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Influence of Sweet Potato/Maize Association on Ecological Properties and Crop Yields in Swaziland

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ABSTRACT

Sweet potato is a major root storage crop in Swaziland, whereas maize (*Zea mays* L.) is the staple food crop in Swaziland. In this experiment, sweet potato cv. Kenya was grown in the field and intercropped with maize cv. SC 603 with the objective of determining the effects of crop association on soil temperature, weed infestation and crop yields. Five plant population treatments (T) were investigated: T_1, Maize alone at 40,000 plants/ha; T_2, sweetpotato alone at 33,333 plants/ha; T_3, maize at 40,000 plants/ha, intercropped with sweetpotato at 33,333 plants/ha; T_4, maize at 40,000 plants/ha, intercropped with sweet potato at 16,666 plants/ha and T_5, sweet potato alone at 16,666 plants/ha. Soil surface temperatures were generally higher than temperatures at 10 cm depth; nonetheless there were no significant differences in soil temperatures among the cropping systems. The three most dominant weed species in all plots were *Bidens pilosa* L. (37.5-59.3% relative abundance), followed by *Cynodon dactylon* L. (15.7-43.6%) and *Oxalis* latifolia (7.1-18.7%). *Sida rhombifolia* (0-0.4%); *Schkuhria pinnata* (0-0.4%) and *Leucas martinicensis* (0-0.4%) were the three least abundant weed species. Land equivalent ratio (LER) values indicated that Sweet potato-maize mixture at the recommended sole sweet potato population (33,333 plants per hectare) was a better cropping system (LER, 0.77) than intercropping at 50% of the recommended Sweet potato (LER, 0.74). Correlation data showed that maize cob yield was not significantly correlated to the 100-grain mass (r = 0.508; R^2 = 0.2581; N, 12); the resultant correlation of determination showed that 25.8% in the variation in cob yield could be ascribed to 100-grain mass. In sweet potato, correlation data showed that the number of tubers per plant was positively correlated to tuber yield ha^{-1} (r = 0.676; R^2 = 0.4570; N, 16); from the co-efficient of determination, 45.7% of tuber yield could be associated with the number of tubers per plant. In conclusion, sweet potato monocropping was the best system; nonetheless, if it has to be intercropped with maize, there should be 33,333 and 40,000 plants ha^{-1} of sweet potato and maize, respectively.

Key Words: Cereal; Intercropping; Mixed cropping; Polycropping; Root storage crop; Soil temperature; Weed species distribution

INTRODUCTION

Intercropping is the growing of two or more crops simultaneously on the same piece of land (Sullivan, 2000). It is the predominant cropping system in the tropics and sub-tropics and is typically practiced by small-scale and subsistence farmers (Sullivan, 2000). It would be beneficial to investigate if it would be advantageous to grow both maize (*Zea mays* L.) and sweet potato [*Ipomoea batatas* (L.) Lam.] in the same field and in the same cropping season, as a method to ensure against maize failure. Previous research showed advantages of intercropping sweet potato (Ossom *et al*., 2006) or cereals (Hauggaard-Nielsen, 2006) with grain legumes because of nitrogen fixation by grain legumes.

Maize is the staple food in Swaziland. However, it is sensitive to water deficit hence is prone to crop failure and low yields, if rains are not timely and regular during the cropping season. Odjugo and Osemwenkhae (2009) identified gas flaring as one of the causes of low maize yields in southern Nigeria. During 2008, maize production in Swaziland was 64 thousand tonnes (World Food Program, 2008). However, as reported by World Food Program (2008), Swaziland would still face a total cereal import requirement of around 136,000 tonnes in the consumption year (April, 2008 to March, 2009). Maize production in Swaziland has been declining steadily for the past decade.

Sweet potato is the most important tuber crop in Swaziland (Ossom *et al*., 2004). Most of Swaziland's shortfall in maize results from drought. One way of mitigating the drought effects is to produce and consume a relatively drought-tolerant crop such as sweet potato. Sweet potato is a strategic crop that is drought-tolerant and produces reasonable yields, where a maize crop fails. The shortage of chemical input and organic matter and the limited irrigation facilities in Swaziland also make sweet potato a crop of choice for Swazi farmers.

