# DETERMINING ADAPTABILITY OF POTATO GENOTYPES IN MOUNT ELGON REGION OF UGANDA

## Abstract

Potato(*Solanum tuberosum* L.) in Uganda is mainly produced in the highland areas of Kabaleand Kisoro in southwesternand Bugisuand Sebei areas on the slopes of Mt. Elgon in the eastern part of the country. However, the yields have continuously reduced due to lack of suitable high yielding and disease resistant varieties. The purpose of this study was to identify high yielding disease resistant potato genotypes adapted to Mt. Elgon region. Eight CIP potato clones were evaluated alongside ten commonly grown Ugandan varieties in RCBD for two seasons atBuginyanya station, Bulambuli District. Results showed significant differences ($P<0.05$) in tuber size, tuber uniformity, marketable tuber yield and the total tuber yield among genotypes. Potato clones 392797.22 and 398208.29 produced significantly ($P<0.001$) higher tuber yield 44.8t/haand 39t/ha respectively compared to the local check Cruza with 34.5t/ha. rAUDPC for LB showed significant differences ($P<0.001$) among genotypes in both seasons. The most resistant genotypes were Kinigiand clone 399985.39 with rAUDPC of 0.0135and 0.025 respectivelywhereas Bumbamagara (0.413)and 396036.201 (0.392) were the most susceptible. 396036.201(0.051)and Kinigi were the most resistant genotypes for bacterial wilt while Shangi (0.66)and Cruza (0.46) were the most susceptible to BW.Generally, genotypes 392797.22and 398208.29 were the highest yieldingand disease resistant hence recommended for release as commercial varieties.

**Key words:**Adaptability, clones, bacterial wilt,late blight, genotypes

## Introduction

Potato (*Solanum tuberosum* L.) is one ofthe most important crops in the world,with the current production estimated at 376 million tons from 18 million hectares (FAOSTAT, 2023). Potatois a versatile vegetable, and staple food consumed in most areas (Buru, 2015; Mickiewicz*et al.*, 2022). The global shift in consumer demand from freshtubers to processed products is a testament to the adaptability and potential of this crop (Abong *et al.*, 2010; Devaux*et al.*,2020;

Kajunju*et al.,* 2021). This expanding trend in potato consumption is mainly attributed to increasing urban populations, rising incomes, diversification of diets, and lifestyles that leave less time for preparing the fresh product for consumption (Lutaladio and Castaldi,2009; Devaux*et al.,* 2020). The development of the potato industry in sub-Saharan Africa (SSA) is critical for poverty eradication, as potatoesare an important food and cash crop (Schulte-Geldermann,2013; Muthoni and Shimelis, 2023). Potatoes have a short cropping cycle and high productivity (35 t/ha) per unit area in a given timedepending on environmental conditions and the variety of potatoes (Schulte-Geldermann,2013; Nasir and Toth, 2022). It is one of the most efficient crops in converting natural resources, labor and capital into a high-quality meal (Kajunju*et al.,* 2021). Potato is considered as one of the cash crops suited for the future for the densely populated East African highlands especially in Uganda and is a source of livelihoods for smallholder farmers(Priegnitz*et al.,*2019; Muthoni and Shimelis, 2023).Potatoesarereasonably priced but nutritionally wealthy staple food required bythe rapidly growing population, contributing protein, nutrients, zinc and iron to people's diets(Schulte-Geldermann,2013).

Potatoes in Uganda is mainly produced in the southwestern highland areas of Kabale and Kisoro and onthe slopes of Mt. Elgon in eastern Uganda, in Bugisu and Sebei (Bonabana, 2013; Namugga*et al.,*2017). Statistics show that the Kabale district alone produces up to 50-60% of the potatoes consumed in Uganda (Bonabana, 2013; Priegnitz*et al.,* 2019). Potatocultivationin Uganda has been increasing over the years due to its high production per unit area(more than 30 t/ha), marketability, highly nutritious produceand early maturity (Schulte-Geldermann, 2013; Priegnitz*et al.,* 2019; Kajunju*et al.,* 2021), which allow it to be grown at least twice a year (Namugga *et al.,* 2017).

Despite the importance of potatoes in Uganda, theirproduction and marketing are abattle against biotic stresses, especially late blight and bacterial wilt diseases (Namugga*et al.,* 2018; Priegnitz*et al.,* 2019). This is compounded by the lack of suitable high yielding and disease resistant varieties coupled with poor agronomic practices, and a deficientpotato seed system that limits the use of good quality seed (Gildemacher, 2012;Schulte-Geldermann,2013;Priegnitz *et al.,*2019; Kajunju*et al.,*2021). The short shelf life and high perishability of potatoes soon after harvesting lead to over -flooding in the market, resulting in low prices (Tewodros, 2014), thus reducing profits forproducers. The situation calls for immediate action.There is a pressing need to diversify the range of potato varieties grown in Uganda to capture those with the requisite attributes to increase yields, disease resistance, usability, and marketability. This studyevaluated the performance, adaptability, and suitability of new potato genotypes in thehighland environments of Uganda.

