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Full-Length Research Paper

Field Assessment of Resistance in Potato *(Solanum Tuberosum L.)* to Late Blight Disease *(Phytophthora Infestans (Mont.) DE Bary)* in Jos, Plateau State

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ABSTRACT: Potato (*Solanum tuberosum* L.) is one of the most widely farmed and consumed crops in the world. Many diseases, including late blight disease caused by the fungus *Phytophthora infestans* (Mont.) De Bary, have been shown to negatively impact the quality of the tubers and the yield of the crop. Late blight disease is considered to be the most severe of these diseases. In recent years, new strains of the disease have evolved, making potato production more difficult to maintain. Application of fungicides on a regular basis or altering the planting season are common control strategies. However, fungicides are not only expensive, but their long-term use has negative consequences on the environment, human health, and livestock. Our study sought to determine the natural field resistance of different potato types in Jos, to the late blight disease, which was discovered by chance. To evaluate the field resilience of potato types to late blight, ten potato varieties were planted in the Kuru experimental field of the National Root Crops Research Institute (NRCRI). Infection began at approximately the same period (6WAP) for the majority of the types. The final disease scores were considerably different at the conclusion of the disease assessment. The number of outbreaks indicated a positive and statistically significant relationship with the course of late blight. Several types, with the exception of Connect and Nicola, showed rapid disease progression, with the gradient of the regression lines becoming gradually steeper over time. According to the findings of this investigation, Nicola and Connect have a certain amount of field tolerance to late blight. Thus, selection for late blight resistance is achievable, and resistant R-genes can be isolated and inserted into susceptible types in order to bestow resistance on the plants.

Keywords: Potato late blight, disease progression, field tolerance

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the world's third most consumed food, trailing only rice and wheat (Haverkort, 1990; Scott *et al*., 2000). It is well adapted to meet the increasing food demand caused by population increase in poor and emerging countries around the world, particularly in Africa and countries like Nigeria (Devaux *et al*., 2014). Potato, being a high-yielding nutritional food, is regarded as one of the most promising crops for reducing global hunger, malnutrition, and poverty (Thiele *et al*., 2010; Andre *et al*., 2015; Devaux *et al*., 2020). Potato, due to its ease of growing and high energy content, has become a major income crop for millions of farmers all over the world (Singh *et al*., 2011). Potato produces high-value food in a short period of time, and its adaptability to cropping techniques makes it a popular choice crop (Hussain, 2016). It is one of the principal crops farmed in

Nigeria (Ugonna *et al*., 2013) and is an important part of the farming system of the local farmers in Jos, who produce over 1,500,000 metric tons, accounting for around 92 percent of Nigeria's yearly output (NRCRI annual Reports, 2005 and Chuwang, 2014).

Potato grows well in cool temperate climes, subtropical winters, and tropical mountainous places (Kumar *et al*., 2013). Despite the fact that potato output in Nigeria has increased by more than 12% in the last decade, it remains well behind demand (Ugonna *et al*., 2013). Low quality seeds, inadequate storage facilities, and diseases, particularly late blight caused by *Phytophthora infestans*, are major impediments to potato production in Nigeria (Ugonna *et al*., 2013). In Nigeria, potatoes are farmed during both the rainy and dry seasons. The rainy season accounts for up to 82 percent of total annual potato production. However, the crop is predisposed to many diseases due to the moist environment, particularly early blight caused by *Alternaria solani* and late blight caused by *Phytophthora infestans* (Chingle and Kwon-Ndung, 2019).

Late blight is one of the most vexing potato diseases in Nigeria and throughout the world where potatoes are grown (Fry *et al*., 2015). The disease's influence was first detected in Ireland in the mid-nineteenth century (1940s) (Bourke, 1993), which resulted in devastating human consequences (Mercure, 1998; McConnell and Reid, 1998; Donnelly, 2002). In 2014, a large epidemic of late blight damaged approximately 500 hectares of potato farms in Plateau State, Nigeria (Ibrahim, 2014). Chuwang (2014) claimed that the potato business, a multi-billion Naira enterprise in Jos, has recently suffered substantial setbacks due to increased instances of late blight. If a sensitive cultivar is left exposed, losses of up to 85 percent have been documented (Duncan, 1999).

