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Effect of Intercropping and Spraying with Amino Acids on Growth and Productivity of Sweet Corn (*Zea mays* L. *Var. Saccharata*) and Sweet Potato (*Ipomoea batates* L.) under Siwa Conditions

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Abstract: The field experiments were conducted at Siwa Experimental Research Station, Khimisa Experimental Farm (29.12_N latitude and 25.29_E longitude) during two successive seasons of 2017 and 2018. The aim of the present study was to investigate the impact of amino acids foliar spray at concentrations 1 and 2 gm per liter, in addition of tap water treatment as a control on growth, yield, competitive indices and yield advantage of intercropped sweet corn (Misthi F1 Hybrid) and sweet potato (Mabrouka cultivar). Intercropping treatments were: 100% sweet corn (pure stand), 100% sweet potato (pure stand), 66.7 % sweet corn + 33.3% sweet potato (2 s.c.:1 s.p.), 33.3% sweet corn + 67.7% sweet potato (1 s.c. : 2 s.p.) and 50% sweet corn + %50 sweet potato (1 s.c. : 1 s.p.). Results showed that, sweet corn growth, yield and its characters were slightly affected by amino acids and intercropping treatments, while the effect on sweet potato affect was more pronounced. Amino acids as 0.2 % gave the highest values followed by 0.1 % compared with control treatment. Sweet corn was the dominant with its lower proportions and sweet potato was dominated with its higher proportions. On the contrary, sweet potato was the dominated with its highest proportion and sweet potato was the dominant one with its lower proportions. So, the highest sweet corn yield was obtained with either pure stand or intercropping mixtures while for sweet potato was obtained only with pure stand planting system. The highest land equivalent ratio (LER) for combined intercrop yield, were 1.308 and 1.320 in both seasons respectively which was obtained with 1:1 mixture system. That's mean, 0.308 and 0.320 yield advantage were obtained in first and second season, respectively. Moreover, obtained data revealed that, 0.277 and 0.305 yield advantage were attributed to sweet corn, while, 0.031 and 0.015 yield advantage were achieved to sweet potato in the first and second season respectively.

Key words: Sweet corn · Sweet potato · Intercropping systems · Amino acids · Growth · Yield and competitive relationships

INTRODUCTION

Sweet corn (*Zea mays* L. *var. saccharata*) is a non-popular fresh market vegetables produced in Egypt. It has only been available since the 1700s and cultivars vary by kernel color, sugar content, maturation times [1]. But it is one of the most popular vegetables in the USA, Canada and Australia and becoming popular in India and other countries. Sweet corn differs from other corns (field maize and popcorn) because it's high sugar content [2, 3]. Maize is also good source of fiber, minerals and some vitamins [4, 5]. Sweet corn has been widely considered more beneficial than maize production due to its shorter growing season and higher cropping index, consequently increases farmer's income [6]. In addition, its economic values might be double when it is intercropped with other vegetables especially sweet potato as a root crop [7].

Sweet potato (*Ipomoea batatas* L.) was recorded as a staple food source for many indigenous populations in many countries because its playing important role in human nutrition, especially in human diets, β-carotene and anthocyanin contents and its potential as value-added products in human food systems [8]. It has been grown exclusively for tuber roots, while foliage has been considered a wasted material, but tuber roots has only 3.4% crude protein, however the forage contains 11% crude protein and the digestibility of the principal

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nutrients is greater than 62%. This material could therefore provide an important resource as livestock feed in the tropics [9, 10]. In addition starch and flour processing from sweet potato tuber roots can create new economic and employment activities for farmers and rural households and can add nutritional value to food systems. Moreover, the starch yield of sweet potato in the tropical and subtropical conditions can be 1.5 times higher than rice or maize and two times higher than potato [11]. Thus, repositioning sweet corn and sweet potato either as essential food for human and animals, or as value add products are critical issues should be studied locally, especially under indigenous populations and poverty communities such as Siwa oasis and other western desert areas.

Siwa Oasis located in the northern part of the Western Desert of Egypt, at The GPS (Global Positioning System) of 29.12_N latitude and 25.29_E longitude with an elevation of 18 meter below sea level and 315 kilometers Mediterranean coast away. Although, total area of oasis is about one thousand square kilometers, the cultivated area occupied only (20940 fed.) and it's have being slightly increasing. It is characterized by very hot and dry climate conditions especially during summer and the main activity of Siwean people is agriculture which is depending on the groundwater and flood irrigation system [12]. Because that oasis is desert closed area and have irregular climate and consequently heat stress during summer season, (temperatures can be amounted to 45°C), almost crops and vegetables productivity negatively affected. Ugur and Maden [3] found that, adverse environmental factors decreased corn cob yield and quality of sweet corn, although it is a warm-season crop adapted to temperate climates though usually affected by whether conditions [13]. Also, maize is a tropical species adapted to growing in hot climates, especially in the initial growth period, have a decisive effect on the vegetation course of the plants [14, 15].

Application of amino acids can improve vegetables growth, yield and protect plants from adverse conditions during hot months due to proline accumulation, homocysteine (Hcy) formation during methionine metabolism, phytochemicals which have antimicrobial and antioxidant effects, increasing plant height, heaviest bulb weight of garlic and increasing strawberry growth and yield [16-20].

Intercropping is an agricultural practice mainly aims to maximize yielding of land unit area to fulfill the requirements of the market and the consumers with high population increasing rate and food excessive demand. The main goal of intercropping is to produce a greater yield on a given piece of land by making better use of growth resources that would otherwise not be utilized by a sole crop and to overcome adverse impact of irregular environmental conditions especially heat stress during summer season under Siwa conditions [21-23]. Many previous researchers studied intercropping between maize and sweet potato or other vegetables and they found that, total dry matter and total tuber yields of sweet potato was significantly reduced by up to 56% in mixtures with maize due to the production of smaller tuber roots than those from pure stands, while maize yields were not affected [24]. Moreover, sweet potato yield significantly reduced by high maize density [7]. Some late tuber-bulking of sweet potato cultivars were more tolerant to intercropping and productivity was highest in the mixture with maize grown at 1:1 ratio while under this mixture sweet corn gave maximize yield [25, 26]. Under, Middle Egypt conditions, sugarcane intercropping significantly deceased yield of both sweet potato and cowpea by about twenty and thirty percent, respectively [27]. Also, potato yield was decreased by sixty percent when intercropped with maize compared with sole cropping [28]. Other intercropping impacts between maize and potato showed maximum potato yield obtained from 3:1 intercropping ratio, while maximum maize yield obtained from 1:1 ratio [29, 30]. Though, almost previous studies revealed that, land equivalent ratio showed high values with intercropping systems compared with sole cropping [25, 27, 29, 30, 23].