## Materials and Methods

### Description of the study area

Field experiments were conducted under rain-fed conditions for the two cropping seasons of 2015B and 2016A at the Buginyanya Zonal Agricultural Research and Development Institute (BugiZARDI) in the Mt. Elgon region ofEastern Uganda. The instituteis located at an altitude of 1800m above sea level, and its soils generally described as well-drained deep sandy loam.

### Experimental treatment and design

A total of 18 potato genotypes, comprising 8 potato clones from CIP and 7 released commercial varieties in Kenya. Popular Ugandan commercial varieties Nakpot 5 and Cruza were included as tolerant local checks while Victoria was included as a susceptible check for late blight (Table 1). The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replicatesin plots measuring 0.7m by 3.0m wide consisting of two rows at spacing of 70cm by 30cm. Plantingof the experiments was done in October 2015 and April 2016.Soil fertilization was done using NPK (17:17:17) applied at a rate of 60g/m in the ridges during the planting. The crop was maintained following standard agronomic practices for potatoes, including dehaulming 10-15 days before harvest.

**Table 1: Identity and description of potato genotypes used in the study**

| Genotype | Origin | Status | Attributes |
|---|---|---|---|
| 393077.159 | CIP | Advanced line | High yielding, resistant to LB, potato virus X, potato leaf roll virus. |
| 398208.29 | CIP | Advanced line | Resistant to potato virus X and Y, LB |
| 392797.22 | CIP | Advanced line | Resistant to potato virus X and Y, root knot nematode. |
| 393079.4 | CIP | Advanced line | Resistant to LB, PVX and PLRV |
| 393385.39 | CIP | Advanced line | Resistant to LB, PVX and high yielding |
| 396036.201 | CIP | Advanced line | Resistant to LB and high yielding |
| 398208.704 | CIP | Advanced line | Resistant to LB and PVX |
| Bumbamagara | CIP | Released in Kenya | Early maturing |

|  |  |  |  |
|---|---|---|---|
| Cruza | CIP | Released in Uganda | BW tolerant |
| Kachpot 1 | CIP | Released in Uganda | Early maturing |
| Kimori | CIP | Released in Kenya | Early maturing |
| Kinigi | CIP | Released in Kenya and Rwanda | High yielding |
| Nakpot 5 | CIP | Released in Uganda | High yielding |
| Rutuku | CIP | Released in Kenya | LB tolerant, high yielding |
| Rwangume | CIP | Released in Kenya and Rwanda | High yielding |
| Rwanshaki | CIP | Released in Kenya | High yielding, early maturing, big tuber size |
| Shangi | CIP | Released in Kenya | High yielding, tolerant to LB |
| Victoria | CIP | Released in Uganda | High yielding, early maturing, LB and BW susceptible |

Data was collected on severalparameters, including thenumber of emerged tubers (NPE) ,determined 40 days after planting by counting emerged tubers. Plant uniformity data were also recorded 40 days after planting using a 1-9 scale developed by Salas (2007). Plant vigor was determined 40 days after planting and scored using a 1-9 scale (Salas, 2007). Flowering Degree (Flower) was determined 60 days after planting for every genotypeusing a scale of 0-7(Biodiversity & CIP, 2009; Gomez, 2004). The senescence stage was evaluated 90 days after planting using a 1-9 scale.Late blight severity was recorded at an interval of 10 days after plant emergence. Severity was assessed as a percentage of the blighted foliage and then converted into an Area under the Disease Progress Curve (AUDPC) to measure resistance. AUDPC was calculated from the estimated percentages of leaf area affected recorded at different times during the epidemic according to Campbell and Madden (1990), as shown below.

$$AUDPC = \sum_{i-1}^{n-1} \frac{y_1 + y_{i+1}}{2} \ X \ (t_{i+1} - t_i)$$

Where $y_i$ is an assessment of a disease (percentage) at the $i^{th}$ observation, $t_i$ is time (in days) at the $i^{th}$ observation, and n is the total number of observations. The AUDPC was standardized to RAUDPC values, according to Fry (1978). The relative AUDPC (rAUDPC) was calculated by dividing the AUDPC by the maximum potential AUDPC. AUDPC was calculated from the date of the first occurrence of late blight until the last observation of the disease in the trial at 90 days after planting.

Bacterial wilt (BW) incidence: BWincidence was assessed at an interval of 10 days until 90 days after planting. Disease incidence was calculated as the percentage of diseased plants over the total number of plants. In addition, the area under the disease progress curve (AUDPC) was calculated andconverted to rAUDPC (Campbell and Madden, 1990).

The following data were recorded during the harvest:Number of Plants Harvested (NPH); Tuber Uniformity was determined by observing harvested tubers. A scale of 1-9 was then used to categorize tubers for uniformity(Amoros andGastelo, 2011).Tuber size was determined based on a 1-9 scale(Amoros and Gastelo, 2011). Tubers were categorized as very small (if tuberswere<2 cm), small (if tubers were between 2 and 4cm), medium tubers (for tubers between 4 and 6 cm), large (for tubers between 6 and 9 cm), very large (for tubers over 9 cm).Tubers were separated into twocategories of marketability, i.e., marketable tubers Category I and Category II. Marketable Tubers Category I comprised tubers weighing between 200 and 300g or with a diameter> 60 mm.  On the other hand, Marketable Tubers in Category II weighed between 80 and 200g or had a diameter ranging from 30 to 60 mm.

