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Production and energy-use efficiency of greater yam (*Dioscorea alata*)-based intercropping system as influenced by intercrops and planting patterns

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ABSTRACT

A field experiment was conducted at Bhubaneshwar during 2001–02 and 2002–03 on acid laterite soils under rainfed conditions, to assess the production and energy-use efficiency of various greater yam (*Dioscorea alata*) based intercropping systems. Greater yam was planted at normal (90 × 90 cm), paired (60/120 × 90 cm) and skipped rows (90/180 × 90 cm) with 1,2 and 3 rows of maize (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench] and pigeonpea [*Cajanus cajan* (L.) Millsp.] respectively as intercrop. Sole greater yam was planted as control. The maximum tuber-equivalent yield (18.7 t/ha), land-equivalent ratio (1.37) and production efficiency (89.2 kg/ha/day) were obtained with maize as an intercrop in greater yam (normal planting), followed by greater yam (paired row planting). Pigeonpea and sorghum were the next best intercrops in the order. Similarly, intercropping with normal row and paired row planting irrespective of intercrops produced higher output energy (84.25–100.70 × 10^3 MJ/ha). Skipped row planting, due to lower greater yam tuber yield, recorded lower tuber-equivalent yield, land-equivalent ratio, production efficiency and energy output than sole greater yam cropping. However, energy output : input ratio and energy-use efficiency of greater yam + pigeonpea in skipped row planting was highest due to its lowest seed as well as manures and fertilizers energy inputs. Greater yam + maize (normal row planting) intercropping system was the next best in energy output : input ratio due to higher energy from the yields. Thus, maize was the best intercrop (1 row) with greater yam planted at normal rows (90 cm × 90 cm).

Key words : Energy-use efficiency, Greater yam, Intercrops, Land-equivalent ratio, Planting pattern

Greater yam (*Dioscorea alata*) is grown commercially in southern, eastern and northeastern states of India for its tuberous root. It serves as a subsidiary food crop in majority of the tribal dwellings. Greater yam being a trailing herb requires staking. Higher yield of yams was noticed with the traditional wooden stakes (Ikeorgu and Igwilo, 2002). However, wooden stakes are costly input in yam cultivation. The cost of staking was 25–35% of cost of cultivation of yam (Ndegwe, 1992). Availability of staking material is a big constraint for large-scale cultivation. Hence plants are unstaked in commercial cultivation. Production in unstaked plants is being constrained by the increasing prevalence of the fungal disease anthracnose caused by *Colletotrichum gloeosporioides* (Mignouna *et al.*, 2002). Seasonal and perennial plants were recommended as alternative to traditional wooden staking in Nigeria (Getahun and Njenga, 1990; Igwilo, 2004), but such information is not available for Indian conditions. Hence an investigation was carried out to find out the influence of intercrops on production and energy-use efficiency of various greater yam-based intercropping systems.

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MATERIALS AND METHODS

A field experiment was conducted at Regional Centre of Central Tuber Crops Research Institute, Bhubaneshwar, during rainy season of 2001–02 and 2002–03 on acid laterite soils under rainfed conditions in randomized block design with 3 replications. There were 10 treatments, viz. greater yam (normal row planting) + maize, greater yam (normal row planting) + sorghum, greater yam (normal row planting) + pigeonpea, greater yam (paired row planting) + maize, greater yam (paired row planting) + sorghum, greater yam (paired row planting) + pigeonpea, greater yam (skipped row planting) + maize, greater yam (skipped row planting) + sorghum, greater yam (skipped row planting) + pigeonpea and greater yam (sole crop) (control). Greater yam was planted at 3 spacings, viz. 90 cm × 90 cm, 60/120 cm × 90 cm and 90/180 cm × 90 cm for normal, paired and skipped row method of planting respectively. One (37,037 plants/ha), two (37,037 plants/ha) and three rows (55,555 plants/ha) of maize/sorghum/ pigeonpea were raised between normal, paired and skipped row respectively. The intra-row spacing of 30 cm was adopted in all the intercrops. Greater yam tuber of 200 g was planted in 30 cm × 30 cm size pits. Greater yam 'Hinjalicut', maize 'Ganga 5', sorghum 'Swarna' and pigeonpea 'S 5' were used. Greater yam, maize, sorghum and pigeonpea were planted or sown simultaneously. The recommended fertilizer dose of N:P:K @ 80:60:80 kg/ha along with FYM @ 10 t/ha was given for greater yam at normal and paired row plantings, whereas 50% of the recommended NPK and FYM was given at skipped row planting. The recommended fertilizer doses for maize, sorghum and pigeonpea were N:P:K @ 80:17.5:33.3, 60:13.1:25.0 and 20:17.5:0 kg/ha respectively. For normal and paired row planting 60% and for skipped row planting 100% of the recommended fertilizer dose was given for maize, sorghum and pigeonpea. Total P of both main and intercrops was applied basal along with FYM. Nitrogen and potassium were applied in 2 equal splits 30 and 60 days after planting immediately after weeding. Greater yam was trailed on intercrops 1 month after planting, whereas in sole crop it was allowed to spread on the ground. Maize cobs and sorghum ears were harvested at physiological maturity stage 90 and 105 days after sowing, respectively, and the stalks were left in the field as such. Pigeonpea and greater yam were harvested 7 months 210 days after planting.

