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Seasonal effects on potato production under conventional and small seed plot technologies in the Mt. Elgon zone

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Abstract

Potato production in the Mt. Elgon zone of Uganda is constrained by seasonal variations, lack of clean seed and the challenges of pests and diseases. Consequently, yield hardly exceeds 2.9 t ha^{-1} yet a potential of 10 t ha^{-1} can be realised. This study was conducted to determine the effect of seasons and the small seed plot technology in enhancing seed potato production in the Mt. Elgon zone. On-farm trials were conducted in Bududa, Sironko, Manafwa, Kapchorwa and Kween districts in the first and second seasons of 2011. Results showed higher potato yield in Kapchorwa and Kween in the second season compared to the other districts. However, Bududa district has potential to achieve relatively higher potato yield in both seasons. Number of tubers were more in small seed plots than conventional potato planting with significant effects ($P < 0.05$) in Bududa and Kapchorwa. Number of tubers with bacterial wilt were higher in conventional potato planting than the small seed plots, with Manafwa and Sironko registering the highest incidence. Though bacterial wilt and late blight incidence was not significantly different in the two seasons, infected tubers for both pathogens were more in Manafwa and Sironko for bacterial wilt, and Bududa and Kapchorwa for late blight. Principal component analysis revealed that tuber numbers and potato tuber moth damage was more associated with environment in Kween. The results demonstrated that potato productivity in the Mt. Elgon zone is higher in the second season, with the small seed plot technology being favourable for small land holdings than conventional potato planting.

Key words: Bacterial wilt, conventional potato planting, late blight, seed potato, small seed plot technology

Introduction

Potato (*Solanum tuberosum*, L.) is a key crop serving both as a food and cash crop in the Mt. Elgon highlands, specifically, in districts of Bududa, Kapchorwa, Kween, Bukwo, Sironko, Manafwa and Mbale (MAAIF, 2011). However, production has remained below 2.9 t ha^{-1} yet a potential of 7.5 - 10 t ha^{-1} harvest can be realised under a good crop growing conditions (MAAIF, 2011). Seed potato production constitutes about 40% of the total potato production costs (Tindimuboona *et al*., 2000). For the Mt Elgon area, this scenario is further confounded by the long distances for transporting the seed from Kachwekano ZARDI, over 700 km from the potato growing areas of Mt Elgon, adding another 5 -10% of total production costs. To reduce this cost, percentage of resource limited farmers have been producing seeds used in the growing season. However, this is hampered mainly by diseases especially; bacterial wilt which is both seed and soil-borne diseases (Turkensteen, 1987). Bacterial wilt occurs in many potato growing areas and its spread is increasing mainly due to increase in potato cultivation, reduction of rotation period, seed potato recycling, water run-offs and flooding (CIP, 1996).

Attempts to improve seed potato systems in terms of quality, quantity and timely availability have not fully achieved the desired goal (Kinyua *et al*., 2001). Inadequate supply of healthy, high-yielding planting materials dominates a myriad of factors that cause the paltry national potato yield. The shortage, which has recently deteriorated to absolute lack of affordable good quality potato seed tubers in some countries, has encouraged the common practice among potato farmers of planting own-saved tubers from previous harvests or sourced from markets or neighbours (Barton *et al*., 1997). Such tubers are often of poor health status owing to latent infections by *Ralstonia solanacearum*, viruses and other tuber-borne pathogens. Since the crop is vegetatively propagated, the situation presents a great opportunity for perpetuation and spread of the pathogens to non-infested areas (Ajanga, 1993) resulting into high yield losses. Conversely, increasing the availability of high quality seed potato to farmers would be a major step towards effective management of these diseases.The small seed plot technology (SSPT)focuses on self-sustaining on-farm seed potato production by maintaining the good health status of seed tubers through intensive prevention and control of pests and diseases (Kinyua *et al.*, 2001). The technology also requires 50% less land than the conventional production system to meet on-farm seed tuber requirements. However, the success of the SSPT is known to depend on a wide range of circumstances (Kinyua *et al.*, 2001), therefore, modifications to adapt the technology to local circumstances is necessary. The conventional potato planting (CPP), involves planting tubers in open fields. Such fields are prone to soil borne diseases especially when proper management techniques are not adhered to (Wagoire *et al.,* 2005).