## Data Analysis

Area under disease progress curve (AUDPC) for late blight and bacterial wilt wasstandardized to give relative AUDPC (rAUDPC). The rAUDPC for both diseases (LB and BW), yield and yield components data were then subjected to analysis of variance (ANOVA) using Genstat 16.

## Results

There were significant differences among the potato genotypes for plant vigor, flowering degree and senescence stage in the two study seasons (Table 2). The genotype effect ontuber size, tuber uniformity, marketability and total tuber yield was only significant during 2015B.

**Table 2: Mean squares for evaluation of potato genotypes for phenotypic and growth traits in cropping seasons 2015B and 2016A in Buginyanya ZARDI**

| Source of variation | d.f | TS | TU | PV | FD | S | MTY (T/HA) | TTY (T/HA) |
|---|---|---|---|---|---|---|---|---|
| **2015B** | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Rep** | 3 | 0.7778 | 0.8124 | 1.606 | 1.519 | 0.241 | 27.6 | 36.74 |
| **Geno** | 17 | 1.359** | 2.6299** | 17.416** | 11.663** | 29.529** | 29.4** | 160.54** |
| **Residual** | 51 | 0.1895 | 0.6321 | 1.93 | 3.626 | 1.898 | 11.57 | 29.57 |
| **Total** | 71 | | | | | | | |
| | | | | | **2016A** | | | |
| **Rep** | 3 | 1.569 | 1.051 | 2.458 | 3.866 | 0.94 | 842.6 | 1547.5 |
| **Geno** | 17 | 3.24ns | 3.739ns | 7.89** | 13.279** | 21.739** | 809ns | 772.1ns |
| **Residual** | 51 | 1.766 | 1.992 | 1.89 | 3.425 | 1.705 | 444.7 | 455.4 |
| **Total** | 71 | | | | | | | |

TS, Tuber Size; TU, Tuber Uniformity; PV, Plant Vigour; FD, Flowering Degree; S, Senescence, MTY, Marketable Tuber Yield; TTY, Total Tuber Yield. **Significant at *P*≤0.001, * significant at P ≤0.05

### Plant vigor

In 2015B, many of the genotypes tested were categorized as medium with respect to plant vigor. Genotypes Rwangume, Kinigi and 398208.704 were vigorous with a score of 6.5. Genotypes 392797.22, Rutuku, Rwanshaki, Bumbamagara and Shangi, which had a mean score between 3 and 5 were categorized as weak. Four genotypes (396036.201, 393385.39, Kimori and Nakpot 5) had a mean vigor score of less than three and were described as very weak in vigor (Table 3). There was a great improvement in vigor registered during the second cropping season (2016A), with many genotypes having medium vigor compared to 2015B. Similar to 2015B, the potato genotype Kimori was also very weak in 2016A season, with a score of less than 3. However, genotypes 396036.201, 393385.39 and Nakpot 5 improved in vigor to a mean between 3 and 5 and were considered weak in vigor. Rwangume was vigorous with a mean score of 7, while genotypes 392797.22, 393077.159, 393079.4, 3398208.29, 398208.704, Cruza, Kachpot 1, Kinigi, Rutuku, Rwanshaki and Victoria had a mean score of between 5 and 6 and were categorized as medium in regards to plant vigor (Table 3).

### Flowering Degree

Genotypes 393077.159, 393385.39, Nakpot 5, Rutuku, Rwangume, Shangi and Victoria were characterized as profuse, while 396036.201, 3398208.29, 398208.704, Cruza, Kachpot 1, and Rwanshaki were considered moderate. Kinigi, Kimori, and Bumbamagara had low flowering degrees (Table 3).

### Senescence

Senescence ranged from early to very late. Genotypes Victoria, Shangi, Rwangume, Cruza, Bumbamagara and 393077.159 turned yellow 90 days after planting, which isconsidered as early maturing. Meanwhile, genotypes 393385.39, 396036.201 ,and 3398208.29 were still green at 90 DAP and thus categorized as very late (Table 3).

