TWT) for the two varieties tested in the screen house is summarized in Table 1. Highly significant differences were observed for starter materials and varieties for TNT ($p \leq 0.001$). Seasonal differences were only significant for TWT ($p \leq 0.001$).

3.2 | Number of tubers per plant and tuber weight per plant in the screen house

The average number of tubers per plant and tuber weight for the two varieties and test starter materials are presented in Table 2. Mean number of tubers was higher for NAROPOT4 for both TC (13.8) and RACs (10.1). More tubers per plant were obtained from TC for both varieties: NAROPOT4 (24.5) and NAROPOT1 (15.5). Generally, the mean tuber weight was higher from RACs (98.5 g for NAROPOT4) compared to TC (47.3 g for NAROPOT1).

3.3 | Analysis of variance for field performance of TC and RACs at Kachwekano and Karengyere for two seasons

The combined analysis of variance for TNT per plant and TWT is summarized in Table 3. There were significant differences observed at different levels in the performance of TC and RACs for the two seasons, varieties, and across locations. Significant interactions were observed between varieties, starter materials, and locations. The interaction of locations, seasons, variety, and starter materials was only significant ($p \leq 0.001$) for tuber weight per plant.

3.4 | Mean number of tubers per plant and tuber weight under field conditions

The mean number of tubers per plant and TWT for the two varieties and starter materials is presented in Tables 4 and 5, respectively. More tubers per plant were obtained from TC than RACs. NAROPOT4 produced more tubers per plant from both locations with the highest mean number of 18.0 and 10.9 tubers for NAROPOT1 from Kachwekano. Differences between the performances of starter materials were significant in both locations. TWT per plant was higher from RACs, for example, NAROPOT4 produced a mean weight of 180.5 g than TC (114.9) in Karengyere. The correlation (0.62) between the number of tubers per plant and weight was highly significant at $p \leq 0.001$ in this study (Table 6).

4 | DISCUSSION

This study aimed at determining the productivity of in vitro plants and RACs as planting stock in the production of early generation seed. There was a differential performance of varieties and type of starter material in the screen house under field conditions and for the different traits between environments. In general, TC produced more tubers than RACs

TABLE 2 Mean performance of varieties and starter materials in the screen house.

Variety	NAROPOT4				NAROPOT1			
	TNT		TWT(g)		TNT		TWT(g)	
Plant No.	TC	RACs	TC	RACs	TC	RACs	TC	RACs
1	24.5	12.5	139.8	128.5	1.5	4.5	31.5	61.8
2	16.5	7.5	74.5	82.3	10.5	6.0	75.3	66.0
3	10.5	4.0	92.6	39.2	7.0	8.5	19.8	73.2
4	13.5	6.5	65.9	32.5	6.0	10.0	49.5	85.2
5	7.0	9.0	25.1	160.9	12.5	10.5	121.5	151.8
6	17.5	11.0	67.5	119.5	7.5	8.5	55.2	96.8
7	16.5	7.0	83.8	62.0	11.0	10.0	122.4	149.9
8	13.0	5.0	45.9	26.7	8.0	7.0	43.5	70.7
9	11.0	14.0	46.1	158.2	9.0	6.0	98.7	47.8
10	11.0	13.5	48.0	93.6	3.5	4.5	40.3	35.9
11	15.5	12.0	48.9	138.1	8.5	4.0	33.0	52.3
12	15.0	15.0	51.2	167.7	5.0	6.0	22.7	62.6
13	13.0	12.5	45.9	157.3	5.5	8.0	30.7	170.2
14	11.5	11.0	50.3	117.2	7.5	5.5	111.4	57.1
15	13.5	14.5	43.0	154.3	9.0	5.5	100.0	61.5
16	21.5	6.0	55.6	92.4	9.5	5.0	37.4	41.8
17	18.5	8.0	68.1	69.9	8.5	6.0	42.6	127.7
18	16.0	9.5	65.5	108.1	8.0	6.0	57.5	62.4
19	9.0	5.5	37.2	24.5	6.0	8.5	58.3	97.6
20	20.5	7.0	92.6	42.6	6.5	8.5	40.8	118.2
21	13.5	6.5	47.5	120.6	7.5	6.0	57.7	92.2
22	18.0	7.5	42.5	68.7	10.0	5.0	83.6	67.4
23	15.0	14.5	39.5	119.4	7.0	6.5	75.7	90.3
24	14.0	14.5	89.6	119.4	9.0	5.5	82.5	46.5
25	11.0	10.0	38.6	62.3	10.0	6.0	65.4	81.3
26	11.0	9.5	23.9	119.3	15.0	8.0	31.6	102.5
27	12.5	8.0	31.5	107.9	14.0	8.5	54.5	72.0
28	14.5	10.5	77.6	54.6	15.0	7.0	33.0	68.6
29	12.5	15.0	53.6	138.5	15.5	4.5	15.5	61.0
30	12.0	8.0	49.7	59.8	8.5	10.5	30.0	153.3
31	19.0	17.5	42.7	188.5	3.5	4.0	17.3	80.0
32	9.0	9.0	20.4	90.6	8.0	4.5	23.2	61.9
33	7.5	8.0	69.0	36.7	8.0	9.0	34.6	116.2
34	20.5	8.0	48.2	82.4	5.5	9.0	31.8	55.2
35	8.5	8.5	44.9	58.0	11.0	6.0	39.5	82.4
36	14.0	12.5	59.2	114.5	9.0	5.5	34.7	63.9
37	17.0	22.5	75.5	326.0	6.0	5.5	21.8	62.0
38	8.0	7.5	37.3	48.5	10.5	6.5	32.3	110.9
39	9.5	14.0	38.5	136.6	9.5	3.5	33.4	37.4
40	13.0	7.5	64.6	41.2	6.5	8.0	30.9	124.3
41	11.5	12.5	44.5	163.7	8.5	4.5	15.0	54.4
42	9.0	9.5	47.0	131.9	8.5	13.5	15.7	115.1
43	12.0	5.5	39.9	40.0	6.0	5.5	15.9	67.2

