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RESISTANCE TO LATE BLIGHT AND YIELD OF POPULATION B3 POTATO SELECTIONS IN UGANDA

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ABSTRACT

Population B3 is the most advanced source of horizontal resistance available at the International Potato Centre (CIP). In this population, testing and selection for horizontal resistance to late blight, unlike those previously applied to population A clones, were simplified significantly (P<0.05) due to the absence of known R-genes. This study, conducted in southwestern and eastern Uganda, evaluated 20 selected potato genotypes in Population B3 for late blight resistance and tuber yield. Late blight severities on many of the Population B3 genotypes were lower than on most local cultivars, including the resistant cultivar, Rutuku. Population B3 genotypes performed better when sprayed with fungicide, Mancozeb, but the reduction in late blight severities due to spraying varied with genotype and location. Although spraying did not significantly (P>0.05) increase yields, almost all genotypes gave higher yields with than without spraying, with significant (P<0.05) differences among genotypes. Population B3 entries 389746.2, 383382.44, 393371.58, 392637.10, 391002.6, 393349.63, 393617.18, 391011.17, 391580.30, 393385.39, 393339.242, 393077.54, 393280.64 and 392657.8 performed well and could be considered for on-farm trials.

Key Words: *Phytophthora infestans,* resistance genes, *Solanum tuberosum*

RÉSUMÉ

La variété B3 est la source la plus avancée de la résistance horizontale disponible au International Potato Centre (CIP). Dans cette variété, le teste et la sélection pour la résistance horizontale au mildiou, différent de ceux précédemment appliqués à cette variété clones A, étaient simplifiés d'une manière significative (P<0.05) à cause de l'absence des gènes-R connues. Cette étude, conduite dans le sud-ouest et l'est de l'Ouganda, a évalué 20 génotypes de patate sélectionnée dans la variété B3 de mildiou retardé résistant et la production de tubes. Les difficultés de mildiou retardé, sur beaucoup de variétés de génotypes B3 étaient inférieures que sur la plupart des cultures locales, incluant la résistante culture Rutuku. Les génotypes de variété B3 se sont mieux exécutés une fois pulvérisés aux champignons Mancozeb, mais la réduction dans la variété retardée à cause des variétés pulvérisées avec le génotype et la location. Néanmoins, la pulvérisation n'a pas augmenté la production d'une manière significative (P<0.05), presque tous les génotypes ont donné des productions supérieures avec sans la pulvérisation, avec une différence significative (P<0.05) entre les génotypes. Les entrées de la variété B3, 389746.2, 383382.44, 393371.58, 392637.10, 391002.6, 393349.63, 393617.18, 391011.17, 391580.30, 393385.39, 393339.242, 393077.54, 393280.64 et 392657.8 ont bien reproduit et pouvaient être considérées pour une ferme d'essai.

Mots Clés: *Phytophtora infestant*, gènes résistants, *tuberosum Solanum*

INTRODUCTION

Most potato (*Solanum tuberosum* L.) genotypes that have been released or are available to farmers in Uganda and other parts of Eastern Africa today, either have genes for vertical resistance to late blight (LB), *Phytophthora infestans* or have been improved for horizontal resistance to late blight in the presence of unknown resistance (R) genes, thus named population A clones (Landeo *et al.*, 1997). Recent evidence suggests that most Population A clones in Uganda have now succumbed to late blight, recording substantial yield losses (Mukalazi *et al.*, 2001; Kankwatsa *et al.*, 2002). However, some released varieties such as Rutuku and several recently developed lines (Nakpot 1, 2, 3, 4 and 5) selected from population A after a number of field trials, still exhibit appreciable levels of partial resistance to the disease (Kankwatsa *et al.*, 2002). Other potato genotypes such as those in the Standard International Field Trials (SIFT) that have been tested in Uganda and Kenya (El-Bedewy *et al.*, 2001) have shown high susceptibility to the disease.

In the 1990s, breeders at the International Potato Centre (CIP) selected a potato population (Population B) with high levels of partial resistance to *P. infestans*, but lacking any of the known R genes (R1 – R11) (Landeo *et al.*, 1997). This breeding strategy was thought to generate potato lines with improved, non-specific and durable resistance to *P. infestans*. Population B1 was developed through several recombination cycles of resistance sources of *Solanum andigena*. Population B2 was obtained from crosses between *S. andigena* and *S. tuberosum* sources of resistance, while B3, the most advanced source of horizontal resistance currently available at CIP, was selected from population A. B3 contains mostly *S. demissum*-derived horizontal resistance improved mainly in an *S. tuberosum* germplasm background (Landeo *et al.*, 1997). During the improvement process, suitable agronomic traits, tolerance to abiotic and biotic stresses, early tuberisation and bulking, table and processing quality as well as adaptation to a wide range of environments were taken into consideration (Landeo *et al.*, 2000a,b). An important feature of Population B3 is that testing and selection for horizontal resistance to late blight, unlike those previously applied to population A clones, were simplified significantly due to the absence of R-genes.

