Australian Journal of Crop Science
3(4):213-220 (2009)
ISSN: 1835-2707

Southern Cross Journals©2009
www.cropj.com

Yield stability analysis of *Ipomoea batatus* L. cultivars in diverse environments

Osiru M.O[1,3], O.M. Olanya*[2], E. Adipala[1,3], R. Kapinga[4] and B. Lemaga[5]

[1]*Makerere University, Department of Crop Science, P.O. Box 7062, Kampala, Uganda.*
[2]*USDA-ARS, New England Plant, Soil and Water Laboratory, Orono, ME 04469, U.S.A.*
3RUFORUM- Makerere University, P.O. Box 7062, Kampala, Uganda.
[4]*International Potato Center (CIP), P.O. Box 22274, Kampala, Uganda.*
[5]*PRAPACE, P.O. Box 22274, Kampala, Uganda.*

**Corresponding author: m.osiru@ruforum.org*

Abstract

Sweet potato is an important food crop in tropical and sub-tropical regions of the world. There is limited published research on yield stability of sweet potato in tropical environments. To identify cultivars with improved agronomic and stable yield characteristics, five elite genotypes obtained from the sweet potato breeding program in Uganda and International Potato Center (CIP) and five land race genotypes were evaluated for yield stability at 12 environments. The Additive Main Effects and Multiplicative Interaction (AMMI) model was used for stability analysis. The analysis of variance of yield data (t ha^{-1}) for genotypes x locations, genotypes x seasons and locations x seasons was highly significant ($P < 0.01$) showing the variable response of the genotypes across environments and seasons. The average root yield of sweet potato genotypes was significantly ($P < 0.01$) greater at Kachwekano (KARDC) than at Namulonge (NAARI) and Serere (SAARI) locations. Based on AMMI statistical model, Araka Red and Tanzania were the most stable genotypes; while NASPOT 6 and NASPOT 2 had the lowest stability. The model predicted the highest yield from Dimbuca cultivar in 4 of 12 environments and New Kawogo as the cultivar with the lowest yield in 6 of 12 environments. Within each environment and cropping season, the ranking of the genotypes for yield stability was not consistent. Selective deployment of cultivars across environments can improve Sweet potato tuber yield in the lowland and highland tropics.

Key words: Sweet potato; AMMI model; Yield; Cultivars; Genotype × Environment.

Introduction

Sweet potato (*Ipomoea batatus* L.) is an important food crop in many tropical and sub-tropical regions of the world. In Uganda, approximately 2.2 million tonnes of Sweet potato is produced per year making it the second largest producer of the crop in the world (CIP, 1996; Hakiza *et al.*, 2000; FAO, 2002). The utilization of Sweet potato as a food security crop and source of pro-Vitamin A for malnourished children has greatly enhanced the production of the crop in diverse locations (Osiru *et al.,* 2007, Mwanga *et al.*, 2001, 2002). However, current on-farm yields remain low (4.1 t ha^{-1}; FAO, 2002) when compared with potential yields in sub-Saharan Africa (45 t ha^{-1}; PRAPACE, 2003). The low yields are attributed to various biotic and edaphic factors such as the Alternaria leaf petiole and stem blight disease (Lenne, 1991; Bashaasha *et al.*, 1995; Carey *et al.*, 1997; Skoglund & Smit, 1994).

Although Sweet potato is widely cultivated, agronomic performance and yield stability of crop cultivars under standard management conditions in various agro-ecological conditions are not well documented. The Sweet potato breeding programme in Uganda has registered and released six cultivars (Mwanga *et al.*, 2003) for increased crop production based on dry matter content, tolerance to Sweet

