RESEARCH PROGRAM ON Roots, Tubers and Bananas

CGIAR

Technical report: Evaluation of Potato (Solanum tuberosum L.) Genotypes for Adaptability in Mt. Elgon Region of Uganda

Expanding Utilization of Roots, Tubers and Bananas and Reducing Their Postharvest Losses

RTB ENDURE

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The CGIAR Research Program on Roots, Tubers and Bananas (RTB) is a broad alliance led by the International Potato Center (CIP) jointly with Bioversity International, the International Center for Tropical Agriculture (CIAT), the International Institute for Tropical Agriculture (IITA), and CIRAD in collaboration with research and development partners. Our shared purpose is to tap the underutilized potential of root, tuber and banana crops for improving nutrition and food security, increasing incomes and fostering greater gender equity, especially among the world's poorest and most vulnerable populations.

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EXECUTIVE SUMMARY

To increase diversity of potato grown in Uganda, variety evaluations were undertaken in the Mt Elgon region of eastern Uganda to evaluate varieties already registered in Uganda that are commonly grown in western Uganda, and clones from the International Potato Center's breeding program. The varieties and clones were evaluated at Buginyanya Zonal Agricultural Research and Development Institute over two seasons in 2016. Yield differed significantly between the two seasons. In season one, variety Rwangume commonly grown in western Uganda, performed the best at 19.3 t/ha, while in season two, clone 392797.22, commonly known as Unica in countries where it is registered, yielded 62.5 t/ha. All but one variety/clone in season two yielded greater than the best performing clone of season one at 24.2 t/ha and greater. While plant vigor was slightly better in season two, this does not justify the massive differences in yield between the two seasons, particularly as disease incidences overall were not so different between the two seasons. Conclusions over the two seasons are that clones 392797.22 and 398208.704 were the most adapted, therefore recommended for the Mt. Elgon region because they are more resistant to disease and are high yielding.

1. BACKGROUND

Potato (*Solanum tuberosum* L.) is primarily cultivated in high altitude areas. World potato production was estimated at over 360 million tons in 2012 (FAOSTAT, 2014). Uganda is ranked the 51st largest producer in the world (FAOSTAT, 2013) and statistics show that Kabale district in south-western Uganda alone produces up to 50-60% of the potatoes harvested in Uganda. The second most important production region is eastern Uganda, particularly the districts of Mbale and Kapchorwa on the slopes of Mt. Elgon (Bonabana, 2013).

Potato production in eastern Uganda is constrained by several issues including lack of suitable varieties, poor agronomic practices, diseases, especially late blight which causes losses ranging from 30 to 70% (Nyakangu *et al.,* 2001, Olanga *et al.,* 2001), lack of proper storage facilities (Tewodros, 2014) and low potato prices fetched by farmers.

2. OBJECTIVES

The overall objective of this study is to evaluate CIP clones and introduced varieties for production in Mt. Elgon region.

Specific objectives

i. To determine agronomic performance of 18 new potato genotypes in Mt Elgon region
ii. To assess the effect of staggered planting on potato tuber yield and occurrence of late blight and bacterial wilt diseases.

3. MATERIAL AND METHODS

3.1. Study Site

- Field trials were set up in Buginyanya research station, Masira sub-county, Bulambuli district
- Latitude: 1.2786N; Longitude: 034.3747E; Altitude: 1937masl in eastern Uganda
- Each trial was observed as single dispersed replication and evaluated at physiological maturity and after harvest.

3.2. Field evaluation of performance of potato genotype

- Field trials were set up in randomized block design (RCBD), with four replications. The trials were established during the first and second rainy season of 2016.
- The eighteen (18) potato genotypes were evaluated on a number of criteria
- Plots measured 3mx2.1m.
- NPK fertilizer (17:17:17) was applied at a rate of 10g/hill.

3.3. Data were collected

- At planting: No. of tubers planted
- At 30 DAP: Number of plants emerged (NPE)
- At 40 DAP: Plant Uniformity, Plant Vigor, Late blight and Bacterial wilt
- At 60 DAP: Flowering Degree, Late blight and Bacterial wilt
- At 90 DAP: Senescence stage, Late blight and Bacterial wilt
- At harvest: Tuber uniformity, tuber size, No. of plants harvested, No. of tubers harvested and their weights and No. of marketable tubers.

