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Growth and Yield Response of Improved Sweet Potato Cultivars to Intercropping with Hybrid Maize and Inorganic Fertilizers

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Abstract: A field study was conducted in 2018 to determine the growth and yield response of improved sweet potato cultivars to intercropping with hybrid maize and inorganic fertilizer application using a randomized complete block design in a split-plot arrangement and three replications. Maize was intercropped with NASPOT 1, NASPOT 8 and NASPOT 11 potato cultivars. Sole crops and the potato/maize intercrops were fertilized with graded levels of N, P and K comprising a control without fertilizer, 40-20-30, 80-40-60, 120-60-90 and 160-80-120 kg/ha of N-P-K. Vine lengths, and numbers of vine branches and leaves of potato plants under intercropping were higher ($P < .05$) than those of plants under sole cropping system. In both systems, NPK fertilizer application didn't ($P >.05$) affect the vine lengths and numbers of vine branches compared to the control. But numbers of vine branches of plants under sole cropping for all the fertilizer treatments were higher ($P < .0001$) than those of plants under intercropping system. Generally, NPK application in the sole potato cropping significantly ($P =.02$) affected the leaf numbers, and the fertilized potato plants had greater ($P < .05$) leaf numbers than the control. In both systems, NASPOT 11 produced the highest tuber yield, followed by NASPOT 8. Tuber yields were better ($P < .01$) under sole cropping (43.36 MT/ha) than under intercropping (33.35 MT/ha). Maize grain yields were also better ($P < .0001$) under sole cropping than under intercropping. But grain yields from all the fertilized intercrops were greater ($P < .05$) than those of their corresponding control treatments. In all the intercrops, the land equivalent ratios (LERs) were greater than unity indicating yield advantage of intercropping over sole cropping. It was concluded that applying 120-60-90 kg/ha of N-P-K into the potato/maize intercrops results in better tuber yields compared to the unfertilized control. Also, N-P-K application in quantities greater than 40-20-30 kg/ha does not lead to significant differences in tuber yields between the potato/maize intercropping and sole potato cropping systems indicating that inter-specific competition for nutrients in the intercrops is eliminated by the fertilizer. In addition, the application of 80-120 kg N/ha, 40-60 kg P/ha and 60-90 kg K/ha in the intercrops results in better intercrop performance as revealed by higher LERs indicating that improved potato cultivars and hybrid maize are compatible for intercropping. Therefore, farmers can intercrop improved sweet potato cultivars with hybrid maize and apply 120-60-90 kg/ha of N, P and K in the intercrops to maximize yields.

Keywords: Hybrid Maize, Inorganic Fertilizer, Intercropping, Potato Tuber Yield, Sweet Potato Cultivars, Vine Branches, Vine Lengths

1. Introduction

Sweet potato [*Ipomoea batatas* (L.) Lam] is ranked as the sixth most important food crop after rice, wheat, potatoes, maize and cassava in the world with an annual production of over 138 million metric tonnes [1]. It is a starchy crop belonging to the family *convolvulaceae*, and is grown in tropical and subtropical countries. China is the world leading producer while Nigeria is the leading producer in Africa. Sweet potato is vegetatively propagated, and is a good source of complex carbohydrates, antioxidants, carotenes, vitamins A, B2, B5, B6, B9 and C, and is rich in minerals like K, Na, Cl, P, Cu and Ca [2]. Thus it can serve as a high value-added food particularly for children and pregnant women who are vulnerable to vitamin A deficiency [3]. In Uganda, sweet potatoes are consumed in steamed, boiled or roasted form [4]. Products made from potato and consumed include dried chips and chunks, pastries and confectioneries [5].

In Uganda, sweet potato is ranked as the fourth most important crop in terms of production volumes after maize, cassava and banana [6]. In 2017, annual production of potato was estimated at 1.66 million metric tons, with per capita consumption of 73 kg/annum [7, 8]. However, potato productivity is constrained by several factors including unfavourable weather, pest and diseases, incorrect agronomic practices and lack of knowledge on the types and rates of fertilizer nutrients needed by the crop. Most important macronutrients for crops grown in Uganda including sweet potato are nitrogen (N), phosphorus (P) and potassium (K). Nitrogen is the most important nutrient in yield formation and quality of crop products [9]. Phosphorus is an important component of organic compounds that are vital for metabolic processes, blooming and root development [10]. Potassium is involved in metabolic processes like photosynthesis, translocation of assimilates, and synthesis of protein and starch [2]. The demand for K by sweet potato plants is quite high as it is used in the formation of leaves, vines and tubers, and is responsible for the number and sizes of tubers formed.