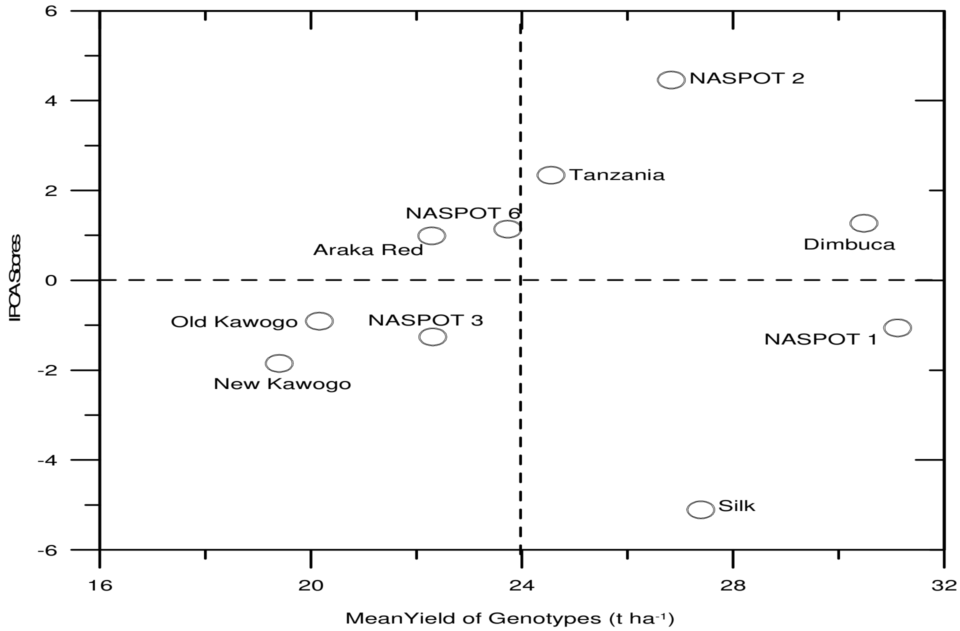

Fig 1. Plot of mean tuber yield (t ha-1) and AMMI interaction (IPCA) scores for 10 Sweet potato genotypes evaluated for yield stability in 12 environments. The IPCA scores are on the Y-axis and root yield are on the X-axis. The genotype Tanzania is a resistant check and NASPOT1 is susceptible check. NASPOT 2, NASPOT 3, and NASPOT 6 are registered cultivars, while Araka Red, Old Kawogo, New Kawogo, Silk and Dimbuca are cultivars selected from diverse regions. The genotypes to the right of mid-point along the X-axis are classified as high yield potential and those to the left side as low yield potential.

potato viruses and high tuber yield. Knowledge of genotype performance and yield adaptation in diverse agro-ecological zones would be highly beneficial for cultivar deployment. Previous research has shown that other crop genotypes can exhibit differences in traits such as yield and disease resistance when grown in diverse environments and may often have various response because of genotype x environment (G x E) interaction (Eberhart & Russell, 1996; Cooper et al., 1996; Crossa et al; 1990; Mulema *et al.,* 2008). Further, differences in yield adaptability among Sweet potato cultivars were noted in other locations (David *et al*., 1998).

Due to the widespread cultivation of Sweet potato in tropical and sub-tropical regions, assessment of cultivar adaptability is crucial for improved yield. In this research, a multivariate technique known as the additive main effects and multiplicative interaction (AMMI) analysis (Gauch, 1993; Gauch & Zobel, 1990) was used for evaluation of agronomic performance (Sweet potato yield) and genotype adaptation in diverse environments. This manuscript complements a publication on stability of sweet potato cultivars to *Alternaria* leaf and stem blight diseases (Osiru *et al*., 2009), using the same materials and experimental approach. The objective of this research was to determine the yield performance and assess yield stability of ten Sweet potato genotypes across a range of environments (seasons and locations) in Uganda using the AMMI statistical model.

Materials and Methods

Site characterisation

The experiments were conducted at three distinct locations of Namulonge Agricultural and Animal Production Research Institute (NAARI), Serere Agricultural and Animal Production Research Institute (SAARI), and Kachwekano Agricultural Research and Development Center (KARDC). These locations represented the main agro-ecologies for Sweet potato production in Uganda as previously described (Osiru *et al.*, 2009).