Thus, it was thought that intercropping and spraying with amino acids can be useful in agricultural intensification. So the present study aimed to produce newly summer crops , *i.e*., sweet corn and sweet potato to achieve a high bio mass for both humans and animals. As well as enhancement yield of both crops by reducing the hazardous environmental impact on growth and yield of both crops and studying their competitive relations under Siwa conditions.

MATERIALS AND METHODS

Two field experiments were conducted at Siwa Experimental Research Station, Khimisa Experimental Farm (29.12_N latitude and 25.29_E longitude) during two successive seasons of 2017 and 2018. The aim of this study was to investigate the impact of amino acids foliar spray (commercial product called Aminozeid, produced by U.A.D. Company, Egypt) using concentrations at rates of 1 and 2 gm per liter, in addition of tap water treatment as a control on both intercropped sweet corn and sweet potato growth, yield, competitive indeces and yield advantage of both crops cultivated as a sole or mixture system. Misthi F1 Hybrid sweet corn seeds belonging to the super sweet group which produced by Nuziveedu Seeds Limited Company and imported by Gaarah Establishment for Imports and Exports. Seeds were sown at three rows, 30 cm apart, 1m width and 10.5 meters length for every plot (plot area was 10.5 m^2 for both crops). The same arrangement of Mabrouka cultivar sweet potato cuttings has been planted at the same sweet corn sowing time (mid of March in both seasons). Intercropping treatments were: 100% sweet corn pure stand (all the three rows contained sweet corn) , 100% sweet potato pure stand (all the three rows contained sweet potato), 66.7 % sweet corn + 33.3% sweet potato 2 s.c.:1 s.p. (two rows contained sweet corn and the third row sweet potato), 33.3% sweet corn + 67.7% sweet potato 1 s.c. : 2 s.p. (one row contained sweet corn and the other two rows contained sweet potato) and 50% sweet corn + %50 sweet potato 1 s.c. : 1 s.p. (the three rows were arranged as crosswise and planted by sweet corn time and sweet potato other).

All experimental plots received equal amounts of fertilizers and other agricultural practices were practiced as recommended for sweet corn program using drip irrigation system.

Data Recorded

Days to Harvest: Number of days from planting sweet corn and sweet potato were calculated.

Vegetative Growth: Randomly sample of 5 plants of each experimental plot were randomly taken at 70 days for sweet corn and 120 days for sweet potato from planting and the following data were recorded: plant height, leaves number per plant and average plant fresh weight for both crops.

Yield Components: Marketable sweet corn cobs and sweet potato tuber roots were harvested at their mature stages, counted and weighed to record number of marketable cobs, average cob and tuber roots weight, average cob and tuber root diameter and total yield per feddan were calculated.

Seeds and Tuber Roots Quality: Five cobs and five tuber roots were collected from each experimental plot at harvest during the second season and the following data were recorded: Total soluble solids (T.S.S) was determined using a hand refractometer, L. ascorbic acid content was determined according A.O.A.C. [31] and dry matter percent of sweet potato tuber roots and sweet corn seeds were calculated.

Competitive Relationships

Land Equivalent Ratio (LER): It is the relative land area under sole crops that is required to achieve the same yield produced with intercropping. LER calculated according to the equation described by Willy [32] as follow:

LER= (Yab/Yaa) + (Yba/Ybb). Where: Yaa = sweet corn pure stand yield, Ybb = sweet potato pure stand yield, Yab = sweet corn yield in combination with sweet potato and Yba = sweet potato yield in combination with sweet corn.

Relative Crowding Coefficient (RCC): It was calculated according to equations described by Hall [33].

In case of 1:1 ratio, the equation was ka = Yab / (Yaa-Yab), kb = Yba / (Ybb-Yba). Where, ka is the relative crowding coefficient of sweet corn in mixture with sweet potato, kb is the relative crowding coefficient of sweet potato in mixture with sweet corn.

In case of different intercropping ratios, ka = (Yab x Zba) / (Yaa – Yab) x Zab
kb = (Yba x Zab) / (Ybb – Yba) x Zba.

where, Zab is proportion of sweet corn in mixture with sweet potato, Zba is the proportion of sweet potato in mixture with sweet corn.

Finally K = ka x kb.

Aggressivity (A): It was calculated according to equations described by McGilchrist [34]. In case of 1:1 ratio, the equations are Aa = (Yab / Yaa) – (Yba / Ybb),

Ab = (Yba/Ybb) – (Yab / Yaa).
In case of different intercropping ratios, Aa = (Yab / (Yaa x Zab)) – (Yba / (Ybb x Zba)),
Ab = (Yba / (Ybb x Zba)) – (Yab / (Yaa x Zab)).

Experimental Design and Statistical Analysis: Split plot design with three replicates was used, where, amino acids foliar spray treatments were placed in main plots, while intercropping treatments occupied sub-plots. Data were subjected to statistical analysis according to Thomas and Hills [35]. The differences among means were performed using least significant difference (LSD) at 5% level.

RESULTS AND DISCUSSION

Growth Characters: Effect of amino acid foliar spray, intercropping treatments and their interaction on growth characters are shown in Tables (1 and 2). Data presented showed that, both amino acid foliar spray and intercropping treatments have a significant effect on growth characters expressed as plant height, leaves number and average plant fresh weight of sweet corn and sweet potato, respectively, in both seasons. Obtained results revealed that the investigated growth parameters of both sweet corn and sweet potato were increased as amino acids concentration was increased. While number of days to harvest of both crops were decreased with increasing amino acids concentration.

In addition, amino acid treatment as concentrate 0.2 % increased both sweet corn height and sweet potato length, leaves number and average plant fresh weight followed by 0.1 % treatment compared with control which produced the lowest values in both seasons, except sweet potato shoot length and leaves number in first season which showed superiority of 0.1 % treatment.