Population B cycles 1 and 2 have been evaluated in Uganda but results indicate that these genotypes are still susceptible to the disease and give unsatisfactory yields (Mulema, 2003). Population B recombination cycle 3 (Pop B3) clones are the latest set of clones released by CIP and are thought to have considerable horizontal resistance to late blight (Landeo *et al.*, 2000a,b). Correlation studies conducted on LB evaluation data from Mexico and Colombia have shown that B3 resistance is stable under those two diverse environments and pathogen populations (Landeo *et al.*, 2000a).

In Uganda, the major potato growing areas are in the highlands, as is the case with other eastern African countries, where the crop is an important staple and generates cash income (Sikka *et al.*, 1991). These areas have moderate temperatures of about 15-22^{0}C and relatively high amounts of rainfall averaging more than 1200mm per annum. Much as these conditions are favourable for potato production (Sikka *et al.*, 1991), they also favour severe epidemics of LB. The disease is, thus, a major hindrance to potato production in these humid highlands, causing yield losses of up to 75% on susceptible varieties (Olanya *et al.*, 2001). Indeed, late blight has been reported to be the single most important production constraint to potato production in Uganda (Adipala *et al.*, 2000). The objective of this study was to assess the level of late blight resistance and the yield potential of the recently introduced population B cycle 3 potato genotypes under Ugandan conditions and select promising ones for advanced yield trials.

MATERIALS AND METHODS

A cohort of 20 Population B3 potato germplasm selections (Table 1) received from CIP sub-Saharan Africa Region office in Nairobi, Kenya in 2001, were evaluated in this study. Four local cultivars were included in the trial, namely; Rutuku, Victoria, Nakpot 4 and Nakpot 5 (all in one location due to limited seed). Victoria was used as the local susceptible cultivar and Rutuku as a popular resistant cultivar in eastern Africa (Hakiza, 1997), while Nakpot 4 and Nakpot 5 are recent releases in Uganda. A description of the tuber characteristics of the potato genotypes in population B3 and the cultivars used in this study is presented in Table 1.

The study was conducted during the short (March-July) and long (September-December) rains of 2002, hereafter referred to as 2002A and 2002B seasons, respectively. The experimental sites were; Kalengyere Research Station (2450 metres above sea level (m.a.s.l.) in southwestern Uganda and Buginyanya Agricultural Research and Development Centre (1980m.a.s.l.) in eastern Uganda, representing two major potato growing areas of the country (Sikka *et al.*, 1991). At the end of 2002A season at Kalengyere, 8 potato genotypes in population B3 were selected (because of limited seed to repeat the spray experiment as most genotypes had not yet sprouted), based on tuber yield, resistance to late blight and length of the dormancy period. The 8 population B3 genotypes and 4 local cultivars were grown at Kalengyere in 2002B. At Buginyanya, all the genotypes evaluated in 2002A were re-evaluated in 2002B. Mean temperature, rainfall and relative humidity of the two experimental sites are presented in Table 2.

The field plots were laid out in a randomised complete block design (RCBD) of a split-plot arrangement, with three replications. The spray regimes (spray vs. "unsprayed") were the main plots, while the potato genotypes were the sub-plots. Each sub-plot consisted of 2-3 m long rows each with 10 plants. Spacing was 70 cm by 30 cm. Each main plot was given a prophylactic spray of Mancozeb (Dithane M45®) at 40 days after planting to enhance the genotypic resistance. Additional spraying in the spray treatment was done as deemed necessary (resulting in three sprays during both seasons at Buginyanya and four sprays during 2002A at Kalengyere). The objective of the two spray treatments was to assess the yield potential with and without fungicide sprays. The prophylactic spray was administered to ensure no loss of the genotypes to late blight, since the materials were only recently received and were few. In 2002B, at Kalengyere Research Station, the experiment was laid out as

TABLE 1. Physical tuber characteristics of potato genotypes in population B3 and cultivars evaluated in this study

Genotype	Tuber shape	Skin colour	Flesh colour
385524.9	Oval	White	White
389746.2	Oval	Red	White
391002.6	Oval	White	White
391011.17	Oval	White	White
391580.30	Round	Cream /white eyes	Yellow
391696.96	Round	Purple/black eyes	Cream
393617.54	Round	Red /white eyes	White
392637.10	Round	White/red eyes	Cream
392657.8	Round	White /red eyes	Cream
392661.18	Oval	Red /Pink eyes	White
393077.54	Oval	White / red eyes	Cream
393242.50	Oval	White	Yellow
393280.57	Round	Red	Yellow
393280.64	Round	Red	Yellow
393339.242	Oval	Purple	Cream
393349.63	Round	White / pink eyes	Yellow
393371.58	Oblong	White	Cream eyes
393382.44	Round	Red	Yellow
393385.39	Round	Red	White
393385.47	Round	White / red eyes	White
Nakpot 4[1]	Round	Red	Cream
Nakpot 5[1]	Round	Cream	White
Rutuku[2]		Round	Red White
Victoria[2]	Round	Red	Light Yellow
Kabale[2]	Round	Purple white	White

[1] Recently released varieties from Population A; [2]Local cultivars

a RCBD with three replicates. All necessary agronomic practices such as weeding and hilling were carried out whenever necessary. Dehaulming in each season was done at 90 days after planting, while harvesting was done 10 to 14 days after dehaulming, to allow for adequate curing of the tubers before harvesting.