Most potato farming in Eastern Africa occurs under rainfed conditions (Gildemacher, 2012). In Eastern Uganda, two main potato production seasons exist per year, coinciding with the short and long rainy seasons. The short rains are associated with warm conditions which favour pests such as aphids and the potato tuber moth (*Phthoriamaea operculella zeller)* (De Temmerman *et al*., 2002) and bacterial wilt (CIP, 1996). On the other hand, the long rains offer cool conditions for the manifestation of late blight (*Phytophthora infestans*) (Kankwatsa *et al*., 2003).The objectives of this study were therefore to (i) determine the season of the year which favours more potato production, and (ii) assess the efficiency of the SSPT in comparison to CPP in enhancing seed potato production in the Mt. Elgon zone.

Materials and methods

Field experiment was conducted with full participation of the farmers in Kapchesombe sub-county, Kapchorwa district; Bushiyi sub-county, Bududa district; Moyok sub-county, Kween district; Masaba sub-county, Sironko district and Kaato sub-county, Manafwa district in 2011 first season (March - June) and 2011 second season (September - December), hereafter referred to as

2011a and 2011b, respectively. Kapchorwa and Kween districts are found in Sebei region whereas Bududa, Sironko and Manafwa are found in Bugisu region. At each sub-county, an average of four small seed plots were established with cv. Victoria and each of them treated as a replicate. Beds for each small seed plot were 2m x 9m, with hills spaced at 30 x 30 cm and 10g of NPK (17:17:17) fertiliser applied per hill. A total of 174 seed potato tubers were planted per bed. The conventional production fields, established on ridges, were much larger with hills spaced at 0.7m x 0.3m and fertiliser applied at a rate of 60g per 1 m in the furrows. The SSPT and CPP trials were established in neighbouring blocks to enable easy comparison of the two technologies. During data collection, plants/hills equivalent to the SSPT plots were marked off from the large conventional fields and data collected from them. Farmers were trained to practice roguing of diseased plants, and dehaulming in all the trials prior to harvesting. Data were collected on total number of tubers harvested, small sized tubers (< 2.5 cm diameter), medium sized tubers (2.5-5.5cm), large sized tubers (> 5.5cm); number of tubers with bacterial wilt (BW), late blight (LB) and potato tuber moth (PTM) damage. Data were subjected to analysis of variance (ANOVA) as randomised complete block design (RCBD) using Genstat Software (Payne *et al.*, 2006) and differences among the treatment means compared using Fisher's Protected LSD test at 5% probability level. Principal component analysis (PCA) was conducted using PAST Statistical Software (Hammer *et al.,* 2001) to assess the correlation between sites (environment) with the potato tuber variables, and data presented as a bivariate plot.

Results and discussion

Effect of planting season on tuber yield and incidence of pests and diseases

Planting season had high significant effects ($P \leq 0.01$)on the total number of tubers harvested and the number of potatoes damaged by PTM but no significant effects on number of tubers infected with BW and LB (Table 1). Season x site interaction further exhibited significant effects ($P \leq 0.05$) on the total tuber number.At all the sites, the second season (2011b) exhibited higher yields than the first season (2011a) (Fig. 1). However, it was at Kapchorwa where a significantly

Table 1. Mean squares for potato cv. Victoria tuber number (plant^{-1}) and damage under small seed plots in 2011a and 2011b