**Table 3: Plant Vigour, flowering degrees and senescence stage of (2015B and 2016A), Buginyanya ZARDI**

| **Genotype** | **2015B** | | | **2016A** | | |
|---|---|---|---|---|---|---|
| | Plant vigor | Flowering degree | Senescence | Plant vigor | Senescence | Flowering degree |
| **392797.22** | 4.5 | 6 | 5 | 5 | 3 | 4.5 |
| **393077.159** | 6.5 | 7 | 7 | 6.5 | 7 | 7 |
| **393079.4** | 6 | 4 | 4 | 6 | 7 | 4 |
| **393385.39** | 0.75 | 7 | 1 | 4.5 | 5 | 2.5 |
| **396036.201** | 0 | 5 | 1 | 3.5 | 3.25 | 2.5 |
| **398208.29** | 5.5 | 5 | 2 | 6 | 7 | 3 |
| **398208.704** | 6.5 | 6 | 5 | 5.5 | 6 | 1 |
| **Bumbamagara** | 4 | 3 | 7 | 4.5 | 4 | 5 |
| **Cruza** | 5 | 5.25 | 7 | 5.5 | 7 | 5 |
| **Katch pot 1** | 5.5 | 6.5 | 3 | 5 | 6.5 | 7.5 |
| **Kimori** | 1.25 | 2.5 | 1.75 | 1.5 | 2.5 | 2 |
| **Kinigi** | 6.5 | 1.75 | 3 | 5.5 | 1.75 | 3 |
| **Nakpot5** | 1.75 | 7 | 0.75 | 3.25 | 5.25 | 2.25 |
| **Rutuku** | 4.5 | 7 | 3 | 5.5 | 7 | 3.5 |
| **Rwangume** | 6.5 | 7 | 7 | 7 | 7 | 8.5 |
| **Rwanshaki** | 4.5 | 6 | 4 | 5 | 6 | 6 |
| **Shangi** | 4.5 | 7 | 9 | 2.5 | 7 | 8 |
| **Victoria** | 5.5 | 7 | 9 | 5.5 | 7 | 7.5 |
| **mean** | 4.40 | 5.56 | 4.42 | 4.88 | 5.51 | 4.6 |
| **LSD** | 1.972 | 2.703 | 1.956 | 1.951 | 2.627 | 1.853 |
| **CV %** | 6.8 | 5.2 | 2.6 | 7.6 | 8.4 | 5 |

### Yield parameters

The tuber sizes ranged between 0.25 and2.75 cm in 2015B andbetween 2.5 and 6.5 cm in 2016A cropping season. The genotype 392797.22 generally had the biggest tuber sizes across the two seasons, while the genotype Kimori had the smallest tubers (Table 4).

There was high heterogeneity among genotypes for tuber uniformity. A large number of the genotypes were categorized as heterogeneous since all the tuber sizes were present but with a predominant size except for Kimori, which was very heterogeneous comprising all tuber sizes (Table 4).In 2016A, most of the genotypes were categorized as intermediate. However, Shangi and Bumbamagara scored 7, and they had uniform tubers. As for tuber shape, the genotype effect was insignificant (Table 4), with most of them being round-shaped.

### Marketable tuber yield

The genotype effect on marketable tuber yield was significant (P<0.001) in 2015B but insignificant in 2016A (Table 2). Generally, there was a very low marketable tuber yield recorded in the 2015B season compared to the 2016A cropping season. Generally, across both seasons,genotype 392797.22 had the highest marketable tuber per hectare followed by 398208.29 with the least yielding being Kachpot 1 and Kimori (Table 4).The average marketable tuber yield registered in 2015B, was 4.14 t/ha while in 2016A, it was 38 t/ha (Table 4). The three best genotypes with respect to marketable tuber yield in 2015B were clones 392797.22 (8.45 t/ha), 398208.29 (8.26 t/ha), and 393079.4 (7.37 t/ha) whereas, in 2016A they were 392797.22 (63.7 t/ha), 398208.29 (57 t/ha), and variety Victoria (50.4 t/ha) (Table 4). In 2016A, the least marketable tuber yield was recorded from Kimori (11.5 t/ha), and Kachpot 1 (14.4 t/ha). Potato varieties Bumbamagara and Cruza were highly affected by drought in the 2015B season, resulting in no marketable yields. However, in 2016A,they yielded 22 t/ha and 44.4 t/ha, respectively (Table 4).

### Total tuber yield

Total tuber yield was significantly (P<001) influenced by genotype in 2015B but not in 2016A. Results revealed a big gap between the mean total tuber yields recorded in the two cropping seasons. The highest mean total tuber yield was recorded in 2016A (46.9 t/ha), while the lowest mean total tuber yield (15.98 t/ha) was attained in 2015B (Table 4). Across seasons, genotype 392797.22 had the highest mean tuber yield, followed by Cruza.  Kachpot 1 and Rwanshaki hadthe least tuber yield. In season 2016A, 392797.22 (71.43 t/ha), 398208.29 (60.9 t/ha), Cruza (58.12 t/ha), Rutuku (57.91 t/ha), Victoria (57.25 t/ha), and Kimori had the least total tuber yield.