Plot establishment and experimental design

At each location, 10 Sweet potato genotypes were evaluated for yield. Five cultivars obtained from the Sweet potato breeding programme (Mwanga *et al*., 2001; 2002; 2003) and five Sweet potato landraces (farmer's varieties) selected from various parts of the country (Osiru *et al*., 2007).

Table 1. Total tuber yield (Kg ha^{-1}) of ten sweet potato genotypes evaluated for root yield at three locations during four cropping seasons[W]

Genotype[X]	2001A[Y]			2001B			2002A			2002B		
	NAARI	SAARI	KARDC	NAARI	SAARI	KARDC	NAARI	SAARI	KARDC	NAARI	SAARI	KARDC
Dimbuca	30.98	27.95	20.97	23.45	21.27	62.65	9.29	11.87	62.47	23.69	20.04	63.34
Tanzania	24.42	34.83	29.74	18.83	3.78	48.42	7.91	7.66	40.74	18.72	4.04	47.73
NASPOT 1	33.93	35.09	30.41	35.86	8.48	68.81	7.89	9.43	35.81	34.37	8.28	65.08
NASPOT 2	31.04	58.68	21.88	18.87	23.35	40.43	6.56	8.57	28.65	16.58	23.83	38.99
Silk	26.74	34.58	19.82	19.45	10.48	90.99	3.73	3.56	9.61	18.50	9.58	84.37
New Kawogo	23.90	13.21	11.80	11.20	2.83	59.79	1.75	4.66	22.65	12.01	3.59	61.19
NASPOT 3	25.51	20.53	30.55	12.18	3.46	61.37	4.28	9.24	24.05	12.29	4.07	60.74
NASPOT 6	15.57	32.84	23.81	12.75	4.74	59.79	3.97	5.26	54.26	13.21	5.68	59.22
Araka Red	6.67	34.85	28.90	9.33	17.47	54.20	2.95	3.43	20.19	9.54	17.08	52.28
Old Kawogo	31.51	24.37	13.76	21.72	8.43	52.69	11.78	0.55	8.31	21.48	8.42	53.88
Means	21.92	31.69	23.16	18.36	10.43	59.91	5.99	6.42	30.67	18.04	10.46	58.68
LSD (0.05)	9.82	11.27	12.21	15.15	12.81	23.05	6.43	6.37	20.95	13.98	12.30	18.98

[W]Experimental locations consist of Namulonge Agric. Res. Station (NAARI), Serere Animal Agric Res. Station (SAARI) and Kachwekano Agricultural Research & Development Center (KARDC),.

[X]Genotypes evaluated for yield stability in diverse environments, [Y]Seasons consist of 2001A , 2001B, 2002a and 2002B.