Although the need to increase food production is becoming more apparent due to rapidly increasing human population, the agricultural land is shrinking rapidly. Competition for land between agriculture and other uses such as housing, industries and roads is steadily building up. By 2050, human population is estimated to have reached nine billion people, which along with changing dietary preferences, will require stepping up food production [11]. Attainment of high yields on existing agricultural land in regions that are still producing below the optimum is of great importance if global food demand is to be met without degrading the environment [11]. In the face of declining agricultural land coupled with a growing human population with ever increasing food demand, increasing the crop yields through sustainable intensification provides a prospective avenue to sustain the future viability of agriculture, and in turn ensure food security [12]. Intensification of land use is vital in the attainment of the UN Sustainable Development Goal of ending hunger, achieving food security and improving nutrition and promoting sustainable agriculture (SDG2).

Traditionally, food production can be increased either by expanding cultivated land area, or improving yield potentials of individual crops. But given the increasing competition for land, large-scale expansion of agriculture is no longer a feasible strategy for future food security. Land use intensification through intercropping can possibly increase the total yield per unit land area. Intercropping is productive when it is done wisely by selecting compatible crops, by planting the component crops in such a way that their peak demands for growth resources do not coincide, optimizing population densities of component crops, and judicious application of fertilizers [13, 14, 15, 16]. There is efficient utilization of growth resources by the companion crops in both temporal and spatial dimensions due to their differential growth habits.

Intercropping maize and sweet potato has been found to be one of the strategies that enhances household food security and incomes by boosting the productivity per unit land area [17]. Intercropping sweet potato with hybrid maize is likely to be compatible since both crops possess different photosynthetic pathways, different growth habits and require different growth resources [18]. Thus this study evaluated land use efficiency of intercropping sweet potato and hybrid maize, coupled with the judicious application of inorganic fertilizers.

2. Materials and Methods

This section describes the materials and methods that were utilized to execute the study. Specifically, it comprises the description of area where the study was performed, nature of soils in the experimental plots, materials and experimental design that was used, field preparation and crop management, and the data collection methods and analysis.

2.1. Description of the Study Area

The field study was conducted at Makerere University Agricultural Research Institute Kabanyolo (MUARIK) during the first (April-July) and second (September-December) seasons of 2018. MUARIK is located 19 km north of Kampala city, and on spatial coordinates 0˚27'60" N and 32˚36'24" E at an altitude of 1204 m above sea level. It receives mean annual rainfall of 1218 mm and slightly drier periods in June – July and December – February. The average annual temperature is 21.5°C [19].

2.2. Soil Sampling and Analysis

At the onset of the study, soil samples were collected from the site at the depths of 0-15 and 15-30 cm using a soil auger, and taken to the laboratory for analysis to determine their physico-chemical properties. The samples were air-dried, grounded and sieved with a 2 mm mesh sieve, and then analyzed for organic carbon, total nitrogen, available phosphorus, exchangeable potassium and bases, and pH [20].

The results showed that the soil was sandy-clay loam (sand 71.0%, silt 7.5%, clay 21.5%) with a pH 4.6, organic matter 2.41%, total N 0.16%, available P 3.85%, exchangeable K 0.45 cmol/kg, sodium 0.08 cmol/kg, calcium 3.34 cmol/kg, magnesium 1.20 cmol/kg, CEC 19.50 cmol/kg.

2.3. Experimental Materials

Water Efficient Maize for Africa (WEMA) hybrid maize (WE 2115) from Pearl Seeds Limited was intercropped with three sweet potato cultivars, namely NASPOT 1, NASPOT 8 and NASPOT 11. Hybrid maize (WE 2115) is a high yielding variety (2.5-3.5 MT/ha), drought and low nitrogen tolerant, and resistant to major leaf diseases and pests (climate smart hybrid). Potato cultivars NASPOT 1, NASPOT 8 and NASPOT 11 were developed at the National Crops

Resources Research Institute (NaCRRI), Namulonge [21, 22]. They have good storage root shapes when grown in light soils, high dry matter contents (32-34%), and good consumer acceptance [23, 24]. They also have moderate levels of field resistance to sweet potato virus disease (SPVD) and *Alternaria bataticola* blight, and have high storage root yields (10-30 MT/ha^{-1}) [25].

2.4. Experimental Setup

The experiment was a 2x3x5 split-split plot laid out in a randomized complete block design with three replications. The main plot treatments comprised two cropping systems (sole and intercropping), while subplot treatments were three sweet potato cultivars (NASPOT 1, NASPOT 8, NASPOT 11), and five NPK fertilizer combinations formed the sub-sub plots. Sole hybrid maize and sweet potato cultivars, and the intercropping treatments were fertilized with graded levels of N, P and K. The five fertilizer treatments comprised a control where no fertilizer was applied, 40-20-30, 80-40-60, 120-60-90 and 160-80-120 kg/ha of N-P-K. Graded levels of P and K were applied at the time of planting in the form of triple superphosphate (46% P_2O_5) and muriate of potash (62% K_2O) fertilizers. But graded levels of N in the form of calcium ammonium nitrate (CAN) (27% N) fertilizer were split into two, and the half was applied during planting and the second half was side dressed 30 days after planting (DAP).