Source of variation	d.f.	Total tuber number	Bacterial wilt number	Late blight number	Potato tuber moth
Replication	3	0.246	0.009	0.002	0.002
Season	1	3.87**	0.009	0.007	0.024***
Site	2	0.038	0.011	0.004	0.003
Season*Site	2	1.78*	0.017	0.006	0.003
Residual	15	0.364	0.009	0.002	0.001

*, **, and *** represent significance at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$. d.f = degree of freedom

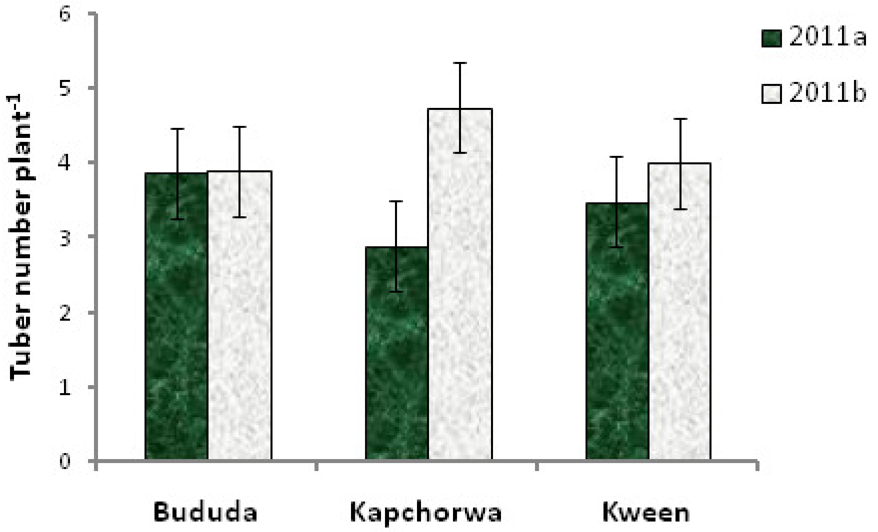

Figure 1. Effect of planting season on potato tuber number in small seed plots across sites.

higher number (P≤0.05) of tubers were harvested in 2011b compared to 2011a.

According to Okoboi (2001), seasons greatly influence the potato yields with greater yields in the second than the first season in Kabale district and other potato growing areas in south western Uganda. Season x site interaction will definitely influence potato yields due to variations in precipitation, landscape, soil texture and farming systems even in the same agro-ecology (Okoboi, 2001). The higher potato yields in Kapchorwa and Kween in the second season compared to Bududa indicates that the Sebei region has more potential for potato production than other regions of South eastern Uganda. However, Bududa district has the capacity to achieve relatively higher potato yields in both seasons unlike Kapchorwa and Kween where yields are higher only in the second season. Though season had no significant effects on number of tubers with LB, the disease is known to be more rampant in cool conditions (Kankwatsa *et al.*, 2003), which are more prevalent during long rainy periods.The number of tubers per plant damaged by the PTM were significantly more (P < 0.05) in 2011a (0.1 damaged tubers)than 2011b (no damaged tuber). This is similar to reports by De Temmerman *et al.* (2002) that the short rains are associated with warm conditions which favour pest infestation.

Comparison of conventional and SSPT methodsat different sites of the Mt. Elgon zone in 2011b

Analysis of variance showed significant site effects (P≤0.001) on number of large, medium and small tubers (Table 2). Site also had significant effects (P ≤ 0.001) on number of tubers attacked by BW, LB and PTM.Technology effects (SSPT vs.CPP) were significant for number of large tubers, small tubers and tubers with LB but not for the medium tuber number and PTM damage. Site x Technology interaction had significant effects (P≤ 0.01) on the number of large, medium and small tubers, and the tubers with LB. The significant site effects onnumber of large, medium and small tuberscould be attributed to variations in soil fertility and

Table 2. Mean squares for potato cv. Victoria tuber number(plant^{-1}) and damage under different technologies in 2011b