(Continues)

TABLE 2 (Continued)

Variety	NAROPOT4				NAROPOT1			
	TNT		TWT(g)		TNT		TWT(g)	
Plant No.	TC	RACs	TC	RACs	TC	RACs	TC	RACs
44	13.5	11.0	38.1	83.5	9.0	4.5	20.2	59.8
45	11.0	4.5	75.6	26.2	4.5	4.5	63.1	42.0
46	19.5	4.5	90.4	17.5	6.0	5.5	68.4	69.0
47	12.5	15.5	32.6	153.9	13.5	6.5	38.6	57.8
48	11.5	8.0	49.3	65.3	8.5	6.0	39.8	62.2
49	17.0	4.5	97.7	46.9	12.5	5.0	29.7	52.2
50	17.0	19.0	46.5	126.3	11.5	5.0	39.4	49.8
Mean	**13.8**	**10.1**	**56.0**	**98.5**	**8.6**	**6.6**	**47.3**	**79.0**

Abbreviations: RACs, rooted apical cuttings; TC, tissue culture plantlets; TNT, total number of tubers; TWT, total weight of tubers.

TABLE 3 Combined analysis of variance for number of tubers per plant and tuber weight per plant for two varieties tested for two seasons.

Source of variation	df	TNT MS	TWT MS
Location	1	631.43***	48,000*
Season	1	388.75**	140,935***
Starter material	1	1740.71***	4726
Variety	1	8691.83***	184,589***
Location, season	1	432.53**	105,425***
Season, starter material, variety	1	129.03*	54,719**
Location, starter material, variety	1	229.44*	383,600***
Location, season, starter material, variety	1	22.15	99,830***
Residual	738	43.53	7879.
Total	746	61.07	9844.79

Abbreviations: df, degrees of freedom; TNT, total number of tubers; TWT, total weight of tubers.
***$p \leq 0.001$; **$p \leq 0.01$; *$p \leq 0.05$;

under both growing conditions and seasons. This may be explained by the fact that plants originating from micro-plants have a longer period of tuber initiation and reduced resorption as compared to cuttings. Sharma and Pandey (2013) also observed that in vitro plants produce smaller sized but a greater number of tubers. Significant differences were observed between the number of tubers ($p < 0.05$) from in vitro derived plants and those from apical cuttings under aeroponics conditions (Tsoka et al., 2012). In this study, the average number of tubers from RACs was fewer but the average tuber weight was higher compared to the average weight from TC. This means that tuber size contributed more to the average weight than numbers. However, tuber weight (g) differences between mini-tubers produced from in vitro and RACs were not significant (Tsoka et al., 2012).