2.5. Preparation of Ridges and Agronomic Operations

The site was ploughed twice with a tractor, and ridges constructed using hand hoes and spades. Ridges were 3 m long, 0.75 m wide at the base and 0.4 m high. Unit plot size was 3 x 6 m, and each plot contained five ridges. There was 1 m spacing between plots and between replications. Net plot size from which growth and yield attributes were estimated was 2.25 x 1.8 m (4.05 m^2).

Maize seed and potato vines were planted at the same time. Maize was planted at 0.75 x 0.6 m both in sole and in intercrops. In the intercrops, one row of maize spaced at 0.75 m was planted between two rows of potato ridges. This gave a population of 22222 maize plants ha^{-1} both in sole and in the intercrops. Three seeds were planted per hole and thinned to two plants 30 DAP.

Disease free potato vine cuttings from the terminal shoots of 25-30 cm length with 4-6 nodes were planted along the crests of ridges at a spacing of 0.3 m, giving a plant population of 55555 plants ha^{-1}. Potato vine cuttings were obtained from the MUARIK disease screening study and from NaCCRI Namulonge. Planting was done by inserting two-thirds length of each cutting into the soil inclined at about 45 degrees. Hand weeding was done at 30 and 75 DAP. Pests were controlled using Striker insecticide at the rate of 10 ml in 20 litres of water using Knapsack sprayer.

2.6. Data Collection and Analysis

Data on potato growth parameters (vine length, numbers of vine branches and leaves per plant) were recorded at 40, 80 and 120 DAP. Vine length (cm) was measured on the longest vine of each of five tagged plants from ground level to the apical bud of the plant using measuring tape. Numbers of branches and leaves were determined by counting branches and leaves from each of the tagged plants, and the means calculated for each plot.

Data on yield parameters of sweet potato and maize were recorded at harvesting which was done 120 DAP. Potato tubers were harvested by digging them out of the ridges using hand hoes from the net plot size of 4.05 m^2 with 18 plants per unit plot. From 18 plants harvested in the net plot area, the tuber yield attributes determined were: number of tubers per plant, number of marketable tubers per plant, fresh weight of marketable tubers per plant and fresh tuber yield per hectare.

Numbers of tubers per plant and numbers of marketable tubers were determined by counting the harvested tubers from 18 plants in the net plot area, and their average numbers were calculated. Fresh weight of marketable tubers per plant was determined by weighing the tubers from each of 18 plants in the net plot area of each unit plot using weighing scale. Fresh tuber yield per hectare was determined from a 4.05 m^2 area and extrapolated to yield per hectare.

For the case of maize, whole maize plants from the net plot area of 4.05 m^2 were cut at ground level, cobs/ears removed, sun-dried and then shelled. Grain yield was determined by weighing the shelled grain obtained from each plot and converting it into kilograms per hectare (kg/ha).

The data collected were subjected to the analysis of variance (ANOVA) using GenStat 12^{th} Edition. Treatment comparisons were done using Least Significant Difference at $P < .05$. Land equivalent ratio (LER) was estimated for each potato/maize intercrop and NPK fertilizer rate using the following formula [26].

$$LER = (Ypm/Yps) + (Ymm/Yms) \quad (1)$$

Where Yps and Yms are yields as sole crops of sweet potato and maize and Ypm and Ymm as intercrops of sweet potato and maize.

3. Results

This section describes the results of the study that were derived from the data collected. It describes the growth and yield response of improved sweet potato cultivars to intercropping with hybrid maize and inorganic fertilizers. Also, grain yield response of hybrid maize to intercropping with the potato cultivars and to inorganic fertilizers, as well as the performance of sweet potato/maize intercrops based on land equivalent ratios are described.

3.1. Growth Response of Sweet Potato Cultivars to Intercropping with Hybrid Maize

3.1.1. Vine Lengths

Results showed that the cropping system, potato cultivar trait and treatments as well as their interactions significantly

(*P* < .05) affected the vine lengths of potato plants. The vines of potato plants in the intercropping system (77.75 cm) were longer (*P* =.02) than those of plants in the sole cropping system (75.10 cm) (Table 1).

In the sole cropping system, the vine lengths of NASPOT 11 were similar to those of NASPOT 1, but were longer (*P* < .05) than those of NASPOT 8 (Table 1). For the case of the intercropping system, the vine lengths of NASPOT 1 were greater than those of NASPOT 8 and NASPOT 11, but both latter cultivars had similar vine lengths. Apart from NASPOT 1, intercropping the potato cultivars with maize did not significantly (*P* >.05) influence their vine lengths (Table 1).