Late blight disease is a severe danger to potato output since it can cause full defoliation, tuber rot, and plant mortality (Garelik, 2002 and Gergely, 2004). As a polycyclic disease, it may go through numerous cycles of infection and inoculum formation in the course of a single growing season. The amount of inoculum produced is determined by the host, pathogen, environmental circumstances, and management parameters (Forbes *et al*., 2014). Every year, infection occurs in epiphytotic forms in both hills and plains (Hussain, 2016). Because potatoes play a significant role in global food security, this troubling development and increase in crop devastation may predispose the entire population to food insecurity and economic decline (Devaux *et al*., 2014). In Nigeria, for example, the potato industry is projected to be valued more than N 300 billion (FAO, 2008 and NRCRI, 2005). However, the need for fresh tubers was never fully addressed (Ugonna *et al*., 2013). Thus, various studies have been conducted to improve seed varieties by current selection and breeding procedures in order to develop resistant types against late blight so as to increase potato production; nevertheless, this has not been very successful on a larger scale (Gergely, 2004). Regardless, researchers have continued to develop methods for testing field resistance of potato types to late blight in order to identify and harness resistant genes. Several approaches for relating disease development to time and yield losses to disease severity have been described (James *et al*.,1972). These methods include the disease progression curves used in this investigation (Van der Plank, 1963). Henfling (1987) created a score system to quantify disease progression that is extremely effective in visual therapy comparisons.

The objective of this study therefore was to assess the natural field resistance of different potato varieties growing in Jos to the late blight disease. This is to ascertain if any of these varieties possess inherent resistant or tolerant genes to the late blight disease which can be explored and harnessed for further studies.

MATERIALS AND METHODS

Experimental site

The field experiment was carried out in one of the research farms of the National Root Crops Research Institute (NRCRI), Kuru, Nigeria which is a location well noted for late blight incidence (Kwon-Ndung and Ifenkwe, 1993; Chuwang, 2014). The Institute has latitude of 9.72 ºN and longitude of 08.85 ºE. The average annual temperature is 19.5 ºC and the annual rainfall is about 1975mm (NRCRI, 2005).

Plant materials

Ten varieties of potato were obtained from the germplasm collection of NRCRI, Kuru. These varieties are: Marabel, Condor, Caruso, Nicola, Sp, Oceania, Delice, Connect, Famosa and Yellow.

Experimental design

The ten varieties were planted in a randomized complete block design (RCBD) and replicated three times. Each experimental unit (plot) was made up of two ridges measuring 3m in length and 2m wide. The treatments were the 10 potato varieties.

Cultural practices

The field was approximately 17 m × 16 m in size. Ridges were built on June 15th, 2019. The experiment consisted of 30 plots in all. Each plot was made up of two ridges that were 3 m long and 2 m wide. To manage weeds, the herbicides Premixtra and Altrazine (41/ha) were applied using a knapsack sprayer (20 L). The following day, planting was completed at 30 cm between rows and 90 cm between rows. One seed tuber was placed in each hole, which was drilled to a depth of 8-10 cm. In each plot, twenty tubers were planted. Weeds were then manually managed. At planting, NPK (15:15:15) fertilizer was applied to all plots at a rate of 600 kg/ha. Six weeks after planting (WAP), the plots were earthed up to conceal exposed tubers due to rain splash.

Field observations and data collection

Field observations and data collection were carried out at 4 WAP and at 6-10 WAP. Data collected include emergence count, plant height, numberof leaves, leaf area index, internode length and late blight score. At harvest, data collected were final stand count (FSC) per plot, number and weight of marketable, unmarketable and diseased tubers.

Emergence count

The emergence count was recorded at 4 WAP by counting the number of plants that emerged per plot.

Plant height

At 6, 8, and 10 WAP, the plant height was determined by measuring the greatest height of the potato plants in the centre of each plot's ridge using a graduated wooden meter. Each plant was measured vertically from the base to the terminal of the leaf using the meter rule. Five plants were collected per plot, and the mean height was calculated by determing the average height of the five plants sampled.