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Swazi farmers have grown sweet potato for many years (Nsibande, 1999), usually, for human food, but sometimes, the plants are used as livestock feed in the winter (Ogwang *et al*., 1994). Farmers have also been known to allow the vines to regenerate after harvest, if sufficient rain falls; tubers are usually dug and used for food, when the land is prepared the following season (M.P. Dlamini, University of Swaziland, personal communication, 2008). Nsibande (1999) reported that sweet potato was predominantly planted as a monocrop. In Swaziland, there is now increased emphasis to produce more food from a limited piece of farmland; current research efforts (Edje, 1995; Ossom & Nxumalo, 2003; Ossom, 2007a) and extension activities are now focused on encouraging the introduction of new sweet potato varieties (Cheng, 2006) and intercropping practices that had been the backbone of small-scale farming for centuries.

Sweet potato is a promising raw material for producing both biodegradable plastics and hydrogen gas for use as an energy source for cell batteries (Kozai *et al*., 1997). Zakir *et al*. (2008) reported on the usefulness of sweet potato glycemic index in relation to serum glucose level in Human Participants, thus indicating further use of this crop in nutrition and medicine. The annual starch yield of sweet potato in tropical and subtropical countries is 1.5 times higher than those of rice (*Oryza sativa* L.) or maize (*Zea mays* L.) and two times higher than that of Irish potato, *Solanum tuberosum* L. (Kozai *et al*., 1999), when the plants are protected from pests and diseases.

Maize faces difficult environmental situations in southern Africa. For many years now, drought in the Southern Africa Development Community (SADC) region has led to decreased maize production. The result of this state of affairs has been widespread famine and increased maize prices. Since 1989/1990, Swaziland has been unable to meet its domestic maize production requirement (Anonymous, 1998), relying instead on imports and food donations. Swaziland's total maize requirement is about 159,000 tonnes, consisting of 156,700 tonnes of domestic consumption requirements and 3000 tonnes of desired minimum stock (NEWU, 2002). Shortfalls in maize yields mainly due to drought were: 69.4%, 42.1%, 53.1% and 60.2% in 1992, 2000, 2004 and 2006, respectively (SADC Regional Early Warning Unit, 2002). One means to address the malnutrition problem in Swaziland and indeed in the SADC region is through the production and consumption of more drought-tolerant crops such as sweet potato under intercropping with the staple crops. This study was therefore conducted to evaluate the effects of sweet potato intercropping with maize on soil temperature, weed infestation and crop yields.

MATERIALS AND METHODS

Duration, location of the experiment and land preparation: This experiment was conducted in two locations in the same Middleveld ecological zone from November, 2008 to July, 2009. One location was Malkerns Research Station (26.57°S, 31.17°E; altitude, 740 m above sea level; rainfall range, 800-1460 mm during the cropping season; mean temperature range, 7.3°C-26.6°C during the growing season). The second site was at a farmer's field located 2.0 km from Malkerns. Land preparation was done at both sites by plowing with a mould board plow, after which disc harrowing was done. After harrowing, ridges were constructed using tractor-mounted ridgers.

Treatments, experimental design and plot size: The investigation was a field experiment consisting of five population treatment combinations, arranged in a randomized complete block design. Each treatment was replicated four times. Each plot measured 8.0 m long and 6.0 m wide and consisted of nine (gross) ridges, each measuring 8.0 m in length and four ridges of net plots. There was a 1.0 m distance between treatments and between blocks. There were five discard ridges, two at each end of the plot. Inter-row spacing was 100 cm and the intra-row spacing was as shown in Table I.

Soil analysis and liming: Soil chemical analysis, using standard methods (AOAC, 1990), was carried out at the start and end of the experiment, to assess the chemical composition of the soil. Because the soil pH in the farmer's plots was 4.65 and below 5.3, the lower pH limit below which agricultural lime needs to be applied (Anonymous, 1991), lime was applied at the rate of 1000 kg ha^{-1}, based on the recommendation from Malkern's Research Station soil science laboratory. At the farmer's field, lime was applied on 7 November, 2008 by broadcasting on the ridges and working into the soil using garden forks and spades. The workers wore protective clothing (gum boots, face masks and heavy-duty gloves during this exercise). In Malkerns Research Station plots, no liming was done because the soil pH was 5.3, at which pH liming was not recommended (Anonymous, 1991).

Planting and filling of gaps: The crops were planted on the same day after plowing, disking and ridging were completed. At the farmers' field, planting was done on 10 and 11 November, 2008. Because of tractor-hiring and tractor unavailability problems, land preparation and planting were delayed in Malkerns Research Station and planting was done on 07 January, 2009.

