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YIELD STABILITY ANALYSIS OF LATE BLIGHT RESISTANT POTATO SELECTIONS

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SUMMARY

Potato is an important source of food and income in the highlands of East Africa. Identification of superior genotypes for improved agronomic characteristics will enhance tuber yield. Seven promising clones from population B potato selections (quantitative resistance to late blight) obtained from the International Potato Center, two genotypes from population A (qualitative resistance) and three control cultivars were evaluated for three cropping seasons at four locations in western Uganda in order to determine performance and yield stability. The additive main effects and multiplicative interactive (AMMI) model was used for the analysis. The analysis of variance of yield data for genotypes × locations, genotypes × seasons and genotypes × locations × seasons was significant ($p < 0.05$) showing the variable response of genotypes and the need for stability analysis. The AMMI statistical model showed that the most stable genotypes were 392618.250 (B5) and 392127.270 (B6) (high yield) and 392618.256 (B1), 391049.255 (B2) and 392127.256 (B7) (low yield) and had negligible interactions with the environments. Across environments, the ranking of genotypes for tuber yield was not consistent. The clones 381471.18 (A2), 387121.4 (A1) and cultivar Victoria had high average yields, but these yields were below average in a few environments. Selective deployment of cultivars can improve tuber yield in the highland tropics.

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INTRODUCTION

Potato (*Solanum tuberosum*) is an important food and cash crop in the highlands of East Africa, and a highly preferred food in urban areas (Low, 1997). Current production of the crop in Uganda is estimated to average only 8.0 t ha^{-1}. This is low compared to average tuber yields of more than 25 t ha^{-1} recorded at research stations in Uganda. The low yields are attributed to a number of biotic and abiotic factors, which include cultivation of low yielding cultivars, high cost of agro-inputs, poor crop management, pests and diseases (Hakiza *et al.*, 1999). The most important diseases include bacterial wilt (*Ralstonia solanacearum*) and late blight (*Phytophthora infestans*) (Hakiza *et al.*, 1999). The development of potato cultivars with high and stable tuber yield, with durable disease resistance to various pests, is an important component of the research activity of

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the National Potato Programmes in Uganda and other sub-Saharan African countries (Hakiza *et al.*, 1999).

The potato programme in Uganda in collaboration with the International Potato Center (CIP) is evaluating genotypes for disease resistance and yield performance as part of their cultivar development process. The breeding programme at CIP has developed some advanced potato clones with horizontal or quantitative resistance to late blight and improved agronomic characteristics (Population B) (Landeo *et al.*, 1995). However, the yield performance and adaptation of the clones to tropical Africa are not known. Three hundred cohorts of population B germplasm were introduced from CIP for evaluation for yield attributes, late blight resistance and adaptation under mid and high altitude conditions (1800 to 2300 m asl) at Kalengyere in southwestern Uganda for four years. This resulted in the identification of seven elite population B potato genotypes with good yields and generally acceptable agronomic characteristics. Due to the increase in potato cultivation in this region, yield stability and clonal adaptation across many environments are important evaluation criteria for improved crop production. Similarly, yield adaptation and stability over seasons and sites are important components of cultivar registration (Lung'aho *et al.*, 2006).

In previous research, it has been shown that identification of superior genotypes is complicated by genotype × environment (G × E) interaction (Eberhart and Russell, 1966). Analysis of G × E interactions and estimation of phenotypic yield stability has been done for many cropping systems (Cooper *et al.*, 1996; Crossa *et al.*, 1990; Eberhart and Russell, 1966). Similar discussions on phenotypic stability and methods for estimation of G × E interaction parameters have been outlined (Steyn, 1993). In addition to the above, the reaction of cultivars to disease pressure can affect genotype stability (Mulema *et al.*, 2004/5). Resistant materials are more stable and susceptible ones less so.