Number of leaves

Five plants were randomly selected per plot and the number of leaves physically counted at 6, 8 and 10 WAP. The average value was obtained and recorded.

Leave area index

Five plants were also sampled per plot at 6, 8 and 10 WAP. The length and width of the leaves were measured using a graduated wooden meter. The leave area was obtained by multiplying the length and breath. Leave area index (LAI) was then estimated using the formula by Mokhtarpour, (2010):

$$LAI = \frac{\text{Leaf Area (L x B) } m^2}{\text{Plant Spacing (Ground cover) } m^2}$$

Internode length

Internode length was determined at 6, 8 and 10 WAP by measuring the distance between two nodes from the base of the stem of the five plants sampled per plot. The average was taken and recorded.

Late blight score

Late blight scores were recorded on a weekly basis from 6 -10 WAP following the method described by Henfling, (1987) on a scale of 1-9 (Appendix 1).

Harvesting

Harvesting of the potato tubers was done when all the foliage was 90-100% dead (12-WAP). This was done by hand pulling of the haulms, opening up the soil at the base using a small hoe and picking the tubers from the soil. The following parameters were assessed afterwards:

Final stand count

The final stand count (FSC) was recorded by counting the total number of plants remaining per plot.

Ware tuber number/weight

Tubers where separated and those which measure from 55mm and above with no visible sign of infection were considered marketable. The number of marketable or ware tubers per plot were counted and recorded. The ware tubers per plot were also weighed and recorded.

Number/weight of seed tubers

Tubers with no visible disease symptoms but weighed less than 55mm were considered seed tubers. Their numbers were counted per plot and recorded. The weight of seed tubers per plot were measured and recorded.

Number/weight of diseased tubers

Tubers which showed visible signs of disease where tagged diseased tubers. The numbers per plot was counted and recorded. The weight of diseased tubers per plot were measured and recorded.

RESULTS

Mean plant establishment and growth performances

Table 2, 3 and 4 show the various means of the different growth parameters measured at four WAP for Emergence Count (EMC) and at six, eight and ten WAP for other growth parameters i.e. Plant Height (PLH), Number of leaves per plant (NL), Leaf area index (LAI) and Internode Length (INL).

Emergence count at 4 weeks after planting

At four WAP, all the ten varieties planted emerged; although there were some significant differences in the number of plants emerged. Variety 'Delice' had the highest number of emergence (83.33) which was significantly different from the others. 'Oceania' (46.67) and 'Connect' (50.00) had statistically the same mean for emergence count which were significantly lower than the others. The seven other varieties showed no significant difference in their emergence count (Table 1).

Plant height at 6 WAP

For plant height, varieties 'Condor' (25.10 cm), 'SP' (24.13 cm), 'Delice' (24.81 cm) and 'Yellow' (24.75 cm) recorded similar mean values, which were significantly higher than the means from other varieties, while Oceania had the lowest plant height at 12.92 cm (Table 1).

Number of leaves at 6 WAP

Varieties 'Marabel' (78.73) and 'Nicola' (85.37) had similar number of leaves which were significantly higher than all the other varieties. Like plant height, 'Oceania' (27.80) had the lowest number of leaves per plant (Table 1).

Leave area index at 6 weeks after planting

The leave area index of almost all the ten varieties showed significant differences. However, 'Nicola' had the highest leave area index (18.31) while 'Oceania' had the lowest leave area index (7.12) (Table 1).

Length of internode at 6 WAP

Almost all the varieties had similar internode length except for 'Sp' (2.55) which was significantly higher than others and 'Oceania' (1.77) which had the shortest internode (Table 1).

Plant height at 8 weeks after planting

At 8 WAP almost all the varieties had similar heights which were significantly higher than 'Connect' (21.88), while 'Oceania' (15.32) had the lowest plant height, (Table 2).

Number of leaves at 8 weeks after planting

At 8WAP, 'Marabel' (105.70) still had the highest number of leaves, significantly higher than all the other varieties while 'Oceania' (24.60) had the lowest number of leaves per plant, (Table 2).