Regarding the intercropping treatments effect, sweet corn pure stand system or 2 sweet corn: 1 sweet potato gave the highest plants followed by 1:1 then 1:2 ratio. But 1:1 ratio gave the highest leaves number and heaviest plant fresh weight followed by 1:2 ratio compared with 2:1 ratio which gave the lowest values followed by sweet corn pure stand. On the other hand, sweet potato showed opposite response, where, pure stand system produced the highest shoot length, leaves number and heaviest shoot fresh weight of sweet potato compared with other treatments especially when intercropped with sweet corn as 2:1 mixture ratio in both seasons. All interaction effects were not significant except the effect of interaction on sweet potato plant fresh weight, where, sweet potato pure stand treated with either 0.2 or 01 % of amino acids gave the heaviest plants in the first and second seasons, while control treatment with 1:2 intercropping ratio produced the lowest value.

Increment of growth characters with amino acids treatments was expected and in agreement with results of Shehata *et al*. [20] and Shalaby and El-Ramady [19]. Although, sweet corn growth slightly affected by intercropping treatments, since the best growth was obtained either with pure stand or with intercropping systems, sweet potato growth sharply decreased by intercropping systems especially with 2:1 ratio. This depression of sweet potato growth may be due to inter-crop competition for light, nutrients and water which reflected on light interception and led to sweet potato weak growth Sharaiha and Saoub [28]. While sweet corn behavior indicated that, its seemed to be the dominant crop and sweet potato was dominated. Similar results were found between maize and potato Sharaiha and Saoub [28], Jamshidi, *et al.* [29] and Saddam [30].

Days to harvest: amino acids applications and intercropping treatments have a significant effect on both sweet corn and sweet potato harvesting date, while interaction was not significant (Table 1 ad 2). Early harvest of both crops obtained with 0.2 amino acids treatment compared with control treatment which gave the highest number of days to harvest in both seasons. Moreover, both crops were harvested early with 1:1 intercropping ratio followed by 1:2 compare with 2:1 which gave the highest value (latest harvesting date) in both seasons. High intercropping proportion of sweet corn (2 sweet corn: 1 sweet potato) resulted in intra-competition within sweet corn plants especially for light, consequently, late maturity compared with low densities which matured earlier. This observation could be attributed to maize plants which reduce light interception by the sweet potato, which resulted in reduced biosynthesis and consequently reduced net assimilation of biomass especially in the case of high population of the tall and aggressive plants. Similar results were found by Asiimwe *et al*. [7].

Foliage Yield: At harvest time effect of amino acids foliar spray, intercropping systems and their interaction on total foliage were recorded and shown Table (3). Data revealed that investigated factors had a significant effect on foliage crop, while interaction between them was not significant. Amino acids foliar spray with 0.2 % concentration produced the highest foliage weight of both investigated crops, followed by 0.1 % treatment compared with control treatment which gave the lowest values in both seasons. Regarding intercropping treatments, foliage yield of both crops were increased with increasing their proportion in both investigated seasons. On the other hand, sweet corn or sweet potato pure stand gave the lowest foliage as compared with total combined foliage yield which obtained with intercropping treatments in both seasons indicating the existence of foliage yield advantage due to intercropping. No significant differences were found among the three investigated intercropping ratios in both seasons.

Yield and its Component

Sweet Corn: Data concerned with the effect of amino acids foliar spray, intercropping system and their interactions on total yield, number of cobs and weight and

Table 1: Effect of amino acids foliar spray, intercropping systems and their interaction on plant height, leaves number/plant, average plant fresh weight at 70 days after sowing and days number to harvest of sweet corn during 2017 and 2018 seasons

Treatments		Plant height (cm)		Leaves number/plant		Average plant fresh weight (g)		Days number to harvest	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	Sole crop	283.63	283.77	15.65	15.67	521.78	525.27	80.67	79.33
	2sc:1sp	285.90	283.67	14.65	14.68	472.67	518.37	82.00	81.00
	1sc:2sp	263.54	256.00	16.43	16.21	555.33	560.63	80.67	78.67
	1sc:1sp	268.87	270.67	16.63	16.49	636.20	633.83	80.33	78.00
0.1% amino acids	Sole crop	291.45	296.17	15.73	16.03	552.61	539.87	78.67	76.67
	2sc:1sp	289.58	292.18	14.67	14.60	500.67	513.75	79.67	76.00
	1sc:2sp	268.70	263.68	16.24	16.53	591.71	593.95	77.67	75.67
	1sc:1sp	274.00	278.79	16.67	16.68	673.81	603.01	77.33	74.67
0.2% amino acids	Sole crop	291.97	297.27	15.90	15.95	578.68	582.90	77.67	76.00
	2sc:1sp	290.83	295.01	15.18	15.32	524.29	537.98	78.67	77.33
	1sc:2sp	265.70	266.24	16.52	16.55	616.19	621.97	76.67	75.67
	1sc:1sp	283.10	281.49	16.81	17.04	676.50	699.70	76.33	75.00
LSD at 0.05 for interaction		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Control		275.49	273.53	15.84	15.76	546.50	559.53	80.92	79.25
0.1% amino acids		280.93	282.70	15.83	15.96	579.70	562.65	78.33	75.75
0.2% amino acids		282.90	285.00	16.10	16.22	598.92	610.64	77.33	76.00
LSD at 0.05 for amino acids		2.89	2.29	0.16	0.13	3.43	9.58	0.54	0.22
Sole crop		289.02	292.40	15.76	15.88	551.03	549.35	79.00	77.33
2sc:1sp		288.77	290.29	14.83	14.87	499.21	523.36	80.11	78.11
1sc:2sp		265.98	261.97	16.39	16.43	587.75	592.19	78.33	76.67
1sc:1sp		275.32	276.98	16.70	16.74	662.17	645.52	78.00	75.89
LSD at 0.05 for intercropping		2.82	3.07	0.27	0.35	10.22	16.31	0.44	0.37

sc=sweet corn ; sp= sweet potato

Table 2: Effect of amino acids foliar spray, intercropping systems and their interaction on plant length, leaves number//plant and average plant fresh weight of sweet potato at 120 days after planting and days number to harvest during 2017 and 2018 seasons