3.4. Data analysis

Statistical analyses was done using Gen stat 14th edition. The mean of each trait was separated using the least significant difference (LSD) test at 5%.

4. RESULTS

4.1. PHENOTYPIC AND GROWTH CHARACTERISTICS OF POTATO GENOTYPES

4.1.1. Tuber size

There was no variability in tuber size of the potato genotypes evaluated in this study in the first season (2016A, Table 1). All the genotypes were scored as very small with tubers smaller than 3cm. Conversely, a small variation was observed in the size of potato tubers among genotypes in the second season (2016B). Majority of the potato tubers of different genotypes were medium size (4-6cm). Only Bumbamagara and Cruza had small tubers (2-4cm). Generally when genotypes were planted in the second season, they produced larger tubers compared to the first season.

4.1.2. Tuber appearance and tuber uniformity

Tuber appearance varied across the potato genotypes evaluated in this study. In the first season (2016A), most of the tubers scored between 3 and 5 or <3 described as having poor or very poor tubers, respectively (Table 1). In the second season (2016B), most of genotypes scored 5-7 and were grouped as regular. Only one genotype, 392797.22 having a score of 8, had its tubers scored as good. In the same season, genotypes 396036.201, Cruza, Katchpot 1 and Nakpot 5 having a score 4.0-4.5 were scored as having poor tubers.

As for tuber appearance, there was a small variation in tuber uniformity across the potato genotypes evaluated in the two seasons. In 2016A, majority of the genotypes had heterogeneous tubers except genotype Bumbamagara which had intermediate tubers (Table 1). In 2016B, most of the genotypes scored 5 qualifying to be categorized as having intermediate level of uniformity. However, genotypes Bumbamagara and Shangi with a score of 7 had uniform tubers while Nakpot5 produced heterogeneous tubers.

4.1.3. Plant vigor and flowering degree

There was a variation in plant vigor among the genotypes tested in both seasons (Table 1). In 2016A, majority of potato genotypes tested were categorized as medium. However, genotypes 396036.201, 393385.39 and Nakpot 5 with a mean score of less than 3 were described as having very weak vigor. Notably, five genotypes - 392797.22, Victoria, Bumbamagara, Rwanshaki and Shangi - which had a mean score between 3 and 5 were described as having a weak vigor (Table 1). In 2016B, majority of the genotypes showed medium vigor. However, genotype Rwangume with a score of 7 was described as a vigorous grower while Shangi with a score less than 3 had a very weak vigor (Table 1). Furthermore, four genotypes - 393385.39, 396036.201, Bumbamagara and Nakpot5 - scoring 3-5 were grouped as having a weak vigor.

Flowering degree also varied among potato genotypes in this study (Table 2). Majority of the genotypes were scored as moderate flowering (Table 2). However, five genotypes - Shangi, Rwangume, Rutuku, 393077.159 and Victoria - with score of 7.0 showed profuse flowering. Notably, genotypes 396036.201, 392797.22 and Bumbamagara had low flowering while genotype Kinigi with a score <1 was grouped as aborted bud (Table 2).