The higher proliferation of NAROPOT4 in both TC and RACs compared to NAROPOT1 in this study may be explained by the varietal and genotype differences. NAROPOT4 produces many tubers of different sizes while NAROPOT1 produces few and big tubers. According to Sharma et al. (2013) and Venkatasalam et al. (2011), mini-tuber production is affected by genotype and cultivars differ widely in their capacity to produce mini-tubers, some being much more prolific than others. These varietal differences were also made by Wauters and Parker (2021) in a study on farmer and seed multiplier feedback on potato variety preferences and RACs on the high number of tubers harvested per plant (NAROPOT1 = 53 and NAROPOT4 = 59). Ahloowalia (1994) reported a 10-fold difference in the yield of mini-tubers between the highest and the lowest yielding varieties. Significant differences among the potato cultivars with respect to establishment of plantlets in the greenhouses, canopy cover, number, and yield of mini-tubers were also reported (Kumar et al., 2007).

The correlation (0.62) between the number of tubers per plant and TWT was positive and significant ($p \leq 0.001$). Hirut

TABLE 4 Mean performance of varieties and type of starter materials in Karengyere.

Variety	NAROPOT 4				NAROPOT1			
Starter material	TC		RACs		TC		RACs	
Plant No.	TNT	TWT (g)	TNT	TWT (g)	TNT	TWT (g)	TNT	TWT (g)
1	11.5	70.5	19.5	270.0	9.5	136.5	3.5	30.0
2	12.5	41.5	10.5	165.0	7.5	100.5	4.0	64.0
3	6.0	74.5	9.5	147.0	7.0	96.5	5.5	46.0
4	12.5	73.5	10.5	101.0	7.0	79.5	9.0	71.5
5	8.5	43.5	17.5	259.0	8.0	182.0	9.5	124.5
6	20.5	42.5	12.0	163.0	12.5	143.0	8.5	71.5
7	15.0	62.5	8.0	102.0	9.0	193.0	11.0	113.5
8	9.5	43.0	6.0	68.5	9.0	275.0	6.5	58.5
9	9.5	39.0	18.5	262.0	3.5	119.5	3.5	65.0
10	12.5	69.5	21.0	173.0	8.0	160.0	5.0	51.0
11	19.5	91.0	15.0	182.0	6.0	66.5	3.5	34.5
12	30.5	106.0	11.5	290.5	9.0	95.5	5.0	43.0
13	20.5	68.5	17.5	213.5	9.0	245.0	10.0	121.0
14	9.5	104.0	14.0	204.5	6.0	70.0	4.5	65.5
15	10.5	108.0	18.0	260.5	11.0	173.5	4.0	53.5
16	26.0	191.5	10.5	197.0	9.0	179.5	3.0	54.0
17	23.0	216.5	14.5	140.5	3.5	37.5	4.5	82.5
18	21.0	117.5	14.0	170.0	9.0	80.5	8.5	85.0
19	8.0	51.5	14.5	88.0	8.0	84.0	7.0	87.5
20	14.0	75.0	8.0	93.5	8.0	144.5	8.5	104.5
21	8.5	109.5	14.0	261.5	8.0	54.0	5.5	120.5
22	17.5	102.0	12.5	181.0	7.5	107.0	5.5	43.0
23	18.0	137.0	23.0	308.0	10.5	155.5	5.5	86.5
24	19.5	124.5	23.0	297.0	8.0	113.5	4.0	49.0
25	13.5	94.0	18.5	107.0	18.5	203.5	4.5	40.0
26	28.5	197.0	16.0	295.5	14.0	104.5	5.5	75.0
27	13.0	85.0	18.0	206.0	16.5	226.5	3.5	29.0
28	22.5	118.5	9.5	94.0	15.5	183.0	3.5	53.5
29	21.5	167.5	20.0	193.5	8.0	192.0	4.5	58.0
30	11.5	59.5	12.0	134.0	5.0	90.0	10.0	123.5
31	20.0	125.0	21.0	256.5	7.5	88.0	3.5	73.5
32	11.5	62.5	20.5	238.0	7.5	39.5	3.0	48.0
33	17.5	390.5	12.0	130.5	7.5	78.0	6.0	94.5
34	29.0	114.0	9.0	113.5	9.0	252.5	9.0	65.0
35	15.5	119.0	15.0	120.0	5.5	65.0	6.0	52.0
36	13.5	76.0	13.0	187.5	8.5	98.0	6.0	67.0
37	25.5	170.5	26.0	412.5	8.0	125.5	5.0	67.5
38	13.5	146.0	16.0	160.0	9.0	42.0	5.5	52.5
39	16.5	257.5	15.0	195.0	9.5	63.5	3.5	75.0
40	17.5	189.0	10.5	105.5	8.0	63.0	7.5	95.0
41	22.5	141.0	20.0	238.5	12.0	115.5	6.0	39.5
42	10.0	83.0	10.5	164.0	6.0	37.5	4.5	65.5
43	22.0	163.0	7.5	108.5	8.8	122.8	5.0	57.0
44	9.5	85.5	19.5	164.5	8.0	125.5	4.5	51.5