Stem cuttings of the 'Kenya' variety of sweet potato were used; each cutting was from a mature stem and measured 30 cm in length. Cuttings were planted on top of the ridges. To simulate the small-scale farmers' condition of minimal use of agro-chemicals, there was no chemical treatment of cuttings before planting. Maize (SC 603), one grain per stand was planted on top of the same ridges with sweet potato, if both crops appeared in the same plot. Gaps were filled within one week of emergence of maize seedlings or sprouting of sweet potato cuttings.

Fertilizer application: Fertilizer application was carried out at planting, at 4 and 6 weeks after planting (WAP), as follows (Anonymous, 1991).

a). At planting: maize alone or maize interplanted with sweet potato: 200 kg ha^{-1} of N:P:K [2:3:2 (38)].

b). 350 kg ha^{-1} of N:P:K [2:3:2 (38)], that also contained 0.5% Zn, was applied to any plots that had sweet potato.

c). 100 kg ha^{-1} of superphosphate (10.3% P), was also applied to plots that had sweet potato.

d). 100 kg ha^{-1} of KCl (60% K) was also applied only to plots that had sweet potato.

At 4 WAP, further fertilization was carried out as follows (Anonymous, 1991): 100 kg ha^{-1} of limestone ammonium nitrate, LAN (28% N) was applied to all plots that had maize only. At 6 WAP, 100 kg ha^{-1} of LAN was applied as a side dressing to all plots that had sweet potato. In all cases, the fertilizers were applied by the banding and incorporation method, 15 cm away from the crop rows.

Meteorological data and weeding: Meteorological data were collected from records of the Meteorological Department of Malkerns Research Station. Weeding was done at 5 WAP, using hand hoes; the weeding time was determined by the level of weed infestation.

Data collection: Destructive plant sampling (4 plants per plot) was used to collect data every 4 weeks, from 4 to 20 WAP at Malkerns Research Station site. No plant samples were taken from the farmer's plots. This was because sampling from farmer's plots was likely to give farmers the false impression that samples removed from plots could be responsible for yield differences. Final yield data (at 20 WAP) were collected from both experiment sites.

Soil temperatures at soil surface, 5 cm depth and 10 cm depth were measured at 4, 8, 12, 16 and 28 WAP. The temperatures were measured within one hour, between 1400 h and 1600 h (Ossom *et al*., 2001), using the Fisherbrand bi-metal dial soil thermometers, with a stem length of 20.3 cm, gauge diameter of 4.5 cm and an accuracy of $\pm$ 1.0% of dial range at any point on the dial. A similar thermometer was used by Ossom *et al*. (2001). The soil temperature was taken at a distance of 10 cm away from the base of the plants. Readings were taken at four stations in each plot.

Using visual determination, weed infestation was scored at 20 WAP. The weed scores or weed densities (Ossom, 2005; Ossom & Mavuso, 2009) are described in Table II. The weed densities were assessed on a scale of 1-6 on the soil within a 100 cm square quadrat (four determinations per plot). The percentage of the quadrat occupied by all parts, or a portion of each weed species, was regarded as the relative abundance of the species within the plot. A similar weed assessment method was earlier used by other researchers (Daisley *et al*., 1988; Ossom, 2007 a & b). Disease infestation was assessed within the same 100 cm quadrat (four determinations per plot) and disease incidence was scored using a scale of 1-6 (Table III).

Land equivalent ratio: The land equivalent ratio (LER) was calculated for each plant population using the formula (Sullivan, 2003; Ossom, 2005):

$$\text{LER} = \frac{\text{Yield of crop A mixture}}{\text{Yield of pure crop A}} + \frac{\text{Yield of crop B mixture}}{\text{Yield of pure crop B}}$$

$$= \frac{[\text{Yield of sweet potato in mixture}]}{[\text{Yield of pure sweet potato}]} + \frac{[\text{Yield of maize in mixture}]}{[\text{Yield of pure maize}]}$$

Assessment of maize-sweet potato intercropping by farmers: Twice (in the middle of the growing season & on harvest day) 10 small-scale farmers from the neighbourhood were invited to each site to assess the maize-sweet potato cropping system. In the first visit, they assessed the effects of the crop combinations on the general performance of both maize and sweet potato crops using the counter methodology (Edje, 2001). In this method, each farmer was given 30, 20-cent coins and was asked to independently assess each crop association and crop yields. At harvest, the farmers assessed both cropping systems and crop yields. All farmers were initially briefed on how to use the coins and assess the cropping systems or crop yields. Because of delayed land preparation and late planting of the experiment in Malkerns Research Station, crops in the farmer's plots were ready for harvest earlier and were harvested earlier than in Malkerns.