Assessment of late blight (LB) severity started soon after the first symptoms appeared on the leaves and continued once weekly up to physiological maturity. Late blight symptoms were rated based on percentage leaf area affected (Henflings, 1987). At harvest, data were collected on tuber number and fresh weights, which were used to compute number of tubers per plant, mean tuber weight and yield per hectare. Late blight severity scores were used to calculate areas under disease progress curves (AUDPC), which were subsequently standardised to give relative AUDPC (rAUDPC) (Campbell and Madden, 1990). Disease (rAUDPC) and yield data were subjected to analysis of variance (ANOVA) to test for significance of variation due to genotypes, seasons, spray treatment and their interactions using the Genstat computer software (Genstat, 1995). Where the 'F' statistic showed significance, the means were separated using the standard error of difference between means (SED). Two means were considered significantly different from each other if the difference between them was more than twice the SED.

RESULTS

Late blight severity. At Kalengyere in 2002A, there were significant differences among spray treatments ($P = 0.05$), genotypes ($P<0.001$) and spray treatments x genotype interactions ($P = 0.01$). Thus, only means of genotype x spray interactions are presented for 2002A in Table 3. At Kalengyere, the sprayed plots had a lower mean rAUDPC (14.3) than the "unsprayed" plots (24.0). Relative AUDPCs ranged from 4.5 (392657.8 and 393617.54) to 28.5 (Victoria) in the sprayed plots and from 9.6 (393385.39) to 53.8 (Victoria) in the "unsprayed" plots. Victoria, the local susceptible cultivar had the highest disease severity both in the sprayed and "unsprayed" plots. Population A cultivars, namely, Nakpot 4 and Nakpot 5 (10.6 and 12.7, respectively) had lower disease severities than all but five population B3 genotypes namely, 392657.8 (4.5), 393077.54 (7.4), 393385.39 (8.3), 391696.96 (7.2) and 393280.64 (10.1). Even when "unsprayed", Nakpot 4 still had a lower rAUDPC than all Population B3 genotypes except 393385.39 and 391011.17, while Nakpot 5 (24.0) had a lower rAUDPC than all Population B3 genotypes except nine. Similarly, "unsprayed" Rutuku, the resistant local cultivar, had a lower rAUDPC than the other local cultivars (Victoria and Kabale) and most Population B3 genotypes (Table 3).

At Buginyanya, the mean rAUDPCs varied from 0.1 to 4.2 and from 0.9 to 15.6 for the sprayed and "unsprayed" plots during 2002A and 2002B, respectively (Table 3). There was generally less disease in 2002B than in 2002A. In 2002A, there was no disease symptom on 393077.54 in the sprayed plots, while rAUDPC varied from 0.4 on 393617.54 to 26.7 on 393385.39 in the "unsprayed" plots. In 2002B, there was also no disease symptom on 392657.8, when "unsprayed". Across seasons, genotypes 393371.58 and 393242.50 had the lowest while 393385.39 and 391011.17 had the highest rAUDPCs in the sprayed and unsprayed plots, respectively (Table 3).

TABLE 2. Weather and soil characteristics of the experimental sites during the growing seasons; 2002A (March – July) and 2002B (September - December)

Site	Altitude	Mean temperature (^{O}C)		Mean Rainfall (mm)		Mean Relative Humidity (%)	
		2002A	2002B	2002A	2002B	2002A	2002B
Kalengyere	(2450m.a.s.l.)	16.3	NA	60.1	NA	84.1	NA
Buginyanya	(1980m.a.s.l.)	19.2	19.0	203.5	140.1	NA	NA

NA = data not available
Source: Meteorology department, Kampala, Uganda

Total tuber yield and yield components. Spraying had no significant (P>0.05) effect on number of tubers per plant during all seasons (except in 2002A at Buginyanya) at both locations. By contrast, the number of tubers was significantly (P<0.05) different among genotypes during all seasons (except 2002B at Buginyanya) at both locations. Consequently, all interactions were not significantly (P>0.05) different except during 2002B at this site. Overall, the sprayed plots at Buginyanya in 2002A had the highest number of tubers per plant (6.2), while the "unsprayed" plots during the same season had the least (4.7) except for Kalengyere 2002B, which gave 7.4 tubers per plant (Table 4).

Similarly, mean tuber weight was not significantly (P>0.05) influenced by spraying in 2002B season at Buginyanya, but was significantly different (P<0.05) among genotypes during all seasons at both locations. The spray x genotype interactions were significant (P<0.001) only during 2002A at Buginyanya, where the third order interaction, i.e, spray treatment x genotype x season interactions were also highly significant (P<0.001). The highest and lowest mean tuber weights were recorded at Buginyanya in the sprayed plots of 2002A (71.2g) and the "unsprayed" plots of 2002B (40.4 g) (Table 5). Victoria, the local susceptible cultivar, had a higher mean tuber weight (81.8 g) than all the

TABLE 3. Relative areas under disease progress curves (AUDPCs) for late blight on 20 potato genotypes and four local cultivars at Kalengyere and Buginyanya during 2002A and 2002B seasons

