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Productivity potential, biological efficiency and economics of sweet potato (*Ipomoea batatas*) - based strip intercropping systems in rainfed Alfisols*

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Intercropping is gaining importance because not only it provides biological insurance against risks under aberrant rainfall behaviour in dryland environment (Dutta and Bandyopadhyay 2006) but also more labour employment (Nedunchezhiyan *et al*. 2008). In uplands, intercropping and crop substitution stabilizes crop yields (Rao *et al*. 1982). When crops of different growth habits are put together in an intercropping system, it provides greater opportunity to secure higher yield from the same piece of land (Sarkar and Pal 2004). Synergetic effect on component crops under intercropping was widely reported.

In rainfed uplands of Orissa, rice (*Oryza sativa* L.), ragi (*Eleusine coracana* L.), maize (*Zea mays* L.), pigeonpea (*Cajanus cajan* (L.) Millsp.) and sweet potato (*Ipomoea batatas* L.) are the major food crops. Farmers in this region usually grow more than one food crop in their available landholdings, sometimes, 2 crops in the same piece of land separately. Sweet potato, a carbohydrate rich tuber crop has versatile utility. It is known for drought tolerance. Mid season and terminal droughts can reduce the sweet potato yield but there is no chance of crop failure. Intercropping of sweet potato with cereals, millets and pulses could act as contingent crop and increase the land-use efficiency apart from augmenting the farm yield in upland rainfed conditions. Pigeonpea and maize were more profitable in intercropping under rainfed conditions (Dutta and Bandyopadhyay 2006, Satyam *et al*. 2008). Sweet potato is generally planted in ridge and furrow methods, whereas cereals and pulses are sown in flat bed. Strip intercropping is more feasible option when sweet potato is intercropped with cereals and pulses. Strip intercropping system of maize and soybean [*Glysine max* (L.) Merrill] has the potential to reduce soil erosion (Lesoing and Francis 1999a), weed density (Glowaeka 2007) and increase the biological and economic efficiencies (Lesoing and Francis 1999b). Keeping in view of the above, the present investigation was undertaken to assess the production potential, biological efficiency and economics of sweet potato-based strip intercropping.

The field experiment was conducted during 2006–08 at Regional Centre of Central Tuber Crops Research Institute (20º 14' 50" N and 85º 47' 06" E), Dumduma, Bhubaneswar. The experiment was laid out in randomized block design with 3 replications. The experiment consisted of 5 sole crops, viz sweet potato, rice, ragi, maize and pigeonpea, and 4 strip intercropping (1.8 m strip 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). 'Kishan' sweet potato, 'Vandana' rice, 'Nilachal' ragi, 'Navjot' maize and 'UPAS 120' pigeonpea were used in this experiment. Sweet potato, rice, ragi, maize and pigeonpea were sown/planted at 60 cm × 20 cm, 20 cm × 15 cm, 20 cm × 15 cm, 60 cm × 30 cm and 60 cm × 20 cm, respectively. Sweet potato was planted in ridge and furrow methods, whereas other crops were sown in flat bed. 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 were applied. Full dose 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 followed for all the crops. Rice, maize, ragi, sweet potato and pigeonpea were harvested 85, 90, 105, 120 and 210 days after sowing/planting.

The average rainfall during the crop year 2006–08 was 1 684.7 mm in 92.3 rainy days. The average maximum temperature ranges between 29.2 and 37.5º C, whereas the average minimum temperature ranges between 14.6 and 26.5º C. July and August were the highest rain receiving months.

*Short note

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The climate of the region is characterized by hot and humid summer and cold and dry winter. The soil was having *p*H 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 water-holding capacity of the soil was 12.2%.

Different competition indices were calculated as described by Willey (1979). Sweet potato 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.

Among the crops tested, sweet potato as a sole crop recorded higher yield than other crops (Table 1). Sweet potato is able to produce higher biomass per unit area per unit time and efficient in converting biological yield into economic yield (Nedunchezhiyan and Byju 2005). Rice was the next higher yielder and it was followed by maize. Ragi gave lower yield among the crops tested in the sole cropping. This variation in yield was due to genetic potential of the individual crop species. Sweet potato, rice, ragi, maize and pigeonpea yield in strip intercropping was lower than sole cropping. This was due to only 50% of the total area occupied by these crops in intercropping. However, if compared on unit area occupied by these crops, the yield in strip intercropping was higher than sole cropping.