Source of variation	d.f.	Large tuber number	Medium tuber number	Small tuber number	Number of tubers with BW	Number of tubers with LB	Number of tubers with PTM
Replication	3	0.03	0.001	0.17	0.013	0.0001	0.0007
Site	4	0.23***	1.20***	3.26***	0.275***	0.0011***	0.014***
Technology	1	0.06*	0.01	20.9***	0.003	0.0012***	0.00001
Site*Tech	4	0.07**	0.47***	4.0***	0.001	0.001***	0.00001
Residual	27	0.01	0.02	0.09	0.008	0.0001	0.0011

Technology = (SSPT verses CPP)

other environmental conditions at the different sites (Okoboi, 2001).The significant differences in technology (SSPT vs.CPP) on large and small tuber numbers could be attributed to the plant population and spacing. The SSPT has closely spaced plants therefore significantly lower number of large tubers expected due to nutrient sharing. This is what makes the SSPT suitable for production of seed potato. Kakuhenzire *et al.* (2005)similarly observed significant differences in number of tubersharvested m^{-2}, number of tubers plant^{-1} and mean tuber weight (g) under SSPT and CPP.

Overall, total number of tubers was significantly more($P \leq 0.05$) in SSPT than CPP in Bududa and Kapchorwa. The number of large sized tubers was significantly higher ($P \leq 0.05$) in CPP than SSPT only in Kween (Table 3). The number of medium sized tubers were significantly higher in SSPT than CPP in Kapchorwa but the reverse was true in Kween. The SSPT registered more small sized tubers than CPP at all the sites. The previous crop rotational pattern comprising of onions, maize and cabbage might have favoured the generally high number of large sized tubers obtained in Kween because these are non-solanaceous crops. However, the medium sized tubers are more preferred for seed and the SSPT design is targeted to result into more medium sized tubers (Kakuhenzire *et al.* 2005; Infonet-biovision, 2012) unlike the CPP as observed in the data from Kapchorwa.The SSPT resulted in generally more number of tubers than the CPP because it is much easier to maintain proper hygiene under SSPT than CPP therefore very few plants rogued under SSPT. Kakuhenzire *et al.* (2005) similarly obtained higher yield in the SSPT compared to CPP though they attributed it to the high density planting under SSPT.

There were no significant differences in BW under SSPT and CPP practices at all the sites (Table 4). Similar results were obtained by Kakuhenzire*et al.* (2005) but with databased on disease scores. However, since the mean number of tubers with BW were higher in CPP than SSPT, potato productivity can be maximised in small land holdings and in light of BW presence using the SSPT.Notably, the SSPT registered significantly more ($P \leq 0.05$) tubers with BW in Manafwa and Sironko than the rest of the districts.These sites are generally at a lower elevation compared to the rest of the sites yet warmer environments favour BW (CIP,

Table 3. Yield (tubers plant^{-1}) of potato cv. Victoria under CPPand SSPTin 2011b

Tuber size	Techn	Bududa	Kapchorwa	Kween	Manafwa	Sironko
Large	CPP	0.1	0.2	0.7	0.1	0.2
	SSPT	0.0	0.2	0.3	0.1	0.2
$LSD_{0.05}$	0.2					
Medium	CPP	0.3	0.4	1.6	0.6	0.7
	SSPT	0.3	1.1	1.0	0.6	0.5
$LSD_{0.05}$	0.2					
Small	CPP	0.7	0.4	1.7	0.7	1.1
	SSPT	3.6	3.4	2.7	0.8	1.3
$LSD_{0.05}$	0.4					
Total number	CPP	1.1	0.9	4.0	1.4	2.0
	SSPT	3.9	4.7	4.0	1.4	2.0
$LSD_{0.05}$	0.6					

Table 4. Disease and pest damage(tubers plant^{-1}) of potato cv. Victoria at different sites of the Mt. Elgon zone in 2011b