Genotype	Kalengyere[a]				Buginyanya								
	2002A			2002B	2002A			2002B			Across seasons		
	Sp.	Unsp.	Mean		Sp.	Unsp.	Mean	Sp.	Unsp.	Mean	Sp.	Unsp.	Mean
389746.2	17.1	19.5	18.3	11.0	1.2	2.1	1.7	0.8	1.9	1.4	1.0	2.0	1.5
383382.44	14.8	12.6	13.7	9.8	0.6	11.7	6.1	0.1	1.4	0.8	0.3	6.5	3.4
393371.58	15.8	27.6	21.7	9.7	0.2	10.8	5.5	0.0	0.8	0.4	0.1	5.8	3.0
392657.8	4.5	19.1	11.8	10.7	1.0	11.3	6.1	0.8	0.0	0.4	0.9	5.6	3.3
393339.242	13.7	15.8	14.7	12.4	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393077.54	7.4	13.1	10.2	12.8	0.0	7.1	3.5	1.6	3.5	2.6	0.8	5.3	3.1
392637.10	16.9	34.0	25.4	13.9	1.0	13.3	7.2	0.8	0.1	0.5	0.9	6.7	3.8
393385.39	8.3	9.6	8.9	12.3	8.1	26.7	17.4	0.4	0.9	0.6	4.2	13.8	9.0
Nakpot 4[3]	10.6	12.4	11.5	12.2	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Nakpot 5[3]	12.7	24.0	11.3	16.1	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Victoria[4]	28.5	53.8	41.1	13.5	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Rutuku[4]	13.2	34.3	23.7	11.8	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Kabale[4]	24.4	31.9	28.1	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393349.63	N.E	N.E	N.E	N.E	0.9	15.3	8.1	0.0	0.8	0.4	0.4	8.0	4.2
393385.47	12.8	40.2	26.5	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
385524.9	20.0	38.2	29.1	N.E	1.0	12.5	6.8	0.8	2.8	1.8	0.9	7.5	4.2
391580.30	21.1	45.0	33.0	N.E	1.0	12.5	6.8	5.7	7.9	6.8	3.3	10.2	6.8
391002.6	17.3	25.3	21.3	N.E	0.4	1.0	0.7	2.2	6.4	4.3	1.3	3.7	2.5
392661.18	16.6	44.7	30.6	N.E	0.8	19.2	10.0	2.3	2.0	2.2	1.5	10.6	6.1
393280.57	16.6	14.1	15.3	N.E	0.8	7.5	4.1	0.3	0.3	0.3	0.6	3.9	2.2
391696.96	7.2	35.5	21.4	N.E	5.8	7.5	6.7	0.8	15.4	8.1	3.3	11.5	7.4
391011.17	11.6	10.1	10.8	N.E	1.9	23.3	12.6	2.2	7.9	5.0	2.1	15.6	8.8
393280.64	10.1	27.9	19.0	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393242.50	18.9	47.3	33.1	N.E	0.6	0.8	0.7	0.8	11.9	6.4	0.7	0.9	0.8
393617.54	4.5	12.6	4.5	N.E	0.0	0.4	0.2	2.3	2.0	2.2	0.4	6.1	3.3
Mean	14.3	24.0	20.7	12.2	1.5	10.8	6.12	1.2	3.7	2.46	1.4	7.2	4.29
$SED_{0.05}{}^1$	0.8*			N.A	0.1**			0.9n.s			0.4***		
$SED_{0.05}{}^2$	5.1***			3.7n.s	1.1***			2.5*			1.4***		
$SED_{0.05}{}^3$	7.1*			N.A	1.5***			3.6n.s			1.9***		
$SED_{0.05}{}^4$	N.A			N.A	N.A			N.A			3.0***		
CV%	35.0			37.5	24.4			142.1			77.7		

[a]SED= standard error of difference between means; SED^1= separates spray treatment means; SED^2 = separates means of genotypes; SED^3 = separates spray x genotype interaction means; SED^4 = separates spray x genotype x season interaction means*,**,***= means significantly different at 5%, 1% and 0.1% probability levels respectively; n.s = means not significantly different at 5% probability level; Sp. and Unsp. = Fungicide sprayed and "unsprayed" plots; N.E = not evaluated; N.A = not applicable; 2002A and 2002B = First (March – July) and second (September – December) rains of 2002; C.V = coefficient of variation

Population B3 genotypes in 2002A at Kalengyere. When all the genotypes were given three sprays of Mancozeb, Rutuku, the popular east African resistant cultivar gave the highest mean tuber weight of 164.2 g in 2002B at Kalengyere.

At Kalengyere, only the genotypic differences significantly (P<0.001) affected total yield in the 2002 short season. However, a higher total yield was produced in the sprayed than in the "unsprayed" plots (Table 6). Since the spray treatment and the genotype x spray treatment interaction had no significant effects on total yield, the genotype means across spray treatments will be discussed. Among the Population B3 genotypes, total yield values ranged from 2.5 t ha^{-1} in 393242.50 to 19.4 t ha^{-1} in 393371.58. Among the Population A cultivars, Nakpot 4 yielded higher (23.7 t ha^{-1}) than all Population B3 genotypes, while only two Population B3 genotypes, i.e., 393371.58 (19.4 t ha^{-1}) and 393077.54 (17.4 t ha^{-1}) yielded higher than Nakpot 5 (16.8 t ha^{-1}). Only one Population B3 genotype (393371.58) yielded higher than Victoria (19.1 t ha^{-1}), one of the local cultivars. In the 2002 long season, there were also significant (P<0.001) differences in total yields among genotypes, with values for the Population B3 genotypes ranging from 13.4 t ha^{-1} (393339.242) to 37.2 t ha^{-1} (393382.44) (Table 6). Nakpot 5 yielded significantly higher (51 t ha^{-1}) than all Population B3 genotypes. The local cultivars, namely Rutuku (21.7 t ha^{-1}) and Victoria (26.5 t ha^{-1}), yielded