Data analysis: Data were analyzed using MSTAT-C statistical package, version 1.3 (Nissen, 1983). Mean separation was done by the least significant difference (LSD) test (Steel *et al*., 1997).

RESULTS

Weather information: The lowest temperature (7.8^{o}C) was recorded in the month of July, 2009; the highest temperature (30.0^{o}C) was attained in November, 2008. The lowest rainfall (1.9 mm) was in July, 2009 and the highest rainfall (159.4 mm) was in February, 2009 (Table IV).

Soil temperatures: Table V shows the soil temperatures at 4-20 WAP. Soil surface temperatures (mean, 28.8^{o}C) were generally higher than temperatures at 10 cm depth (mean, 27.0^{o}C); at 5 cm depth, mean temperature was 29.2^{o}C.

Weed infestation: Table VI shows the weed species and their distribution in the different cropping systems. No exotic weed species were encountered; all weed species had previously been observed in the Malkerns area. In terms of botanical family distribution of weeds, the different plant populations were made up of the following families: Maize at 40,000 plants ha^{-1}, eight families; sweet potato at 33,333 plants ha^{-1}, five families; maize at 40,000 plants ha^{-1} intercropped with sweet potato at 33,333 plants ha^{-1}, eight families; maize at 40,000 plants ha^{-1} intercropped with sweet potato at 16,667 plants ha^{-1}, seven families; and sweet potato at 16,667 plants ha^{-1}, six families.

The three most dominant weed species in all plots were *Bidens pilosa* L. (37.5-59.3% relative abundance), followed by *Cynodon dactylon* L. (15.7-43.6%) and *Oxalis* latifolia (7.1-18.7%). The three least abundant weed species were *Sida rhombifolia* (0-0.4%); *Schkuhria pinnata* (0-0.4%) and *Leucas martinicensis* (0-0.4%). Disease scores

Table I: Treatment description for the experiment

Description	Maize population ha^{-1}	Sweet potato population ha^{-1}
Maize alone at 25 cm × 100 cm (1 grain per stand)	40,000	0
Sweet potato alone at 30 cm × 100 cm (1 cutting per stand)	0	33,333
Maize at 25 cm × 100 cm intercropped with Sweet potato at 33,333 plants per ha (1 cutting per stand)	40,000	33,333
Maize (25 cm × 100 cm) intercropped with 50% Sweet potato population, spaced at 60 cm × 100 cm	40,000	16,667
Sweet potato alone at 60 cm × 100 cm (1 cutting per stand)	0	16,667

Table II: Scale for assessing weed infestation

Description	Rating
Zero weeds on soil	1
Sparse weed coverage	2
Intermediate weed coverage	3
General weed coverage	4
Severe weed coverage	5
Very severe weed coverage	6

Table III: Scale for scoring for diseases

Description	Rating
Complete absence of disease	1
Sparse disease coverage or presence	2
Intermediate disease coverage or presence	3
General disease coverage or presence	4
Severe disease coverage or presence	5
Very severe disease coverage or presence	6

Table IV: Rainfall and temperature data during the experiment

Month/Year	Temperature (°C)		Total rainfall (mm)
	Minimum	Maximum	
November, 2008	16.8	30.0	104.0
December, 2008	18.5	29.9	56.9
January, 2009	19.4	29.0	137.8
February, 2009	18.7	28.3	159.4
March, 2009	16.9	27.7	51.6
April, 2009	14.0	26.7	7.2
May, 2009	14.7	25.7	72.5
June, 2009	12.0	24.1	18.0
July, 2009	7.8	23.3	1.9
Total	138.8	244.7	609.3
Mean	15.42	27.19	67.7

Source: Malkerns Research Station, unpublished data, 2009

showed significant differences among the cropping systems; the least disease-infested cropping system (disease score, 1.3 out of 6.0) was sole sweet potato planted at 33,333 plants ha^{-1}. However, this disease score was not significantly lower than that of maize at 40,000 plants ha^{-1} intercropped with sweet potato at 33,333 plants ha^{-1} (disease score, 1.5 out of 6.0) or that of sole sweet potato at 16,667 plants ha^{-1} (disease score, 1.5 out of 6.0). The two main diseases observed were *Cercospora* leafspots (caused by *Cercospora* spp.) in sweet potato and maize streak (caused by maize streak virus) in maize.