Treatments		Plant length (cm)		Leaves number/plant		Average plant fresh weight (g)		Days number to harvest	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
control	Sole crop	130.2	126.6	89.6	84.8	415	396	154.7	157.3
	2sc:1sp	76.7	74.7	60.9	50.1	226	212	156.0	158.3
	1sc:2sp	80.1	83.1	55.8	55.7	249	237	153.3	156.7
	1sc:1sp	92.4	89.2	66.7	73.2	358	290	153.7	156.3
0.1% amino acids	Sole crop	137.1	135.2	101.9	90.6	568	455	154.0	156.3
	2sc:1sp	83.6	85.5	63.3	57.3	316	328	155.0	157.7
	1sc:2sp	93.2	96.1	71.2	64.4	349	306	155.0	157.7
	1sc:1sp	108.6	104.6	80.7	80.1	478	380	152.7	155.3
0.2% amino acids	Sole crop	135.4	139.2	93.2	93.3	584	416	152.0	154.7
	2sc:1sp	78.8	84.3	61.4	56.5	442	321	153.0	155.3
	1sc:2sp	87.7	100.4	68.0	67.3	430	330	151.3	154.0
	1sc:1sp	102.1	114.1	77.3	86.4	469	349	152.3	153.3
LSD at 0.05 for interaction		N.S	N.S	N.S	N.S	14	16	N.S	N.S
Control		94.9	93.4	68.2	65.9	312	284	154.4	157.2
0.1% amino acids		105.6	105.3	79.3	73.1	428	367	154.2	156.8
0.2% amino acids		101.0	109.5	75.0	75.9	481	354	152.2	154.3
LSD at 0.05for amino acids		1.4	2.1	3.3	0.5	8	11	0.1	0.3
Sole crop		134.2	133.7	94.9	89.6	522	422	153.6	156.1
2sc:1sp		79.7	81.5	61.9	54.6	328	287	154.7	157.1
1sc:2sp		87.0	93.2	65.0	62.4	343	291	153.2	156.1
1sc:1sp		101.0	102.6	74.9	79.9	435	340	152.9	155.0
LSD at 0.05 for intercropping		4.0	3.5	2.8	3.1	8	9	0.3	0.4

sc=sweet corn ; sp= sweet potato

Table 3: Effect of amino acids foliar spray, intercropping systems and their interaction on foliage yield of sweet corn and sweet potato (kg/fedden) during 2017 and 2018 seasons

Treatments	First season Control	0.1% amino	0.2% amino	Mean	Second season Control	0.1% amino	0.2% amino	Mean
				Sweet corn foliage (kg/fed.)				
Pure stand	5995	6520	6850	6455	6221	6091	6877	6396
2 s.c.: 1s.p.	5129	5525	6016	5557	6194	5849	6100	6048
1 s.c.: 2s.p.	3677	4063	4266	4002	3685	4132	4289	4035
1 s.c.: 1s.p.	4756	5214	5105	5025	4825	4279	5317	4807
Mean	4889	5330	5559		5231	5088	5646	
LSD at 0.05 for amino acids		145				256.0		
LSD at 0.05 for intercropping		258				429		
LSD at 0.05 for interaction		N.S				N.S		
				Sweet potato foliage (kg/fed.)				
Pure stand	7346	8517	8138	8000	5670	6641	6634	6315
2 s.c.: 1s.p.	3558	3625	3910	3697	2538	3122	2970	2877
1 s.c.: 2s.p.	4655	5385	4330	4790	4157	5113	4863	4711
1 s.c.: 1s.p.	4243	4367	4130	4246	3282	4431	4100	3938
Mean	4950	5473	5127		3912	4827	4642	
LSD at 0.05 for amino acids		128				73		
LSD at 0.05 for intercropping		202				168		
LSD at 0.05 for interaction		349				N.S		
				Total foliage of sweet corn + sweet potato (kg/fed.)				
s.c. pure stand	5995	6520	6850	6455	6221	6091	6877	6396
s. p. pure stand	7346	8517	8138	8000	5670	6641	6634	6315
2 s.c.: 1s.p.	8687	9150	9926	9254	8732	8971	9070	8924
1 s.c.:2s.p.	8332	9448	8596	8792	7842	9245	9152	8746
1 s.c.: 1s.p.	8999	9581	9235	9172	8107	8710	9417	8745
Mean	7872	8643	8549		7314	7932	8230	
LSD at 0.05 for amino acids		275				480		
LSD at 0.05 for intercropping		464				611		
LSD at 0.05 for interaction		N.S				N.S		

Sc=sweet corn ; sp= sweet potato

diameter of cob were shown in Table (4). Amino acids treatments and intercropping systems have significant positive effects, while interactions between them were not significant. Foliar spray by amino acids at concentrate 0.1 % in the first and 0.1 and 0.2 % in the second season gave the highest cob yield/fed. as compared with control treatment in both seasons. Total number of cobs/fed. did not affected by amino acids foliar spray, though both concentrates have a slightly effect on average cobs weight in both seasons. Control treatment produced the lowest cobs weight and 0.1 % of amino acids treatment gave the lowest cobs diameter. Regarding intercropping treatments, total yield kg/fed. and cobs number/fed. were increased with increasing its proportion in both investigated seasons. On the contrary, intercropping treatment 1:1 produced the heaviest cobs and highest average cobs diameter followed by 1:2 ratio compared with 2:1 ratio which gave the lowest value in both seasons.

Sweet Potato: As shown in Table (5) data indicated that both concentrations of amino acids foliar spray treatments in the first season and 0.1 % concentration in the second significantly increased sweet potato yield and average tuber weight compared with control treatment which gave the lowest values in both seasons; while there were no significant effect on average tuber diameter in both seasons. Concerning intercropping treatments, sweet potato data indicated that tuber yield, average tuber weight and diameter were significantly increased with increasing its proportion in the intercropping ratio in both investigated seasons. All interactions have significant positive effect and the most pronounced effect on sweet potato yield and its characters was obtained when planted as pure stand and treated with high concentration of amino acids. In other words, sweet potato yield and its characters were increased with increasing its proportion in the intercropping ratio and increasing amino acid concentration.