Sweet potato tuber yield on unit area basis was higher in strip intercropping than sole cropping (Table 1). Among all the strip intercroppings, sweet potato tuber yield was higher in sweet potato + pigeonpea intercropping. The next best was sweet potato + ragi intercropping, followed by sweet potato + rice. Lower sweet potato tuber yield among strip intercropping system was found in sweet potato + maize. The increased sweet potato tuber yield in various strip intercropping systems was due to higher yield attributes (number of tubers/plant, tuber length, tuber mean diameter and tuber yield/plant) than sole cropping. Among the strip intercropping, yield attributes of sweet potato in sweet potato + pigeonpea was higher (Table 1). In sweet potato + pigeonpea intercropping, increase in number of tubers/plant (14.8%), tuber length (8.6%), mean tuber diameter (8.5%) and tuber yield/plant (27.5%), respectively were noticed than sole sweet potato. Similarly, increase in number of tubers/plant (11.1%), tuber length (6.9%), mean tuber diameter (6.1%) and tuber yield/plant (23.4%) of sweet potato, respectively, were observed in sweet potato + ragi intercropping compared to sweet potato sole cropping. Sweet potato yield attributes number of tubers/plant (3.7%), tuber length (4.3%), mean tuber diameter (4.9%) and tuber yield/plant (19.2%) were higher in sweet potato + rice over sole sweet potato. Inter-species complimentary effect in intercropping on yield attributes was widely reported. In sweet potato + maize strip intercropping, marginal increase of tuber yield/plant (5.4%) was noticed. This was due to increase of tuber length (3.4%) and mean tuber girth (8.5%) but decrease of number of tubers/plant (3.7%), number of tubers/plant in sweet potato decided within 40 days after planting (Nedunchezhiyan *et al*. 2004). Maize as a vigourous growing crop suppressed the sweet potato at early stage. Sweet potato a 120 days crop recovered after harvest of maize (90 days after planting).

Similarly, 11.2% higher rice seed yield/plant was noticed in sweet potato + rice intercropping than rice sole cropping (Table 1). This was due to increase of 9.2% number of seeds/panicle and 1.9% number of panicles/plant. In sweet potato + ragi intercropping, ragi seed yield/plant was higher by 4.8% compared to sole ragi, which was mainly due to increase of number of seeds/panicle (4.8%). Owing to increase of number of seeds/cob (9.0%) and 1 000-seed weight (0.2%) of maize in sweet potato + maize intercropping 9.2% higher seed yield/

Table 1 Yield and yield components of sole and intercrops as influenced by strip intercropping system (pooled data of 3 years)

Treatment	Sweet potato					Other/intercrops				
	Tubers/ plant	Tuber length (cm)	Mean tuber diameter (cm)	Tuber yield/ plant (g)	Tuber yield (kg/ha)	Panicles or cobs or pods/ plant	Grains/ panicle or seeds/cob or seeds/pod	1 000- seed weight (g)	Seed yield/ plant (g)	Seed yield (kg/ha)
Sole cropping										
Sweet potato	2.7	11.6	8.2	167	13 367					
Rice						5.3	80.7	20.8	8.9	2 532
Ragi						2.8	1178	1.91	6.3	1 778
Maize						1.0	199	232	46.1	2 395
Pigeonpea						76.2	3.8	83.2	24.1	1 877
Strip intercropping										
Sweet potato + rice	2.8	12.1	8.6	199	7 942	5.4	88.1	20.8	9.9	1 392
Sweet potato + ragi	3.0	12.4	8.7	206	8 221	2.8	1234	1.91	6.6	931
Sweet potato + maize	2.6	12.0	8.9	176	7 043	1.0	217	133	50.4	1 309
Sweet potato + pigeonpea	3.1	12.6	8.9	213	8 538	99.0	3.9	83.4	32.2	1 249

Table 2 Tuber equivalent yield and economics of sweet potato-based strip intercropping systems (pooled data of 3 years)

Treatment	Tuber equivalent yield (kg/ha)	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Sole cropping					
Sweet potato	13 367	18 279	40 101	21 822	2.19
Rice	4 220	8 650	12 660	4 010	1.46
Ragi	2 963	7 899	8 889	990	1.13
Maize	3 991	8 638	11 973	3 335	1.38
Pigeonpea	7 508	7 436	22 524	15 088	3.03
Strip intercropping					
Sweet potato + rice	10 262	13 818	30 786	16 968	2.22
Sweet potato + ragi	9 751	12 914	29 253	16 339	2.27
Sweet potato + maize	9 224	13 365	27 672	14 307	2.07
Sweet potato + pigeonpea	13 534	12 527	40 602	28 075	3.24
CD (P=0.05)	403				

Selling cost: Sweet potato Rs 3/kg; rice/ragi/maize: Rs 5/kg; pigeonpea: Rs 12/kg

plant was observed than sole maize. An increase of 33.6% seed yield/plant in pigeonpea was noticed in sweet potato + pigeonpea intercropping over sole pigeonpea. This was due to higher number of pods/plant, seeds/pod and 1 000-seed weight 29.9%, 2.6% and 0.2%, respectively. Strip intercropping did not influence 1 000-seed weight, irrespective of crops and crop combinations. Harper (1961) considers this to be an internal or physiological homeostasis with respect to the organ that is essential for reproduction and dispersal. Comparison of overall yield obtained by strip intercropping with sole cropping revealed inter-specific facilitation during co-growth (Li *et al*. 2001). When the appropriate crop species are placed side by side, competition between plants is minimized and yields are increased, especially along the border (Burezyk 2003).