TABLE 4. Number of tubers per plant for 20 potato genotypes four cultivars at Kalengyere and Buginyanya during 2002A and 2002B seasons

Genotype	Kalengyere[a]				Buginyanya								
	2002A			2002B	2002A			2002B			Across seasons		
	Sp.	Unsp.	Mean		Sp.	Unsp.	Mean	Sp.	Unsp.	Mean	Sp.	Unsp.	Mean
3389746.2	4.4	4.7	4.5	7.2	4.2	3.3	3.7	2.8	6.2	4.5	3.5	4.7	4.1
383382.44	3.9	3.8	3.9	8.9	8.1	4.5	6.3	6.1	6.5	6.3	7.1	5.5	6.3
393371.58	5.8	6.0	5.9	6.7	5.8	4.8	5.3	4.1	2.9	3.5	4.9	3.9	4.4
392657.8	4.2	3.6	3.9	7.6	4.3	3.3	3.8	2.9	3.3	3.1	3.6	3.3	3.5
393339.242	7.2	5.8	6.5	3.9	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393077.54	6.3	5.7	6.0	8.5	8.2	3.9	6.0	4.6	4.0	4.3	6.4	3.9	5.2
392637.10	6.7	6.2	6.4	8.2	8.1	6.2	7.1	6.3	4.7	5.5	7.2	5.4	6.3
393385.39	5.6	6.6	6.1	12.9	9.1	5.2	7.1	6.1	9.7	7.9	7.6	7.4	7.5
Nakpot 4[3]	8.8	9.6	9.2	7.0	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Nakpot 5[3]	4.9	6.1	5.5	8.6	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Victoria[4]	7.8	7.9	7.9	5.5	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Rutuku[4]	4.6	5.0	4.8	3.4	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Kabale[4]	4.8	3.7	4.3	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393349.63	N.E	N.E	N.E	N.E	7.4	3.6	5.5	5.8	3.3	4.5	6.6	3.5	5.0
393385.47	3.3	4.0	3.6	N.E	5.8	2.9	4.3	5.4	5.8	5.6	5.5	4.3	4.9
385524.9	6.7	5.4	6.1	N.E	6.3	6.3	6.3	7.2	8.6	7.9	6.7	7.4	7.1
391580.30	3.6	3.4	3.5	N.E	7.5	4.2	5.8	5.9	5.9	5.9	6.7	5.0	5.9
391002.6	3.4	3.2	3.3	N.E	5.2	4.6	4.9	6.0	5.6	5.8	5.6	5.1	5.3
392661.18	7.7	4.7	6.2	N.E	7.2	5.0	6.1	3.9	3.8	3.8	5.6	4.4	5.0
393280.57	5.7	4.1	4.9	N.E	5.3	6.3	5.8	5.9	5.8	5.9	5.6	6.1	5.8
391696.96	5.1	5.0	5.0	N.E	5.1	5.4	5.2	3.8	6.4	5.1	4.4	5.9	5.2
391011.17	6.3	4.8	5.5	N.E	4.2	5.1	4.6	10.1	4.3	7.2	7.1	4.7	5.9
393280.64	6.2	4.9	5.5	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393242.50	3.1	2.9	3.0	N.E	5.8	2.9	4.3	5.4	5.8	5.6	5.5	4.3	4.9
393617.54	4.8	4.9	4.8	N.E	4.3	5.3	4.8	4.0	5.3	4.6	4.1	5.3	4.7
Mean	5.5	5.1	5.3	7.4	6.2	4.7	5.5	5.3	5.4	5.4	5.8	5.0	5.4
$SED_{0.05}^1$	0.3n.s			N.A	0.1*			0.3n.s			0.1n.s		
$SED_{0.05}^2$	1.1***			0.7**	0.4***			1.6n.s			0.8**		
$SED_{0.05}^3$	N.A			N.A	0.6***			2.3n.s			1.2n.s		
$SED_{0.05}^4$	N.A			N.A	N.A			N.A			1.7n.s		
CV%	28.6			15.4	11.2			43.4			31.5		

[a]SED= standard error of difference between means; SED[1]= separates spray treatment means; SED[2] = separates means of genotypes; SED[3] = separates spray x genotype interaction means; SED[4] = separates spray x genotype x season interaction means*,**,***= means significantly different at 5%, 1% and 0.1% probability levels respectively; n.s = means not significantly different at 5% probability level; Sp. and Unsp. = Fungicide sprayed and „unsprayed" plots; N.E = not evaluated; N.A = not applicable; 2002A and 2002B = First (March – July) and second (September – December) rains of 2002; C.V = coefficient of variation

significantly ($P<0.001$) higher than only three Population B3 genotypes i.e., 393339.242 (13.4 t ha^{-1}), 393077.54 (15.7 t ha^{-1}) and 392637.10 (21.0 t ha^{-1}).