Table 4: Effect of amino acids foliar spray, intercropping systems and their interaction on total yield, total cobs number, average cob weight and average cob diameter of sweet corn during 2017 and 2018 seasons

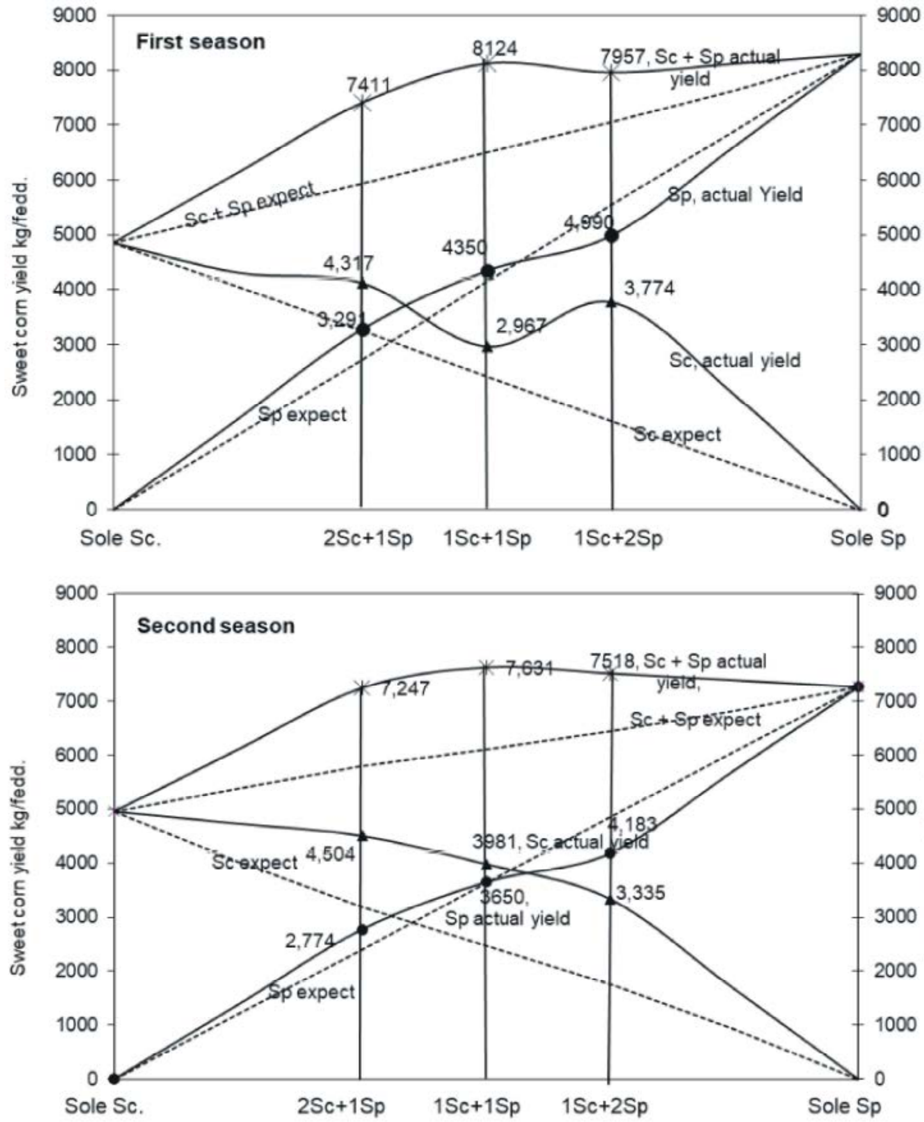
Treatments		Total yield (kg/fed.)		Total cobs no./fed.		Average cob weight (g)		Average cob diameter (cm)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	Sole crop	4722	4709	20533	20800	229.9	226.3	5.62	5.57
	100 sc.+50 s.p.	4011	4417	19333	20400	207.5	216.8	5.30	5.37
	50 sc.+100 s.p.	2908	3269	11867	12400	244.6	264.3	5.85	5.61
	50 sc.+50 sp.	3728	3867	13333	13733	279.6	281.5	5.91	5.95
0.1% amino acids	Sole crop	5052	5067	20933	20667	241.3	245.1	5.49	5.48
	100 sc.+50 s.p.	4157	4436	19333	20000	215.0	221.9	5.29	5.28
	50 sc.+100 s.p.	3041	3395	12000	12667	253.3	268.3	5.54	5.51
	50 sc.+50 sp.	3950	4077	13600	13867	290.4	293.9	5.76	5.83
0.2% amino acids	Sole crop	4804	5099	20133	20533	238.7	248.4	5.62	5.68
	100 sc.+50 s.p.	4192	4669	19467	20000	215.3	233.6	5.36	5.47
	50 sc.+100 s.p.	2951	3342	11733	12267	251.5	272.5	5.84	5.73
	50 sc.+50 sp.	3645	4000	12933	13333	281.6	299.7	5.99	6.10
LSD at 0.05 for interaction		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Control		3842	4065	16267	16833	240.4	247.2	5.67	5.62
0.1% amino acids		4050	4243	16467	16800	250.0	257.3	5.52	5.53
0.2% amino acids		3898	4278	16067	16533	246.8	263.5	5.70	5.74
LSD at 0.05 for amino acids		43	88	N.S	N.S	4.6	3.6	0.02	0.01
Sole crop		4859	4958	20533	20667	236.7	239.9	5.58	5.58
100 sc.+50 s.p.		4120	4507	19378	20133	212.6	224.1	5.31	5.37
50 sc.+100 s.p.		2967	3335	11867	12444	249.8	268.4	5.74	5.62
50 sc.+50 sp.		3774	3981	13289	13644	283.9	291.7	5.89	5.96
LSD at 0.05 for intercropping		102	116	370	439	4.6	6.4	0.04	0.03

sc=sweet corn ; sp= sweet potato

Table 5: Effect of amino acids foliar spray, intercropping systems and their interaction on total yield, average tuber root weight and average tuber root diameter of sweet potato during 2017 and 2018 seasons