In this study, a multivariate technique known as the additive main effects and multiplicative interaction (AMMI) analysis was used. This combines the analysis of variance (ANOVA) of genotype by environment main effects, principal component analysis and the interaction of G × E into a unified approach (Gauch, 1989; Gauch and Zobel, 1990). This paper complements a publication on stability of late blight resistance in potato selections using the same experimental material and locations (Mulema *et al.*, 2004). The objective of this study, therefore, was to determine the yield performance and to assess the yield stability of seven elite late blight resistant population B potato selections across a range of environments (seasons and locations) in Uganda using the AMMI statistical model.

MATERIALS AND METHODS

The experiments were conducted at four locations: Buginyanya in eastern Uganda and Kachwekano, Kalengyere and Mbarara, all in southwestern Uganda. The altitudes at the test locations were 2000, 2200, 2450 and 1524 m asl respectively. The characteristics of these sites are listed in Table 1. The experiments were carried out during three cropping seasons which coincided with the long rains of 2001 (2001B) and 2002 (2002B) from September to February, and short rains of 2002 (2002A)

Table 1. Site characteristics and meteorological parameters of the locations used in the study on yield stability in Uganda[†].

	Buginyanya	Kachwekano	Kalengyere	Mbarara
Site characteristics				
Altitude (m asl)	2000	2200	2460	1524
Latitude	01°06′N	01°16′S	01°15′S	0°37′N
Longitude	34°11′E	29°57′E	29°45′E	30°39′E
Soil temperature	Isomesic	Isothermic	Isothermic	Isothermic
Soil moisture	Udic	Udic	Udic	Ustic
Soil type	Lithic Hapludand	Haplohumults	Haplohumults	Palehumults
Climate characteristics[‡]				
2001B				
Rainfall (mm)	574	846	788	463
Min. temp. (°C)	13.2	11.8	11.1	15.5
Max. temp (°C)	25.5	23.9	20.4	26.3
2002A				
Rainfall (mm)	490	209	304	326
Min. temp. (°C)	13.5	12.1	11.3	15.8
Max. temp (°C)	25.0	24.6	21.2	27.0
2002B				
Rainfall (mm)	694	695	668	386
Min. temp. (°C)	13.7	11.9	11.3	15.5
Max. temp (°C)	24.3	24.1	21.6	26.6

[†]Buginyanya, Kachwekano, Kalengyere and Mbarara are the locations where the study was conducted.
[‡]2001A cropping season is from March to July, the 2001B and 2002B seasons are from October to January.

from March to July. The same trials were repeated at all the experimental sites. The seven population B genotypes tested were: 392618.256 (B1), 391049.255 (B2), 392144.250 (B3), 392170.250 (B4), 392618.250 (B5), 392121.270 (B6) and 392127.256 (B7). Two advanced clones from population A (387121.4 (A1) and 381471.18 (A2)) were also included. In addition, the cultivars Kabale (susceptible to late blight), Victoria (moderately resistant) and Rutuku (resistant) were included as controls. The cultivars Kabale and Victoria (381381.13) are commonly grown in southwestern Uganda and are derived from Population A (Kakuhenzire *et al.*, 1999). Rutuku (720097), derived from an ex-Mexican potato clone is used as a late blight resistant control in East Africa (Lung'aho *et al.*, 2006).

The experiments were established in a randomized complete block design with three replications. Each plot consisted of 60 tubers of the test genotype planted at 70 cm between rows and 30 cm within rows. Four rows each 4.5m long were used. Plots were separated by 1 m wide alleys planted with barley. The field plots were subjected to normal agronomic and cultural practices such as field and seedbed preparation, weeding and hilling. Fertilizers NPK (17:17:17) were also applied at the rate of 500 kg ha^{-1}. Pest control consisted of the application of an insecticide (metasystox) for the control of aphids and leafhoppers. No attempt was made to control late blight with fungicides since yield stability under late blight pressure was the subject of investigation. At natural maturity, tubers from the whole trial were harvested immediately and weighed to determine tuber yield (kg). Total tuber yield (kg) was subsequently converted to mean tuber yield per unit area (t ha^{-1}).

Table 2. Analysis of variance on tuber yield (t ha^{-1}) of twelve potato genotypes grown at four locations during three cropping seasons.