**Table 4: Yield components of the 18 potato genotypes grown in Buginyanya, during the cropping seasons of 2015B and 2016A**

| | **2015B** | | | | | **2016A** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GENOTYPE** | **Tuber size** | **Tuber uniformity** | **Tuber shape** | **Marketable tuber yield (t/ha)** | **Total tuber yield (t/ha)** | **Tuber size** | **Tuber uniformity** | **Tuber shape** | **Marketable tuber yield (t/ha)** | **Total tuber yield (t/ha)** |
| **392797.22** | 2.75 | 4 | 2 | 8.45 | 18.13 | 6.5 | 5 | 2 | 63.7 | 71.4 |
| **393077.159** | 2.25 | 4.25 | 1.25 | 3.82 | 17.89 | 5 | 5.5 | 1 | 27.2 | 33.8 |
| **393079.4** | 2 | 4 | 1 | 7.37 | 20.68 | 4.5 | 5.5 | 1.5 | 38.8 | 54.6 |
| **393385.39** | 2 | 4 | 1 | 4.01 | 13.15 | 5.5 | 5.5 | 1 | 44 | 51.5 |
| **396036.201** | 2 | 4.5 | 1 | 2.81 | 11.24 | 5 | 6 | 1 | 41.4 | 47 |
| **398208.29** | 2.75 | 3.75 | 1 | 8.26 | 17.18 | 6 | 5 | 1 | 57 | 60.9 |
| **398208.704** | 2.5 | 4.25 | 1 | 6.12 | 19.19 | 5.5 | 5 | 1.5 | 44.4 | 52.7 |
| **Bumbamagara** | 1.5 | 5 | 1 | 0 | 7.65 | 4 | 7 | 1 | 22 | 38.4 |
| **Cruza** | 1.75 | 5 | 1 | 0 | 10.79 | 3.5 | 6.5 | 1.25 | 44.4 | 58.1 |
| **Kachpot 1** | 2.25 | 4.77 | 1 | 3.45 | 13.44 | 5 | 6.5 | 1 | 14.4 | 23.9 |
| **Kimori** | 0.25 | 1.25 | 0.5 | 0 | 0.3 | 2.5 | 3 | 0.75 | 11.5 | 17 |
| **Kinigi** | 2.25 | 4.25 | 1 | 4.03 | 19.55 | 5.5 | 6 | 1 | 42.6 | 53.2 |
| **Nakpot5** | 2.5 | 4.25 | 1.25 | 5.39 | 22.26 | 4.75 | 4.75 | 1.25 | 43.5 | 46.7 |
| **Rutuku** | 2.5 | 3.75 | 1 | 5.96 | 21.28 | 5 | 5 | 1 | 47.5 | 57.9 |
| **Rwangume** | 2 | 4.25 | 1 | 2.87 | 24.44 | 5 | 6 | 1 | 40.3 | 50.2 |
| **Rwanshaki** | 2.5 | 4.25 | 1 | 6.24 | 22.02 | 5 | 6.5 | 1 | 27.2 | 36 |
| **Shangi** | 1.75 | 4.75 | 2 | 0.99 | 8.44 | 4.5 | 7 | 1 | 22.6 | 33.5 |
| **Victoria** | 2.5 | 4.25 | 1 | 4.78 | 19.97 | 5 | 6 | 1 | 50.4 | 57.2 |
| **MEAN** | 2.111 | 4.14 | 1.111 | 4.14 | 15.98 | 4.88 | 5.65 | 1.125 | 38 | 46.9 |
| **LSD** | 0.618 | 1.1292 | 0.4111 | 4.83 | 7.72 | 1.886 | 2.004 | 0.5539 | 29.94 | 30.3 |
| **CV %** | 9.8 | 5.1 | 5.8 | 29.9 | 8.9 | 6.1 | 4.3 | 8.4 | 18 | 19.8 |

## Genotype reaction to late blight and Bacterial wilt diseases

### Relative AUDPC for late blight and bacterial wilt diseases

Relative areas under disease progress curves (rAUDPC) showed significant differences among the genotypes (P<0.001) in both 2015B and 2016A seasons for bacterial wilt and late blight diseases.

**Table 5:Mean squares for rAUDPC for late blight and bacterial wilt diseases in cropping seasons 2015B and 2016A, Buginyanya ZARDI**

| Source of Variation | D.F. | LB2015B | LB2016A | BW 2015B | BW 2016A |
|---|---|---|---|---|---|
| **Rep** | 3 | 0.03184 | 0.03425 | 0.05351 | 0.04561 |
| **Genotype** | 17 | 0.09009** | 0.16138** | 0.14172** | 0.11946** |
| **Residual** | 51 | 0.02226 | 0.07618 | 0.0473 | 0.02817 |
| **Total** | 71 | | | | |

LB, late blight; BW, bacterial wilt; **Significant at $p \leq 0.001$, * significant at $P \leq 0.05$

Generally, 2016A had significantly higher rAUDPC compared to 2015B for both late blight and bacterial wilt diseases. Genotype 396036.201(0.706) had the highest rAUDPC for late blight, followed by 398208.29 (0.497) and Bumbamagara (0.434). Genotypes Kinigi and 398208.704 were not affected by late blight at all. In the same season, bacterial wilt most affected genotypes 398208.29 (0.551) and 393079.4 (0.543).