Treatments		Total yield (kg/fed.)		Average tuber root weight (g)		Average tuber root diameter (cm)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	Sole crop	6850	5584	216.3	172.9	5.60	5.22
	100 sc +50 s.p.	3012	2505	144.0	121.8	5.21	4.86
	50 sc +100 s.p.	4659	3833	153.8	124.7	5.72	4.30
	50 sc+50 sp	4017	3268	179.1	147.5	5.68	5.31
0.1% amino acids	Sole crop	8828	7795	278.6	241.7	6.16	5.92
	100 sc +50 s.p.	3211	2868	153.9	139.7	5.16	4.79
	50 sc +100 s.p.	5490	4653	181.2	151.3	4.63	4.25
	50 sc+50 sp	4873	4111	217.8	185.8	5.41	5.09
0.2% amino acids	Sole crop	9198	8412	289.9	260.7	6.44	6.07
	100 sc +50 s.p.	3650	2949	174.3	143.6	4.70	4.32
	50 sc +100 s.p.	4820	4064	159.2	132.2	4.69	4.39
	50 sc+50 sp	4161	3572	186.0	161.4	5.24	4.83
LSD at 0.05 for interaction		313	356	16.2	17.0	0.48	0.12
Control		4635	3798	173.3	141.7	5.56	4.92
0.1% amino acids		5600	4857	207.9	179.6	5.34	5.01
0.2% amino acids		5457	4749	202.3	174.5	5.27	4.90
LSD at 0.05 for amino acids		174	104	6.3	3.5	N.S	N.S
Sole crop		8292	7264	261.6	225.1	6.07	5.74
100 sc +50 s.p.		3291	2774	157.4	135.1	5.03	4.66
50 sc +100 s.p.		4990	4183	164.7	136.1	5.01	4.31
50 sc+50 sp		4350	3650	194.3	164.9	5.45	5.08
LSD at 0.05 for intercropping		181	205	9.3	9.8	0.28	0.07

sc=sweet corn ; sp= sweet potato



Sc expect = Sweet corn expected yield, Sp expected = Sweet potato expected yield, Sc+Sp expect = Sweet corn expected yield + sweet potato expected yield, Sc yield = Sweet corn actual yield, Sp yield = Sweet potato actual yield, Sc + Sp yield = Sweet corn actual yield + Sweet potato actual yield

Fig. 1: Effect of intercropping between sweet corn and sweet potato on their actual and expected yield during both investigated seasons

Previous results showed increment of sweet potato yield when treated with amino acids foliar spray and this increment was conspicuous than sweet corn. This may be due to, sweet corn has narrow leaf shape which could not receive much amounts of foliar spray, but sweet potato which has broad leave shape and high density foliage which in turn, led to receive much of foliar spray solution. In general, amino acids application enhanced both crop yields and this may attributed to free amino acids which accumulated in plants and play a great role in improving physiological status which, in turn, reflected on plant growth and yield Liu, *et al*. 1998 [16], Jelonek*, et al*. [17] and Shalaby and EL-Ramady [19].

Positive response of sweet corn to intercropping treatments was more conspicuous than sweet potato which was increased with increasing its proportion in the intercropping ratio. With this respect, it may be worth to mention that, intercropping effects on the intercropped species can examined using a simple diagram easy to read as illustrated in Fig. (1). It showed actual yields (un-dotted lines) and expected yields (dotted lines) for each species and for the total combined of both species. It was clear from the Fig. (1) that, sweet corn gave yield advantage with the three investigated intercropping ratio, which may be attributed to its leave area value and light interception Sharahia and Saoub [28]. In addition, sweet potato gave yield advantage with the treatment 2 sweet corn Sc: 1 Sweet potato Sp, slight yield advantage with treatment 1Sc:1Sp and yield disadvantage with 1Sc:2Sp ratio. In other wards sweet potato gave yield advantage when intercropped with the highest proportion of sweet corn which could be attributed to improving micro climate for sweet potato plants especially lowering temperature caused by taller sweet corn plants Nkrumah, *et al*. [25]. Moreover, sweet corn yield advantage was greater than that of sweet potato. As for the total combined yields of both crops, it gave yield advantage with the three investigated intercropping treatments due to sweet corn compensation. Similar results were found with intercropped maize and potato by Sharahia and Saoub [28], Jamshidi *et al*. [29] and Saddam [30].

Chemical Composition: The effect of amino acid foliar spray, intercropping treatments and their interaction on dry matter percent, T.S.S. and L. ascorbic acid content of sweet corn kernels and sweet potato tuber roots in the second season was shown in Table (6). Amino acids and intercropping treatments had a significant effect on both crops dry matter, T.S.S. and L. ascorbic acid content except sweet corn dry matter and sweet potato T.S.S content while the effect of the interaction was not significant. Amino acids foliar spray gave the highest sweet corn T.S.S content compared with control (sprayed with water), while control treatment produced the highest L. ascorbic acids. Regarding intercropping effects, the investigated chemical composition characters of sweet corn kernels were increased as the proportion of sweet corn was decreased in the intercropping treatments. The highest values were obtained with 1 sweet corn: 2 sweet potato. Also, amino acids foliar spray have a positive effect on sweet potato dry matter, T.S.S and L. ascorbic acid content; 0.2 % treatment gave the highest values followed by 0.1 % compared with control treatment which produced the lowest values. Concerning intercropping treatments, sweet potato pure stand clearly enhanced dry matter and L. ascorbic acid content compared with mixture treatments especially with 2:1 mixture ratio which produced the lowest values. Obtained results revealed also that, sweet corn plants were slightly affected by amino acids and intercropping systems compared with sweet potato which showed clear response to amino acid spray. From the previous results, it can be noted that, almost chemical characters followed the same trend of growth and yield of both sweet corn and sweet potato. Similar results and interpretation were in agreement with Ossom [22], Zamir *et al*. [36] and Asiimwe *et al*. [7].

Competitive Indices

Land Equivalent Ratio (LER): Effect of foliar amino acids spray treatments, intercropping systems and their interactions on land equivalent ratio presented in Table (7) showed that amino acids foliar spray treatments have a significant effect on LER for sweet potato, while sweet corn was not affected significantly. Moreover, interaction was significant in first and non-significant in second s eason. Regarding intercropping treatments effect on LER, data presented in Table (7) showed that, LER values of both sweet corn and sweet potato were increased as their proportions in the intercropping ratios increased. In general, LER for sweet corn was higher than those of sweet potato at equal which indicated that sweet corn considered the dominant crop and sweet potato is the dominated crop.

Also revealed that, the highest LER values for sweet corn in both seasons were 0.837 and 0.911 with 2 sweet corn : 1 sweet potato mixture ratio and those for sweet potato were 0.610 and 0.591 with 1 sweet corn : 2 sweet potato mixture ratio. Regarding LER for total combined intercrop yield, data showed that, the highest values were 1.308 and 1.320 in the first and second season, respectively, which were obtained with 1:1 mixture system. The latest values for total combined intercrop yield means that, 0.308 and 0.320 yield advantage were obtained in first and second season, respectively. Moreover, data revealed, also, that 0.277 and 0.305 yield advantage were attributed to sweet corn, while, 0.031 and 0.015 yield advantage were achieved by sweet potato in the first and second season, respectively. Such results went along with those previously discussed concerning yield of both investigated crops and their yield advantage.