At Buginyanya, there were highly significant differences among genotypes ($P<0.001$), seasons ($P<0.001$), spray x genotype interactions ($P<0.001$), season x genotype interactions ($P = 0.003$) and spray x genotype x season interactions ($P<0.001$), while the spray treatment ($P = 0.417$) and the spray x season interaction ($P = 0.702$) had no significant effects on total yield (Table 6). In the 2002A season, total yield ranged from 7.4 t ha^{-1} and 7.1 t ha^{-1} (393242.50) to 32.1 t ha^{-1} (393382.44) and 31.7 t ha^{-1} (393280.57) for the sprayed and "unsprayed" plots, respectively (Table 6). In the 2002B season, total yields ranged from 3.3 t ha^{-1} (393371.58) and 2.1 t ha^{-1} (393349.63) to 16.1 t ha^{-1} (393349.63) and 15 t ha^{-1} (391002.6) in the sprayed and "unsprayed" plots, respectively. Test genotype 391696.96 (7.3 t ha^{-1} and 5.8 t ha^{-1}) had the lowest yields, while 391002.6 (20.4 t ha^{-1}) and 393280.57 (21.8 t ha^{-1}) had the highest in the sprayed and "unsprayed" plots, respectively when seasons were combined. Across seasons and spray treatments, total yield at Buginyanya

TABLE 5. Mean tuber weight of 20 potato genotypes and four cultivars at Kalengyere and Buginyanya during 2002A and 2002B seasons

Genotype	Kalengyere[a]				Buginyanya								
	2002A			2002B	2002A			2002B			Across seasons		
	Sp.	Unsp.	Mean		Sp.	Unsp.	Mean	Sp.	Unsp.	Mean	Sp.	Unsp.	Mean
389746.2	71.3	48.1	59.7	107.5	131.2	64.7	97.9	42.0	22.2	32.1	86.6	43.4	65.0
383382.44	75.6	68.7	72.2	90.9	77.6	41.2	59.4	26.7	28.8	27.8	52.2	35.0	43.6
393371.58	94.3	64.9	79.6	120.0	86.2	56.9	71.5	30.6	39.6	35.1	58.4	48.3	53.3
392657.8	82.2	67.8	76.0	93.5	72.2	65.2	68.7	48.6	28.1	38.3	60.4	46.6	53.5
393339.242	54.4	48.3	51.3	87.2	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393077.54	67.1	60.9	64.0	82.7	71.8	65.4	68.6	56.5	36.5	46.5	64.1	51.0	57.5
392637.10	50.4	68.6	59.5	55.7	33.4	98.2	65.8	39.3	36.7	38.0	36.4	67.5	51.9
393385.39	82.3	36.2	59.2	55.1	48.7	83.5	66.1	57.6	37.2	47.4	53.1	60.3	56.7
Nakpot 4[3]	54.7	61.3	58.0	112.5	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Nakpot 5[3]	82.9	57.8	70.4	122.5	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Victoria[4]	129.4	34.1	81.8	107.6	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Rutuku[4]	67.8	58.3	63.1	164.2	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Kabale[4]	71.3	54.6	62.9	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393349.63	N.E	N.E	N.E	N.E	41.9	113.1	77.5	82.9	45.0	64.0	62.4	79.1	70.7
393385.47	69.4	31.6	50.5	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
385524.9	46.7	37.1	41.9	N.E	38.6	33.3	36.0	23.9	26.3	25.1	31.2	29.8	30.5
391580.30	69.0	49.0	59.0	N.E	51.7	80.7	66.2	39.7	46.1	42.9	45.7	63.4	54.6
391002.6	63.7	45.9	54.8	N.E	105.8	66.3	86.1	61.9	58.1	60.0	83.8	62.2	73.0
392661.18	39.7	21.5	30.6	N.E	43.7	55.5	49.6	40.3	51.4	45.8	42.0	53.5	47.7
393280.57	53.2	44.6	48.9	N.E	44.3	105.6	75.0	42.5	66.4	54.4	43.4	86.0	64.7
391696.96	39.2	19.4	29.3	N.E	44.3	36.1	40.2	40.1	38.0	39.0	42.2	37.0	39.6
391011.17	38.5	41.8	40.2	N.E	63.5	89.1	76.3	36.9	42.8	39.9	50.2	66.0	58.1
393280.64	37.3	51.9	44.6	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393242.50	31.6	11.1	21.4	N.E	25.9	51.7	38.3	42.7	41.7	42.2	34.3	46.7	40.5
393617.54	62.2	50.8	56.5	N.E	87.5	103.2	95.3	41.3	41.7	41.5	64.4	72.4	68.4
Mean	63.9	47.3	55.6	100	71.2	62.8	67.0	44.3	40.4	42.3	53.6	55.8	54.7
$SED_{0.05}^{1}$	6.8n.s			N.A	2.3n.s			0.2*			1.2n.s		
$SED_{0.05}^{2}$	14.8*			11.4***	5.9***			8.4**			5.4***		
$SED_{0.05}^{3}$	N.A			N.A	8.4***			11.5n.s			7.5***		
$SED_{0.05}^{4}$	N.A			N.A	N.A			N.A			10.5***		
CV%	37.5			14.0	12.5			28.0			19.1		