Source of variation	*d.f.*	Mean squares	$p > F$
Locations	3	14265	0.001
Seasons	2	12636	0.023
Locations × seasons	6	4378.82	0.004
Reps (locations × seasons)	24	10.23	0.458
Genotypes	11	1706.32	0.01
Locations × genotypes	33	554.26	0.03
Seasons × genotypes	22	545.21	0.046
Locations × seasons × genotypes	66	200.08	0.001
Error	264	66.02	

Data on yield were then subjected to analysis of variance (ANOVA) using the General Linear Model procedure of the Statistical Analysis System (SAS, 1995). The means and least significant differences were calculated. In this model, genotypes were designated fixed effects, while locations, seasons and replications were considered to be random effects. Yield data were also subjected to additive main effects and multiplicative interaction analysis using Matmodel 2.0 (Gauch, 1989). The additive main effects for yields of potato genotypes and environments were determined by the analysis of variance procedure. The multiplicative effects of G × E interactions were assessed by principal component analysis (PCA). The AMMI model was calculated as follows:

$$Y_{ge} = \mu + \alpha_g + \beta e + \Sigma_n \lambda_n \gamma_{gn} \delta_{en} + \rho_{ge}$$

Where Y_{ge} = observed yield of genotype g in environment e; μ = grand mean; α_g = deviation of the genotype g from the grand mean; β_e = deviation of environment e from the grand mean; λ_n = square root of the eigenvalues; γ_{gn} = PCA scores for genotypes; δ_{en} = PCA scores for environment e; n = number of PCA axes retained in the model and ρ_{ge} = the residual.

RESULTS

Tuber yield

Variation in tuber yield was recorded among genotypes, locations and cropping seasons, but the differences between locations and seasons were not significant when tested against the locations × seasons interaction, which was significant. The interactions of genotypes × locations, genotypes × seasons and genotypes × locations × seasons were significant ($p<0.05$) for yield (Table 2). Among the cropping seasons, the highest yield was recorded during 2002B (40.3 t ha^{-1}), followed by 2001B (29.2 t ha^{-1}) with 2002A (21.7 t ha^{-1}) having the lowest yield (Table 3). Among the test locations, yield was highest at Kalengyere in 2001B (50.2 t ha^{-1}) and 2002A (43.3 t ha^{-1}) whereas the highest yield was recorded at Kachwekano in 2002B (52.3 t ha^{-1}). When comparisons of tuber yield among genotypes were made across the cropping

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Table 3. Total tuber yield (t ha^{-1}) of 12 potato genotypes grown at four locations during three cropping seasons in Uganda.

	Cropping seasons															
	2001B††					2002A††					2002B††					
Genotypes†	Bug	Kac	Kal	Mba	Mean	Bug	Kac	Kal	Mba	Mean	Bug	Kac	Kal	Mba	Mean	Mean
B1	27.1	17.0	48.0	28.6	30.2	33.0	9.7	50.5	0.8	24.1	28.9	45.0	29.3	18.1	30.3	28.2
B2	25.9	5.5	39.7	18.7	22.5	23.8	10.2	31.9	2.2	17.0	34.9	24.9	36.0	17.1	28.2	22.6
B3	21.3	7.2	20.0	19.7	17.1	25.6	11.2	21.6	4.2	15.6	31.8	64.0	28.2	29.5	38.4	23.7
B4	20.3	17.1	31.9	19.5	22.2	28.3	9.2	30.3	4.6	18.1	50.2	70.4	37.8	19.1	44.4	28.2
B5	25.6	11.7	56.1	19.8	28.3	32.4	15.9	56.0	6.0	27.6	51.6	52.9	53.5	19.2	44.3	33.4
B6	27.7	9.0	64.1	26.1	31.7	44.4	20.5	41.8	5.1	28.0	52.1	53.5	52.5	20.9	44.7	34.8
B7	9.1	20.2	42.4	17.8	22.4	34.8	11.4	32.5	1.9	20.2	32.1	32.8	15.3	22.3	25.6	22.7
A1	33.8	41.1	87.0	36.6	49.6	30.5	14.5	59.0	2.9	26.7	31.6	51.9	62.4	30.3	44.0	40.1
A2	22.9	47.5	83.5	41.3	48.8	17.4	17.5	53.4	6.7	23.8	60.3	75.7	56.8	54.2	56.8	43.1
Kabale‡	18.5	7.6	60.5	18.1	26.2	2.9	8.1	35.8	0.8	11.9	42.5	48.7	63.8	17.7	48.2	27.1
Victoria§	34.8	19.3	19.8	27.9	25.3	39.5	13.7	47.3	4.5	26.3	70.3	64.0	56.7	26.2	54.3	35.3
Rutuku¶	13.4	11.2	49.7	22.1	24.1	12.2	13.0	59.7	1.8	21.7	11.4	44.4	23.5	39.7	29.8	25.2
Grand mean	23.3	17.9	50.2	24.7	29.2	27.1	12.9	43.3	3.7	21.7	41.5	52.3	43.0	24.5	40.3	30.4
s.e.d.	4.6	2.1	6.8	5.7	5.6	5.5	3.6	9.0	1.8	5.9	8.7	8.2	7.3	6.1	8.0	6.6
C.V. (%)‡‡	24.0	14.7	16.7	28.1	23.7	24.7	34.3	25.4	59.0	33.5	25.6	19.3	20.8	30.6	24.5	26.8