The experiment was conducted in laterite soil having low available N, high available P and low K. The crop received 1,804.9 mm rainfall in 66 rainy days during 2001–02 and 1,299.7 mm rainfall in 52 rainy days during 2002–03. The prevailing market prices of different commodities were used for calculating tuber-equivalent yield. Tuber-equivalent yield was calculated by multiplying yield with price of produce and divided by price of greater yam. Production efficiency was calculated by dividing tuber-equivalent yield by 210 days (greater yam) duration. The following energy equivalents were used for computing energy input and output : greater yam tuber 4.61 MJ/kg, maize/sorghum/pigeonpea 14.7 MJ/kg, FYM 380.9 MJ/tonnes fertilizer N 60.6 MJ/kg, P 11.1 MJ/kg, K 6.7MJ/kg, men 1.96 MJ/day, women 1.57 MJ/day and diesel 56.31 MJ/l. Energy-use efficiency (q × 10^3 MJ) was calculated by dividing total produce in terms of tuber-equivalent yield (q) by total input energy ×10^3 MJ).

RESULTS AND DISCUSSION

Yield

Significant effect of intercrops on greater yam tuber yield was noticed in both the years. The highest greater yam tuber yield was noticed with greater yam (normal planting) + maize followed by greater yam (paired row planting) + maize (Table 1). Greater yam recorded 22.8% and 30.4% higher yield in greater yam (normal planting) + maize intercropping over sole greater yam during 2001–02 and 2002–03 respectively. In greater yam (paired row planting) + maize system, greater yam gave 18.8% and 27.2% higher yield over sole greater yam during 2001–02 and 2002–03 respectively. The increase in yield of greater yam was owing to vertical spread of the foliage of greater yam to the height of maize, which in turn harvested more sunlight. Least damage to greater yam vines in staked plants during weeding, earthing up and fertilizer application led to higher tuber yield (Heredia *et al.,* 1999). Pigeonpea and sorghum were the next best crops in the order. In general, the greater yam yield was higher under normal planting than under paired row planting. The lowest greater yam tuber yield was recorded in skipped row planting irrespective of intercrops.

The intercrops maize, sorghum and pigeonpea apart from staking support provided additional yield (Table 1). The higher yield of intercrops in skipped row planting was because of higher plant population. In general, greater yam and intercrop yields were higher during 2001–02 than during 2002–03. This was owing to higher rainfall and more rainy days during 2001–02.

Maximum tuber-equivalent yield was obtained from greater yam (normal row planting) + maize, followed by greater yam (paired row planting) + maize (Table 1). An increase of 36.7% and 32.7% tuber-equivalent yield in greater yam + maize (normal row planting) and greater yam + maize (paired row planting) over sole greater yam was noticed. Higher tuber-equivalent yield under these treatments was because of higher greater yam yield in addition to intercrop maize yield. Quick and tall growth of maize supported the greater yam at early stages, which led to higher advantage of maize over other intercrops. Inclusion of other intercrops sorghum and pigeonpea increased the tuber-equivalent yield in both normal and paired row planting of greater yam. Ano (2003) also reported higher productivity of yam + pigeonpea cropping system than that of sole yam. Tuber-equivalent yield under normal row planting was higher than under paired row planting irrespective of intercrops, indicating that wide row planted long-duration crop was affected by pairing the rows. Tuber equivalent yields in skipped row planting were lower than in sole yam cropping, due to lower plant population of greater yam irrespective of intercrops.

