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Evaluation of sweet potato (*Ipomoea batatas*) based strip intercropping systems for yield, competition indices and nutrient uptake

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ABSTRACT

Field experiments were conducted at Dumduma, Bhubaneswar, for three consecutive years (2006-2008) to assess the sweet potato based strip intercropping systems with respect to productivity, nutrient uptake, competition and economic parameters. Sweet potato (*Ipomoea batatas* L.) + pigeonpea [*Cajanus cajan* (L.) Millsp.] strip intercropping system recorded significantly higher root equivalent yield (13.53 t/ha) compared to other cropping systems except sole sweet potato. The total yield gain in sweet potato + pigeonpea system was 28.8% and 24.7% over sweet potato + rice (*Oryza sativa* L.) and sweet potato + ragi (*Eleusine coracans* L.) strip intercropping system. Root equivalent yield of sole sweet potato was significantly higher than the sole stand of other crops and strip intercropping systems except sweet potato + pigeonpea. Competition indices like land equivalent ratio (LER), area time equivalent ratio (ATER), aggressivity (A) and monetary advantage index (MAI) values were higher for sweet potato + pigeonpea strip intercropping system. Sweet potato appears more competitive than companion crops like rice or ragi. Partial competition ratio value of companion crops like maize (*Zea mays* L.) and pigeonpea had an edge over sweet potato in sweet potato + maize and sweet potato + pigeonpea strip intercropping systems. The uptake of N, P and K were observed to be more when sweet potato, maize and pigeonpea were included in the strip intercropping systems. The root equivalent yield and competition indices and economic parameters indicated that the strip intercropping of sweet potato with pigeonpea is biologically sustainable and economically viable.

Key words : Area time equivalent ratio, Competition ratio, Land equivalent ratio, Nutrient uptake, Root equivalent yield, Sweet potato.

Crop production systems aims to achieve high productivity and to promote sustainability over time. These include crop rotation, multiple cropping, relay cropping and intercropping. Intercropping is widely followed practice in rainfed uplands. It has some of the established and anticipated advantages such as greater yield stability, greater land-use efficiency, increased competitive ability toward weeds and improvement of soil fertility due to N fixation.

In Orissa, sweet potato is one of the major food crop grown under small holding farming system in rainfed uplands. In India, it is grown in 1,29,400 ha and in Orissa over 43,000 ha (NHB, 2006). The other major food crops in rainfed uplands are rice, ragi, maize and pigeonpea. Usually, farmers in this region grow more than one food crop in their landholdings. Some times, two crops in the same piece of land separately. The carbohydrate rich tuberous root crop sweet potato is known for drought tolerance. Mid season and terminal droughts can reduce the sweet potato yield but there is less chance of crop failure. Intercropping of sweet potato with cereals, millets and pulses could act as contingent crop and increase land use efficiency apart from augmenting farm yield in upland rainfed conditions.

Generally, sweet potato is planted in ridge and furrow methods, whereas cereals and pulses are sown in flat beds. Hence, strip intercropping is more feasible option when sweet potato is intercropped with cereals and pulses. An investigation on strip intercropping of sweet potato with popular food crops rice, ragi, maize and pigeonpea was carried out to assess the best strip intercropping system with respect to productivity, competition and economic parameters.

MATERIALS AND METHODS

The field experiment was conducted at the Regional Centre of Central Tuber Crops Research Institute (20º 14' 50'' N and 85º 47' 06'' E), Dumduma, Bhubaneswar for consecutive three years (2006-2008). The climate of the region is characterized by hot and humid summer and cold and dry winter. The water-holding capacity of the soil was

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12.2%. The soil pH was 5.4, available N 242 kg/ha, available P 18.6 kg/ha and available K 158 kg/ha before start of the experiment. The experiment was laid out in randomized block design (RBD) with three replications. The experiment consisted of five sole crops *viz*. sweet potato, rice, ragi, maize and pigeonpea, and four strip intercropping (1.8 m strip of each component crop) in replacement series, sweet potato + rice (3:9 rows), sweet potato + ragi (3:9 rows), sweet potato + maize (3:3 rows) , sweet potato + pigeonpea (3:3 rows). Variety 'Kishan' of sweet potato, 'Vandana' of rice, 'Nilachal' of ragi, 'Navjot' of maize and 'UPAS 120' of pigeonpea were used in this experiment. Sweet potato was planted in ridge and furrow methods, whereas other crops were sown in flat bed. Sweet potato, rice, ragi, maize and pigeonpea were sown/planted at 60 x 20 cm, 20 x 15 cm, 20 x 15 cm, 60 x 30 cm and 60 x 20 cm, respectively. The recommended dose of fertilizer for sole crop of sweet potato, rice, ragi, maize and pigeonpea were $N:P_2O_5:K_2O$ @ 50:25:50, 40:40:40, 30:30:40, 60:60:60 and 40:40:20 kg/ha. In strip intercropping, component crops occupies 50% of the area, hence 50% of the recommended dose of fertilizers of each crop was applied. Full dose of phosphorus and half dose of nitrogen and potassium were applied as basal at the time of sowing/ planting. The remaining half dose of nitrogen and potassium were applied 30 days after sowing/planting to all the crops. The other recommended package of practices was duly followed for all the crops. Rice, maize, ragi, sweet potato and pigeonpea were harvested at 85, 90, 105, 120 and 210 days after sowing/planting.