Bug, Kac, Kal, and Mba refer to Buginyanya, Kachwekano, Kalengyere and Mbarara.

†Advanced clones used in the study: Population A genotypes = A1 (387121.4), A2 (381471.18); Population B genotypes = B1 (392618.256), B2 (391049.255), B3 (392144.250), B4 (392170.250), B5 (392618.250), B6 (392127.270), B7 (392127.256).

‡Susceptible.

§Moderately resistant.

¶Resistant check.

††The cropping seasons were: 2001B and 2002B refer to the second cropping season (October–January); and 2002A refers to the first cropping season (March–July).

‡‡C.V.: Coefficient of variation.

Table 4. Combined additive, multiplicative interaction and analysis of variance for tuber yield of twelve potato genotypes grown at four locations and three cropping seasons.

Source of variation	*d.f.*	Sum of squares	Mean squares	
Treatment	143	156904.3	1097.2	***
Genotype	11	18770.1	1706.4	***
Environment	11	94643.6	8603.9	***
G × E	121	43490.6	359.4	***
IPCA 1	21	17432.5	830.1	***
Residual G × E	100	26058.1	260.6	***
Error (includes reps)	288	189027.6	65.6	
Total	431	175806.9	407.9	

***Significant at $p < 0.001$ probability level

seasons, the genotypes 381471.18 (A2) and 387121.4 (A1) had mean yields of 43.1 and 40.1 t ha^{-1}, respectively. The yield of population B clones ranged from 22.6 to 34.8 t ha^{-1}. Low yields of 22.6 and 22.7 t ha^{-1} were recorded for clones 391049.255 (B2) and 392127.256 (B7), respectively. Yields of population B genotypes were comparable to Rutuku, a late blight resistant control cultivar. Generally population A genotypes 381471.18 (A2) and 387121.4 (A1) had high yields at all locations during the three seasons.

Yield stability across environments

The analysis of variance for tuber yield across locations and seasons resulted in significant differences in the interactions of genotypes × environments (Table 4). Based on the components of variance (which were estimated from the mean squares), the proportion of the environment and G × E interaction variation was much larger than that due to genotype main effects (components were 229, 98 and 37, respectively). The AMMI analysis indicated that the treatment sum of squares was partitioned into genotypes (11), environments (11), G × E due to IPCA1 (21) and residual G × E (100) degrees of freedom (Table 4). The second principal component was not significant when tested against the residual G × E.

There were differences in the ranking of genotypes within environments when the predictions from the AMMI model were compared with the observed yields (Table 5). In four out of 12 environments (E6, E8, E9 and E12), prediction of genotypes with high tuber yield based on the AMMI model varied. However, the prediction of the best yielding genotypes within environments by the AMMI model was 50 % accurate. For example, our results predicted that the potato genotype 381471.18 (A2) would have the highest rank in yield in six environments, compared with three in practice, while 387121.4 (A1) would have the best yield in two environments, compared with one in practice (Table 5). Among the population B clones, genotypes 392127.270 (B6) and 392618.250 (B5) had above average yields in many environments.