Maize yield and yield components at Malkerns Research Station site: Table VII shows the yield and yield components of maize from Malkerns Research Station site. Though sole maize was superior in yield to intercropped maize, the differences were not significant. The 100-grain mass was not significantly different among the three cropping systems.

Maize yields from Mr. Sipho's farm: Table VIII shows the trends in maize yield data from Mr. Sipho's plots. Sole maize yielded significantly ($p < 0.05$) higher (4287.5 kg ha^{-1}) than the other two maize cropping systems. Maize interplanted through the recommended sweet potato population yielded 1818.4 kg ha^{-1}, which was not significantly higher than the yield of maize (1741.9 kg ha^{-1}) associated with 50% of sweet potato population.

Correlation data showed that cob yield was positively, but not significantly correlated to the 100-grain mass (r = 0.508; R^2 = 0.2581; N, 12); the resultant correlation of determination showed that 25.8% in the variation in cob yield could be ascribed to 100-grain mass.

Coin assessment: In Mr. Sipho's farm, the preferred cropping system by farmers was sole sweet potato at the recommended plant population and the least preferred cropping system was a mixture of maize and sweet potato, each at the recommended plant population. Regarding the crop yields, the farmers ranked sole maize as the best in yields, followed by sweet potato at the recommended plant population. Both cropping system and crop yields from Malkerns Research Station plots received a similar assessment as at Mr. Sipho's farm (Table IX).

Sweet potato yields: Data on sweet potato yields (Table X) from the farmer's plots showed that sweet potato at the recommended population yielded significantly ($p < 0.05$) higher (16,707.7 kg ha^{-1}) than intercropped sweet potato, which was significantly ($p < 0.05$) higher than all the other cropping systems.

The least-yielding sweet potato was from the association of maize with 50% sweet potato population (3,659.2 kg ha^{-1}). Similarly, tuber yields from the Research Station were significantly ($p < 0.05$) higher in sole sweet potato (14,700.5 kg ha^{-1}) at the recommended spacing and lowest (6064.4 kg ha^{-1}), when maize was associated with 50% of the recommended sweet potato plant population. Correlation data showed that the number of tubers per plant was positively correlated to the yield ha^{-1} (r = 0.676; R^2 = 0.4570; N, 16). The resultant coefficient of determination showed that 45.7% of tuber yield could be associated with the number of tubers per plant.

Land equivalent ratio: In the farmer's plots, at sweet potato population of 33,333 plants ha^{-1}, LER was 0.77. At sweet potato population of 16,666 plants ha^{-1} LER was lower (0.74).

DISCUSSION

Weather information: Among the climatic factors that are known to affect crop production are temperature,

Table V: Effects of Sweet potato and maize cropping systems on soil temperature (ºC) at the soil surface, 5 cm depth and 10 cm depth in Swaziland

Cropping system	Soil depth	Weeks after planting					Means
		4	8	12	16	20	
	Surface	33.9	32.3	36.8	20.7	25.4	29.8
Maize alone at 25 cm × 100 cm	5-cm	39.2	30.0	32.1	24.3	27.7	30.7
	10-cm	37.2	28.2	28.8	23.3	22.3	28.0
	Surface	33.2	29.9	31.7	23.3	24.1	28.7
Sweet potato alone at 30 cm × 100 cm	5-cm	38.1	28.3	29.2	23.7	24.3	28.7
	10-cm	37.0	25.8	26.2	23.7	22.2	27.6
	Surface	34.0	30.4	35.2	24.1	23.2	29.4
Maize at 25 cm intercropped with Sweet potato at 30 cm × 100 cm	5-cm	38.4	28.1	30.5	24.0	23.1	28.8
	10 -cm	36.3	25.7	25.9	22.7	21.8	26.5
	Surface	34.5	30.1	29.7	22.8	23.0	28.0
Maize (25 cm × 100 cm) intercropped with 50% sweet potato population spaced at 60 cm × 100 cm	5-cm	37.9	29.4	29.1	23.9	25.9	29.2
	10-cm	36.1	26.1	24.8	23.9	21.9	26.6
	Surface	33.5	28.2	34.3	22.5	22.6	28.2
Sweet potato alone at 60 cm × 100 cm	5-cm	37.9	26.5	30.8	24.4	24.7	28.9
	10-cm	35.8	24.7	28.0	23.9	21.9	26.8
	Surface	33.8	30.2	33.5	22.7	23.7	28.8
Mean	5-cm	38.3	28.4	30.3	24.1	25.1	29.2
	10-cm	36.5	26.1	26.7	23.5	22.0	27.0
	Surface	2.54	1.38	4.16	2.47	2.87	-
Least significant difference (0.05)	5-cm	2.63	2.19	2.97	1.25	3.35	-
	10-cm	2.26	2.26	3.01	2.14	2.92	-