Table 1. *Growth traits of improved sweet potato cultivars at 120 days after planting as influenced by intercropping with hybrid maize.*

Growth trait	Cropping system	Potato cultivar			Mean	$LSD_{(0.05)}$
		NASPOT 1	NASPOT 8	NASPOT 11		
Vine lengths (cm)	Sole potato	75.66^{ab}	69.76^{b}	79.89^{a}	75.10	6.50
	Potato + Maize	82.73^{a}	75.63^{b}	74.89^{b}	77.75	6.17
	Mean	79.20	72.70	77.39		
	$LSD_{(0.05)}$	6.77	5.91(ns)	6.32(ns)		
Number of branches/plant	Sole potato	14.54^{b}	16.74^{a}	15.29^{b}	15.52	1.42
	Potato + Maize	7.66^{b}	9.15^{a}	6.76^{b}	7.94	1.26
	Mean	11.10	13.08	11.02		
	$LSD_{(0.05)}$	1.19	1.50	1.31		
Number of leaves/plant	Sole potato	20.18^{c}	24.03^{a}	22.20^{b}	22.13	1.35
	Potato + Maize	24.11^{b}	28.21^{a}	27.92^{a}	26.75	1.88
	Mean	22.14	26.12	25.06		
	$LSD_{(0.05)}$	1.60	1.61	1.71		

^{abc}Means within the same row having different superscripts are significantly (*P* < .05) different.

3.1.2. Numbers of Vine Branches Per Plant

Results revealed that the cropping system and potato cultivar trait as well as the interactions between the cropping system and potato cultivar, and between the cropping system, potato cultivar and treatments significantly (*P* < .05) affected the numbers of vine branches of potato plants. Numbers of vine branches of potato plants in the intercropping system (15.52) were greater (*P* < .0001) than those of potato plants in the sole cropping system (7.94) (Table 1).

In the sole potato cropping system, number of vine branches of NASPOT 8 were higher (*P* < .05) than those of NASPOT 1 and NASPOT 11, but both latter potato cultivars had similar numbers of vine branches (Table 1). A similar trend of number of vine branches was observed in the potato plants under the intercropping system. The numbers of vine branches for all the three cultivars, were significantly (*P* < .0001) reduced by intercropping with maize (Table 1).

3.1.3. Numbers of Leaves Per Plant

The cropping system, potato cultivar trait and treatments and the interactions of cropping system x treatment, and cropping system x potato cultivar x treatment significantly (*P* < .05) affected the numbers of leaves of potato plants. Numbers of leaves of potato plants in the intercropping system (26.75) were greater (*P* = < .0001) than those of potato plants in the sole cropping system (22.13) (Table 1). In the sole potato cropping system, numbers of leaves of potato cultivars varied significantly (*P* < .05) in the order NASPOT 8 > NASPOT 11 > NASPOT 1. On the other hand, in the intercropping system the numbers of leaves for NASPOT 8 and NASPOT 11 were similar, but higher (*P* < .05) than those of NASPOT 1. Numbers of leaves per plant for all the potato cultivars, were significantly (*P* < .0001) increased by intercropping with maize (Table 1).

Comparisons of cropping systems indicated that the vine lengths of NASPOT 1 under the intercropping system (82.73 cm) were greater (*P* < .05) than when NASPOT 1 was grown as sole crop (75.66 cm) (Table 1). But for NASPOT 8 and NASPOT 11, their vine lengths under the intercropping and sole cropping systems were not (*P* >.05) different. For the case of numbers of vine branches, all the three potato cultivars produced higher (*P* < .05) numbers of vine branches under the sole potato cropping system than when they were intercropped with maize (Table 1). But for the case of leaf numbers, all the potato cultivars produced higher (*P* < .05) numbers of leaves when they were intercropped with maize than when they were grown as sole crops.

3.2. Growth Response of Improved Sweet Potato Cultivars to Intercropping with Hybrid Maize and Inorganic Fertilizer Application

3.2.1. Vine Lengths

In the sole potato cropping system, NPK application did not (*P* >.05) have an effect on the lengths of potato vines (Table 2). For the intercropping system, lengths of vines from all fertilizer treatments were similar (*P* >.05) to that of the control, apart from the treatment that received 160-80-120 kg/ha of NPK. The mean vine lengths of potatoes in the intercropping system (77.75 cm) were longer (*P* =.016) than those of potato plants in the sole cropping (75.10 cm) (Table 2).

Comparisons of fertilizer treatments in both cropping systems showed that the application of N-P-K fertilizers at low rates into both cropping systems did not have a significant (*P* >.05) effect on the vine lengths of the potato plants (Table 2). However, high NPK application rates (160-80-120 kg/ha of NPK) caused the vines of potato plants under the intercropping system to grow longer (*P* =.03) than those of potato plants under the sole cropping system (Table 2).

3.2.2. Number of Nine Branches Per Plant

In both cropping systems, the application rates of NPK fertilizer did not (P >.05) have an effect on the numbers of vine branches of potato plants (Table 2). But the numbers of vine branches of potato plants in the sole cropping system for all the fertilizer treatments were higher (P < .0001) than those of plants in the intercropping system (Table 2). Also, the mean number of vine branches of potato plants in the sole cropping system (15.52) was higher (P < .0001) than that of plants in the potato + maize cropping system (7.94) (Table 2).

