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EVALUATION OF POTATO (*Solanum tuberosum* L.) GENOTYPES FOR RESISTANCE TO LATE BLIGHT AT SINANA SOUTHEASTERN ETHIOPIA

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Abstract

Late blight caused by *Phytophthora infestans* (Mont.) de Bary, is one of the most significant constraints to potato production in Bale high lands and other regions of Ethiopia. Hence, this requires to develop high yielding and late blight resistant varieties. Therefore, this study was conducted to determine host resistance of potato against *Phytophthora infestans* in order to develop late blight resistant/tolerant genotypes. The experiment was laid out in randomized complete block design with three replications at Sinana Agricultural Research Center during 2014 main cropping season. The genotypes showed highly significant ($P \leq 0.01$) differences for all the characters studied. Genotypes exhibited wide ranges of mean values for all characters. The highest total tuber yield (46.1 t ha^{-1}) was obtained from the advanced clone, CIP-392640.524 followed by *Belete* (41 t ha^{-1}). Late blight appeared early on farmer's cultivar *Kellacho* (48 days after planting) and late on advanced clones CIP-399062.102(74 days after planting). Percent severity index (PSI) and area under disease progress curve (AUDPC) ranged from 33.91 to 91.67% and 105 to 2370, respectively. Eleven newly introduced clones and the released variety "*Belete*" recorded PSI 33 to 39.7% and AUDPC 105 to 264.1. Hence, these genotypes can be categorized as moderately resistant. The study revealed the presence of considerable variability in tested genotypes for economically important traits and the higher chance of selecting genotypes with high yield and moderately resistant to late blight. However, it appears that further evaluation of genotypes across seasons and locations to identify genotypes that could be released as varieties seem to be quite pertinent.

Keywords: Disease Progress Curve; Genotype; Late Blight; Percent Severity Index

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Introduction

Potato late blight, caused by the *Phytophthora infestans* (Mont.) de Bary, is one of the primary problems faced by small-scale potato producers in high lands of Ethiopia. Late blight can destroy a potato field within a few days (Razukas and Jundulas, 2005). If not controlled, losses may reach 100% (Rubio-Covarrubias *et al*., 2005) and even lower infection levels may make the crop unfit for storage (Heinfnings, 1987). In the highlands of Ethiopia, late blight and bacterial wilt (*Ralstonia solanacearum*) are the most important economic diseases that cause an estimated yield loss of up to 70% (Shiferaw *et al*., 2009). Late blight is especially important in the traditional potato growing areas.

The search for genetic resistance to late blight has intensified, since it is a practical and economic way of controlling the disease. Initially, the search concentrated on specific resistance (Forbes and Landeo, 2006). The resistant variety development, which involves evaluation, selection, release and registration procedures pass through several stages. Some countries such as Ethiopia, the potato breeding programs depend entirely on CIP materials. In the absence of creating variation through crossing in the country, it is necessary to introduce potato genotypes every time from the source. The introduced genotypes need to be evaluated for target areas or for wide adaptability across regions in the country. Accordingly, this study was conducted to determine host resistance of potato against *Phytophthora infestans* and to develop late blight resistant/tolerant genotypes.

Materials and Methods

Experimental site

The experiment was conducted in Southeastern Ethiopia, Bale Zone, at Sinana Agricultural Research Center during 2014 main cropping season. Sinana is located at 07^0 N and 40^0 10' E at an altitude of 2400 (m.a.s.l). The area possesses a bimodal rainfall type. This bimodal rainfall system has created conducive opportunities to

produce crops twice annually or double production in a season. Average annual maximum and minimum temperatures are 21 and 9ºC, respectively. The dominant soil type is pellic vertisol and slightly acidic (Nefo *et al.,* 2008).

Experimental materials and design

A total of 24 potato genotypes which consists of 20 advanced clones, three released varieties as standard checks and one farmers' cultivar in Bale were planted during the main cropping season of 2014. The farmers' cultivar *Kellacho* that is susceptible to late blight was used as local check. *Belete* is known as resistant variety to late blight while *Ararsa* and *Guddane* are moderately resistant varieties.