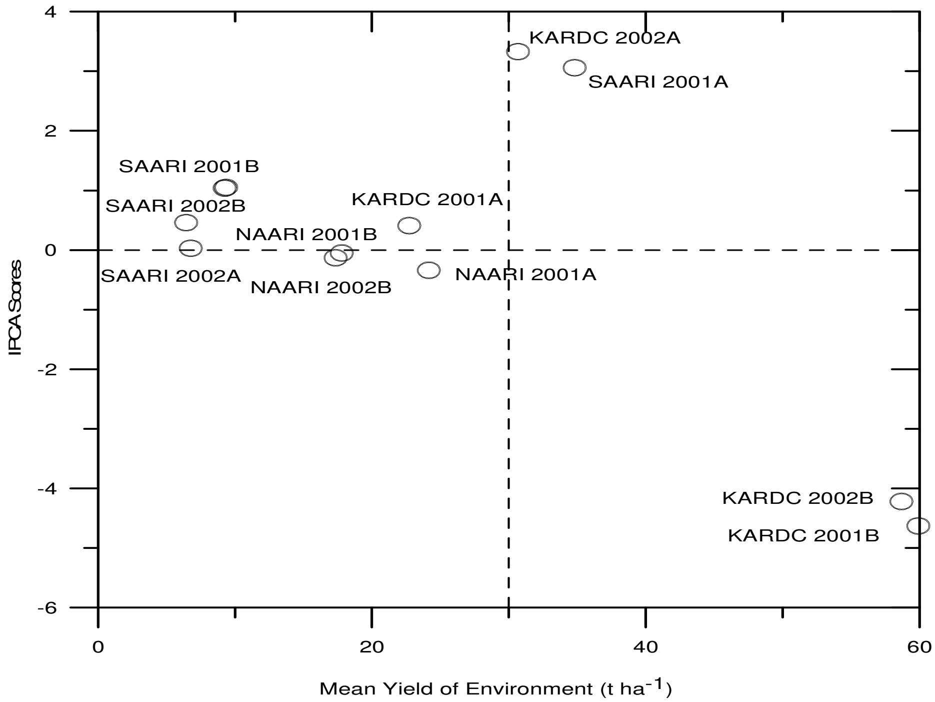

Fig 2. Plot of mean tuber yield (t ha^{-1}) averaged across genotypes and AMMI interaction (IPCA1) scores for 12 environments in which sweet potato was evaluated. The IPCA1 scores are on the Y-axis and root yield for each environment are on the X-axis. NAARI= Namulonge; SAARI= Serere; KARDC= Kachwekano; 2001A and 2002A correspond to first rains (March to July) of 2001 and 2002, respectively; 2001B and 2002B refer to second rains (September – December) of 2001 and 2002, respectively. The environment to the right of the mid-point along the x-axis is classified high yield potential and those to the left as low yield potential.

The experiments were established in a randomized complete block design (RCBD) with four replications. Each plot consisted of four rows (ridges of 40 cm high) which were 6 m in length. Stem cuttings (30 cm in length with 6 nodes) were planted at a spacing of 25 cm apart within rows and 90 cm between rows. A total of 20 cuttings were planted in each row. Field plots were subjected to normal agronomic and cultural practices. At all locations, the cropping seasons were as described (Osiru *et al.*, 2009).

Yield evaluation

At maturity, fresh foliar weight /10 plants, weight and number of roots per plant; non-marketable, marketable, and total root yield (t ha^{-1}) were recorded after sizing. Yield data were obtained by harvesting ten plants from the two middle rows of each plot (Kg). Total root yield was then converted to mean tuber yield per hectare (t ha^{-1}). The marketable tubers consisted of large clean roots (>45 mm diameter) and medium roots were 25-45 mm, while the unmarketable portion consisted of small roots (<25 mm diameter).

Data analysis

Root yield for each cultivar and location were subjected to analysis of variance (ANOVA) using the General Linear Model procedure of the Statistical Analysis System (SAS, 1995). The means, standard errors (SE), and least significant differences, coefficients of variation were computed (Steel *et al.,* 1997; Gomez & Gomez, 1984). In the GLM model, genotypes were designated fixed effects, while locations, cropping seasons and replications were designated random effects. Yield data were additionally subjected the Additive Main Effects and Multiplicative Interaction (AMMI) statistical model (Gauch, 1993; IRRISTAT- IRRI, 2005). The AMMI model was calculated as previously described (Osiru *et al.*, 2009).