Tuber damage	Techn	Bududa	Kapchorwa	Kween	Manafwa	Sironko
BW	CPP	0.07	0.03	0.0	0.41	0.29
	SSPT	0.03	0.00	0.0	0.41	0.28
$LSD_{0.05}$	0.1					
LB	CPP	0.03	0.04	0.0	0.0	0.0
	SSPT	0.02	0.00	0.0	0.0	0.0
$LSD_{0.05}$	0.01					
PTM	CPP	0.04	0.05	0.1	0.0	0.0
	SSPT	0.03	0.06	0.1	0.0	0.0
$LSD_{0.05}$	ns					

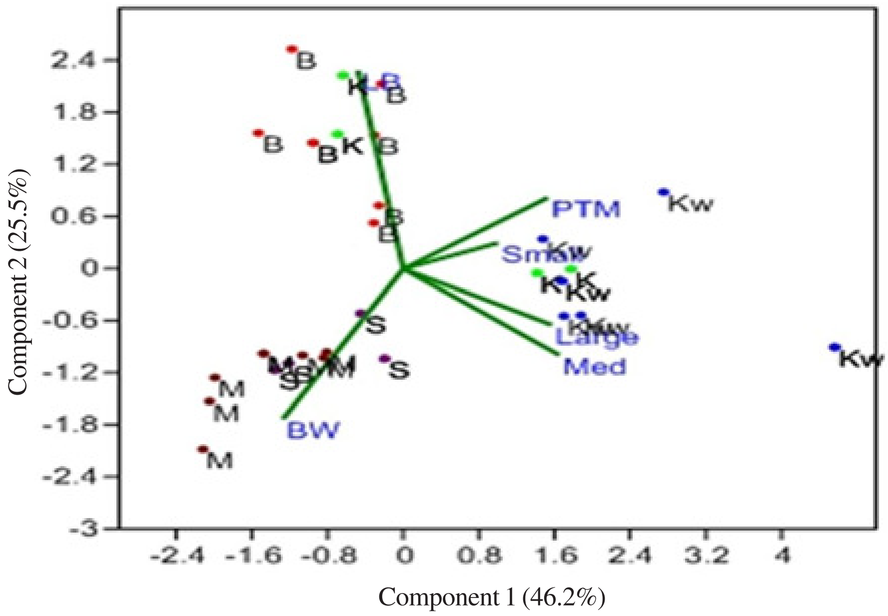

Figure 2. Bivariate plot of the relationship between component 1 and component 2 variables obtained after principal components analysis of the potato tuber counts, where B = Bududa, K = Kapchorwa, Kw = Kween, M = Manafwa and S = Sironko.

1996). The LB was generally low or absent in most locations except in Bududa and Kapchorwa under CPP. Number of tubers with PTM were not significantly different across sites with Manafwa and Sironko registering no PTM at all under CPP and SSPT.

Principal components analysis of site data against the different tuber counts generated two major components, 1 and 2, representing 46.2 and 25.5% of the total variation. Major variables contributing positively to component 1 were the small and medium sized tubers whereas for component 2, it was the large and medium sized tubers. Tubers with BW and LB contributed negatively to the components. A bivariate plot of component 2 against component 1 coefficient variables revealed that the small, medium and large tubers were more associated with environments in Kween district and least associated with Bududa district (Fig. 2). The PTM damaged tubers were more in Kween and least in Sironko and Manafwa. The reverse was true for BW. The tubers with LB were associated with the environment in Bududa and Kapchorwa and least associated with Kween.

Conclusion

The second season of the year (September - December) exhibited higher potato yield than the first season (March - June), with the highest number of tubers per plant obtained in the Sebei region (Kapchorwa and Kween). Consequently, potato productivity in the Mt. Elgon zone can be maximised in the second season of the year with more potential in the Sebei region. The SSPTcan be relied upon for production of seed potato on small land holdingsand therefore needs further promotion.

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