The experiment was arranged in randomized complete block design (RCBD) with three replications. The spacing between rows and plants was 0.75 m and 0.30 m, respectively. The spacing between plots and adjacent replications was 1 m and 1.5 m, respectively. At both end of each row, tubers of known late blight susceptible (*Kellecho*) was planted and were used as inoculum sources or "spreader rows". Thus, each genotype or plant in each plot had a chance to receive ample amount of inoculum sources under natural inoculum distribution. The middle rows were used for data collection.

Data collection

Days to late blight appearance (DLA) was recorded by counting days from planting to the first appearance of late blight symptoms in each plot (genotype).

Disease severity was taken on the basis of the percentage of leaf area affected by late blight. The reading was started on the onset of late blight (1-5% infection). After onset of the disease scoring was continued at an interval of seven days until nearly 74 days after planting. The 1-9 disease score scale described by Heinfnings (1987) was used.

Percent severity index (PSI) was calculated from disease severity.

$$\text{Percent Severity index \%} = \frac{\text{Summation of numerical rating}}{\text{No. plants examined} \times \text{Maximum disease score}} \times 100$$

The calculated percent severity index was used to classify genotypes in to highly resistant (up to 5), resistant (5-20), moderately resistant (21-40) and susceptible (>40) (Mohan and Thind, 1999).

Area under disease progress curve: was calculated according to Campbell and Madden (1990) formula and it was interpreted directly without transformation as the higher the AUDPC, the more susceptible genotype (CIP, 2006).

$$\text{AUDPC} = \sum_{i=1}^{n-1}\left(\frac{yi + yi+1}{2}\right)\left(t_{i+1} - t_{i}\right)$$

Where "t" is the time of each reading, "y" is the percent of affected foliage at each reading and "n" is the number of readings. The variable "t" can represent Julian days, days after planting.

Data analysis

Collected data was subjected to analysis of variance (ANOVA) for RCBD following the procedure outlined by Gomez and Gomez (1984) using SAS ver. 9.1.3 computer software. Means that are significantly different were compared using Duncan Multiple Range Test (DMRT) of probability at 1% and 5% probability of significance.

Results and Discussion

Analysis of Variance

Analysis of variance indicated the presence of highly significant ($P \leq 0.01$) differences among genotype for all traits. This may allow breeders to select resistant genotypes to enhance the productivity of the crop. This is in line with Jaime *et al.* (2014) who indicated significant different among 10 potato cultivars under studies.

Mean performance of genotypes

Potato genotypes had a wide range of variations. Total tuber yield ranged from 0.8 to 46.1 t ha^{-1} with mean performance of 19.4 t ha^{-1} (Table 1). Mean total tuber yield of released varieties (*Belete*, *Gudanie* and *Ararsa)* was within the range of 15.9 to 41 t ha^{-1}. The four advanced clones gave total tuber yield higher than the mean tuber yield of the two released varieties (*Gudanie* and *Ararsa*) while one clone (CIP-392640.524) had statistically the same mean total tuber yield with the best performing released variety *Belete*. Addisu *et al.* (2013) and Baye (2002) also reported some of the newly introduced potato genotypes had higher tuber yield than the existing commercial potato varieties. This indicated the presence of variation in genotypes under study for total tuber yield that can be exploited in improving the crop.

Late blight appeared early at 48 days after planting on farmers cultivar *Kellacho* and other five advanced clones (CIP-399053.15, CIP-397079.26, CIP-396039.103, CIP-391930.1 and CIP-391381.9) followed by three advanced clones

(CIP-399078.11, CIP-396031.201 and CIP-393382.44) which appeared at 53 days after planting. Late blight appeared very late on CIP-399062.102 at 74 days after planting. The disease appeared at 70 days on *Belete* and at 63 days on *Ararsa* and *Guddanie*. There was wide range difference of 26 days between the first disease symptom appearance on susceptible and relatively resistant genotypes. Jaime *et al.* (2014) also reported that potato genotypes which developed late blight symptom early are susceptible and genotypes that developed late blight in the crop cycle are resistant.