Table 2. *Growth traits of improved sweet potato cultivars at 120 days after planting as influenced by intercropping with hybrid maize and NPK fertilizer.*

Growth trait	Cropping system	N-P-K fertilizer rates (kg/ha)					Mean	$LSD_{(0.05)}$
		0-0-0 (Ctrl)	40-20-30	80-40-60	120-60-90	160-80-120		
Vine lengths (cm)	Sole potato	72.64	73.63	77.93	76.72	74.57	75.10	8.44(ns)
	Potato + Maize	73.23[b]	75.62[b]	76.77[ab]	78.94[ab]	84.20[a]	77.75	7.97
	Mean	72.94	74.63	77.35	77.83	79.38		
	$LSD_{(0.05)}$	7.8(ns)	8.17(ns)	8.31(ns)	8.16(ns)	8.67		
Number of branches/plant	Sole potato	16.11	15.22	16.05	15.12	15.12	15.52	1.84(ns)
	Potato + Maize	7.53	7.09	8.24	8.43	8.43	7.94	1.64(ns)
	Mean	11.82	11.16	12.15	11.78	11.78		
	$LSD_{(0.05)}$	1.78	1.70	1.71	1.73	1.82		
Number of leaves/plant	Sole potato	20.98[b]	21.61[ab]	22.80[a]	23.06[a]	22.23[ab]	22.13	1.78
	Potato + Maize	26.74	26. 46	25.41	27.50	27.62	26.75	2.46(ns)
	Mean	23.86	24.03	24.11	25.28	24.93		
	$LSD_{(0.05)}$	2.06	2.06	2.01	2.30	2.31		

[abc]Means within the same row having different superscripts are significantly (P < .05) different.

3.2.3. Number of Leaves Per Plant

In the sole potato cropping system, of NPK fertilizer application significantly (P =.02) affected the numbers of leaves formed in the potatoes (Table 2). Potato plants that were fertilized had greater (P < .05) leaf numbers than the control, apart from plants that received 40-20-30 and 160-80-120 kg/ha of NPK. But leaf numbers of plants in the fertilized treatments were alike (P >.05).

In the intercrops, NPK fertilizer application had no significant (P >.05) effect on the numbers of leaves that were formed (Table 2). But the numbers of leaves of potato plants in the intercropping system for all the fertilizer treatments were higher (P < .05) than those of plants in the sole cropping system (Table 2). Also, the mean number of leaves of plants in the intercropping system (26.75) was higher (P < .0001) than that of plants in the sole cropping system (22.13).

3.3. Yield Response of Improved Sweet Potato Cultivars to Intercropping with Hybrid Maize and Inorganic Fertilizer Application

Under both cropping systems, the potato tuber yield of NASPOT 11 was higher (P < .0001) than that of NASPOT 1 and NASPOT 8 (Table 3). Also in both systems, the order of performance followed the same trend, and NASPOT 11 was the best yielder followed by NASPOT 8 and NASPOT 1. The results also show that the potato cultivars performed better (P < .01) in the sole cropping system than under intercropping with maize. Mean comparison of the cropping systems further showed that the potatoes performed better (P < .0001) under the sole cropping system (43.36 MT/ha) than when intercropped with maize (33.35 MT/ha) (Table 3).

Table 3. *Tuber yields of improved sweet potato cultivars to intercropping with hybrid maize.*

Cropping system	Potato cultivar			Mean	$LSD_{(0.05)}$
	NASPOT 1	NASPOT 8	NASPOT 11		
Sole potato	32.32[c]	40.75[b]	57.03[a]	43.36	7.85
Potato + Maize	22.47[c]	32.20[b]	45.39[a]	33.35	5.70
Mean	27.39	36.47	51.20	38.36	4.69
$LSD_{(0.05)}$	5.82	6.22	8.33	3.83	

[abc]Means within the same row having different superscripts are significantly (P < .05) different.

Under the sole cropping system, tuber yields of all the fertilizer treatments were not (P >.05) different from that of the control (Table 4). But the treatment that received 40-20-30 kg/ha N-P-K performed better than that which received 80-40-60 kg/ha N-P-K. For the intercropping system, only the treatment that received 120-60-90 kg/ha N-P-K yielded better than the control.

Comparison of fertilizer treatment means showed that none of the treatments yielded better (P >.05) than the control (Table 4). However, the treatments which received 40-20-30, 120-60-90 and 160-80-120 kg/ha N-P-K performed better than the one that received 80-40-60 kg/ha N-P-K. Apart from the control where no fertilizer was applied and the treatment that received 40-20-30 kg/ha N-P-K, there were no significant (P > .05) differences between the tuber yields that were obtained from the sole potato and the potato + maize cropping systems (Table 4).