Figure 1 illustrates yield of the potato selections in the various environments. The genotypes or environments with large PCA1 scores (negative or positive) indicated

Table 5. Ranking of genotypes based on AMMI-1 estimates and observed means (in parenthesis) for tuber yield (t ha^{-1}) of 12 potato genotypes grown in 12 environments

	Genotypes[‡]											
Environment[†]	B1	B2	B3	B4	B5	B6	B7	A1	A2	Kabale	Victoria	Rutuku
E1	7 (4)	11 (5)	8 (8)	6 (9)	5 (6)	4 (3)	10 (12)	3 (2)	2 (7)	9 (10)	1 (1)	12 (11)
E2	8 (4)	9 (9)	6 (8)	2 (7)	5 (5)	4 (1)	10 (3)	7 (6)	3 (10)	11 (12)	1 (2)	12 (11)
E3	7 (11)	9 (7)	4 (9)	2 (5)	6 (4)	3 (3)	10 (8)	8 (10)	5 (2)	11 (6)	1 (1)	12 (12)
E4	7 (6)	11 (12)	12 (11)	9 (5)	4 (7)	3 (9)	10 (3)	2 (2)	1 (1)	5 (10)	8 (4)	6 (8)
E5	7 (10)	12 (9)	9 (8)	6 (11)	5 (3)	4 (1)	11 (7)	3 (4)	1 (2)	8 (12)	2 (5)	10 (6)
E6	8 (9)	10 (12)	6 (3)	4 (2)	5 (6)	3 (5)	11 (11)	7 (7)	2 (1)	9 (8)	1 (4)	12 (10)
E7	7 (7)	9 (9)	12 (11)	10 (10)	5 (5)	6 (3)	8 (8)	1 (1)	2 (2)	4 (4)	11 (12)	3 (6)
E8	7 (5)	11 (10)	12 (12)	10 (11)	4 (3)	3 (7)	9 (9)	1 (2)	2 (4)	5 (8)	8 (6)	6 (1)
E9	6 (9)	11 (8)	12 (10)	9 (7)	4 (5)	3 (6)	10 (12)	2 (2)	1 (3)	7 (1)	5 (4)	8 (11)
E10	6 (3)	11 (10)	12 (8)	8 (9)	4 (7)	3 (5)	10 (12)	2 (2)	1 (1)	7 (11)	5 (4)	9 (6)
E11	7 (7)	11 (9)	8 (6)	6 (4)	5 (2)	4 (3)	10 (10)	3 (8)	1 (1)	9 (12)	2 (5)	12 (11)
E12	6 (10)	12 (12)	10 (4)	7 (9)	5 (8)	4 (7)	11 (6)	2 (3)	1 (2)	8 (11)	3 (5)	9 (1)

[†]E1-Buginyanya 2001B, E2-Buginyanya 2002A, E3-Buginyanya 2002B, E4-Kachwekano 2001B, E5- Kachwekano 2002A, E6- Kachwekano 2002B, E7-Kalengyere 2001B, E8-Kalengyere 2002A, E9-Kalengyere 2002B, E10-Mbarara 2001B, E11-Mbarara 2002A, E12-Mbarara 2002B.

[‡]The genotypes are represented by: B1-392618.256, B2-391049.255, B3-392144.250, B4-392170.250, B5-392618.250, B6-392127.270, B7-392127.256, A1-387121.4, A2-381471.18 respectively.