Table 1: Salient characteristics of 18 potato genotypes in eastern Uganda

Seasons	2016A				2016B			
Genotype	**Tuber size**	**Tuber appearance**	**Tuber uniformity**	**Plant vigor**	**Tuber size**	**Tuber appearance**	**Tuber uniformity**	**Plant vigor**
392797.22	2.7 **(VS)**	3.5 **(P)**	4.0 **(H)**	4.5 **(W)**	6.5 **(M)**	8.0 **(G)**	5.0 **(I)**	5.0 **(M)**
393077.159	2.3 **(VS)**	3.3 **(P)**	4.3 **(H)**	6.5 **(M)**	5.0 **(M)**	5.0 **(R)**	5.5 **(I)**	6.5 **(M)**
393079.4	2.0 **(VS)**	2.8 **(VP)**	4.0 **(H)**	6.0 **(M)**	4.5 **(S)**	5.0 **(R)**	5.5 **(I)**	6.0 **(M)**
393385.39	2.0 **(VS)**	2.8 **(VP)**	4.0 **(H)**	0.8 **(VW)**	5.5 **(M)**	5.5 **(R)**	5.5 **(I)**	4.5 **(W)**
396036.201	2.0 **(VS)**	1.5 **(VP)**	4.5 **(H)**	0.0 **(VW)**	5.0 **(M)**	4.5 **(P)**	6.0 **(I)**	3.5 **(W)**
398208.29	2.8 **(VS)**	3.3 **(P)**	3.8 **(H)**	5.5 **(M)**	6.0 **(M)**	5.0 **(R)**	5.0 **(I)**	6.0 **(M)**
398208.704	2.5 **(VS)**	3.5 **(P)**	4.3 **(H)**	6.5 **(M)**	5.5 **(M)**	6.0 **(R)**	5.0 **(I)**	5.5 **(M)**
Bumbamagara	1.5 **(VS)**	1.5 **(VP)**	5.0 **(I)**	4.0 **(W)**	4.0 **(S)**	5.0 **(R)**	7.0 **(U)**	4.5 **(W)**
Cruza	1.8 **(VS)**	1.5 **(VP)**	5.0 **(I)**	5.0 **(M)**	3.5 **(S)**	4.5 **(P)**	6.5 **(I)**	5.5 **(M)**
Katchpot 1	2.3 **(VS)**	2.5 **(VP)**	4.8 **(H)**	5.5 **(M)**	5.0 **(M)**	4.0 **(P)**	6.5 **(I)**	5.0 **(M)**
Kinigi	2.3 **(VS)**	4.0 **(P)**	4.3 **(H)**	6.5 **(M)**	5.5 **(M)**	6.5 **(R)**	6.0 **(I)**	5.5 **(M)**
Nakpot 5	2.5 (**VS**)	1.8 **(VP)**	4.3 **(H)**	1.8 **(VW)**	4.8 **(S)**	4.3 **(P)**	4.8 **(H)**	3.3 **(W)**
Rutuku	2.5 **(VS)**	3.0 **(P)**	3.8 **(H)**	4.5 **(W)**	5.0 **(M)**	6.5 **(R)**	5.0 **(I)**	5.5 **(M)**
Rwangume	2.0 **(VS)**	3.5 **(P)**	4.3 **(H)**	6.5 **(M)**	5.0 **(M)**	6.0 **(R)**	6.0 **(I)**	7.0 **(V)**
Rwanshaki	2.5 **(VS)**	3.5 **(P)**	4.3 **(H)**	4.5 **(W)**	5.0 **(M)**	5.0 **(R)**	6.5 **(I)**	5.0 **(M)**
Shangi	1.8 **(VS)**	1.5 **(VP)**	4.8 **(H)**	4.5 **(W)**	4.5 **(S)**	5.5 **(R)**	7.0 **(U)**	2.5 **(VW)**
Victoria	2.5 **(VS)**	3.3 **(P)**	4.3 **(H)**	5.5 **(M)**	5.0 **(M)**	5.5 **(R)**	6.0 **(I)**	5.5 **(M)**

Salient characteristics of potato genotypes were evaluated using scales as follows; Tuber appearance: 1-very poor (VP),3-poor (P), 5-regular (R), 7-good (G) and 9-very good (VG) (Gastelo, 2011); Tuber size: 1-very small (VS), 3-small (S), 5-medium (M), 7-large (L) and 9-very large (VL) (Gastelo, 2011); Plant vigor: 1-very weak (VW), 3-weak (W), 5-medium (M), 7-vigorous (V) and 9-very vigorous (VV) (Salas, 2007); Tuber uniformity: 1-very heterogeneous (VH), 3-heterogenous (H), 5-intermediate (I), 7-uniform (U) and 9-very uniform (VU) (Salas, 2007).

4.1.4. Tuber shape

There was no variability in tuber shape of the potato genotypes evaluated in this study (Table 2). Generally all the potato genotypes evaluated had round tubers.