The calculated percent severity index ranged from 33.00 for CIP-391058.175, CIP-395096.2, CIP-395114.5, CIP-396031.201 and *Belete* to 91.67% for advanced clone (CIP-391930.1). From all 24 genotypes, there was no genotype with percent severity index of <20 at nearly 80 days after planting. Hence, there were no highly resistant and resistant genotypes from the newly introduced materials and released varieties. However, eleven advanced clones and *Belete* had percent severity index that ranged from 33.00 to 39.70 and can be categorized as moderately resistance while others including released varieties *Guddine* and *Ararsa* recorded above 40% and categorized as susceptible.

The calculated AUDPC ranged from as low as 105 for CIP-391058.175, CIP-399062.102, CIP-395096.2, Bellete and as high as 2370 for CIP-397079.26. Most of the genotypes including the released variety *Ararsa* and *Gudenie* had high AUDPC. According to Campbell and Madden (1990), from 24 potato genotypes- CIP-395096.2, CIP-395077.12, CIP-99062.102, Belete, CIP-395114.5, CIP395017.242, CIP-396240.23, CIP391058.175, CIP396029.205, CIP396031.201, CIP-3920524 and CIP-396244.12 categorized as tolerant. However, other genotypes including released varieties *Ararsa* and *Gudaine* were considered as susceptible. The AUDPC is very convenient summary of plant disease epidemics that incorporates initial intensity, the rate parameter and duration of epidemic, which determine final disease intensity (Andre *et al*., 2014). Hence, the effect of disease resistance on crop can be evaluated by using area under disease progress curve (Boiteux *et al*., 1995). This is in agreement with the finding of Jaime *et al.* (2014) who reported that high susceptible cultivar Shepody had the highest AUDPC value among 10 potato cultivars in Argentina.

Table 1. Mean performance of 24 potato genotypes for yield and late blight disease parameters at Sinana in 2014 bona cropping season

Genotypes	MTY	unMTY	TTY	DLA	PSI(%)	AUDPC
CIP-395096.2	0.06^{n}	0.7 $^{h-j}$	0.8 ^{j}	63 $^{b-d}$	33.0^{a}	105^{a}
CIP-391381.9	3 $^{l-n}$	3.2 ^{b}	6 $^{h-j}$	48 ^{e}	80.3^{c-e}	1753 ^{e}
CIP-395077.12	11.3 $^{h-l}$	0.7 $^{h-j}$	12^{g-i}	63 $^{b-d}$	39.7^{a}	248.6 ^{a}
CIP-399062.102	23.2^{d-f}	1.3 $^{f-i}$	24.5 $^{c-f}$	74.67 a	38.67^{a}	105^{a}
Belete	39.4^{ab}	0.7 h-j	41 ^{ab}	70^{ab}	33^{a}	105 ^{a}
CIP-396039.103	21 $^{e-g}$	1.3 $^{f-i}$	23.5^{c-f}	48 ^{e}	68^{b-e}	1119.^{d}
CIP-399078.11	15.2 $^{f-i}$	0.7 $^{h-j}$	15.9 $^{f-h}$	53 ^{de}	67^{b-e}	575.2^{ab}
CIP-395112.19	13.2^{g-k}	0.3 ^{j}	13.6^{eh}	72.3^{ab}	55.3 $^{a-c}$	332.3 ^{ab}
CIP395017.242	21.5^{e-g}	1.4 $^{e-i}$	22.9 $^{c-f}$	72.3^{ab}	38.67 ^{a}	145.8^{a}
Kellacho	1.4 ^{mn}	1.3^{f-i}	2.7 ^{ij}	48^{e}	82.0^{de}	2014.1^{ef}
CIP-395114.5	32.7^{bc}	0.6 $^{h-j}$	33.6 ^{bc}	62.6 $^{b-d}$	33.0a	122.5^{a}
CIP-396240.23	25.5^{c-e}	1.5 $^{e-i}$	26.8 $^{c-e}$	62.6 $^{b-d}$	36.67^{a}	180.8^{a}
CIP-397079.26	4.1 $^{k-n}$	0.2 ^{j}	4 ^{ij}	48.^{e}	91.33^{e}	2370^{g}
CIP391058.175	29 $^{c-e}$	1.5^{e-h}	31^{bc}	65.3^{a-c}	33^{a}	105^{a}
CIP396029.205	26^{c-e}	0.7 $^{h-j}$	27^{cd}	63 $^{b-d}$	37.0 ^{a}	189.1^{a}
Ararsa	13 $^{g-j}$	1.1^{g-j}	14^{eh}	63 $^{b-d}$	57.$^{a-d}$	372.1 ^{ab}
CIP-399053.15	7.5 $^{i-n}$	2.2 $^{c-f}$	9 $^{g-j}$	48 ^{e}	66 $^{b-d}$	1191.6^{d}
CIP-393382.44	10 $^{i-m}$	0.6 $^{h-j}$	11 $^{g-j}$	53 ^{de}	65.6 $^{b-d}$	1134.5^{d}
CIP396031.201	5.5 $^{j-n}$	1 h-j	6.6 $^{h-j}$	53de	33.33^{a}	161.2 ^{a}
CIP395017.229	14 $^{f-j}$	2.9 $^{b-d}$	16^{d-h}	58 $^{c-e}$	56.67^{ad}	750.5^{c}
Guddane	20 $^{e-h}$	2.3 $^{c-e}$	23 $^{c-f}$	63 $^{b-d}$	43.3^{ab}	581.0^{bc}
CIP-3920 -524	43.7^{a}	2.4 $^{c-e}$	46.1 ^{a}	58 $^{c-e}$	36.67^{a}	186.7^{a}
CIP-391930.1	3.3 $^{i-n}$	8.7^{a}	11^{g-i}	48^{e}	91.67^{e}	2165.6^{fg}
CIP-396244.12	31^{b-d}	1.4 $^{f-i}$	33 ^{bc}	65.3 $^{a-c}$	37.00 ^{a}	264.1^{a}
Range	0.06-43	0.65-8.7	0.76-46	48-74.67	33-91.67	105-2370
Mean	17.5	1.721	19.41	59.31	53.7	680
CV%	28.2	29.2	29.3	10.3	24.9	24.6
Level of significance	**	**	**	**	**	**