***Table 4.** Tuber yields of improved sweet potato cultivars as influenced by intercropping with hybrid maize and NPK fertilizer.*

Cropping system	N-P-K fertilizer rates (kg/ha)					Mean	$LSD_{(0.05)}$
	0-0-0 (Ctrl)	40-20-30	80-40-60	120-60-90	160-80-120		
Sole potato	44.15^{ab}	49.33^{a}	34.47^{b}	44.58^{ab}	44.30^{ab}	43.36	10.75
Potato + Maize	30.25^{b}	31.15^{ab}	31.42^{ab}	38.80^{a}	35.13^{ab}	33.35	8.13
Mean	37.20^{ab}	40.24^{a}	32.94^{b}	41.69^{a}	39.71^{a}	38.36	6.05
$LSD_{(0.05)}$	10.29	10.72	7.97(ns)	8.89(ns)	9.84(ns)	3.83	

[abc]Means within the same row having different superscripts are significantly (*P* < .05) different.

3.4. Grain Yield Response of Hybrid Maize to Intercropping with Improved Sweet Potato Cultivars and Inorganic Fertilizer Application

Hybrid maize responded differently to intercropping with the potato cultivars and to the fertilizer (Table 5). Generally, intercropping severely reduced (*P* < .0001) the grain yield when compared with sole maize cropping. Among the intercrops, the mean grain yield of NASPOT 11 + maize (2.50 MT/ha) was higher (*P* < .05) than that of NASPOT 1 + maize (2.16 MT/ha) and NASPOT 8 + maize (1.16 MT/ha). Apart from NASPOT 1 + maize that received 160-80-120 kg/ha N-P-K, and NASPOT 11 + maize that received 40-20-30 kg/ha N-P-K, grain yields from all the fertilized intercrops were greater (*P* < .05) than those of their corresponding control treatments.

Grain yields of NASPOT 1 + maize intercrop under all the fertilizer treatments were higher (*P* < .05) than that of the control, apart from the treatment that received 160-80-120 kg/ha of N-P-K (Table 5). But among the fertilized treatments, the one that received 80-40-60 kg/ha N-P-K performed better (2.68 MT/ha) than the rest, except the one that received 40-20-30 kg/ha N-P-K.

For NASPOT 8 + maize intercrop, all the NPK fertilized treatments performed better than the control (Table 5). But among the fertilized treatments, the one that received 160-80-120 kg/ha of N-P-K performed better (2.09 MT/ha) than the rest, apart from the treatment that received 80-40-60 kg/ha of N-P-K. For NASPOT 11 + maize intercrop, there was gradual increase in grain yield as the fertilizer increased (Table 5). Grain yields of all the fertilized treatments were higher (*P* < .05) than that of the control, apart from the one that received 40-20-30 kg/ha of N-P-K. Best grain yield (3.76 MT/ha) was registered at the fertilizer rate of 160-80-120 kg/ha of N-P-K.

Sole maize also responded positively to fertilizer application, with grain yields of all the fertilized treatments being higher (*P* < .05) than that of the control, apart from the one that received 40-20-30 kg/ha of N-P-K (Table 5). Best grain yields (3.33 and 3.30 MT/ha) were registered at the fertilizer rates of 80-40-60 and 160-80-120 kg/ha of N-P-K, respectively.

***Table 5.** Maize grain yield as influenced by intercropping with improved sweet potato cultivars and NPK fertilizer.*

Cropping system	N-P-K fertilizer rates (kg/ha)					Mean	$LSD_{(0.05)}$
	0-0-0 (Ctrl)	40-20-30	80-40-60	120-60-90	160-80-120		
NASPOT 1 + Maize	1.59^{d}	2.50^{ab}	2.68^{a}	2.19^{bc}	1.82^{cd}	2.16	0.46
NASPOT 8 + Maize	1.02^{d}	1.76^{bc}	1.87^{ab}	1.55^{c}	2.09^{a}	1.66	0.27
NASPOT 11 + Maize	1.43^{d}	1.57^{d}	2.43^{c}	3.28^{b}	3.76^{a}	2.50	0.43
Sole maize	2.41^{c}	2.50^{c}	3.33^{a}	3.00^{b}	3.30^{a}	2.91	0.28
Mean	1.61^{d}	2.08^{c}	2.58^{ab}	2.50^{b}	2.74^{a}	2.30	0.21
$LSD_{(0.05)}$	0.55	0.46	0.25	0.24	0.28	0.19	

[abc]Means within the same row having different superscripts are significantly (*P* < .05) different.