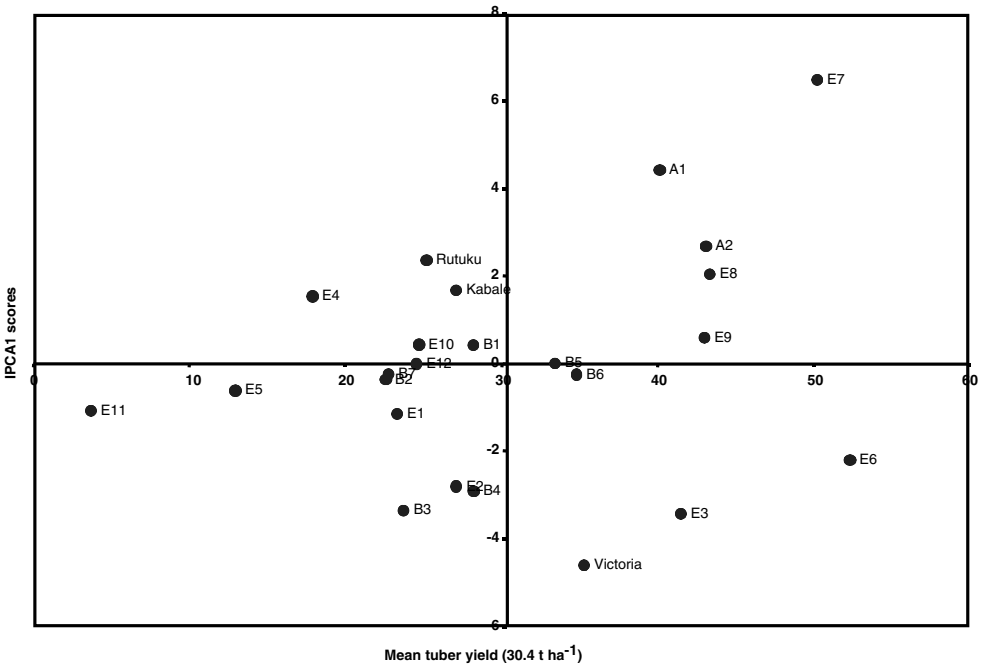

Figure 1. Plot of unadjusted mean tuber yield (t ha^{-1}) and AMMI interaction with (IPCA1) scores for twelve potato genotypes evaluated at four locations and three cropping seasons. The average tuber yield of potato clones from 3.65 to 52.34 t ha^{-1} are plotted on the x-axis), while the principal component analysis scores (IPCA1) are plotted from −4.59 to 6.49 on the y-axis. The variable along the x-axis reflect differences in the main effects, and the values along the y-axis show differences in the interaction effects. The genotypes to the right side of the mid-point are classified as high yield potential, and those to the left side as low yield potential. The designations for the genotypes are: B1-392618.256, B2-391049.255, B3-392144.250, B4-392170.250, B5-392618.250, B6-392127.270, B7-392127.256, A1-387121.4, A2-381471.18. The environments are represented by: E1-Buginyanya 2001B, E2-Buginyanya 2002A, E3-Buginyanya 2002B, E4-Kachwekano 2001B, E5-Kachwekano 2002A, E6-Kachwekano 2002B, E7-Kalengyere 2001B, E8-Kalengyere 2002A, E9-Kalengyere 2002B, E10-Mbarara 2001B, E11-Mbarara 2002A, E12-Mbarara 2002B.

high interactions, while the genotypes with low or PCA scores near zero resulted in small interactions. The clones 392618.256 (B1), 391049.255 (B2), 392618.250 (B5) and 392127.270 (B6) had negligible interactions with the environments, with 392127.270 (B6) being the most stable genotype. Entries 392170.250 (B4) and 392144.250 (B3) were unstable but were more adapted to Buginyanya 2002 while 381471.18 (A2) was better adapted to Kalengyere 2002. Entries 392618.250 (B5), 391049.255 (B2) and 392127.256 (B7) were better adapted to Mbarara 2001B and Mbarara 2002B.