Yield attributes and yield were recorded at the time of harvest. Sweet potato root equivalent yield was worked out by converting the yields of intercrops to the yield of sweet potato on the basis of prevailing market price of each crop. The economics of different crops and crop combinations were computed on the basis of prevailing market rates of produce and agro inputs. The N, P and K were determined in aerial parts of all the crops, but in sweet potato roots also included along with aerial parts. Nutrient uptake was estimated by multiplying the nutrient content with respective dry matter yields. The land equivalent ratio (LER), area time equivalent ratio (ATER), relative crowding coefficient (RCC), aggressivity (A), competition ratio (CR), actual yield loss (AYL), intercropping advantage (IA) and monetary advantage index (MAI) were worked out as per the method given by Willey (1979), Heibsch (1980), De Witt, (1960), McGilchrist, (1965), Willey and Rao (1980), Banik *et al*. (2000), Dhima *et al*. (2007) and Ghosh, (2004), respectively.

The data collected were subjected to analysis of variance appropriatly to the design using Genstat software. The trends in all the three years were found similar. Then the homogeneity of error variance was tested using Bartlett's c^2-test. As the error variance was homogeneous, pooled analysis was done. Comparison of treatment means for significance at 5% was done using the critical differences (CD) as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Yield and yield attributes

Yield attributes of sweet potato in strip intercropping systems were found higher than sole sweet potato (Table 1). However, number of roots/plant of sweet potato in sweet potato + maize strip intercropping system was observed lower than sole sweet potato. Yield attributes of intercrops (rice, ragi, maize and pigeonpea) were also higher in strip intercropping systems than respective sole crops. However, 1000-seed weight was found not influenced by strip intercropping systems. Harper (1961) defined this phenomenon as internal or physiological homeostasis with respect to the organ that is essential for reproduction and dispersal. Yields of component crops in strip intercropping systems were lower than respective sole crops. This was because of reduction of 50% sown area for component crops in strip intercropping. Yields of component crops on net area sown basis, were higher than respective sole crops (Table 2). This was mainly due to higher yield attributes of component crops in strip intercropping systems (Table 1).

The root equivalent yield of sweet potato strip intercropping with rice, ragi, maize and pigeonpea was found higher than sole rice, ragi, maize and pigeonpea (Table 2). Sweet potato + pigeonpea intercropping system had recorded significantly higher root equivalent yield (13.53 t/ ha) compared to other cropping systems. This system had recorded 80.3% higher root equivalent yield than sole pigeonpea and 1.3% higher root equivalent yield than sole sweet potato. Sweet potato with maize registered lower sweet potato root equivalent yield compared to its intercropped stand with other crops. This marked reduction is attributed to aggressive competition ability of maize at early stage with sweet potato (Table 2). Irrespective of intercrop species, maize induced more competition for sunlight and nutrients (Dutta and Bandopadhyay, 2006). However, sweet potato + maize intercropping had registered 131.1% higher root equivalent yield than sole maize. An increase of 143.2% root equivalent yield was observed in sweet potato + rice over sole rice. Sweet potato + ragi intercropping system had produced 229.1% higher root equivalent yield than sole ragi.

Economics

Economic returns worked out for all the cropping systems indicated that the sweet potato + pigeonpea intercropping system recorded higher benefit cost ratio (3.24) compared to other cropping systems (Table 2). This was due to higher net returns (₹28,075/ha). It was followed by pigeonpea alone (3.03). This was owing to lower cost of cultivation. But sole sweet potato was the next best treatment with regard to net returns (₹21,822/ha) (Table 2).