**Table 6: Relative Area under disease progress curve (rAUDPC) for late blight and bacterial wilt of the 18 potato genotypes grown in Buginyanya ZARDI during the seasons of 2015B and 2016A.**

| **GENOTYPE** | **2015B** | | **2016A** | |
|---|---|---|---|---|
| | rAUDPC LB | rAUDPC BW | rAUDPC LB | rAUDPC BW |
| **392797.22** | 0.034 | 0 | 0.233 | 0.221 |
| **393077.159** | 0.038 | 0.019 | 0.034 | 0.051 |
| **393079.4** | 0.008 | 0.122 | 0.239 | 0.543 |
| **393385.39** | 0 | 0 | 0.050 | 0.185 |
| **396036.201** | 0.078 | 0 | 0.706 | 0.051 |
| **398208.29** | 0.133 | 0 | 0.497 | 0.551 |
| **398208.704** | 0.057 | 0 | 0 | 0.069 |
| **Bumbamagara** | 0.392 | 0.428 | 0.434 | 0.355 |
| **Cruza** | 0.265 | 0.506 | 0.230 | 0.406 |
| **Kachpot 1** | 0.091 | 0.425 | 0.201 | 0.38 |
| **Kimori** | 0.093 | 0.250 | 0.291 | 0.083 |
| **Kinigi** | 0.027 | 0 | 0 | 0.054 |
| **Nakpot5** | 0.108 | 0 | 0.163 | 0.080 |
| **Rutuku** | 0.059 | 0.200 | 0.241 | 0.112 |
| **Rwangume** | 0.106 | 0.159 | 0.012 | 0.217 |
| **Rwanshaki** | 0.157 | 0.153 | 0.38 | 0.036 |
| **Shangi** | 0.538 | 0.512 | 0.003 | 0.145 |
| **Victoria** | 0.362 | 0.084 | 0.009 | 0.065 |
| **MEAN** | 0.141 | 0.159 | 0.207 | 0.2 |
| **LSD** | 0.2118 | 0.3087 | 0.3918 | 0.2383 |
| **CV %** | 29.8 | 34.3 | 21.1 | 25.1 |

*rAUDPC (Relative Area under disease progress curve), BW (Bacterial wilt), LB (Late Blight).*

In 2015B, genotype 393385.39 was neither affected bylate blight nor bacterial wilt, while Bumbamagara (0.392) and Shangi (0.538) were the most affected byLate blight. Shangi and Cruza had the highest bacterial wilt with rAUPDC , 0.512 and 0.506, respectively (table 6).

## Discussion

Variation in plant vigor among the genotypes is attributed to both genotype and environmental factors (Ungerer *et al.*, 2003; Pereira*et al.*, 2017). Plant vigor is influenced by nutrient uptake and utilization by the different genotypes. Numerous studies have reported correlations of medium magnitude between plant vigor and plant size, tuber number and tuber yield, indicating that the more vigorous plants produce larger, higher number and higher yield of tubers (Silva *et al.*, 2007; Pereira*et al.*, 2017; Silva*et al.*, 2019; Luitel*et al.*, 2020). According to Salas, (2007), genotypes with weak plant vigor have few leaves and thin stems. Genotypes 396036.201, Kimori, and Nakpot 5 were weak in 2015B, while most genotypes had normal vigor. Genotypes exhibiting normal vigor under optimum environmental conditions exploit environmental resources well, resulting in good yields (Pereira*et al.*, 2017). On the other hand, excessive vigor may be disadvantageous as it results in vegetative growth at the expense of tuberization (Abbas *et al*., 2012), resulting in lower yields. Breeders, therefore, have to strike a balance between vegetative growth and maximum tuberization. The genotypic differences in vigor seen in the study could also be attributed to differences in the genetic backgrounds of the potato clones. It could also be due to the interaction of genotypesandenvironment. The season 2015B was dry, and more genotypes with poor vigor scores were recorded. A review by Nasir and Toth, (2022) heightens the importance of sufficientsoilmoisture as a key requirementfor plant growth.

Flowering in potatoes is highly variable, with some genotypes not flowering at all. This trait is also attributed to differences in genetic makeup of the genotypes (Soares *et al*., 2013; Asnake*et al.*, 2023). This best explains the significant variation in flowering observed among the different genotypes tested in this study. The results showed that most of the genotypes had moderate and profuse flowering. According to Biodiversity and CIP (2009), such genotypes have either 8-12 orabove 20 flowers per inflorescence, respectively. Much as flowering has nothing to do with tuber yield, it influences the choice of a genotype for use as parents in potato breeding programs (Asnake*et al.*, 2023). Genotypes Kinigi,whose flowers aborted,and 392797.22, Bumbamagara, and 396036.201, which had small rudimentary inflorescence, cannot be used in conventional breedingas they will never easily produce viable pollen and fertile stigma (Wyss *et al.*, 2001). This makes it hard to transfer any desirable attribute in such genotypes to another well adapted, farmer preferred variety that lacks the trait in question.