DISCUSSION

In this research, population A and population B genotypes were assessed for yield performance in replicated trials. Yields varied between locations and across seasons. The clone 381471.18 (A2) had the highest yield (43.1 t ha^{-1}), while the lowest yield (22.6 t ha^{-1}) was recorded from clone 391049.255 (B2). Tuber yields of population

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A clones were generally higher than those for population B clones. The variation in yield may be due to the differences in genotype response and resistance to late blight, a significant disease constraint on potato in this region. In general, late blight severity varied across locations and genotypes (Mulema *et al.*, 2004). The genotype response to disease may have accounted for some of the observed variation in yield recorded. The highest yielding clone A2 also had the best disease resistance, but the susceptible control, Kabale, had the same yield as the resistant control, Rutuku. Furthermore, the two most stable and high yielding B clones (B5 and B6) were not the most stable and best for disease resistance (Landeo *et al.*, 1995; Mulema *et al.* 2004/5; Olanya *et al.*, 2006).

Seasonal variation in tuber yield was recorded. Potato tuber yield was considerably lower in 2002A than in the 2001B and 2002B cropping seasons. This may be explained by the low rainfall and prolonged dry weather or water stress recorded in 2002A compared to the evenly distributed and adequate rainfall recorded in 2001B and 2002B cropping seasons. In 2002A, Mbarara was a very low yielding environment and Kalengyere was a high yielding environment, where the rainfall was less. The lack of rainfall may have impacted on tuber bulking and consequently tuber yield to some extent. Previous research has indicated that inadequate water during the critical periods of tuber bulking may lead to low tuber yield and quality defects (Martin *et al.*, 1992).

The variation in tuber yield could be attributed in part to late blight severity. Based on our previous publication (Mulema *et al.*, 2004), we recorded variable late blight levels among genotypes and across seasons and locations. There was a negative and significant correlation coefficient for late blight severity and total tuber yield ($r = -0.14$, $p < 0.004$), and late blight severity and marketable yield ($r = -0.17$, $p < 0.001$) (data not shown), suggesting that some of the variations in tuber yield could be attributed to late blight severity. It is apparent, therefore, that yield stability is related to late blight stability, since the two clones (381471.18 and 387121.4) with the most stability for late blight resistance identified in the previous publication were also among the most stable genotypes for yield.

Variation in yield was detected among potato genotypes across testing locations and seasons, and there were significant interactions of genotypes × locations × seasons. These interactions imply the differential yield response of genotypes across environments, and therefore the main effects alone were not adequate in explaining the observed yields. The environment and G × E interactions had greater influences on yield than genotypes. Previous research on yield of potato clones has shown similar results on G × E interaction effects (Abalo *et al.*, 2001; Dixon and Nukenine, 1997; Steyn *et al.*, 1993).

The ranking of genotypes based on estimates of tuber yield from the AMMI analysis differed in most environments from the ranking of genotypes based on observed yields. Nevertheless, the AMMI model consistently ranked genotypes B5, B6, A1 and A2 as the best performers across a wide range of locations, indicating their adaptation to various environments. Therefore, this model was useful in predicting observed tuber yields for potato genotypes. This finding is in agreement with the research results of

Gauch and Zobel (1990), who showed that AMMI analysis increased the accuracy of yield predictions in other environments.

The PCA scores for genotypes were useful in explaining their yield stability across environments. In the plots of PCA1 scores versus tuber yield, the genotypes with principal component scores near zero indicate a small interaction with the environment. Low PCA scores for particular genotypes suggest that those genotypes are poorly adapted to some environments. High and positive PCA scores imply that potato genotypes will do better in an environment with a high positive PCA score than would be expected from the main effects. Similarly, with high and negative PCA scores, genotypes will be expected to have a lower yield performance in an environment with a high and positive PCA score. Therefore, genotypes 392618.250 (B5) and 392127.270 (B6) were noted to be very stable and to have high yield. However, entries from population A, 387121.4 (A1), 381471.18 (A2) and Victoria recorded high yields but were generally more variable as indicated from the high IPCA scores from the graphical plot, and are therefore poorly adapted to some environments. Similarly, the clones 392127.256 (B7) and 391049.255 (B2) were stable but did not have high yields. Therefore, the correlation of main effects and PCA scores can be used in making predictions of yield performance in other environments. This finding is in agreement with the research of Cooper *et al.* (1996) who suggested that principal component values of genotypes close to zero is indicative of low interaction with environment and high yield stability.

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