4.1.5 Senescence stage (90 days after planting)

There was substantial variation in senescence stage among the genotypes evaluated. Genotypes Shangi, Victoria, Rwangume and 393077.159 were characterized by early senescence (Table 2). Notably, three improved genotypes - 393385.39, 396036.201, 398208.29 - and one local genotype Nakpot 5 showed very late senescence.

Furthermore, improved genotypes 393079.4, 392797.22, 398208.704 and one local genotype Kinigi scored between 3and 5 and were categorized as having late senescence. All the remaining genotypes took neither long nor short time to senescence (medium).

4.1.6 Tuber yield

Tuber yield varied significantly ($P<0.001$) among the genotypes in the study. Generally there was an increase in tuber yield in the second season across genotypes. In the first season (2016A) genotype Rwangume with tuber yield of 19.29t ha^{-1} had significantly ($P<0.001$) higher prodcutivity than other genotypes except for Kinigi, Rwanshaki, 393077.159, 398208.29, 392797.22 Victoria, 398208.704, 393079.4 and Rutuku whose tuber yields were not significantly ($P>0.001$) lower. Notably, improved genotype 396036.201 (3.93t ha^{-1}) produced the lowest tuber yield in 2016A. In the same season, the average tuber yield was 11.41t ha^{-1} (Table 3)

In 2016B, genotype 392797.22 (62.5t ha^{-1}) produced significantly ($P<0.001$) more than genotype Katchpot (13.21t ha^{-1}) which showed the lowest tuber yield (Table 5). Tuber yield of the rest of the genotypes was not statistically ($P>0.001$) different from that of 392797.22. The average tuber yield in the second season was three times higher than that in the first season. Improved genotypes 392797.22, 393385.39, 398208.29 and 398208.704 produced a higher tuber yield than the local checks except for Kinigi, Rutuku and Rwangume (Table 3).

Table 2: Salient characteristics of 18 potato genotypes in Eastern Uganda

Genotype	Tuber shape	Flowering degree	Senescence at 90 days
392797.22	2.0 (Round)	4.5 (Low)	4.8 (Late)
393077.159	1.1 (Round)	7.0 (Profuse)	7.0 (Early)
393079.4	1.3 (Round)	5.5 (Moderate)	4.0 (Late)
393385.39	1.0 (Round)	6.0 (Moderate)	1.8 (Very late)
396036.201	1.0 (Round)	4.1 (Low)	1.8 (Very late)
398208.29	1.0 (Round)	6.0 (Moderate)	2.5 (Very late)
398208.704	1.3 (Round)	6.0 (Moderate)	3.0 (Late)
Bumbamagara	1.0 (Round)	3.5 (Low)	6.0 (Medium)
Cruza	1.1 (Round)	6.1 (Moderate)	6.0 (Medium)
Katchpot 1	1.0 (Round)	6.5 (Moderate)	5.3 (Medium)
Kinigi	1.0 (Round)	1.8 (Aborted bud)	3.0 (Late)
Nakpot 5	1.3 (Round)	6.1 (Moderate)	1.5 (Very late)
Rutuku	1.0 (Round)	7.0 (Profuse)	3.3 (Late)
Rwangume	1.0 (Round)	7.0 (Profuse)	7.8 (Early)
Rwanshaki	1.0 (Round)	6.0 (Moderate)	5.0 (Medium)
Shangi	1.5 (Round)	7.0 (Profuse)	8.5 (Early)
Victoria	1.0 (Round)	7.0 (Profuse)	8.3 (Early)

Salient characteristics of potato genotypes were evaluated using scales as follows; Tuber shape: 1-Round, 3- Short oval, 5- Oval, 7- Long oval and 9-Very long (Wooster and Farooq, 1995); Flowering degree: 0-No bud, 1-Aborted bud, 3-Low, 5-Moderate and 7-Profuse (Gomez, 2004); Senescence degree: 1-Very late, 3-Late, 5-Medium, 7-Early and 9-Very early (Gastelo, 2011).