Results and discussion

Site characterisation

Rainfall patterns and annual total rainfall (mm), average relative humidity (%), and average temperatures (ºC) during the cropping cycle were previously described in a previously published

Table 2. Combined additive, multiplicative interaction and the analysis of variance for root yield of 10 sweet potato genotypes grown in 12 environments

Source of variation	Df	F-value	P>F
Treatments	119	10.29	0.004**
Genotypes	9	65.55	0.008**
Environments	11	934.18	0.01**
Replications	24	5.75	0.394
G x E	99	2.79	0.052*
AMMI 1	19	32.37	0.043*
AMMI 2	17	26.35	0.085
AMMI 3	15	16.8	0.149
Residuals	63	2.05	-

** Significant at *P<0.01*, * significant at *P<0.05*, ns = non significant

manuscript. Similarly, the morphological characteristics of Sweet potato genotypes as well as agronomic, tuber yield and disease reaction were previously described (Osiru *et al*., 2009)

Tuber yield

Variation in root yield was recorded among genotypes, locations and cropping seasons Averaged root yield was significantly greater (P<0.05) at KARDC (41.10 t ha^{-1}) than at NAARI (16.08 t ha^{-1}) or SAARI (14.75 t ha^{-1}) across genotypes and seasons (Table 1). The highest mean root yield was recorded at NAARI and SAARI during the 2001A, followed by the 2001B seasons (Table 1). At KARDC, the highest average yield (59.91 t ha^{-1}) was recorded in 2001B season. Overall, Sweet potato yield varied among genotypes. The variation in yield among locations may be attributed to weather or climatic factors, and the duration of growing periods (Osiru *et al*., 2009). The maturity period or duration of Sweet potato cultivation at KARDC location (2200 m.a.s.l) is considerably longer than at NAARI or SAARI (lower altitude locations), contributing to vigorous physiological growth, and perhaps more dry matter accumulation. Previous research has shown that greater physiological growth and dry matter accumulation could be expected at high altitude locations in the tropics (Mcharo *et al*., 2001). The variation in yield may also be attributed to genotype response to the environment at specific locations. Our results are similar to the findings of yield differences among Sweet potato genotypes previously reported in other environments (Ngeve, 1993; Nawale & Salvi, 1983).

The seasonal variation in root yield may be due to climatic or soil factor differences among locations, especially during the root bulking period at SAARI and NAARI. Water stress during critical periods of root bulking have been shown to result in low root yield and quality defects in Sweet potato (Carey *et al*., 1997; Ekanayake *et al*., 1988,).

Yield adaptation across environments

The analyses of variance for root yield across environments and seasons resulted in significant differences (P<0.052) in the interactions of genotypes x environments (Table 2). The significant interactions of genotypes x environments suggest that root yield of Sweet potato genotypes varied across environments. Previous research has shown similar results of differences in yield of Sweet potato cultivars among locations (Naskar & Singh, 1992; Mcharo *et al*., 2001).

Although this research was conducted with the intention of assessing Sweet potato genotype interactions with Alternaria leaf spot disease, the disease level was relatively low (data not shown) and did not significantly impact yield. At KARDC, where Alternaria disease was slightly greater than other locations (Osiru *et al,*. 2009), disease incidence was not significantly correlated to total yield. We hypothesize that the disease effects was manifested at 5 months after planting at KARDC, and occurred after the critical root bulking period, resulting in minimum effects on Sweet potato yield. It is also possible that the relatively longer duration of crop growth at KARDC may have contributed to yield compensation at this location. It is possible that under intense Alternaria disease pressure, differences in yield of Sweet potato may be detected. There is little published data on yield loss relationship between Alternaria disease and yield of Sweet potato genotypes. Similarly, pathogen effects on yield were not significant in other studies conducted on the

Table 3. Ranking of genotypes based on AMMI estimates and unadjusted means (in parenthesis) for total root yield of 10 Sweet potato genotypes grown in 12 environments (location by season combinations)