Relative Crowding Coefficient (RCC): Data presented in Table (8), showed the effect of amino acids and intercropping system treatments between sweet corn and sweet potato on their relative crowding coefficient (RCC). Obtained results revealed that, all values of sweet corn (ka) were higher than those of sweet potato (kb)

Table 6: Effect of amino acids foliar spray, intercropping systems and their interaction on dry matter percent, total soluble solids (T.S.S) and L. ascorbic acid of sweet corn and sweet potato

	Dry matter percent				T.S.S. %				L. ascorbic acid (mg/100g F.W.)			
Treatments	Control	0.1% amino	0.2% amino	Mean	Control	0.1% amino	0.2% amino	Mean	Control	0.1% amino	0.2% amino	Mean
						Sweet corn						
Sole crop	21.00	21.33	21.33	21.22	13.67	16.00	16.33	15.33	17.33	16.67	16.33	16.78
2 s.c.: 1s.p.	20.67	21.00	21.00	20.89	13.67	16.67	16.67	15.67	17.33	15.67	15.33	16.11
1 s.c.:2s.p.	22.67	22.67	22.33	22.56	14.33	17.33	17.67	16.44	17.00	17.00	16.67	16.89
1 s.c.: 1s.p.	22.67	22.67	22.67	22.67	14.33	17.00	17.67	16.33	17.00	16.67	16.33	16.67
Mean	21.75	21.92	21.83		14.00	16.75	17.08		17.17	16.50	16.17	
LSD at 0.5 for amino acids		N.S.				0.16				0.36		
LSD at 0.5 for intercropping		0.24				0.27				0.30		
LSD at 0.5 for interaction		N.S				N.S				N.S		
						Sweet potato						
Sole crop	23.86	25.57	25.76	25.06	6.00	7.33	7.33	6.89	22.67	24.67	25.00	24.11
2 s.c.: 1s.p.	22.61	22.95	22.94	22.83	6.67	6.33	6.67	6.56	21.33	22.00	21.67	21.67
1 s.c.:2s.p.	23.37	23.16	23.40	23.31	6.00	6.00	6.67	6.22	21.33	23.00	22.67	22.33
1 s.c.: 1s.p.	23.62	23.47	23.66	23.58	6.33	6.67	7.33	6.78	21.67	23.00	23.33	22.67
Mean	23.36	23.79	23.94		6.25	6.58	7.00		21.75	23.17	23.17	
LSD at 0.5 for amino acids		0.07				0.33				0.22		
LSD at 0.5 for intercropping		0.34				N.S				0.37		
LSD at 0.5 for interaction		N.S				N.S				N.S		

sc=sweet corn; sp= sweet potato

Table 7: Effect of amino acids foliar spray and intercropping system on land equivalent ratio (LER) between sweet corn and sweet potato during 2017 and 2018 seasons

	First season				Second season			
Treatments	Control	0.1% amino acids	0.2% amino acids	Mean	Control	0.1% amino acids	0.2% amino acids	Mean
			Partial LER for sweet corn					
2 s.c.: 1s.p.	0.850	0.824	0.873	0.837	0.940	0.877	0.917	0.911
1 s.c.:2s.p.	0.615	0.602	0.614	0.610	0.695	0.672	0.656	0.674
1 s.c.: 1s.p.	0.789	0.782	0.759	0.777	0.824	0.805	0.786	0.805
Mean	0.752	0.736	0.749		0.820	0.784	0.786	
LSD at 0.05 for amino acids		N.S	N.S					
LSD at 0.05 for intercrop.		0.042	0.033					
LSD at 0.05 for interaction		N.S	N.S					
			Partial LER for sweet potato					
2 s.c.: 1s.p.	0.440	0.364	0.397	0.400	0.452	0.369	0.351	0.310
1 s.c.:2s.p.	0.680	0.624	0.525	0.610	0.688	0.602	0.484	0.591
1 s.c.: 1s.p.	0.586	0.554	0.454	0.531	0.587	0.533	0.425	0.515
Mean	0.569	0.514	0.458		0.576	0.501	0.420	
LSD at 0.05 for amino acids		0.073	0.129					
LSD at 0.05 for intercropping		0.021	0.035					
LSD at 0.05 for interaction		0.037	N.S					
			Total LER for sweet corn + sweet potato					
2 s.c.: 1s.p.	1.291	1.188	1.269	1.249	1.391	1.245	1.268	1.301
1 s.c.:2s.p.	1.295	1.226	1.138	1.220	1.383	1.274	1.140	1.266
1 s.c.: 1s.p.	1.375	1.336	1.213	1.308	1.411	1.337	1.211	1.320
Mean	1.320	1.250	1.207		1.395	1.286	1.206	
LSD at 0.05 for amino acids		0.064	0.132					
LSD at 0.05 for intercropping		0.056	N.S					
LSD at 0.05 for interaction		0.098	N.S					

sc=sweet corn; sp= sweet potato

Table 8: Effect of amino acids foliar spray, intercropping system on relative crowding coefficient (RCC) between sweet corn and sweet potato during 2017 and 2018 seasons