Table 3: Yield components of 18 potato genotypes in Eastern Uganda in the two seasons

Seasons	2016A		2016B
Genotype	**Tuber yield (tons/ha)**	**Genotype**	**Tuber yield (tons/ha)**
Rwangume	19.29e	**392797.22**	62.5b
Kinigi	17.14de	**Kinigi**	51.90ab
Rwanshaki	15.48de	**Rutuku**	46.19ab
393077.159	14.88cde	**398208.704**	44.03ab
398208.29	14.17bcde	**393385.39**	42.50ab
392797.22	14.05bcde	**Rwangume**	42.02ab
Victoria	14.05bcde	**398208.29**	41.31ab
398208.704	12.86abcde	**Victoria**	38.93ab
393079.4	12.74abcde	**Cruza**	38.33ab
Rutuku	12.38bcde	**393079.4**	36.55ab
393385.39	9.05abcd	**Nakpot 5**	34.52ab
Katchpot 1	8.69abcd	**393077.159**	31.19ab
Nakpot 5	8.10abcd	**Bumbamagara**	30.71ab
Cruza	7.38abcd	**Rwanshaki**	29.64ab
Shangi	4.88abc	**396036.201**	29.52ab
Bumbamagara	4.84ab	**Shangi**	24.17ab
396036.201	3.93a	**Katchpot 1**	13.21a
S.E	**3.92**	**S.E**	**18.21**
C.V	**34.4**	**C.V**	**48.6**

Means with the same letters are not significantly different using Tukey HSD test at P<0.05

4.2. GENOTYPE RESPONSE TO BACTERIAL WILT AND LATE BLIGHT

4.2.1. Area under disease progressive curve

The analysis of variance (ANOVA) results for the relative area under disease progressive curves (AUDPC) revealed a significant ($P<0.01$) difference for bacterial wilt in the first season ($P<0.001$) and in second season (Table 4).

In 2016A, mean relative area under disease curve of bacterial wilt was significantly ($P< 0.01$) higher for genotypes Cruza (981.3) compared to improved genotypes 393385.39, 396036.201, 398208.29, 398208.704, 392797.22, 393077.159 and local genotypes Kinigi and Nakpot5 (Table 4). Mean relative area under disease curve of the rest of the genotypes was not significantly ($P>0.01$) different from that of Cruza (Table 4).

In the same season, all the improved genotypes 393385.39, 396036.201, 398208.29, 398208.704, 392797.22, 393077.159 except 393079.4 were not significantly affected by bacterial wilt (Table 4).

In 2016B, results indicated that improved genotypes 393079.4 (1368.8) and 398208.29 (1375) showed the highest AUDPC that was significantly ($P<0.001$) higher than genotypes except Bumbamagara, Cruza, Katchpot1 and Rwangume (Table 4). Four improved genotypes 396036.201, 398208.704, 393077.159 and 392797.22 and four local genotypes Kinigi, Nakpot5, Rutuku and Rwanshaki recorded lower AUDPC values compared 393079.4, 398208.29 and Katchpot 1 (Table 4).

The area under disease progressive curve (AUDPC) for late blight varied significantly across the genotypes for the two seasons. In 2016A, local genotype Victoria (2921.9) registered significantly ($P>0.001$) higher AUDPC for late blight tham the rest of the genotypes except Cruza (1856.2), Rwanshaki (1187.5), Shangi (2609.4) and 396036.201 (893.8) (Table 4). All the improved genotypes 398208.704 393385.39, 392797.22, 393077.159, 393079.4 and 398208.29 except 396036.201 registered lower AUDP for late blight compared to local check Victoria. Only four local genotypes Katchpot 1, Kinigi, Rukutu and Rwangume recorded lower AUDPC for late blight than Victoria in 2016A.

In 2016B, improved genotype 396036.201 (2034.4) had significantly ($P<0.001$) higher AUDPC for late blight than 393385.39, 398208.704, Rwangume, Victoria, Shangi and Kinigi (Table 4). The mean AUDPC for late blight of the rest of the genotypes were not significantly ($P> 0.001$) different from 396036.201.