Maturity time was also variable among the tested genotypes, ranging from early to late. Genotypes that take a short time to mature are desirable because they have high chances of escaping the attack of pests, and diseases,and drought. The results of this study indicated that genotypes Shangi, Victoria, Rwangume, and 393077.159 take a short time to reach senescence. These could potentially mature earlier than genotypes 393385.39, 396036.201, and 398208.29. Late maturing genotypes tend to have higher yields due to having a longer time for tuber filling. A study by Amoros and Gastelo (2009) found that leaves of plants that reached senescence early turned yellow much earlier than the stem, and the berries changedcolor from green to yellow. This was the case with genotypes 393385.39, 396036.201, 398208.29, Shangi, Rwangume, and Victoria. The rest of genotypes.except Bumbamagara, Cruza, Kachpot1 and Rwashaki were still green 90 days after planting, implying that they were late maturing (Namugga, 2017).

Variation was also recorded for tuber size among genotypes. Results showed that all the genotypes in the first season had very small tubers. However, in the second season,mostof the genotypes were medium sized, clearly indicating the effect of an improvement inenvironmental conditions that allowed better crop growth. The season had sufficient rainfall to support proper plant growth. Differences in tuber size influence growth and processing qualities (Silva*et al.*, 2019). According to Pandy *et al*. (2000), large tubers have more sprouts andproduce more stems per plant. Stem numbers are positively related to tuber yield (Negero, 2017; Pereira*et al.*, 2017).

Tuber uniformity across genotypes was also variable. Genetic and environmental factors could also account for the difference in potato tuber uniformityamong the genotypes (Pereira*et al.*, 2017; Silva*et al.*, 2019). The difference in the absorption rate of nutrients during tuberization affects tuber uniformity and consequently yield, implying that very heterogeneous tubers result in lower yield and vice versa (Da Silva *et al.*, 2006; Pereira*et al.*, 2017). The majority of genotypes in 2015B were heterogeneous, while in 2016A, most of the genotypes were intermediate in uniformity,mainlydue to differences in rainfall received in the two seasons.

Only three improved genotypes 39279.22, 398208.29, and 398208.704 had a higher marketable yield than the locally cultivated genotypes Bumbamagara and Kachpot 1 (Table 4). The variation in marketable tuber yield among genotypes is also related to genetic and environmental factors (Abbas *et al.,* 2012). Kumar *et al*. (2007), state that genetic differences influence marketable tuber yield. Marketable tubers are usually large in size above 80 gm (De Haan *et al.,* 2014). Therefore, the high marketable yield among the improved genotypes 39279.22, 398208.29, and 398208.704 compared to the local genotypes could be due to the latter producing a high number of small tubers. Many tubers on a plant may induce excessive competition for resources like photosynthates among themselves, thus resulting into small unmarketable tubers (Silva*et al.,* 2019). Since marketable tubers are those larger,clearly indicates increased bulking of the tubers among these genotypes. The significantly low yield recorded in 2015B is largely attributed to the long dry spell during the period of November 2015 to January 2016, when the crop was at the critical stage of tuberization and tuber filling. This is in line with other studies that have reported a considerable reduction in tuber yield and quality when drought sets in at these critical growth stages(Abbas and Ranjan, 2015; Nasir and Toth, 2022; Siano*et al.,* 2024). Apart from moisture stress, high temperatures is another significant environmental factor that negatively affects the yield and quality of tubers (Nasir and Toth, 2022; Siano*et al.,* 2024). A study by Rykaczewska (2017) demonstrated that potato responses to heat stress depends on the growth stage and soil moisture level. Therefore, the low yields observed during the 2015B could be attributed to the long dry spell and high temperatures in the months of November 2015 to February 2016.

Total tuber yield varied among the genotypes, with 392797.22 and Rwangume being the highest yielders. Although genotype 392797.22 had a high yield, it had lower tuber number compared to Kinigi and Bumbamagara on account of their largetuber sizes. On the other hand, genotypes Kinigi and Bumbamagara had a high number of tubers, although most were unmarketable. These results suggest that the number of tubers a genotype produces does not necessarily correlate positively with marketable yield, although it may correlate well with total yield. A genotype with very many small tubers will normally have a low yield of marketable tubers (Mehdi *et al*., 2008; Pereira*et al.,* 2017; Silva*et al.,* 2019). Studies by Chandra, (2015) reported a high total yield among genotypes that had a high number of tubers.

Genotype Victoria despite the high rAUDPCs for both bacterial wilt in season 2016A and late blight in season 2015B,yielded higher than genotypes 393077.159, 393079.4, 396036.201, Shangi, Rwanshaki, Nakpot 5 and Kachpot 1. Victoria is early maturing (about 90 days after planting), therefore, it is possible that most tuber bulking takes place before the disease peak stage. Therefore, early maturing genotypes often escape the adverse effects of diseases thus producing high yields (Mariita*et al.,* 2016). Genotype Kachpot 1 had the lowest yield in the two seasons. It also produced the lowest number of tubers, with a high number of undersized tubers. Cruza also had a high rAUDPC but still yielded high despite being late maturing. This implies that genotype Cruza is tolerant to the effects of the two diseases.