(Continues)

TABLE 4 (Continued)

Variety	NAROPOT 4				NAROPOT1			
Starter material	TC		RACs		TC		RACs	
Plant No.	TNT	TWT (g)	TNT	TWT (g)	TNT	TWT (g)	TNT	TWT (g)
45	8.5	109.0	9.0	69.5	9.0	42.0	4.5	44.5
46	15.0	90.0	7.5	79.5	9.5	63.5	6.0	25.0
47	14.0	57.0	17.5	220.5	8.0	63.0	7.5	71.5
48	16.0	101.5	6.0	101.0	12.0	115.5	7.0	65.5
49	20.0	211.5	9.5	144.0	6.0	37.5	4.0	36.0
50	18.0	167.5	22.0	188.5	8.8	122.8	3.5	33.5
Mean	**16.2**	**114.9**	**14.5**	**180.5**	**8.8**	**117.0**	**5.7**	**65.7**

Abbreviations: RACs, rooted apical cuttings; TC, tissue culture plantlets; TNT, total number of tubers; TWT, total weight of tubers.

TABLE 5 Mean performance of varieties and type of starter materials in Kachwekano.

Variety	NAROPOT4				NAROPOT1			
Starter material	TC		RACs		TC		RACs	
Plant No.	TNT	TWT (g)	TNT	TWT (g)	TNT	TWT (g)	TNT	TWT (g)
1	15.0	161.0	23.5	271.5	9.5	101.0	6.5	51.5
2	21.5	177.5	19.0	243.5	7.0	42.0	6.5	83.0
3	10.5	86.5	16.0	161.0	11.5	112.0	4.0	47.5
4	12.0	112.0	24.5	160.5	11.0	92.5	13.5	328.5
5	12.5	99.5	22.5	261.5	18.5	176.0	10.0	195.5
6	17.0	211.5	17.0	95.0	7.5	98.5	10.5	250.0
7	18.0	141.5	9.5	86.5	9.5	133.0	12.0	205.5
8	17.0	169.0	8.5	51.5	12.5	107.0	12.5	268.0
9	11.5	136.0	10.5	58.0	21.5	220.0	8.5	180.0
10	21.0	202.5	6.5	77.5	11.0	98.5	6.5	125.0
11	23.5	221.5	17.5	85.0	6.0	42.0	14.5	137.0
12	30.5	62.5	11.5	56.5	5.5	69.0	9.0	101.5
13	9.0	87.5	18.0	145.0	16.5	180.5	10.0	138.0
14	16.0	281.5	9.5	98.5	13.5	147.0	8.5	154.0
15	19.0	62.5	10.5	81.5	12.5	114.5	8.5	107.0
16	4.5	61.5	13.0	79.0	7.5	85.5	7.5	114.0
17	32.0	106.5	15.5	62.0	9.0	73.5	7.5	99.0
18	17.5	157.0	17.0	176.5	8.5	148.0	8.0	80.5
19	19.0	62.0	12.0	79.0	7.0	84.0	12.5	302.5
20	15.5	75.5	16.5	211.0	15.5	169.5	9.5	116.0
21	23.0	275.0	12.5	91.5	9.0	60.0	7.5	136.0
22	40.5	257.0	18.0	135.5	4.0	40.5	14.5	286.0
23	23.0	129.5	10.5	121.5	11.0	127.0	13.5	192.0
24	21.0	158.5	14.0	173.5	9.0	142.0	15.5	229.5
25	21.0	110.5	11.5	173.5	11.0	86.0	15.5	265.5
26	20.0	111.0	11.0	90.5	11.5	108.0	8.0	111.0
27	14.5	128.0	19.0	151.5	12.0	93.5	9.0	117.0
28	24.0	234.0	10.5	111.0	11.5	67.5	14.5	230.0
29	24.0	26.0	13.0	78.5	8.5	128.5	6.5	103.5
30	7.5	67.5	8.0	73.5	10.0	125.5	7.0	97.0