Competition indices

Land equivalent ratio (LER) reflects the biological efficiency of intercropping systems. Partial LER of intercropped sweet potato was more than rice and ragi but less than maize and pigeonpea in strip intercropping (Table 3). In sweet potato + pigeonpea strip intercropping system, pigeonpea and sweet potato recorded the highest partial LER of 0.67 and 0.64, respectively. In general partial LER of all the crops in intercropping systems was more than 0.5, indicated that competitive pressures among the component crops were low and that both crops could be complementary in mixture (Njoku *et al.*, 2007). The total LER was more than one in all the intercropping systems (Table 3). When the LER is more than one, it indicates the greater biological efficiency of intercropping system and better use of environmental resources for plant growth. Strip intercropping system of sweet potato + pigeonpea resulted in higher LER (1.31) compared to other intercropping systems. In this treatment, pigeonpea was the major contributor of LER. Sweet potato + rice and sweet potato + ragi were the next best system interm of LER. In these treatments, sweet potato was the major contributor of LER. The strip intercropping system of sweet potato + maize recorded LER of 1.08. In this system, maize had contributed major portion of total LER. All the above results also indicated that 8 to 31% area would be required by a sole cropping system to recover the yield of intercropping system.

Area time equivalent ratio (ATER) provides more real-

Table 1. Yield attributes of component crops in sweet potato based strip intercropping systems (Pooled data of 3 years)

Treatment	Sweet potato				Intercrops			
	Roots/ plant	Root length (cm)	Root diameter (cm)	Root yield/ plant (g)	Panicles/plant, cobs/plant or pods/plant	Grains/ panicle, cob or pod	1000-seed weight (g)	Seed yield/ plant (g)
Sweet potato	2.7	11.6	8.2	167				
Rice					5.3	80.7	20.8	8.9
Ragi					2.8	1178.0	1.9	6.3
Maize					1.0	199.0	232.0	46.1
Pigeonpea					76.2	3.8	83.2	24.1
Sweet potato + rice	2.8	12.1	8.6	199	5.4	88.1	20.8	9.9
Sweet potato + ragi	3.0	12.4	8.7	206	2.8	1234.0	1.9	6.6
Sweet potato + maize	2.6	12.0	8.9	176	1.0	217.0	133.0	50.4
Sweet potato + pigeonpea	3.1	12.6	8.9	213	99.0	3.9	83.4	32.2
SEm±	0.03	0.10	0.07	3.7	-	-	-	-
CD (P=0.05)	0.1	0.3	0.2	11	-	-	-	-

Table 2. Yield of sweet potato and intercrops and root equivalent yield of sweet potato based strip intercropping systems (Pooled data of 3 years)

Treatment	Sweet potato root yield (t/ha)	Intercrop yield (t/ha)	Root equivalent yield (t/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B : C ratio
Sweet potato	13.37		13.37	18,279	40,101	21,822	2.19
Rice		2.53	4.22	8,650	12,660	4,010	1.46
Ragi		1.78	2.96	7,899	8,889	990	1.13
Maize		2.40	3.99	8,638	11,973	3,335	1.38
Pigeonpea		1.88	7.51	7,436	22,524	15,088	3.03
Sweet potato + rice	7.94	1.39	10.26	13,818	30,786	16,968	2.22
Sweet potato + ragi	8.22	0.93	9.75	12,914	29,253	16,339	2.27
Sweet potato + maize	7.04	1.31	9.22	13.365	27,672	14,307	2.07
Sweet potato + pigeonpea	8.54	1.25	13.53	12,527	40,602	28,075	3.24
SEm ±	-	-	0.13	-	-	-	-
CD (P=0.05)			0.40	-	-	-	-

Farm gate selling price of sweet potato ₹3,000/t; rice ₹5,000/t; maize ₹5,000/t; pigeonpea ₹12,000/t istic comparison of the yield advantage of intercropping over sole cropping in terms of variation in time taken by the component crops of different intercropping systems. In all the intercropping systems, the ATER values were lesser than LER values indicating over estimation of resource utilization. ATER is free from problems of over estimation of resource utilization contrary to LER. Partial ATER value was found maximum of pigeonpea in sweet potato + pigeonpea intercropping, followed by sweet potato in sweet potato + ragi strip intercropping system (Table 3). It indicated that pigeonpea and sweet potato were more efficient in utilizing resources in the respective cropping systems. Total ATER value was more than one in sweet potato + ragi intercropping and sweet potato + pigeonpea was next in order (Table 3). The yield advantage was four and eight per cent in sweet potato + pigeonpea and sweet potato + ragi strip intercropping systems, respectively.