Means followed by the same letter within a column are not significantly different at the prescribed level of probability. ** = significant and ns = non-significant (at 1% and 5%). MTY marketable tuber yield, unMTY = unmarketable tuber yield, TTY = total tuber yield t $ha^{-1,}$ DLA= days to late blight appearance, PSI = percent severity index, AUDPC= area under disease progress curve, CV= coefficient of variation

In 2014 main cropping season, there was high severity of late blight on potato in Bale high lands (personal observation). At 48 days after planting, late blight appeared on some genotypes. This indicated that in the process of improving potato variety through selection attention should be given to assess the disease onset as early as possible. Similar results were reported by Sharma *et al.* (2013), which indicated late blight severity observations in the field should be started at 30 days after planting and continued up to 76 days until the susceptible check had 100% infection.

Considering both disease parameters, (PSI and AUDPC) 11 newly introduced genotype and one released variety *Belete* were categorized as moderately resistant. Thus, these genotypes are found promising for further improvement as breeding materials. Others may be considered for cultivation using other late blight management options especially in the case of *Ararsa* and *Gudaine*. Similar results were reported by Shiferaw *et al*. (2009) that moderately resistant cultivar, *Gudanie*, had a clear AUDPC response to additional fungicide sprays, although apparently for about three sprays. Several research on potato late blight have demonstrated that highly resistant (immune or nearly immune) phenotypes can frequently indicate an active major R gene, for which compatibility in the pathogen population is absent or extremely rare.

If an incompatible potato genotype is released for use by farmers in most cases there will be selection of compatible pathogen population and a corresponding "loss" of resistance (Forbes, 2012). For this reason, some researchers have recommended selection of those phenotypes, which demonstrate resistance, but are still infected (Forbes and Landeo, 2006).

Conclusions

In conclusion, the present study revealed the existence of variability for tuber yield and resistance to late blight. This suggested the higher chance of selecting genotypes with moderate resistance/ tolerance to improve the productivity of the crop. In addition, the future potato improvement program in the study area should include genotypes highly resistant to late blight. The identified promising genotypes in this study showed only moderate resistance to late blight which can be surpassed by the disease, as the pathogen is known with high mutable characteristics that make resistant varieties susceptible soon after they are deployed.

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