[a]SED= standard error of difference between means; SED[1]= separates spray treatment means; SED[2] = separates means of genotypes; SED[3] = separates spray x genotype interaction means; SED[4] = separates spray x genotype x season interaction means*,**,***= means significantly different at 5%, 1% and 0.1% probability levels respectively; n.s = means not significantly different at 5% probability level; Sp. and Unsp. = Fungicide sprayed and „unsprayed" plots; N.E = not evaluated; N.A = not applicable; 2002A and 2002B = First (March – July) and second (September – December) rains of 2002; C.V = coefficient of variation

ranged from 6.5 t ha^{-1} (391696.96) to 17.5 t ha^{-1} (391002.6).

DISCUSSION

According to Hakiza *et al.* (2000) and Olanya *et al.* (2001), the introduction of late blight susceptible potato varieties around 1900 is closely linked with the late blight epidemic in sub-Saharan Africa. Potato late blight is not a new phenomenon in Uganda and has been a problem since the introduction of potato into the country in the early 1900s (Akimanzi, 1982). As a result, several attempts towards identifying resistant varieties have been made, resulting in the release of several varieties with resistance to late blight (Kakuhenzire *et al.*, 1999; Hakiza *et al.*, 2000), most of which have now succumbed to the disease (Kankwatsa *et al.*, 2002).

Findings from the present study have shown that Population B3 genotypes consistently performed better when given two additional fungicide sprays compared with only one prophylactic spray ("unsprayed plots"). The reduction in late blight severities due to spraying, however, depended on the genotype. At Kalengyere 2002A, for example, late blight severities were more than halved by spraying on 393242.5 (60.0%), Rutuku (61.5%) and 391696.96 (79.7%). In a few cases, however, the sprayed plots had higher rAUDPCs than the "unsprayed" plots; examples include 391011.17 and 393280.57

TABLE 6. Tuber yield of 20 potato genotypes and four cultivars at Kalengyere and Buginyanya during 2002A and 2002B seasons

Genotype	Kalengyere[a]				Buginyanya								
	2002A			2002B	2002A			2002B			Across seasons		
	Sp.	Unsp.	Mean		Sp.	Unsp.	Mean	Sp.	Unsp.	Mean	Sp.	Unsp.	Mean
389746.2	13.8	10.5	12.1	28.5	25.0	10.0	17.5	3.6	3.1	3.3	14.3	6.5	10.4
383382.44	12.6	11.1	11.8	37.2	32.1	8.8	20.5	5.5	5.2	5.4	18.8	7.0	12.9
393371.58	20.7	18.1	19.4	37.1	23.8	11.9	17.9	3.3	3.6	3.5	13.6	7.7	10.7
392657.8	15.4	11.1	13.2	30.8	13.5	10.2	11.9	6.6	3.3	5.0	10.1	6.8	8.4
393339.242	16.0	12.9	14.4	13.4	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393077.54	19.6	15.1	17.4	15.7	27.9	13.6	20.7	9.3	6.0	7.6	18.6	9.8	14.2
392637.10	15.6	13.9	14.8	21.0	12.9	26.2	19.5	12.3	6.2	9.3	12.6	16.2	14.4
393385.39	20.6	10.1	15.4	27.1	15.7	20.5	18.1	9.1	4.4	6.8	12.4	12.5	12.4
Nakpot 4[3]	21.9	25.5	23.7	30.0	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Nakpot 5[3]	18.8	14.8	16.8	51.1	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Victoria[4]	25.6	12.6	19.1	26.5	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Rutuku[4]	13.3	13.9	13.6	21.7	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
Kabale[4]	16.3	8.9	12.6	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393349.63	N.E	N.E	N.E	N.E	15.0	18.6	16.8	16.1	2.1	9.1	15.6	10.4	13.0
393385.47	8.5	5.5	7.0	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
385524.9	13.0	8.8	10.9	N.E	11.9	9.5	10.7	3.6	4.8	4.2	7.7	7.1	7.4
391580.30	9.8	6.7	8.2	N.E	18.2	16.0	17.1	11.0	11.4	11.2	14.6	13.7	14.1
391002.6	8.6	6.6	7.6	N.E	26.0	14.4	20.2	14.8	15.0	14.9	20.4	14.7	17.5
392661.18	13.1	4.3	8.7	N.E	15.0	12.9	13.9	5.0	6.4	5.7	10.0	9.6	9.8
393280.57	12.5	7.2	9.8	N.E	8.2	31.7	19.9	8.8	11.9	10.3	8.5	21.8	15.1
391696.96	5.6	3.2	4.4	N.E	10.5	9.3	9.9	4.1	2.4	3.2	7.3	5.8	6.5
391011.17	9.9	8.5	9.2	N.E	12.4	21.4	16.9	11.1	5.5	8.2	11.7	13.5	12.6
393280.64	8.2	10.2	9.2	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E	N.E
393242.50	3.7	1.3	2.5	N.E	7.4	7.1	7.3	9.3	9.5	9.4	8.3	8.3	8.3
393617.54	13.6	10.8	12.2	N.E	18.1	26.1	22.1	10.2	9.5	9.9	14.2	17.9	16.0
Mean	14.0	10.5	12.3	28.4	17.3	15.8	16.5	8.4	6.5	7.5	12.9	11.1	12.0
$SED_{0.05}$[1]	0.4n.s			N.A	0.1*			2.5n.s			1.3n.s		
$SED_{0.05}$[2]	2.0**			5.3***	1.9***			2.7**			1.8***		
$SED_{0.05}$[3]	2.8n.s			N.A	2.7***			4.5n.s			2.7***		
$SED_{0.05}$[4]	N.A			N.A	N.A			N.A			3.7***		
CV%	23.0			22.9	16.6			51.2			28.8		