Treatments	First season Control	0.1% amino	0.2% amino	Mean	Second season Control	0.1% amino	0.2% amino	Mean
				ka for sweet corn				
2 s.c.: 1s.p.	1.543	1.229	1.920	1.564	2.870	2.104	2.748	2.574
1 s.c.:2s.p.	6.567	6.155	6.430	6.384	9.223	8.471	6.807	8.167
1 s.c.: 1s.p.	3.865	3.648	3.438	3.650	5.210	4.146	4.308	4.555
Mean	3.992	3.677	3.929		5.768	4.907	4.621	
LSD at 0.5 for amino acids	N.S				N.S			
LSD at 0.5 for intercropping	0.904				1.108			
LSD at 0.5 for interaction	N.S				N.S			
				kb for sweet potato				
2 s.c.: 1s.p.	3.171	2.230	2.644	2.682	3.346	2.338	2.161	2.615
1 s.c.:2s.p.	0.531	0.425	0.276	0.411	0.555	0.406	0.236	0.399
1 s.c.: 1s.p.	1.427	1.264	0.836	1.176	1.438	1.198	0.743	1.126
Mean	1.710	1.330	1.252		1.780	1.314	1.047	
LSD at 0.5 for amino acids	0.296				N.S			
LSD at 0.5 for intercropping	0.281				0.257			
LSD at 0.5 for interaction	N.S				0.444			
				K = ka x kb				
2 s.c.: 1s.p.	5.108	2.850	5.168	4.375	9.522	4.815	5.903	6.747
1 s.c.:2s.p.	3.515	2.631	1.764	2.637	5.163	3.347	1.619	3.376
1 s.c.: 1s.p.	5.440	4.524	2.955	4.306	7.496	5.037	3.079	5.204
Mean	4.687	3.335	3.296		7.394	4.400	3.534	
LSD at 0.5 for amino acids	1.141				3.402			
LSD at 0.5 for intercropping	1.360				1.638			
LSD at 0.5 for interaction	N.S				N.S			

sc=sweet corn; sp= sweet potato

ka, kb and K stand for relative crowding coefficients of sweet corn, sweet potato and total combined crops

Table 9: Effect of amino acids foliar spray, intercropping system and their interaction on agrissivity (A) between sweet corn and sweet potato during 2017 and 2018 seasons

Treatments	First season Control	0.1% amino	0.2% amino	Mean	Second season Control	0.1% amino	0.2% amino	Mean
			Aa Agrissivity for sweet corn to sweet potato					
2 s.c.: 1s.p.	-0.455	-0.317	-0.357	-376	-0.433	-0.299	-0.243	-0.325
1 s.c.:2s.p.	0.891	0.892	0.965	0.916	1.047	1.042	1.070	1.053
1 s.c.: 1s.p.	0.204	0.227	0.305	0.245	0.236	0.272	0.361	0.290
Mean	0.213	0.267	0.305		0.283	0.339	0.396	0.339
LSD at 0.5 for amino acids	0.059	N.S						
LSD at 0.5 for intercropping	0.076	0.065						
LSD at 0.5 for interaction	N.S	N.S						
			Ab Agrissivity for sweet potato to sweet corn					
2 s.c.: 1s.p.	0.455	0.317	0.357	0.376	0.433	0.299	0.243	0.325
1 s.c.:2s.p.	-0.891	-0.892	-0.965	-0.916	-1.047	-1.042	-1.070	-1.053
1 s.c.: 1s.p.	-0.204	-0.227	-0.305	-0.245	-0.236	-0.272	-0.361	-0.290
Mean	-0.213	-0.267	-0.305		-0.283	-0.339	-0.396	
LSD at 0.5 for amino acids	0.059	N.S						
LSD at 0.5 for intercropping	0.076	0.065						
LSD at 0.5 for interaction	N.S	N.S						

sc=sweet corn; sp= sweet potato

which indicated that, sweet corn considered the dominant crop and sweet potato the dominated one. The highest relative crowding coefficient of sweet corn (ka) values were found with the intercropping system 1 sweet corn: 1 sweet potato mixture ratio in both seasons and those for sweet potato (kb) were obtained with 2 sweet corn: 1 sweet potato mixture ratio in both seasons. Moreover, all values of K (ka x kb) were higher than one, which indicated that, there were yield advantages. Regarding amino acids foliar spray sweet potato (kb) was decreased with increasing amino acids concentration in the first season. While its effects on ka in the first season and kb in both seasons were not significant. All values of K were more than one which indicated that there were yield advantage in both seasons. The highest values of total combined crops (K) were obtained with the highest proportion of sweet corn compared with the lowest proportion (1 sweet corn: 2 sweet potato. Such results went along with those of yield advantage and LER values previously discussed.

Aggressivity: The effect of amino acids foliar spray and intercropping systems between sweet corn and sweet potato on their aggressivity was presented in Table (9). Obtained data showed that sweet corn values were positive except with its highest proportion (2 sweet corn: 1 sweet potato)which indicated that sweet corn was the dominant crop when intercropped with sweet potato as 1:1 or 1:2 mixture ratio. While with 2 sweet corn: 1 sweet potato ratio, sweet corn was the dominated crop which indicated that the intra-competition within high proportion of sweet corn was higher than the inter-competition with sweet potato plants. Obtained results were true in both investigated seasons. The highest values of aggressivity were obtained with 1 sweet corn : 2 sweet potato mixture ratio for both crops which indicated that, there were a high differences in competitive ability of sweet corn and sweet potato.

It can be concluded from the previous investigated competitive relationships, i.e., land equivalent ratio (LER), relative crowding coefficient (RCC) and aggressivety (A) that, values for any combination indicated that, sweet corn in general, was the dominant crop while, sweet potato was the dominated. So, we notes that, sweet potato growth and yield clearly increased with decreasing sweet corn population in mixture systems. Moreover LER for combined intercrop yield was obtained with 1:1 mixture system which gave the highest yield advantage, i.e., 0.308 and 0.320 in the first and second season, respectively. 0.277 and 0.305 of the yield advantage were attributed to sweet corn, but only 0.031 and 0.015 were achieved by sweet potato in the first and second season respectively.

Similar results were found by Olson and Sanders [37], Sarlak *et al*. [38] and Abd El-Lateef *et al*. [39]. From previous study on maize and sweet potato, Asiimwe, *et al*. [7] decided that, increasing maize plant densities in intercrops seem to compensate for yield reductions, due to intercropping compared to the sole crop and the reduction was only 25.9% less than that of sole crop, while sweet potato tuber yields were reduced by 63% with higher maize population, but with a lower maize population allows a higher sweet potato yield in the intercrop would be most preferred.

CONCLUSION

There were yield advantages for intercropping sweet corn and sweet potato when intercropped at 1:1 or 1:2 sweet corn: sweet potato mixture ratio under Siwa conditions. Both crops gave a sufficient foliage yield which considered an important source for green fodder during summer months overcome its shortage; the highest total combined foliage yield was obtained, also, with 2 sweet corn: 1 sweet potato. Moreover, intercropping between sweet corn and sweet potato as 1:1 or 1: 2 gave the highest land equivalent ratio (LER) and the highest yield of corn cobs and sweet potato tuber roots.

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