Genotypes	NAARI[1] 2001A[2]		NAARI 2001B		NAARI 2002A		NAARI 2002B		SAARI 2001A		SAARI 2001B		SAARI 2002A		SAARI 2002B		KARDC 2001A		KARDC 2001B		KARDC 2002A		KARDC 2002B	
Dimbuca	9	(10)	5	(10)	1	(9)	3	(10)	4	(3)	1	(3)	4	(9)	1	(3)	4	(4)	6	(7)	1	(8)	6	(8)
Tanzania	1	(4)	9	(2)	3	(2)	9	(2)	6	(7)	5	(2)	6	(1)	5	(2)	3	(7)	4	(3)	4	(1)	5	(3)
NASPOT 1	8	(1)	2	(1)	4	(4)	2	(1)	1	(2)	2	(5)	1	(2)	2	(6)	5	(2)	3	(2)	2	(4)	3	(2)
NASPOT 2	7	(3)	10	(5)	5	(5)	10	(6)	3	(1)	6	(1)	2	(4)	6	(1)	1	(6)	1	(10)	3	(5)	1	(10)
Silk	2	(6)	1	(8)	10	(6)	1	(8)	2	(9)	3	(9)	3	(3)	3	(8)	9	(1)	5	(4)	5	(6)	4	(5)
New Kawogo	4	(9)	3	(7)	7	(7)	4	(7)	10	(6)	9	(7)	10	(6)	8	(7)	10	(5)	10	(6)	10	(2)	10	(6)
NASPOT 3	6	(8)	4	(9)	6	(10)	5	(9)	7	(10)	7	(10)	7	(7)	7	(10)	8	(10)	8	(5)	8	(7)	8	(4)
NASPOT 6	5	(2)	7	(3)	2	(1)	7	(3)	9	(8)	4	(6)	9	(10)	4	(5)	7	(9)	9	(8)	6	(10)	9	(7)
Araka Red	10	(5)	8	(4)	8	(8)	8	(5)	5	(5)	8	(4)	5	(8)	9	(4)	2	(8)	2	(1)	7	(9)	2	(1)
Old Kawogo	3	(7)	6	(6)	9	(3)	6	(4)	8	(4)	10	(8)	8	(5)	10	(9)	6	(3)	7	(9)	9	(3)	7	(9)

[1]NAARI= Namulonge; SAARI= Serere; KARDC= Kachwekano; [2]2001A and 2002A correspond to first rains (March to July) of 2001 and 2002, respectively; 2001B and 2002B to second rains (September – December) of 2001 and 2002, respectively. 1-10 indicate ranking of genotype with respect to the ten genotypes under evaluation at each environment.

Alternaria-potato pathosystem and yield relationship (Shtienberg & Fry, 1990; Rotem, 1994).

A comparison of the ranking of root yield of Sweet potato genotypes predicted by AMMI model resulted in variations in genotype performance across environments (Table 3). Prediction of genotypes with high root yield also varied within environments. The genotype Dimbuca was predicted as the best yielding cultivar in four environments by AMMI model while New Kawogo was predicted as having the lowest yield in six out of twelve environments (Table 3). The low accuracy of prediction implies that AMMI model may not be a good predictor of Sweet potato yield at the tested locations. AMMI prediction of environments where the best root yield could be attained was often accurate suggesting that the model can consistently identify environments (KARDC 2001B, KARDC 2002B) where highest root yield could be attained In previous research, genotype x environment interaction, and yield have been quantified in some Sweet potato genotypes based on regression analysis (Ngeve, 1993; David *et al*., 1998). In contrast to other research findings which indicate that AMMI analysis increased the accuracy of yield predictions in diverse crop genotypes (Gauch and Zobel, 1990), our experimental results did not show increased accuracy of predictions on Sweet potato.

A plot of total root yield of Sweet potato genotypes versus the principal component scores (1PCA) showed that the genotypes Dimbuca, Tanzania, NASPOT 2, NASPOT 6, Araka Red, had positive principal component scores (PCA1), while genotypes Old Kawogo, NASPOT 1, NASPOT 3, Silk and New Kawogo had negative IPCA scores (Fig. 1). The genotypes Araka Red, Old Kawogo and NASPOT 1 showed PCA scores in close proximity to 0, implying a small interaction with the environment. The genotypes or environments with large PCA scores (negative or positive) indicate high interactions with the environment even though the accuracy is low. Mean yield at environments showed differences at KARDC 2002B and KARDC 2001B relative to the rest of the testing locations (Fig. 2).