(Continues)

TABLE 5 (Continued)

Variety	NAROPOT4				NAROPOT1			
Starter material	TC		RACs		TC		RACs	
Plant No.	TNT	TWT (g)	TNT	TWT (g)	TNT	TWT (g)	TNT	TWT (g)
31	16.0	429.0	12.5	197.0	17.0	141.0	10.0	104.5
32	26.0	126.5	7.5	52.5	12.5	196.5	8.0	69.5
33	25.5	160.5	10.5	63.5	15.5	230.0	10.5	251.5
34	18.0	312.0	12.0	92.0	9.0	161.5	10.5	197.0
35	13.5	202.0	20.0	149.5	17.5	72.0	6.5	83.5
36	15.5	130.0	7.5	86.0	10.0	27.0	8.0	195.5
37	13.5	253.0	22.5	134.0	10.0	191.0	12.0	128.0
38	18.0	174.5	10.5	165.0	9.5	66.5	5.0	65.0
39	13.5	205.5	20.0	168.5	12.0	73.0	9.5	124.5
40	25.0	85.5	20.0	93.5	8.5	132.5	12.5	129.0
41	8.0	171.5	17.5	311.0	14.5	110.0	9.5	89.5
42	20.0	97.5	18.0	115.0	12.0	125.0	9.5	155.0
43	7.0	65.5	14.5	113.0	13.0	154.5	11.0	81.5
44	19.0	102.5	8.5	68.5	11.0	137.0	11.5	214.0
45	13.0	66.0	15.0	131.5	7.0	96.0	11.5	207.0
46	9.5	88.0	6.0	60.0	17.0	120.5	7.5	115.0
47	17.0	156.0	8.5	75.0	4.5	56.0	9.0	81.5
48	25.0	86.5	13.5	101.0	5.0	97.5	5.0	40.5
49	14.5	230.5	9.5	102.0	13.0	212.5	13.0	162.5
50	20.5	97.0	12.5	125.0	7.0	173.0	7.0	96.0
Mean	18.0	148.2	13.9	122.9	10.9	116.9	9.7	148.8

Abbreviations: RACs, rooted apical cuttings; TC, tissue culture plantlets; TNT, total number of tubers; TWT, total weight of tubers.

TABLE 6 Correlation of traits.

Number of tubers per plant	–	
Tuber weight	0.6195***	–
	Number of tubers per plant	Tuber weight

(2015) found a slightly higher correlation coefficient between TWT and average tuber weight of 0.88 in combining ability studies of potato clones in Ethiopia. Mehdi et al. (2008) found total tuber yield to be largely influenced by higher number of tubers per plant and tuber size. This implies that TWT can be selected indirectly using average tuber weight.

5 | CONCLUSIONS

The comparative performance of starter materials both in the screen house and field implies that production of mini-tubers can be done by farmers under affordable conditions. Given the higher productivity of in vitro plants from this study, direct planting is recommended for farmers with ability to manage this level of seed in the screen house, field, or both. Integrating RACs into the seed systems reduces time to which high-quality seed potato is available to farmers while increasing the efficiency of seed production compared to current practices. Because of the differential response of genotypes under varying growing conditions, there is need to optimize protocols to maximize mini-tuber productivity. However, the use of tissue culture materials may be challenging for farmers who lack technical growing skills and when environmental conditions are not favorable for plant growth. Also, the cost of tissue culture materials is higher than that of RACs. Since RACs are raised from TC, more numbers can be generated in a given time even under farmer conditions. The two starter materials studied can be used by farmers depending on their management ability.

AUTHOR CONTRIBUTIONS

Prossy Namugga: Conceptualization; formal analysis; funding acquisition; investigation; methodology; resources; writing–original draft; writing–review and editing. **Son Aijuka**: Data curation; methodology; validation. **Osbert Arinda**: Data curation; validation. **Benon Mateeka**: Data curation; methodology; supervision. **Alex Barekye**: Project administration; supervision.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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