Leave area index at 8 weeks after planting

At 8WAP, the leave area index of seven varieties were statistically similar. However, they were significantly higher than 'Connect' (13.17) 'Delice' (12.90) and Oceania (09.85) (Table 2).

Length of Internode at 8 Weeks after Planting

Seven varieties had similar internode lengths which were significantly higher than 'Condor' (1.97), 'Marabel' (1.95) and 'Oceania' (1.8) (Table 3).

Plant height at 10 weeks after planting

At 10 WAP almost all the varieties had similar heights which were significantly higher than Delice (Table 3).

Number of Leaves at 10 WAP

Varieties 'Connect' (81.53), 'Yellow' (76.05), 'Sp' (66.80) and 'Marabel' (63.08) had statistically similar number of leaves at 10 WAP which were significantly higher than the others, with 'Oceania' (24.25) having the lowest (Table 3).

Leave Area Index at 10 WAP

At 10 WAP, the leave area index of eight varieties were statistically similar but significantly higher than 'Oceania' (07.79) and 'Famosa' (09.42) (Table 3).

Table 1: Emergence count at 4 weeks after planting and other growth parameters at 6 weeks after planting.

Group	EMC	PLH	NL	LAI	INL
Marabel	63.33^{ab}	19.13^{ab}	78.73^{a}	12.24^{abc}	1.82^{ab}
Condor	75.00^{ab}	25.10^{a}	60.63^{ab}	13.81^{abc}	1.94^{ab}
Caruso	75.00^{ab}	21.07^{ab}	46.63^{ab}	16.02^{ab}	2.00^{ab}
Nicola	58.33^{ab}	22.23^{ab}	85.37^{a}	18.31^{a}	2.13^{ab}
SP	53.33^{ab}	24.13^{a}	67.87^{ab}	17.25^{ab}	2.55^{a}
Oceania	46.67^{b}	12.92^{b}	27.80^{b}	07.12^{c}	1.77^{b}
Delice	83.33^{a}	24.81^{a}	65.20^{ab}	11.67^{abc}	2.29^{ab}
Connect	50.00^{b}	19.24^{ab}	47.27^{ab}	11.65^{abc}	1.90^{ab}
Famosa	56.67^{ab}	21.96^{ab}	54.47^{ab}	10.61^{bc}	2.44^{ab}
Yellow	63.33^{ab}	24.75^{a}	57.07^{ab}	16.61^{ab}	2.13^{ab}

Means followed by the same letter(s) are not significantly different at 5% level of probability (Duncan's New Multiple-Range Test). Var. = Varieties, EMC= Emergence count, PLH = Plant Height, NL = Number of leaves, LAI = Leave Area Index and INL = Internode length.

Table 2: Growth Parameters at 8 WAP.

Group	PLH	NL	LAI	INL
Marabel	26.99^{a}	105.70^{a}	22.63^{a}	1.95^{ab}
Condor	28.62^{a}	58.53^{ab}	17.48^{a}	1.97^{ab}
Caruso	26.99^{a}	64.70^{ab}	19.64^{a}	2.25^{a}
Nicola	24.43^{a}	75.40^{ab}	20.87^{a}	2.29^{a}
SP	26.53^{a}	66.47^{ab}	19.01^{a}	2.67^{a}
Oceania	15.32^{b}	24.60^{bc}	09.85^{ab}	1.80^{ab}
Delice	27.45^{a}	71.92^{ab}	12.90^{ab}	2.46^{a}
Connect	21.88^{ab}	48.08^{abc}	13.17^{ab}	2.30^{a}
Famosa	27.93^{a}	75.95^{ab}	16.90^{a}	2.77^{a}
Yellow	28.88^{a}	54.65^{ab}	18.09^{a}	2.33^{a}

Means followed by the same letter(s) are not significantly different at 5% level of probability (Duncan's New Multiple-Range Test). Var. = Varieties, PLH = Plant Height, NL = Number of leaves, LAI = Leave Area Index and INL = Internode length.

Table 3: Growth parameters at 10WAP.