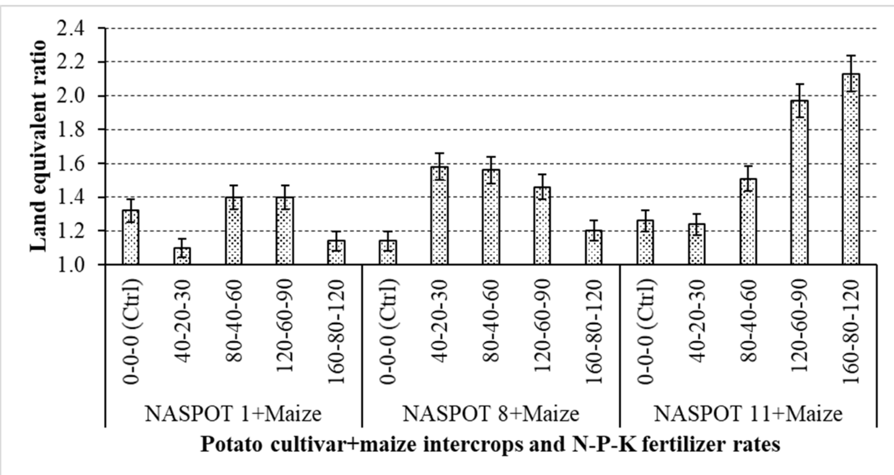

***Figure 1.** Land equivalent ratios of improved sweet potato cultivars intercropped with hybrid maize and supplied with different rates of NPK fertilizer.*

3.5. Land Equivalent Ratios of Sweet Potato + Maize Intercropping

Figure 1 shows the land equivalent ratios (LERs) of different potato cultivars intercropped with hybrid maize and fertilized with NPK fertilizer. In all cases, the LERs were greater than unity indicating yield advantage of intercropping over sole cropping of sweet potato and hybrid maize. Generally for all the intercrops, the application of N, P and K at the rates of 80-120, 40-60 and 60-90 kg/ha respectively, resulted in better intercrop performance as revealed by higher LERs.

4. Discussion

This section discusses the results of the study from the aspects of growth and yield response of improved sweet potato cultivars to intercropping with hybrid maize and inorganic fertilizer application. It also discusses grain yield response of hybrid maize when intercropped with sweet potato cultivars and supplied with inorganic fertilizers, and the performance of sweet potato/maize intercrops based on land equivalent ratios.

4.1. Growth Response of Improved Sweet Potato Cultivars to Intercropping with Hybrid Maize and Inorganic Fertilizer Application

The longer vines in NASPOT 1, and the higher numbers of leaves and branches in all the three potato cultivars under intercropping compared to sole cropping may be due to a combination of genetic and environmental factors such as shading by the hybrid maize plants. Potato plants tried to grow more vegetatively so as to capture as much sunlight as possible, since little sunlight was reaching them. Depending on the plant population density, and the growth habits and light demand of the associated crops, there is usually some degree of competition for sunlight in intercrops which is shown by their growth responses. A variation in the plant heights of hybrid maize and improved cassava genotypes was observed when they were grown together compared to sole cropping [27].

The application of NPK in the sweet potato + maize intercrops did not have a significant effect on the lengths of potato vines, but instead significantly decreased the numbers of vine branches per plant and increased the numbers of leaves per plant when compared with sole potato cropping at all the fertilizer treatments. The fewer vine branches and higher leaf numbers in the intercrops that were fertilized could be attributed to the fact that as the potato plants received limited amount of sunlight, they invested more resources in the production of leaves so as to increase the photosynthetic surface that could capture as much sunlight as possible. These results are in contrast with those of other researchers who observed a significant increase in vine length, and numbers of leaves and branches per plant when they applied K at the rate of 160 kg/ha [28].

4.2. Yield Response of Improved Sweet Potato Cultivars to Intercropping with Hybrid Maize and Inorganic Fertilizer Application

Better performance of the potato cultivars under sole potato cropping system than when intercropped with maize could be attributed to the fact that under sole cropping, there was maximum availability of sunlight on sweet potato canopy throughout the growth period which enhanced tuber formation, tuber bulking and ultimately tuber yield [17]. Intercropping the potatoes with maize decreased their photosynthetic activity due to shading by tall maize plants, especially during tuber bulking which is a critical growth stage that requires high light intensity for optimum photosynthesis. Earlier researchers observed that in the potato-hybrid maize intercropping systems, light availability was 100% up to 20 days after sowing (DAS), and thereafter it reduced gradually with the advancement of canopy development of maize reaching minimum level at 100 DAS [17]. These results are also in conformity with those of other researchers who observed significant reduction in light interception in the maize-cowpea intercrops [29] and sweet potato varieties with soybean compared to the control treatments [30].

Among the potato + maize intercrops, only the treatment that received 120-60-90 kg/ha of N-P-K combination yielded better than the control. These results are in agreement with those of earlier researchers who reported that the application of 125, 60 and 100 kg/ha of N, P_2O_5 and K_2O, respectively resulted in significantly higher potato tuber yields than in the control [31, 32]. It has also been observed that NPK fertilizer application in tuberous crops supplies nutrients for tuber formation and development, and for promoting the photosynthetic capacity of the leaf area that in turn provides photosynthates for tuber bulking [33, 34].