Table VI: Influence of maize-sweet potato intercropping on the relative abundance (%), diversity of weed species and disease scores at 20 weeks after planting

Weed species	Common name	Family name	Cropping systems and weed relative abundance[1]				
			Maize at 40,000 plants ha^{-1}	Sweet potato at 33,333 plants ha^{-1}	Maize at 40,000 plants ha^{-1} + sweet potato at 33,333 plants ha^{-1}	Maize at 40,000 plants ha^{-1} + sweet potato at 16,667 plants ha^{-1}	Sweet potato at 16,667 plants ha^{-1}
Acanthospermum hispidum (DC) Wild.	Upright starbur	Asteraceae	0.0	5.9	1.6	0.4	5.0
Ageratum conyzoides (L.)	Goat weed	Asteraceae	7.3	0.0	0.0	0.0	0.0
Bidens biternata (Lour.) Merri. And Sherff	Five-leaved blackjack	Asteraceae	0.4	0.0	2.0	0.0	1.3
Bidens pilosa L.	Common blackjack	Asteraceae	37.5	38.1	59.3	49.6	53.8
Convolvulus arvensis L.	Field bindweed	Convolvulaceae	0.9	0.0	0.0	0.0	0.0
Corchorus olitorius L.	Jews mallow	Tiliaceae	0.9	0.0	0.0	0.0	0.0
Cynodon dactylon (L.) Pers.	Common couchgrass	Poaceae	16.4	43.6	15.7	20.4	22.9
Digitaria sanquinalis (L.) Scop.	Crab fingergrass	Poaceae	1.3	0.0	0.0	0.0	0.0
Euphorbia hirta L.	Hairy creeping milkweed	Euphorbiaceae	0.4	0.0	0.0	2.2	0.0
Galinsoga parviflora Cav.	Gallant soldier	Asteraceae	0.9	0.0	0.0	0.0	0.0
Hibiscus cannabinus L.	Kenaf	Malvaceae	0.9	0.0	0.4	0.9	2.9
Ipomoea purpurea (L.) Roth.	Morning glory	Convolvulaceae	2.2	0.0	2.4	0.9	2.9
Leucas martinicensis R. Br.	Bobbin weed	Labiataceae	0.0	0.0	0.4	0.0	0.0
Nicandra physalodes (L.) Gaertn.	Apple of Peru	Solanaceae	0.0	0.4	0.8	0.0	0.0
Oxalis corniculata L.	Creeping sorrel	Oxalidaceae	0.0	0.0	0.0	0.4	2.5
Oxalis latifolia H.B.K.	Red garden sorrel	Oxalidaceae	11.6	8.5	10.5	18.7	7.1
Richardia brasiliensis (Moq.) Gomez.	Mexican Richardia	Rubiaceae	15.9	3.4	6.9	6.5	1.7
Schkuhria pinnata (Lam.) Kuntze	Dwarf marigold	Asteraceae	0.4	0.0	0.0	0.0	0.0
Sida rhombifolia L.	Pretoria Sida	Malvaceae	0.4	0.0	0.0	0.0	0.0
Xanthium strumarium L.	Cocklebur	Asteraceae	2.6	0.0	0.0	0.0	0.0
Weed score	N/A	N/A	3.7a	2.5ab	2.1b	3.3ab	2.2ab
Disease score	N/A	N/A	2.1a	1.3b	1.5b	2.0a	1.5b

[1]Because of rounding up of figures, totals of weed abundance may not equal 100.0%; Weed score mean = 2.8; Disease score = 1.7; Numbers in the same row followed by the same letters are not significantly different, according to the least significant difference test.; N/A, not applicable

precipitation (such as rainfall) amounts and distribution, wind speeds and direction. Price (2009) warned that even if global temperatures rise slowly, climate change could slash the yields of some of the world's most important crops almost in half.