All the strip intercropping systems showed superiority over sole crops in terms of sweet potato tuber equivalent yield (Table 2). Tuber equivalent yield of sweet potato strip intercropping with rice, ragi, maize and pigeonpea was higher than sole rice, ragi, maize and pigeonpea. Sweet potato + pigeonpea intercropping system recorded significantly higher tuber equivalent yield (13 538 kg/ha) compared to other cropping systems and sweet potato sole cropping, followed it (13 367 kg/ha) (Table 2). Sweet potato + pigeonpea intercropping system recorded 80.3% higher tuber equivalent yield than sole pigeonpea and just 1.3% higher tuber equivalent yield than sole sweet potato. Strip intercropping of sweet potato with maize gave lower sweet potato tuber equivalent yield compared to other intercropping systems. Aggressive competition ability of maize at early stage with sweet potato, reduced the sweet potato yield in intercropping compared to other crops (Table 1). Irrespective of intercrop species, maize competes for sunlight and nutrients (Dutta and Bandopadhyay 2006). However, sweet potato + maize intercropping registered 131.1% higher tuber equivalent yield than sole maize. An increase of 143.2% tuber equivalent yield was observed in sweet potato + rice over sole rice. Sweet potato + ragi intercropping system gave 229.1% higher tuber equivalent yield than sole ragi.

The land equivalent ratio (LER) more than one indicates greater biological efficiency of intercropping systems. Strip intercropping system of sweet potato + pigeonpea resulted in higher LER (1.31) compared to other intercropping systems (Table 3), which indicated greater biological efficiency of the system. This yield advantage owing to strip intercropping might be attributed to combined effect of better utilization of natural resources than sole cropping of companion crops, resulting in higher productivity per unit area. Sweet potato + rice and sweet potato + ragi were the next best. Among strip intercropping systems, sweet potato + maize recorded lower LER (1.08). Competition ratio worked out for all the strip intercropping systems revealed that in sweet potato + rice and sweet potato + ragi, sweet potato appeared more competitive than companion crop either rice or ragi (Table 3). Companion crops like maize and pigeonpea had an edge over sweet potato in sweet potato + maize and sweet potato + pigeonpea intercropping systems. The relative crowding co-efficient values of sweet potato in all the strip intercropping and intercrops (rice, ragi, maize and pigeonpea) were greater than 1 indicated that sweet potato and other intercrops gave more yield than expected (Table 3). The product of relative crowding co-efficient indicated definite yield advantage to grow sweet potato + pigeonpea intercropping in strips of 1.8 m width (K=3.52).

Economics

The monetary advantage based on LER indicated superior economic viability of sweet potato + pigeonpea intercropping (Table 2). The benefit : cost ratio value (3.24) was higher in sweet potato + pigeonpea intercropping system (Table 2). This was due to higher net returns (Rs 28 075). It was

Table 3 Competition functions of sweet potato, rice, ragi, maize and pigeonpea in strip intercropping system (pooled data of 3 years)

Treatment	Land equivalent ratio (LER)	Competition ratio		Relative crowding co-efficient		Products of relative crowding co-efficient (K)
		CR_{sp}	CR_i	K_{sp}	K_i	
Sweet potato + rice	1.14	1.07	0.93	1.26	1.22	1.78
Sweet potato + ragi	1.14	1.18	0.82	1.60	1.10	1.76
Sweet potato + maize	1.08	0.96	1.04	1.11	1.21	1.34
Sweet potato + pigeonpea	1.31	0.96	1.04	1.77	1.99	3.52

followed by pigeonpea alone (3.03). This was owing to lower cost of cultivation. But sweet potato sole cropping was the next best treatment with regard to net returns (Rs 21 822) (Table 2).

Thus, the tuber equivalent yield, biological parameters and economics indicated that strip intercropping sweet potato with pigeonpea could be biologically sustainable and economically viable in rainfed Alfisols of Orissa.

SUMMARY

A field experiment was conducted during 2006-08 in Alfisols under rainfed conditions to investigate the productivity potential, biological efficiency and economics of sweet potato (*Ipomoea batatas* L.) - based strip intercropping systems. Among the crops tested, sweet potato as a sole crop recorded higher yield (13 367 kg/ha) than other crops. Among strip intercropping, sweet potato tuber yield was higher (8 538 kg/ha) in sweet potato + pigeonpea. In sweet potato + pigeonpea intercropping increase in number of tubers/plant (3.1), tuber length (12.6 cm), mean tuber diameter (8.9 cm) and tuber yield/plant (213 g) were noticed than sole sweet potato. All the strip intercropping systems showed superiority over sole crops in terms of sweet potato tuber equivalent yield. However, sweet potato + pigeonpea intercropping system recorded significantly higher tuber equivalent yield (13 534 kg/ha) than other intercropping systems. Strip intercropping system of sweet potato + pigeonpea resulted in higher LER (1.31), the product of relative crowding co-efficient (K=3.52) and benefit : cost ratio (3.24).

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