4.2.2. Bacterial wilt incidence of selected potato genotypes

Figure 1 shows a variation in bacterial wilt incidence among the genotypes tested. In 2016A, the genotypes Cruza and Shangi had the highest incidences of bacterial wilt. These were affected earlier in the growing season, at 40 days after planting. In the same season, only five improved genotypes 393385.39, 396036.201, 398208.29, 398208.704, 392797.22 and two local checks Nakpot 5 and Kinigi did not register any incidences of bacterial wilt.

In 2016B, all the genotypes except Cruza recorded disease incidences 40 days after planting. Improved genotypes 393079.4, 398208.29 and local genotype Katchpot 1 were the most affected throughout the 90 days of disease evaluation. Generally a higher percentage of wilted plants was recorded across genotypes in 2016B compared to 2016A.

Table 4: Area under disease progress curves (AUDPC) for late blight and bacterial wilt of 18 potato genotypes in eastern Uganda in the two seasons

Seasons	2016A		2016B	
Genotypes	**AUDPC BW**	**AUDPC LB**	**AUDPC BW**	**AUDPC LB**
392797.22	0.0a	140.6a	328.1a	693.7ab
393077.159	18.8a	312.5a	196.9a	309.4ab
393079.4	121.9ab	0.0a	1368.8c	590.6ab
393385.39	0.0a	0.0a	290.6ab	103.1a
396036.201	0.0a	893.8abc	196.9a	2034.4b
398208.29	0.0a	731.2ab	1375.0c	1521.9ab
398208.704	0.0a	93.7a	84.4a	0.0a
Bumbamagara	634.4ab	759.4ab	965.6abc	890.6ab
Cruza	981.3b	1856.2abc	918.8abc	715.6ab
Katchpot 1	425.0ab	43.8a	1175.0bc	909.4ab
Kinigi	0.0a	437.5a	84.4a	0.0a
Nakpot 5	0.0a	775.0ab	93.8a	493.7ab
Rutuku	290.6ab	531.2a	206.3a	653.1ab
Rwangume	321.9ab	328.1a	515.6abc	112.5a
Rwanshaki	209.4ab	1187.5abc	75.0a	1003.1ab
Shangi	881.3ab	2609.4bc	337.5ab	150.0a
Victoria	84.4ab	2921.9c	253.1ab	0.0a
S.E	**16.9**	**400.2**	**363.5**	**136.7**
CV%	**7.2**	**50.0**	**73.0**	**22.8**

AUDPC (area under progressive disease curve), BW (bacterial wilt), LB (late blight).