The Kenyan varieties Bumbamagara, Shangi, Rwanshaki and Kimori were as much affected by the LB as the local check Victoria. These findings are similar towhat has been reported in other previous studies(Kaguongo *et al.*, 2008; Mariita*et al.*, 2016). These genotypes are susceptible to LB, and their production will mostly rely on an integrated approach involving chemical sprays. However, as populations of *P. infestans* become increasingly aggressive, coupled with societal resistance against using environmentally unfriendly chemicals, breeding for resistance should be emphasized. On the other hand, genotypes like 393385.39 and 398208.704 were not affected by LB, most likely because of possession of genes that were resistant to the disease. These results are consistent with what has been reported by Namugga*et al.,* (2018).

The genotypes Shangi and Cruza had the highest incidence of bacterial wilt in this study. It is worth noting that Cruza has been variously reported to be resistant to BW (Namugga*et al.*, 2018; Okiro*et al.,* 2024). Bacterial wilt disease also affects tubers, making them rot in storage. These genotypes, therefore, may not be good for cultivation in fields infested with *R. solanacearum.*

## Conclusion

Results showed significant differences ($P<0.05$) in tuber size, uniformity, marketable tuber yield, and the total tuber yield across all genotypes. Of all the potato genotypes evaluated, 392797.22 (44.8t/ha) and 398208.29 (39t/ha) produced significantly ($P<0.001$) higher tuber yields compared to the local check Cruza (34.5t/ha) on average across both seasons. rAUDPC for LB showed significant differences ($P<0.001$) among genotypes in both seasons. The most resistant genotypes were Kinigi (0.0135) and 399985.39 (0.025) and the most susceptible were Bumbamagara

(0.413) and 396036.201 (0.392). 396036.201(0.051) and Kinigi were the most resistant genotypes for bacterial wilt while Shangi (0.66) and Cruza (0.46) were the most susceptible to BW.Genotypes 392797.22 and 398208.29, which are high yielding and disease- resistant are recommended for release as commercial varieties or as donor parents for potato improvement programs.

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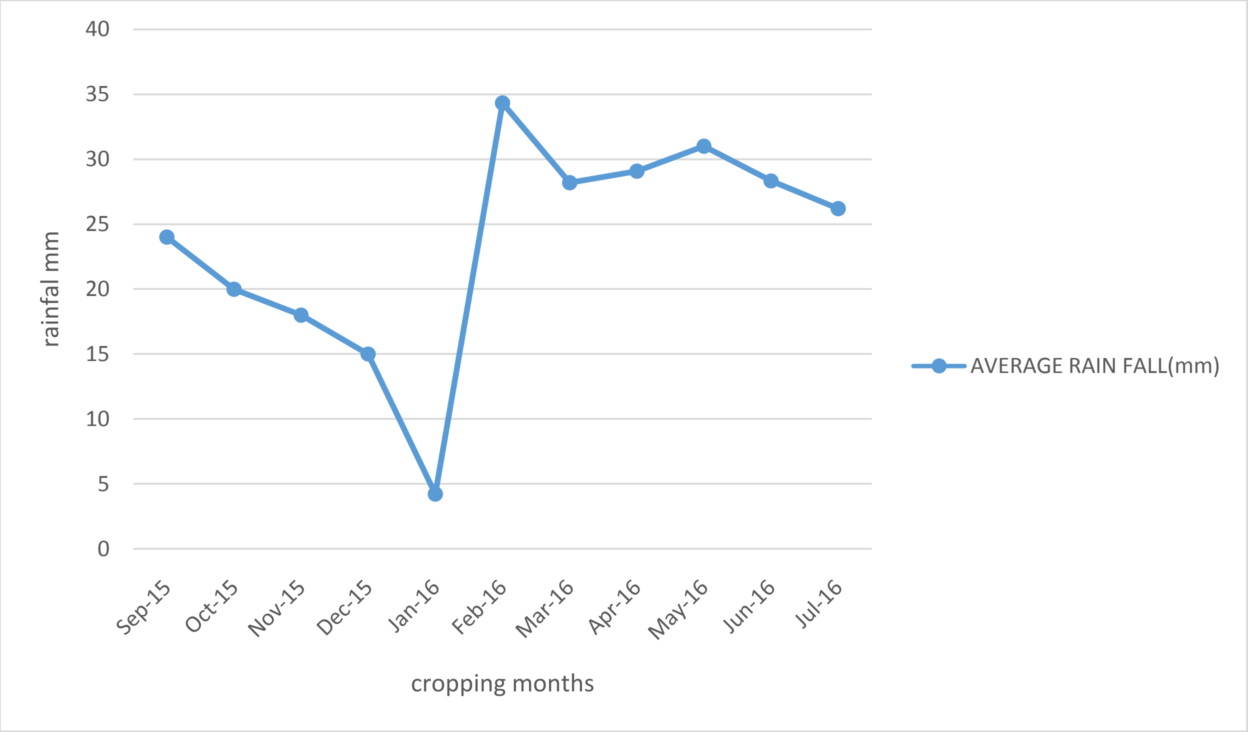
Annex 1. Annual monthly rainfall of the study area during the growing period in the year of 2015B and 2016A.



Source: Buginyanya metrology station