We conclude that high and positive PCA scores derived from AMMI statistical model indicate that Sweet potato genotypes can be expected to perform better in an environment. Similarly, high and negative PCA scores indicate that genotypes may have lower yield potential in an environment, therefore, poorly adapted to the environment. The AMMI statistical model can be utilized to estimate yield performance and adaptation of sweet potato in various environments even though with a lower degree of accuracy. Yield performance of Sweet potato cultivars with similar genotypic characteristics (dry matter content, growth characteristics, reaction to disease or agronomic conditions) to the genotypes described in this experiment can be estimated if environmental parameters are known. Similarly, the root yield of Sweet potato genotypes as impacted by other biological stress agents such as Sweet potato virus disease, Sweet potato chlorotic stunt virus and other fungal agents could be investigated using a similar methodology. Selective deployment of cultivars across environments can greatly improve Sweet potato root yield in the lowland and highland tropics.

Acknowledgements

The study was funded by the Rockefeller Foundation (Agricultural Resource Husbandry Grant No. 2000 FS 051) as part of the first author’s Ph.D. research. Additional funding was provided by the International Foundation for Science (IFS), the International Potato Center (CIP), and Regional Potato and Sweet potato Improvement Programme for East and Central Africa (PRAPACE). We thank the Regional Universities Forum and the USDA-ARS, NEPSWL for support.

Disclaimer

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation for endorsement by Makerere University, Ruforum, US Dept. of Agriculture, International Potato Center or PRAPACE.

References

Bashaasha B, Mwanga ROM, P'Obwoya CNO, Ewell PT (1995) Sweet potato in the farming and food systems of Uganda. In: Fifth Triennial Symposium of International Society of Tropical Root Crops Africa Branch (ISTRC-AB) 22-28 November 1992, Kampala. Pg 225-228.

Eberhart SA, and Russell WA (1996) Stability parameters for comparing varieties. *Crop Sci.* 6: 36-40.

Carey EE, Gichuki ST, Ndolo PJ, Turyamureeba G, Kapinga R, Lutaladio NB (1997) Sweet potato breeding for Eastern, Central and Southern Africa: An overview. *African Potato Assoc. Conf. Proc* .4 : 89-93.

CIP - International Potato Centre (1996) Sweet potato facts: production, use, consumption, and feed use. Lima, Peru.

Cooper M, Delacy IH, Basford KE (1996) Relationships among analytical methods used to analyze genotype adaptation in multi-environment trials. Cooper M, Hammer G L (Edition.). In: Plant

Adaptation and Crop Improvement. Center for Agricultural and Biosciences (CABI), Wallingford, United Kingdom, pp 193-224.

Crossa J, Gauch HG, and Zobel RW (1990) Additive main effects and multiplicative interactions of two international maize cultivars. *Crop Sci.* 30: 493-500.

David PP, Bonsi CK, Mortley DG, Trotman AA (1998) Yield stability differences among Sweet potato genotypes under field and controlled environments. *Tropical Agric.* 75: 204-207.

Ekanayake IJ, Malagamba P, Midmore DG (1988) Effect of water stress on yield indices of sweet potato. In: Tropical Root Crops Changing Role in a Modern World. 8th Symposium of the International Society for Tropical Root Crops (ISTRC) Proceedings, pp 520-528.

FAO- Food and Agriculture Organisation (2002) Agricultural Bulletin Board on Data Collection Dissemination and Quality of Statistics. Available at FAOSTAT Database, http://apps.fao.org/, Rome, Italy.

Gauch HG (1993) Prediction, parsimony and noise. *Am Sci.* 81: 468-478.