Group	PLH	NL	LAI	INL
Marabel	25.20^{a}	63.08^{a}	14.02^{a}	1.79^{ab}
Condor	27.00^{a}	36.70^{ab}	11.66^{a}	2.18^{a}
Caruso	23.90^{a}	33.70^{ab}	12.22^{a}	1.41^{ab}
Nicola	19.63^{a}	54.90^{ab}	12.34^{a}	2.26^{a}
SP	18.47^{a}	66.80^{a}	10.85^{a}	2.23^{a}
Oceania	16.10^{a}	24.25^{b}	07.79^{ab}	1.91^{ab}
Delice	14.04^{ab}	48.08^{ab}	11.04^{a}	2.01^{ab}
Connect	17.10^{a}	81.53^{a}	11.90^{a}	2.25^{a}
Famosa	26.22^{a}	50.50^{ab}	09.42^{ab}	2.66^{a}
Yellow	16.85^{a}	76.05^{a}	10.90^{a}	2.00^{ab}

Means followed by the same letter(s) are not significantly different at 5% level of probability (Duncan's New Multiple-Range Test). Var. = Varieties, PLH = Plant Height, NL = Number of leaves, LAI = Leave Area Index and INL = Internode length.

Length of Internode at 10 WAP

Varieties 'Condor' (2.18), 'Nicola (2.26), 'Sp' (2.23), 'Connect' (2.25) and 'Famosa' (2.66) had similar means for Internode length at 10WAP which were significantly higher than the other varieties (Table 3).

Average yield of varieties

Table 5 shows the different parameters measured at harvest. These include: Final stand count, Number/Weight of Marketable Tubers, Number/Weight of Diseased tubers and Number/Weight of seed tubers.

Table 4: Some Yield and other Parameters Measured at Harvest at 12 Weeks after Planting.

Group	FSC	MKT TU	MKT WGT	SEED TU	SEED WGT	DIS TU	DIS WGT
Marabel	7.00^{ab}	8.50^{ab}	0.39^{ab}	5.50^{ab}	0.033^{b}	3.00^{ab}	0.060^{ab}
Condor	11.50^{a}	21.50^{a}	0.37^{ab}	13.00^{a}	0.080^{ab}	12.50^{a}	0.160^{a}
Caruso	14.00^{a}	22.00^{a}	0.88^{a}	5.00^{ab}	0.590^{a}	10.00^{a}	0.240^{a}
Nicola	10.67^{a}	10.67^{ab}	0.26^{b}	6.33^{ab}	0.310^{ab}	2.00^{ab}	0.020^{b}
SP	4.33^{ab}	5.00^{ab}	0.34^{ab}	4.67^{ab}	0.027^{b}	2.50^{ab}	0.050^{ab}
Oceania	8.00^{ab}	6.50^{ab}	0.19^{b}	2.50^{ab}	0.001^{b}	1.00^{ab}	0.020^{ab}
Delice	6.67^{ab}	6.00^{ab}	0.26^{b}	7.00^{ab}	0.039^{b}	2.00^{ab}	0.038^{ab}
Connect	5.00^{ab}	4.00^{ab}	0.26^{b}	0^{b}	0^{b}	2.00^{ab}	0.020^{ab}
Famosa	13.00^{a}	16.50^{a}	0.52^{ab}	7.00^{ab}	0.095^{ab}	11.00^{a}	0.190^{a}
Yellow	6.33^{ab}	12.33^{ab}	0.27^{b}	9.00^{a}	0.064^{b}	5.00^{ab}	0.090^{ab}

Means followed by the same letter(s) are not significantly different at 5% level of probability (Duncan's New Multiple-Range Test). Var. = Varieties, FSC = Final Stand Count per plot, MKT TU = Number of marketable tubers, MKT WGT = Weight of Marketable Tubers, SEED TU= Number of seed tubers, SEED WGT= Weight of seed tubers, DIS TU= Number of diseased tubers. DIS WGT = Weight of Diseased Tubers.

Final stand count (FSC) per plot

At harvest, variety 'Caruso' had the highest average number of standing plants (14.00) while 'Sp' had the lowest (4.33).