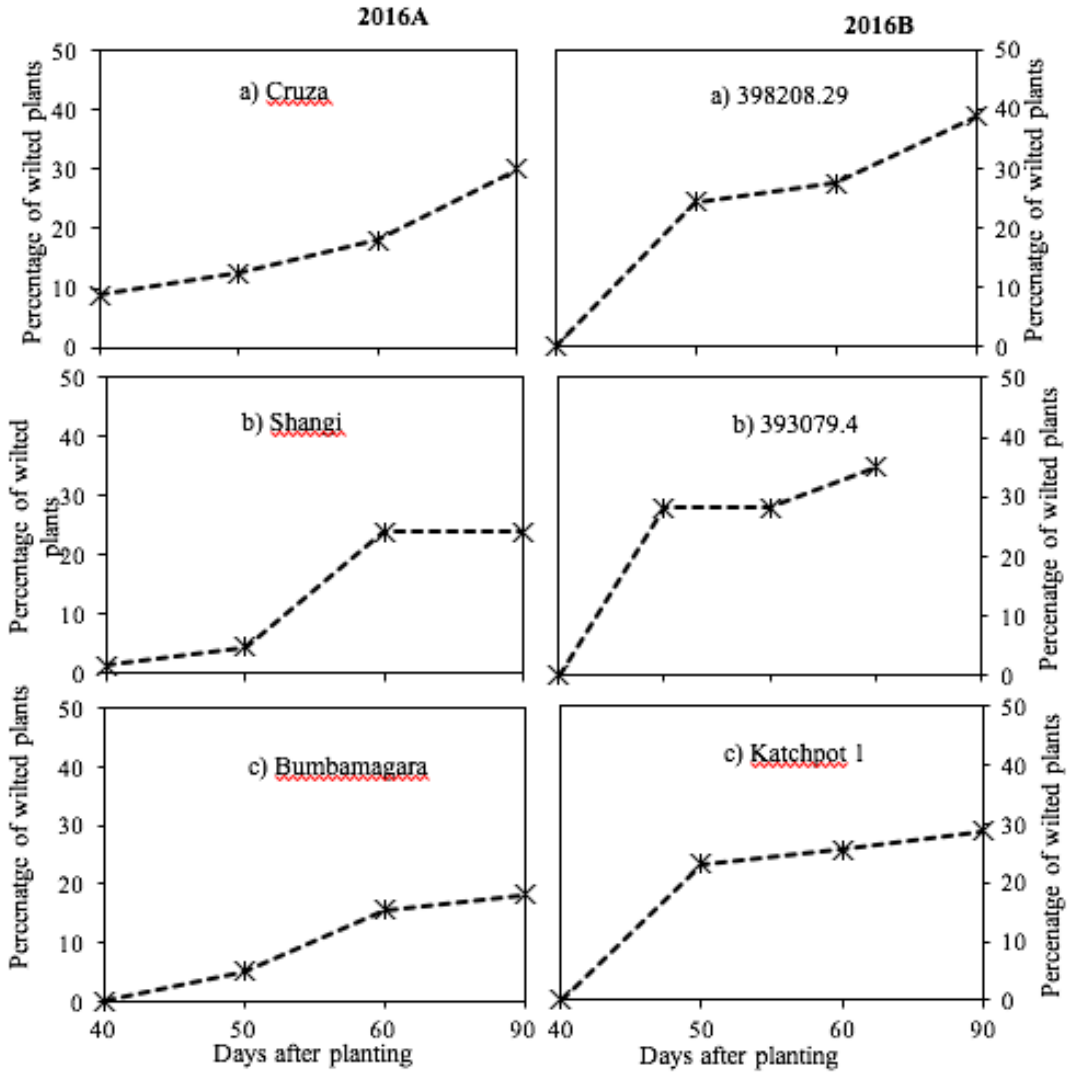

Figure 1: Bacterial wilt disease incidence of a selected set of potato genotypes at 40 to 90 days after planting during the first and second rainy season of 2016 in Eastern Uganda.

4.2.3. Late blight incidence of selected potato genotypes

Results of Figure 2 indicate a variation in disease incidence among the different genotypes evaluated.

In 2016A, the locally cultivated genotypes Victoria, Shangi and Cruza showed the highest late blight incidences. In the same season, all the improved genotypes except 396036.201 and 398208.29 registered lower disease incidences. Notably genotypes 393079.4, 393385.39 and 398208.704 had no incidences of the disease throughout the 90 day period after planting. Furthermore the local genotypes Bumbamagara, Cruza, Nakpot5, Rukutu, Rwangume, Rwanshaki, Shangi and Victoria were infected earlier, beginning at 40 days after planting.

In 2016B, the local check Cruza and two improved genotypes 396036.201 and 398208.29 had the highest incidences of late blight compared to the rest of the genotypes. Apart from Cruza, Rutuku and Shangi with a small percentage of diseased plants at 40 days after planting, the rest of the genotypes did not register any diseased plants at 40 days. Genotypes Kinigi, Victoria and 398208.704 had no incidence of late blight 90 days after planting. The smallest incidence was recorded on Rwangume, Shangi, 393385.39 and 393077.159.