Soil temperatures: Though soil surface temperatures were

Table VII: Maize yield components and yield under sweet potato-maize intercropping

Cropping system	Dry mass of shelled grains (g)	Dry 100-seed mass (g)	Fresh mass of rachis (g)	Shelled grain yield (kg ha^{-1})
Maize alone at 25 cm × 100 cm	1,991.8 a	22.0 a	426.2a	1,659.8 a
Maize at 25 cm × 100 cm intercropped with Sweet potato at 33,333 plants ha^{-1}	1,074.3 a	20.9 a	427.5a	895.2 b
Maize (25 cm × 100 cm) intercropped 50% Sweet potato	1,560.6 a	19.4 a	382.1a	1,300.4 ab
Means	1,542.2	20.8	411.9	1285.1
Least significant difference (0.05)	865.27	5.32	389.07	643.0
Significance at P < 0.05	NS	NS	NS	*

NS, Not significant at p > 0.05, according to LSD; Numbers in the same column followed by the same letter are not significantly different according to the LSD

Table VIII: Maize yields from farmer's plots

Cropping system	100-grain dry mass (g)	Cob yield (kg ha^{-1})	Potential income from sale of cobs per ha (E)†
Maize alone at 25 cm ×100 cm	31.7 a	4,287.5 b	4,930.6b
Maize at 25 cm × 100 cm intercropped with Sweet potato at 33,333 plants ha^{-1}	29.9 a	1,818.4 ac	2,091.2ac
Maize (25 cm × 100 cm) intercropped 50% Sweet potato	28.9 a	1,741.9 a	2,003.2a
Means	30.15	2615.92	3,008.3
Least significant difference (0.05)	6.05	860.81	989.96
Significance at p < 0.05	NS	*	*

NS, Not significant; *, significant at p > 0.05, according to LSD; Numbers in the same column followed by the same letter are not significantly different according to the LSD; †, selling price of maize from the project was E1.15 per 1.0 kg of maize on the cob

Table IX: Coin system assessment on sweet potato-maize cropping systems in farmer's plots and Research Station plots

Cropping system	Farmer's plots		Research Station plots	
	Cropping system assessment	Yield assessment	Cropping system assessment	Yield assessment
Maize alone at 25 cm × 100	6.8 a	8.5 a	6.7 ab	8.8 a
Sweet potato alone at 30 cm × 100 cm	7.0 a	5.9 ab	7.2 a	6.1 b
Maize at 25 cm × 100 cm + Sweet potato at 33,333 plants/ha	4.0 b	5.1 b	3.3 b	4.9 b
Maize (25 cm × 100 cm) + 50% Sweet potato population spaced at 60 cm × 100 cm	5.7 a	5.5 b	6.1 a	5.4 b
Sweet potato alone at 60 cm × 100 cm (1 cutting/stand)	6.5 a	5.0 ab	6.7 a	4.8 b
Mean	6.0	6.0	6.0	6.0
Least significant difference (0.05)	2.78	2.90	2.81	3.17
Significance (P < 0.05)	*	*	*	*

*, Significant at p > 0.05, according to the LSD; Numbers followed by the same letters in the same column are not significantly difference according to the LSD test

Table X: Sweet potato marketable tuber yields from Research Station and farmer's plots

Cropping system	Tuber yield (kg ha^{-1})		Potential income per ha (E)† from farmer's farm
	Research Station	Farmer's plots	
Sweet potato alone at 30 cm × 100 cm	14,700.5 a	16,707.7 a	62,653.9 a
Maize at 25 cm × 100 cm + Sweet potato at 33,333 plants ha^{-1}	7,354.9b c	5,866.5 b	21,999.4 b
Maize (25 cm × 100 cm) + 50% Sweet potato population spaced at 60 cm × 100 cm	6,064.4 b	3,659.2 b	13,722.0 b
Sweet potato alone at 60 cm × 100 cm	13,960.9	10,949.6 c	41,061.0 c
Means	10,520.2	9,295.72	34859.0
Least significant difference	3,061.2	2,782.93	10436.0
Significance at p < 0.05	*	*	*

*, significant at p < 0.05, according to LSD; Numbers in the same column followed by the same letter are not significantly different according to the LSD; †, selling price of Sweet potato tubers from the experiment was E3.75 per kg

generally higher than temperatures at 10 cm depths as reported in previous studies (Ossom, 2005; 2007b), there were no significant differences in soil temperatures among the cropping systems. Higher temperatures at the soil surface can be attributed to greater numbers of living organisms, greater biological activities of these organisms and nearness to solar radiation than deeper soil layers.