Significant tuber yield reduction in the potato + maize intercropping system compared to the sole potato cropping was observed in the control where no fertilizer was applied as well as in the treatment that received 40-20-30 kg/ha NPK, but the application of NPK in quantities greater than 40-20-30 kg/ha resulted in non-significant tuber yields between the two cropping systems. This means that in the potato + maize intercropping system there was inter-specific competition for N, P and K in the control and in the treatment that received 40-20-30 kg/ha of N-P-K. However, when these nutrients were supplied in adequate quantities, this competition was eliminated leading to similar potato tuber yields from both cropping systems. This is in agreement with the findings of earlier researches who observed that competition between plants only occurs when the supply of growth resources does not adequately meet the needs of associated plants [35]. It has also been noted that the level of competition depends on the extent of supply of resources, resource requirements of individual plants, plant population, and the spatial arrangements [36].

4.3. Grain Yield Response of Hybrid Maize to Intercropping with Improved Sweet Potato Cultivars and Inorganic Fertilizer Application

Intercropping depressed the grain yields of hybrid maize component irrespective of the sweet potato cultivar. This could be due to inter-specific competition for the growth resources, especially soil nutrients, water and air. In the intercrops, growth resources are competed for by the associated crops, hence limiting their growth and accumulation of dry matter as they do under sole cropping. Better maize grain yield and optimum tuber yield were observed when maize was intercropped with sweet potato at the ratio of 2 maize seeds per hill to 2 vines per stand [37]. But very high grain yield losses were recorded when the ratio was changed to 2 seeds of maize to 3 vines per stand due to increased competition for growth resources. It has also been reported that increasing maize population density in the improved cassava + maize intercropping systems from the ratio of 1: 1 to 1: 2 of cassava to maize significantly reduced the grain yields compared to yields obtained from sole maize cropping [27].

Significant increases in the yields of grain in both the intercrops and sole maize as the N-P-K fertilizer rates were increased indicate that the fertilizer supplied additional nutrients to the maize plants. The potato + maize intercrops and sole maize responded differently to NPK fertilizer application leading to significant increases in grain yields at different fertilizer rates. This could be due to differences in the demand for growth resources (sunlight, water, nutrients, air) by the different potato cultivars that were intercropped with maize. The growth habits and yield potentials of the three potato cultivars are quite different – the factors that are likely to be responsible for the differences in the quantities of N, P and K fertilizer nutrients needed for optimal maize yield performance under the potato + maize intercropping system.

4.4. Land Equivalent Ratios of Sweet Potato + Maize Intercropping

Land equivalent ratio (LER) determines the efficiency of utilization of environmental resources under intercropping compared to sole cropping. When the LER is greater than unity (one), then intercropping is said to have favoured the growth and the resultant yields of the associated crop species [26]. One of the most important reasons for intercropping is to maximize yields and LER when compared with sole cropping. In all cases, the LERs were greater than unity indicating that there were mutual complementary effects among the component crops in the intercrops, such as efficient utilization of growth resources that resulted in their yield advantage over sole cropping of sweet potato and maize [29, 38, 39]. It has been reported that compared with sole cropping, multiple cropping systems quickly provide a canopy cover to the soil, improve the absorption of photosynthetically active radiation (PAR), suppress weed growth and enhance the capture of available growth resources leading to better yields [40]. Multiple cropping has been shown to be beneficial due to its ability to widen the productivity capacity of arable land by maximizing the exploitation possibilities in time and space, by supporting the complementarity of resource utilization from the physiological, temporal and morphological point of view for the associated species, and by guaranteeing superior yields due to efficient utilization of available resources, canopy space and mutual interactions between heterogeneous canopy components [41- 43].

5. Conclusions and Recommendation

The application of 120-60-90 kg/ha of N-P-K into the potato + maize intercrops resulted in significantly higher potato tuber yields compared to the control where no fertilizer was applied. Also, the application of N-P-K in quantities greater than 40-20-30 kg/ha resulted in non-significant tuber yields between the potato + maize intercropping and sole potato cropping systems indicating that inter-specific competition for nutrients in the intercropping system was eliminated leading to similar potato tuber yields from both cropping systems. Apart from NASPOT 1 + maize intercrop that received 160-80-120 kg/ha of N-P-K, and that of NASPOT 11 + maize that received 40-20-30 kg/ha of N-P-K, maize grain yields from all the fertilized intercrops were higher than those of the their corresponding control treatments. In addition, the application of N, P and K in the intercrops at the rates of 80-120, 40-60 and 60-90 kg/ha respectively, resulted in better intercrop performance as was revealed by higher LERs. All the intercrops gave LERs greater than unity indicating that improved sweet potato cultivars and hybrid maize are compatible for intercropping. Therefore, based on these conclusions it was recommended that farmers can intercrop improved sweet potato cultivars with hybrid maize and apply 120-60-90 kg/ha of N, P and K in the intercrops in order to maximize yields.

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