Number of marketable tubers

'Caruso' (22.00), 'Condor' (21.50) and 'Famosa' (16.50) had the highest average number of marketable tubers which were significantly higher than the other seven varieties with 'Connect' (4.00) having the lowest number of marketable tubers, (Plate 1, Table 4).

Ware tuber weight

The average ware tuber weight of 'Caruso' (0.88 kg) was significantly higher than the other varieties while 'Oceania' with a ware tuber weight of 0.19 kg was the lowest, (Table 4)

Number of seed tubers

The average number of seed tubers of 'Condor' (13) and 'Yellow' (9.00) were higher and significantly different from other varieties while 'Connect' did not record any seed tubers at all, (Plate 2, Table 4).

Seed tuber weight

Variety 'Caruso' (0.59 kg) had the highest average seed tuber weight followed by 'Condor' (0.08kg) and besides 'Connect' which did not have any seed tubers at all; variety 'Oceania' (0.001 kg) had the least average seed tuber weight, (Table 4).

Number of diseased tubers

On average, 'Condor' (12.50) and 'Famosa' (11.00) had the highest number of diseased tubers which were significantly higher than the other varieties while Oceania (1.00) had the lowest number of diseased tubers, (Plate 3, Table 4).

Weight of diseased tuber

The average weight of diseased tubers recorded for 'Caruso' (0.24 kg), 'Famosa' (0.19 kg) and 'Condor' (0.16 kg) were significantly higher than the other varieties while the least weight of diseased tubers were derived from 'Oceania' and 'Connect', both 0.02 kg.

Late blight evaluation

Table 5 shows the late blight evaluation scores recorded at 6, 7, 8, 9 and 10 WAP. Figure 1 shows the pooled disease progress curves for the different varieties planted. These curves were obtained by plotting the amount of disease against time and are purely adequate for the purpose of recording observations, Van der Plank (1968).

Correlation between traits

Phenotypic correlation coefficients between eight traits are shown in Table 7. Most of the correlation coefficients

a b

c d

Plate 1: Harvested ware tubers from some varieties.
a. Caruso
b. Condor
c. Famosa
d. Connect

were significant. Emergence count was significantly and positively correlated with late blight progression (*rp* = 0.91766) and final stand count (*rp* = 0.52438) but was however negatively correlated with leaf area index (*rp* = -0.97149). Plant height was positively correlated with number of leaves (*rp* =0.59236), leave area index (*rp* =0.61483), final stand count (*rp* =0.56132) and total tuber weight (*rp* =0.75992) but negatively correlated with internode length (*rp* = -0.68524) and late blight progress scores (*rp* = -0.73892). Number of leaves was positively correlated with final stand count (*rp* = 0.99928) and total tuber weight (*rp* = 0.97385) but was negatively correlated with internode length (*rp* = -0.9927). Leave area index was positively correlated with plant height (*rp* = 0.61483) and negatively correlated with emergence count (*rp* = -0.97149) and late blight progress scores (*rp* = -0.9857). Internode length showed no positive correlation with any other trait but was negatively correlated with plant height (*rp* = -0.68524), number of leaves (*rp* = -0.9927), final stand count (*rp* = -0.98739) and total tuber weight (*rp* = -0.99415). Late blight progress scores were positively correlated with emergence count (*rp* = 0.91766) but was

a b

Plate 2: Harvested seed tubers from some varieties.
a. Condor
b. Yellow

a b

Plate 3: Harvested diseased tubers from some varieties.
a. Condor
b. Famosa

Table 5: Late blight evaluation scores at 6-10 weeks after planting.

Group	LATE 6WAP	BLIGHT 7WAP	SCORES* 8WAP	(MEANS) 9WAP	10WAP
Marabel	3	5	6	7	8
Condor	3	3	5	6	7
Caruso	3	5	6	7	8
Nicola	1	3	3	4	5
SP	3	5	6	8	8
Oceania	3	4	5	6	7
Delice	3	4	5	6	7
Connect	2	3	4	5	6
Famosa	3	4	5	6	7
Yellow	3	4	5	8	8

*1 = No late blight observable
9 = leaves and stems are dead (Henfling, 1987)
See appendix 1 for detailed scale.