Partial relative crowding coefficient (RCC) values of sweet potato and intercrops were found more than one (Table 3). Partial RCC value of sweet potato was found higher than rice and ragi in sweet potato + rice and sweet potato + ragi intercropping system. It indicated that sweet potato was more competitive than rice and ragi. Partial RCC value of maize and pigeonpea was higher than sweet potato in sweet potato + maize and sweet potato + pigeonpea intercropping system, respectively. It indicated that pigeonpea and maize were more competitive than sweet potato. RCC values of sweet potato in all the strip intercropping and intercrops (rice, ragi, maize and pigeonpea) were greater than one which indicated that sweet potato and other intercrops gave more yield than expected (Table 3). Total RCC value was also more than one and it ranged from 1.34 to 3.52 in various combinations of sweet potato based strip intercropping (Table 3). The highest total K was being with sweet potato + pigeonpea strip intercropping (3.52). The relative crowding coefficient indicated definite yield advantage to grow sweet potato + pigeonpea intercropping in strips of 1.8 m width (K=3.52).

Aggressivity (A) represents a simple measure of how much the relative yield increase in *a* crop is greater than that of *b* crop in an intercropping system. Partial aggressivity (A)value of sweet potato was positive in sweet potato + rice and sweet potato + ragi strip intercropping systems (Table 3). Sweet potato was the dominant crop in the above strip intercropping systems. In sweet potato + maize and sweet potato + pigeonpea strip intercropping systems, the partial aggressivity (A) value of sweet potato was negative (Table 3). It indicated that the sweet potato was dominated crop. The main crop dominance depends on intercrops and agro-ecological situations (Aasim *et al*., 2008).

Table 3. Competition indices and economic feasibility of sweet potato based strip intercropping (Pooled data of 3 years)

Treatment	Land Equivalent Ratio (LER)			Area Time Equivalent Ratio (ATER)			Relative Crowding Coefficient (K)			Aggressivity (A)		Competition Ratio (CR)		Actual Yield Loss (AYL)			Intercropping Advantage (IA)			Monetary Advantage
	Sweet potato	Inter-crop	Total	Sweet potato	Inter-crop	Total	K *sweet potato*	K *intercrop*	K	A *sweet potato*	A *intercrop*	CR *sweet potato*	CR *intercrop*	AYL sweet potato	AYL intercrop	Total AYL potato	IA sweet potato	IA inter-crop	Total IA	Index (MAI)
Sweet potato + rice	0.59	0.55	1.14	0.59	0.39	0.98	1.26	1.22	1.78	0.04	- 0.04	1.07	0.93	0.188	0.100	0.288	300	1440	1740	5614
Sweet potato + ragi	0.62	0.52	1.14	0.62	0.46	1.08	1.60	1.10	1.76	0.10	- 0.10	1.18	0.82	0.230	0.047	0.247	141	1235	1376	4095
Sweet potato + maize	0.53	0.55	1.08	0.53	0.41	0.94	1.11	1.21	1.34	- 0.02	0.02	0.96	1.04	0.054	0.093	0.147	279	735	1014	2214
Sweet potato + pigeonpea	0.64	0.67	1.31	0.37	0.67	1.04	1.77	1.99	3.52	-0.03	0.03	0.96	1.04	0.277	0.331	0.608	993	7296	8289	12590

The similar trend of dominant behavior of sweet potato to its associated intercrops as indicated by K and A values was also observed for competitions ratio (CR). CR worked out for all the strip intercropping systems revealed that in sweet potato + rice and sweet potato + ragi, partial CR of sweet potato was higher than intercrops rice and ragi (Table 3). Sweet potato appears more competitive than companion crop either rice or ragi. Partial CR value of companion crops like maize and pigeonpea had an edge over sweet potato in sweet potato + maize and sweet potato + pigeonpea strip intercropping systems (Table 3).