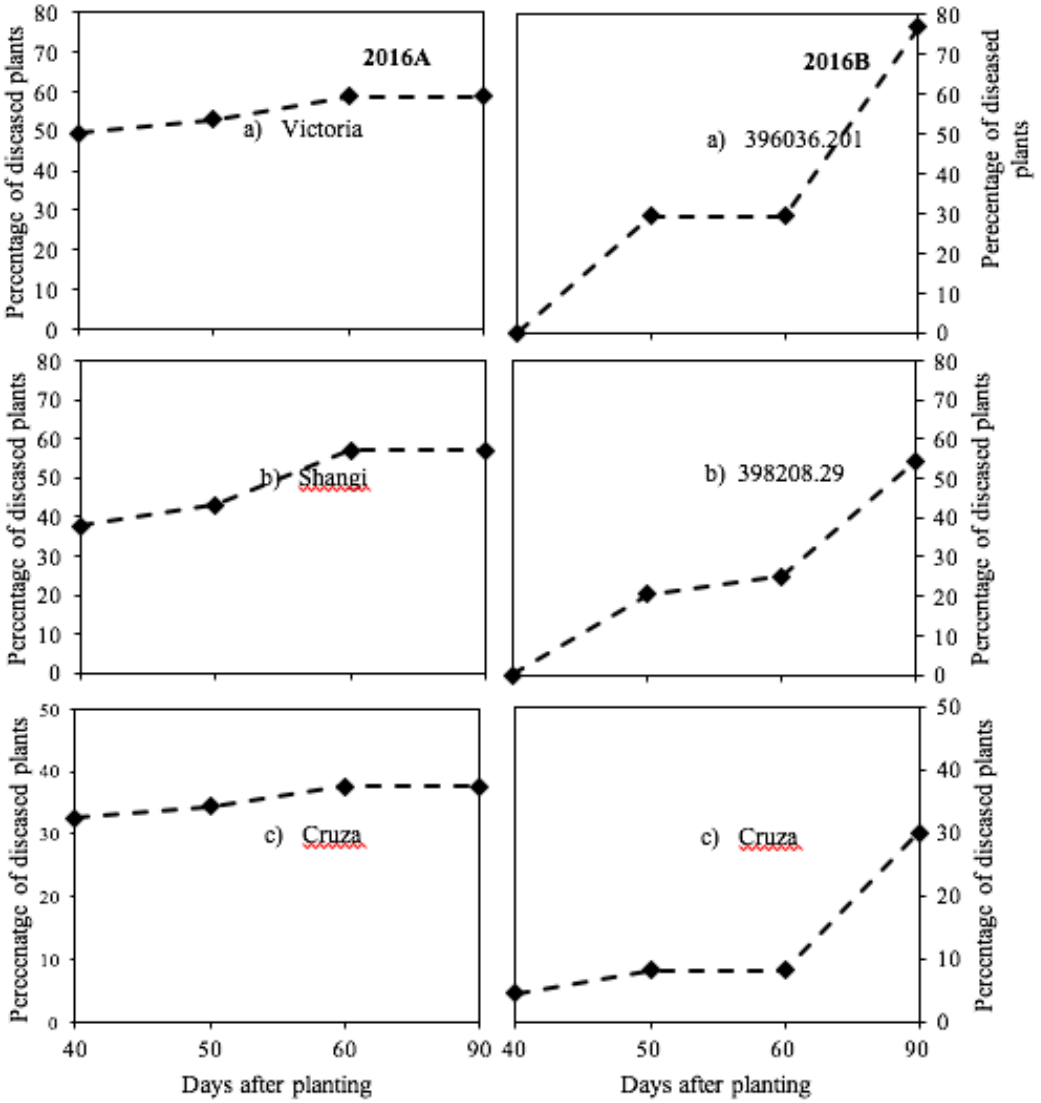

Figure 2: Late blight disease incidence of a selected set of potato genotypes at 40 to 90 days after planting during the first and second rainy season of 2016 in Eastern Uganda.

5. CONCLUSIONS

- Generally there was higher yield in season 2016B compared to season 2016A.
- Improved genotypes like 398208.704, 398208.29, 393385.39 and 392797.22 had higher tuber yield of 31.3 to 46.3t/ha compared to only 30 t/ha for the local genotype Victoria.
- The local genotypes were early maturing by 30 days compared to the improved genotypes.
- Lower rates of disease incidences were recorded on the other improved genotypes 392797.22 and 393079.4.
- The local genotypes like Victoria were infected earlier at 40 days compared to 60 days for the improved genotypes.
- And early Incidence of late blight is often observed in early maturing rather than in late maturing genotypes hence low yield.

6. RECOMMENDATIONS

Genotypes 392797.22 and 398208.704 were the most adapted, therefore recommended for the Mt. Elgon region because they are more resistant to disease and are high yielding.