Table 6: Correlation matrix of growth, yield and late blight progression of the 10 potato varieties grown in NRCRI, Vom.

Parameters	EC	PLH	NL	LAI	INL	LBS	FSC	TTW
EC	1	-0.41034	0.49164	-0.97149**	-0.38299	0.91766**	0.52438*	0.28095
PLH	-0.41034	1	0.59236*	0.61483*	-0.68524*	-0.73892*	0.56132*	0.75992*
NL	0.49164	0.59236*	1	-0.27119	-0.9927**	0.10514	0.99928**	0.97385**
LAI	-0.97149**	0.61483*	-0.27119	1	0.15309	-0.9857**	-0.30757	-0.04542
INL	-0.38299	-0.68524*	-0.9927**	0.15309	1	0.0156	-0.98739**	-0.99415**
LBS	0.91766**	-0.73892*	0.10514	-0.9857**	0.0156	1	0.14286	-0.12354
FSC	0.52438*	0.56132*	0.99928**	-0.30757	-0.98739**	0.14286	1	0.96451**
TTW	0.28095	0.75992*	0.97385**	-0.04542	-0.99415**	-0.12354	0.96451**	1

**, ** Significant at P<0.05, 0.01, respectively.*
EC =Emergence count, PLH = Plant height, NL= Number of leaves, LAI = Leave area index, INL= Internode length, LBS = Late blight scores, FSC= Final stand count. TTW = Total tuber weight.

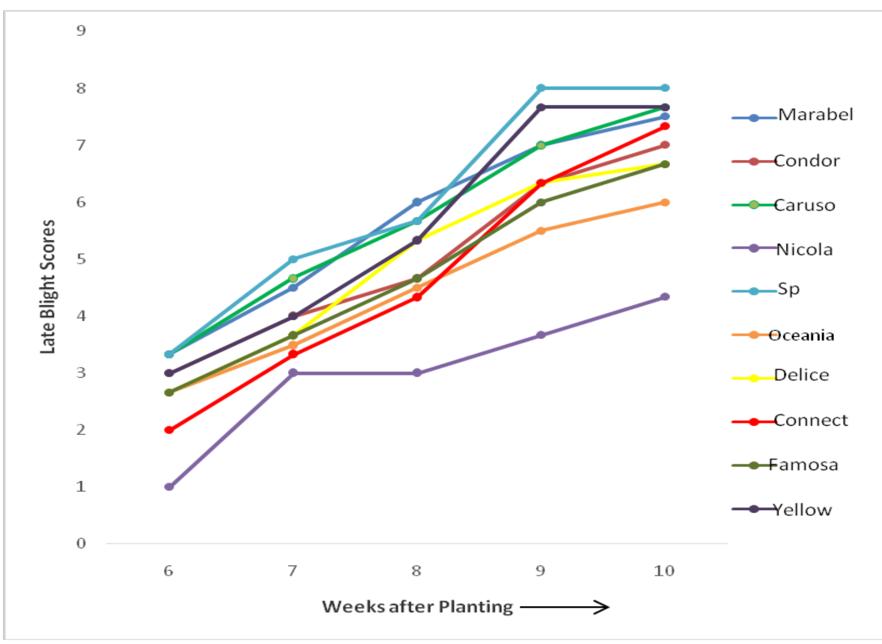

Figure 1: Pooled Disease Progress curve for Varieties 1-10.

negatively correlated with plant height (*rp* = -0.73892) and leave area index (*rp* =-0.9857). Finally, total tuber weight showed high and positive correlation with plant height (*rp* = 0.75992), number of leaves (*rp* = 0.97385) and final stand count (*rp* = 0.96451) but was negatively correlated with internode length (*rp* = -0.99415).

DISCUSSION

All of the cultivars planted proved to be successful in terms of establishment and emergence. However, significant variances were found in nearly all of the characters studied. Because the different seed tubers planted were of the same size grade and physiological age, this might be linked to their genetic make-up (Demo, 1997). The ranges of values for the majority of the characters evaluated were large, and the mean differences observed were significant. This is consistent with the findings of other studies (Sidhu and Pandita, 1979; Birhman and Kaul, 1989; Amadi *et al*., 2008) who found variances in potato varieties for numerous qualities. These changes in plant attribute within a population imply that selection for each trait is conceivable (Bonierbale *et al*.,2020).