[a]SED= standard error of difference between means; SED[1]= separates spray treatment means; SED[2] = separates means of genotypes; SED[3] = separates spray x genotype interaction means; SED[4] = separates spray x genotype x season interaction means*,**,***= means significantly different at 5%, 1% and 0.1% probability levels respectively; n.s = means not significantly different at 5% probability level; Sp. and Unsp. = Fungicide sprayed and „unsprayed" plots; N.E = not evaluated; N.A = not applicable; 2002A and 2002B = First (March – July) and second (September – December) rains of 2002; C.V = coefficient of variation

in which late blight severities increased by 12.9% and 15.1%, respectively.

In general, however, higher late blight severities were recorded at Kalengyere than at Buginyanya, where higher disease severities were recorded during the 2002A season than in 2002B, probably due to late planting in the 2002B season, which coincided with more conducive weather conditions for late blight development. However, reductions in late blight severities due to spraying were greater at Buginyanya than at Kalengyere. For example, there was a reduction of over 90% on all Population B3 genotypes except 389746.2 (42.9%), 391002.60 (60%), 393280.57 (53.5%), 391696.96 (22.7%) and 393242.50 (25%). The lower disease levels at Buginyanya than at Kalengyere may be due to the differences in weather conditions at these sites. Higher rainfall and relative humidity as well as lower average temperature conditions prevailed at Kalengyere Research Station in comparison to Buginyanya (Table 2). Higher late blight severities in south-western Uganda (Kabale district) compared to other potato agro-ecologies have been reported in other studies (Mukalazi *et al.*, 2001; Ochwo *et al.*, 2001). Severe late blight epidemics have been reported to occur during periods characterised by heavy rains, presence of moisture on potato leaves that extends for at least 8-10 day hours for several consecutive days, cool temperatures (<20°C) and high relative humidity (>80%) (Harris, 1992; Low, 1997). The other explanation for the higher disease levels at Kalengyere than at Buginyanya is the all-year-round potato cultivation at the former, since it is the major location for potato research and multiplication in the country; thus there is a steady source of disease inoculum that favours early disease development and spread.

Applying two fungicide sprays over and above the single prophylactic spray, did not significantly affect yield components except total yield in 2002A at Buginyanya and marketable yield at Kalengyere in 2002A. However, the genotypic effects on the yield and all the yield components (except on the number of tubers per plant in 2002B at Buginyanya) were highly significant (P<0.001) at both locations. These results may imply that number of tubers per plant is less affected by disease and other factors; the biotic and abiotic constraints probably interfere with sink assimilation (Hay and Walker, 1989). Although spraying did not significantly increase yields, almost all genotypes gave higher yields when sprayed, the benefit being higher with the more susceptible varieties. These results confirm earlier findings of better benefits accruing from spraying susceptible than resistant cultivars (Kankwatsa *et al.*, 2002). On the other hand, the lack of a significant effect of fungicide spray treatments on yield is probably because the Population B3 genotypes contain sufficient resistance to withstand losses even though late blight symptoms may appear. The appearance of late blight symptoms on Population B3 genotypes implies that the resistance contained in these genotypes may reduce the likelihood of emergence of more aggressive strains of the pathogen, as has been the case in the past (Deahl *et al.*, 1995).

Interestingly, some genotypes, especially those in population B3, actually yielded better in the "unsprayed" than in the sprayed plots. For example, at Kalengyere in the 2002A season, 393280.64 yielded 8.2 t ha^{-1} in the sprayed compared to 10.2 t ha^{-1} in the "unsprayed" plots, while 392637.10 and 393617.54 yielded 12.9 and 18.1 t ha^{-1} in the sprayed plots compared to 26.2 t ha^{-1} and 26.1 t ha^{-1} in the "unsprayed" plots, respectively, at Buginyanya in the 2002A season. The lower yields in these sprayed plots may be due to the phytotoxic effect of the fungicide (Mancozeb) on resistant genotypes. Detrimental effects of Mancozeb on resistant soybean varieties have been reported in Uganda by Kawuki *et al.* (2002) who found Mancozeb-sprayed soybean resistant varieties yielding lower than un-protected plants. This observation further demonstrates the superiority of host plant resistance over all other options in the management of fungal diseases.

Population B3 entries 389746.2, 383382.44, 393371.58, 392637.10, 391002.6, 393349.63, 393617.18, 391011.17, 391580.30, 393385.39, 393339.242, 393077.54, 393280.64 and 392657.8 performed well and could be considered for on-farm trials.

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