Actual yield loss (AYL) index gives more precise information about intercropping than other indices on inter and intra specific competition and behavior of the component crops. Quantification of yield loss or gain due to association with other species or variation of plant population could not be obtained through partial LER's, whereas partial AYL shows yield loss or gain by its sign and as its value (Dhima *et al*., 2007). Results of AYL showed that sweet potato was more dominant than intercrops rice and ragi in sweet potato + rice and sweet potato + ragi strip intercropping systems (Table 3). However, intercrops maize and pigeonpea were more dominant than sweet potato in sweet potato + maize and sweet potato + pigeonpea strip intercropping systems. All the partial AYL values of sweet potato and intercrops were positive probably due to positive effects of intercrops on sweet potato in all the strip intercropping systems, which increased the yield of component crops. Strip intercropping with rice and ragi had increased sweet potato yield 18.8% and 23.0% higher, respectively. Similarly, rice and ragi yield was increased 10.0% and 4.7% higher respectively in the above intercropping systems. Total yield gain was 28.8% and 24.7% in sweet potato + rice and sweet potato + ragi strip intercropping system, respectively. All partial AYL values of sweet potato, maize and pigeonpea in sweet potato + maize and sweet potato + pigeonpea intercropping systems were positive and indicated positive interaction effect of component crops. Partial AYL of maize and pigeonpea values showed more yield advantage than sweet potato in sweet potato + maize and sweet potato + pigeonpea intercropping systems. Maize and pigeonpea registered 9.3% and 33.1% yield increase when intercropped with sweet potato. Whereas, yield increase in sweet potato was found 5.4% and 27.7% with maize and pigeonpea respectively in sweet potato + maize and sweet potato + pigeonpea intercropping systems. Overall yield gain was noticed with 14.7% and 60.8% in sweet potato + maize and sweet potato + pigeonpea intercropping systems, respectively. The highest partial AYL value for sweet potato among all the strip intercropping systems was noticed when grown with pigeonpea, even though it was less than pigeonpea (Table 3). It indicated that there was a higher complimentary effect with pigeonpea.

Economic feasibility

Intercropping advantage (IA) is an economic feasibility indicator of intercropping system. The results of the present investigation revealed that all the strip intercropping systems were advantageous as the total IA values were positive (Table 3). The values of IA followed the same trend with AYL values. The highest total IA was observed with sweet potato + pigeonpea followed by sweet potato + rice strip intercropping system (Table 3). Partial IA values for sweet potato were found positive irrespective of intercropping system. Maximum positive value for sweet potato was noticed in sweet potato + pigeonpea (993). Partial IA values for intercrops were also positive meant intercrops got certain advantage due to intercropping with sweet potato. Maximum partial IA value for intercrops was found in pigeonpea (7296). Monetary advantage index (MAI) values were positive which showed a definite yield advantage in all the strip intercropping systems (Table 3). Maximum MAI value was noticed in sweet potato + pigeonpea strip intercropping system (12590). Whereas, minimum MAI value was obtained from sweet potato + maize strip intercropping system (2214) (Table 3).

Nutrient uptake

The highest total N uptake was found in sweet potato + maize intercropping system (Table 4). This was mainly due to maize which consumes more nitrogen. This was witnessed in sole maize which had the next higher total N uptake. The total N uptake of maize sole and sweet potato + pigeonpea strip intercropping was statistically comparable with maize sole. This was mainly due to higher root yield of sweet potato. The highest total P uptake was observed in sweet potato + pigeonpea strip intercropping system. This may be due to higher yields of sweet potato and pigeonpea (Table 4). The total K uptake was observed higher in sweet potato sole cropping. The sweet potato removes more K than other nutrients (Nedunchezhiyan and Srinivasulu Reddy, 2002). The higher total K uptake in all the strip intercropping systems compared to respective sole crops except sole sweet potato sole crop indorsed the above finding (Table 4).

It was concluded that the yields of sweet potato and intercrops, and the competition indices showed a significant advantage from strip intercropping compared to sole cropping. The root equivalent yield and competition indices and economic parameters indicated that the strip intercropping of sweet potato with pigeonpea is biologically sustainable and economically viable.

Table 4. Nutrient uptake (kg/ha) in sweet potato based strip intercropping systems (Pooled data of 3 years)

Treatment	Nutrient uptake (kg/ha)								
	N			P			K		
	Sweet potato	Intercrop	Total	Sweet potato	Intercrop	Total	Sweet potato	Intercrop	Total
Sweet potato	58.4	-	58.4	14.4	-	14.4	73.0	-	73.0
Rice	-	36.2	36.2	-	10.6	10.6	-	34.4	34.4
Ragi	-	24.2	24.2	-	6.7	6.7	-	23.2	23.2
Maize	-	59.0	59.0	-	14.0	14.0	-	51.2	51.2
Pigeonpea	-	29.8	29.8	-	9.2	9.2	-	28.3	28.3
Sweet potato + rice	34.6	21.0	55.6	8.7	5.7	14.4	44.2	19.8	64.0
Sweet potato + ragi	36.1	13.2	49.3	8.7	3.6	12.3	45.7	12.3	58.0
Sweet potato + maize	30.2	33.2	63.4	7.3	7.8	15.1	39.1	28.4	67.5
Sweet potato + pigeonpea	37.8	19.0	56.8	9.4	5.9	15.3	44.6	18.0	62.6
SEm±	-	-	1.2	-	-	0.3	-	-	1.6
CD (P=0.05)	-	-	3.6	-	-	0.9	-	-	4.7

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