As demonstrated by disease expression on the leaves, all of the cultivars sown were susceptible to late blight. Disease began at the same period (6WAP) for the majority of the types, but towards the end of the assessment, final disease scores varied significantly. This could be due to some measure of disease tolerance found in a few of the cultivars planted (Kwon-Ndung and Ifenkwe, 1993; Iqbal *et al*., 2013). The progression of late blight was found to have a positive and substantial relationship with the emergence count. That is, the late blight disease advanced more quickly in the kinds that bloomed earlier. This discovery is consistent with the findings of Umaerus and Umaerus (1994), who discovered a strong positive relationship between field resistance and maturity. Early maturing cultivars were found to be more sensitive to late blight than late maturing variants. Visker (2005) discovered a close positive link between the length of the vegetative stage and the degree of field resistance in a similar investigation. Except for Connect and Nicola, where the gradient of the regression line was modest, disease progression was relatively rapid in all types.

According to Kiraly *et al*. (2007), field resistance is manifested by the reduction of pathogen development even after infection has occurred. Disease tolerance, on the other hand, refers to the host plant's ability to protect itself from infectious disease by minimizing the pathogen's detrimental influence on host fitness (Medzhitov *et al*., 2012). As a result, the gradual progression of disease found in varieties Connect and Nicola over time indicates that they have some field tolerance to late blight when compared to the other varieties where disease progressed at a much faster rate.

Tuber yields had no significant relationship with the progression of late blight. That is, cultivars with quick disease progression did not always provide lower yields. This could be due to the disease's late appearance in the field. Several writers have documented their findings regarding the relationship between tuber yield and disease severity. Van der Plank (1963, 1968) and Wiik (2014) showed that disease severity had no effect on yield when disease appeared late in the field. According to Kwon-Ndung and Ifenkwe (1993), tuber yields were inversely connected with blight infection in tuber families but positively correlated with clones. This shows that lower yields were obtained for tuber families when disease severity was high, whereas higher yielding clones tended to be more sensitive to late blight. Late blight caused severe yield losses, according to James *et al*. (1972) and Dowley (2008). Ugonna *et al*. (2013) and Ibrahim (2014) both observed significant output losses due to late blight on potato fields in Jos-Plateau, particularly on late planted crops. According to them, the potato growth time in Jos-Plateau is short, thus if late blight occurs early, yield can be severely reduced.

Conclusion

This study found variable levels of resistance/tolerance to late blight in potato types growing in Jos, Plateau State. Nicola and Connect had the highest level of field tolerance to the disease of the 10 types tested, demonstrating that selection for late blight resistance is conceivable. This study will pave the path for identifying and harnessing resistant R-genes that may be introduced into other potato cultivars to confer resistance to late blight.

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Appendix 1: Recommended CIP scale for scoring late blight

CIP SCALE VALUE	MEAN	LIMITS	SYMPTOMS
1	0		No late blight observable
2	2.5	Trace-<15	Late blight present. Maximum 0f 10 lesion per plant.
3	10	5-<15	Plants look healthy, but lesions are seen easily at close distance. Maximum foliage area affected by lesions corresponds to no more than 20 leaflets.
4	25	15-<35	Late blight easily seen on most plants. About 25% covered with lesions or destroyed.
5	50	35-<65	Plots look green, however all plants are affected. Lower leaves are dead. About half of the foliage area is destroyed.
6	75	65-<85	Plots look green with brown flecks. About 75% of each plant is affected. Leaves of the lower half of plants are destroyed.
7	90	85-<955	Plot neither predominantly green nor brown. Only top leaves are green. Many stems have large lesions.
8	97.5	95-<100	Plot is coloured brown. A few top leaves still have some green areas. Most stems have lesions or are dead.
9	100		All leaves and stems are dead.

Source: Henfling (1987)