Gauch HG and Zobel RW (1990) AMMI analysis of yield trials - Additive main effects and multiplicative interaction analysis of two international maize cultivar trials. *Crop Sci.* 30: 493-500**.**

Gomez KA and Gomez AA (1984). Statistical procedure for agricultural research. 2ed. International Rice Research Institute, Philippines. John Wiley and Sons.

Hakiza JJ, Turyamureeba G, Kakuhenzire RM, Odongo B, Mwanga ROM, Kanzikwera R and Adipala E (2000) Potato and sweet potato improvement in Uganda: A historical perspective. *African Potato Association Conference Proceedings* 5: 47-58.

International Rice Research Institute – IRRI (2005). IRRISTAT for Windows, Version 5. Tutorial Manual. Biometrics and Bioinformatics Unit, p. 274.

Lenne JM (1991) Diseases and pests of sweet potatoes: South East Asia, the Pacific and East Africa. *Natural Res. Inst. Bulletin* 46.

Mcharo T, Carey EE, Gichuki ST (2001) Performance of selected Sweet potato varieties in Kenya. *African Crop Sci. Journal* 9: 49-57.

Mwanga, ROM, Odongo B, P'Obwoya CO, Gibson R W, Smit NEJM, Carey EE (2001) Release of five sweet potato cultivars in Uganda. *HortScience* 36:385-386.

Mwanga, R O M, P'Obwoya C O, Odongo B, Turyamureeba G M (2002) Sweet potato (*Ipomoea batatas* (L.) Lam). In*:* Mukiibi J K (Ed.). Agriculture in Uganda. Volume II: Crops. National Agricultural Research Organisation (NARO). CTA. Fountain Publishers, Kampala, Uganda, p.233-251.

Mwanga, ROM, Odongo B, Turyamureeba GM, Alajo A, Yencho GC, Gibson RW, Smit NEJM, Carey E E (2003) Release of six Sweet potato cultivars (NASPOT1 to NASPOT 6) in Uganda. *HortScience* 38:475-476.

Mulema JK, Adipala E, Olanya OM, Wagoire W (2008) Yield stability analysis of late blight resistant potato selections. *Exp. Agric.* 44: 145-155.

Naskar SK and Singh DP (1992) Genotype x environment interaction for tuber yield in Sweet potato. *Journal of Root Crops* 18: 85-88.

Nawale, RN and Salvi MJ (1983) Effect of season on yield of Sweet potato. *Journal of Root Crops* 95:55-58.

Ngeve JM (1993) Regression analysis of genotype x environment interaction in sweet potato. *Euphytica* 71:231-238.

SAS Institute, 1995. SAS User's Guide Statistics.SAS Institute, Cary, NC., USA.

Osiru M, Adipala E, Olanya OM, Lemaga B and Kapinga R (2007). Occurrence and distribution of *Alternaria* leaf petiole and stem blight on Sweet potato in Uganda. *Plant Path. Journal* 6:112-119.

Osiru MO, Olanya OM, Adipala E, Lemaga B and Kapinga (2009) Stability of Sweet potato cultivars to Alternaria leaf petiole and stem blight disease in diverse environments. *Journal of Phytopath.* 157:172-180.

Prapace (2003) Five Year Priority Setting. Regional Potato and Sweet potato Improvement Programme in East and Central Africa, 2003-2008, Kampala, Uganda.

Rotem J (1994). The Genus Alternaria: biology, epidemiology, and pathogenicity. The American Phytopathological Society, St. Paul, Minnesota, p.326.

Shtienberg D and Fry WE (1990) Field and computer simulation evaluation of spray-scheduling methods for control of early and late blight of potato. *Phytopath* 80 : 772-777.

Skoglund LG and Smit NEJM (1994). Major diseases and pests of Sweet potato in East Africa. CIP, Lima, Peru.

Steel RG, Torrie JH, and Dickey DA (1997). Principles and procedures of statistics, A biometrical approach. 3rd ed. McGraw Hill Book Co. Inc., New York, p. 633.