Weed infestation: That no exotic weed species were encountered was consistent with a previous report Ossom (2010). Weed species distribution can be affected by a number of factors including: tillage and herbicides (Yenish *et al*., 1992); soil properties [Andreasen *et al*., 2006 & weed management practices (Gibson *et al*., 2006)]. *Cercospora* leafspots are common in areas that grow sweet potato or cassava (*Manihot esculenta* Crantz). It was reported (FAO, 2004) that both early planted (August-September) maize and late-planted (December-January) maize is susceptible to streak in Swaziland.

Maize yield and yield components at Malkerns Research Station site: That the 100-grain mass was not significantly different among the three cropping systems was contrary to the findings of Bahoush and Abbasdokht (2008), who observed direct and indirect effects of 100-seed mass on maize grain yield and produced highly significant ($p < 0.01$) correlation coefficient ($r = 0.68$), but the number of seed per ear was negatively associated with 100-seed mass ($r = -0.06$). In agreement with previous reports, Zamir *et al*. (1999) noted that the variability in 1000-grain weight could be attributed to the better growing facilities (more aeration, light, nutrients) available at wider spacings used in their investigation.

Maize yields from Mr. Sipho's farm: The positive association between cob yield and 100-grain mass agreed with the result of Abdel Raman *et al*. (2001), who noted positive and highly significant ($p < 0.01$) correlations between maize grain yield ($r = 0.807$) and between 1000-seed mass and grain yield ($r = 0.732$). The results of this experiment were also consistent with the reports of Saleem *et al*. (2007), that grain yield per plant in maize was strongly associated with 1000-grain weight and with biomass per plant, under irrigated conditions.

Coin assessment: Edje (2001) reported that farmers were able to use the coin technology and differentiate between preferred farming systems or farming practices. Ossom and Rhykerd (2008) earlier reported a positive, but not significant correlation between number of tubers per plant in sweet potato and marketable tuber yield. Potential incomes were significantly ($p < 0.05$) higher in monocrops than in mixed crops.

Sweet potato yields: That sole sweet potato yielded higher than intercropped sweet potato was consistent with several previous reports (Keswani & Ndunguru, 1982; Sullivan, 2000; Ossom & Nxumalo, 2003; Ossom, 2007a & b; Njoku *et al*., 2007; Ossom & Rhykerd, 2008). Dereje and Basavaraja (2005) reported a positive correlation between tuber yield and number of tubers in Irish potato.

Land equivalent ratio: LER is a measurement of how an intercrop performs when compared to the pure stand of the crop. Knowledge of LER gives us the yield advantage that the intercrop had over pure stands, if any (Sullivan, 2000). An LER of 1.0 would indicate that the amount of land required for both crops in the mixture (e.g., maize & sweeet potato) was the same as that for each crop grown as a monocrop. This would imply that there was no advantage of intercropping over pure crops. An LER greater than 1.0 would show a yield advantage of intercropping over pure crops, whereas an LER less than 1.0 would indicate that intercropping was a disadvantage.

Thus, the LER of 0.77 and 0.74 obtained in the 33,333 plants ha^{-1} of sweet potato and 16,666 plants ha^{-1}, respectively, shows that intercropping in both cases was a disadvantage. However, LER values indicated that sweet potato-maize mixture at the recommended sweet potato population was a better cropping system (LER, 0.77) than intercropping at 50% of the recommended sweet potato (LER, 0.74). Leihner (1983) warned that though LER is a useful concept, it might lead to an over-estimation of a system's efficiency especially, when the cropping system involves a large number of crops.

Sullivan (2003) reported higher cereal yield with strip intercropping compared to sole cropping and noted that narrow strips accommodate the pest management and soil building advantages of rotations and the yield boost of border rows. In all instances, soya bean grain yield was depressed by intercropping with maize in this experiment. Sullivan (2003) noted higher yield depression in border rows and attributed this to shading, but also observed that yield of middle rows of soya bean was higher than they would be in a sole field and attributed this to a possible windbreak effect.

CONCLUSION

Based on the farmers' coin assessment for yields and cropping systems, as well as the LER values, sweet potato monocropping was the best system among the five cropping systems; nonetheless, if sweet potato has to be intercropped with maize, there should be 33,333 and 40,000 plants ha^{-1} of sweet potato and maize.

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