Land-equivalent ratio

Land-equivalent ratio of all intercrops was higher than 1.00 and ranged from 1.21 to 1.37 except in skipped row planting (Table 1). Land-equivalent ratio of greater yam + maize (normal row planting) and greater yam + maize (paired row planting) was 1.37 and 1.33, indicating that they were 37% and 33% more productive, respectively, than sole greater yam cropping. Land-equivalent ratio of greater yam + pigeonpea (normal row planting) and greater yam + pigeonpea (paired row planting) were 1.31 and 1.26, whereas those of greater yam + sorghum (normal row planting) and greater yam + sorghum (paired row planting) were 1.24 and 1.21 respectively (Table 1). However, land-equivalent ratio in skipped row planting recorded less than 1.00, indicating that all intercropping in skipped row planting were less productive than sole cropping.

Production efficiency

The production efficiency was the maximum in greater yam + maize (normal row planting) (89.2 kg/ha/day), followed by greater yam + maize (paired row planting) (86.6 kg/ha/day) (Table 1). Production efficiency of 85.7 and 82.3 kg/ha/day were noticed in normal as well as paired row planting, respectively, with the inclusion of pigeonpea. Sorghum as an intercrop recorded production efficiency of 81.0 kg/ha/day in normal row planting and 79.0 kg/ha/day in paired row planting. The production efficiency of skipped row planting irrespective of intercrops was lower than of sole yam cropping. This was due to lower yield of yam (Table 1). Sole yam cropping recorded production efficiency of 65.2 kg/ha/day.

Energetics

Energy used in different intercropping systems was computed to augment the energy-use efficiency. Total energy input differed due to difference in energy use under different cropping systems and it was 13.26–25.82 × 10^3 MJ/ha (Table 2).

The maximum amount of energy input was used in greater yam + maize (normal row planting) and greater yam + maize (paired row planting) perhaps due to higher

Table 1. Influence of intercrops and planting patterns on tuber yield, intercrop yield, tuber-equivalent yield, land-equivalent ratio and production efficiency of greater yam-based intercropping

Treatment	Tuber yield (t/ha)		Intercrop yield (t/ha)		Tuber-equivalent yield (t/ha)	Land-equivalent ratio	Production efficiency (kg/ha/day)
	2001–02	2002–03	2001–02	2002–03			
Greater yam (normal row planting) + maize	18.3	16.3	1.58	1.28	18.73	1.37	89.2
Greater yam (normal row planting) + sorghum	17.5	14.4	1.13	0.91	17.02	1.24	81.0
Greater yam (normal row planting) + pigeonpea	17.4	15.0	1.04	0.77	18.00	1.31	85.7
Greater yam (paired row planting) + maize	17.7	15.9	1.55	1.22	18.18	1.33	86.6
Greater yam (paired row planting) + sorghum	17.1	14.0	1.09	0.88	16.58	1.21	79.0
Greater yam (paired row planting) + pigeonpea	16.9	14.2	0.95	0.73	17.28	1.26	82.3
Greater yam (skipped row planting) + maize	9.3	8.9	1.65	1.44	10.64	0.78	50.7
Greater yam (skipped row planting) + sorghum	8.9	7.9	1.16	0.99	9.48	0.69	45.2
Greater yam (skipped row planting) + pigeonpea	8.7	8.4	1.11	0.83	10.53	0.77	50.1
Greater yam (sole crop)	14.9	12.5			13.70	1.00	65.2
SEm±	0.8	0.7			0.74		1.2
CD (P=0.05)	1.6	1.5			1.52		2.6

Price : Greater yam, maize and sorghum, Rs 5.00/kg; pigeonpea, Rs 10.00/kg

Table 2. Total energy inputs and outputs × 10^3 MJ/ha) of greater yam based cropping systems (mean data of 2 years)

Treatment	Input energy: Field operations	Input energy: Seed	Input energy: Manures and fertilizers	Total energy input	Energy output from yields	Energy output : input ratio	Energy-use efficiency (×10^3 MJ)
Greater yam (normal row planting) + maize	1.01	11.61	13.20	25.82	100.70	3.90	7.25
Greater yam (normal row planting) + sorghum	1.00	11.61	12.36	24.97	88.74	3.55	6.82
Greater yam (normal row planting) + pigeonpea	1.02	11.61	10.85	23.48	87.91	3.74	7.67
Greater yam (paired row planting) + maize	1.01	11.61	13.20	25.82	97.79	3.79	7.04
Greater yam (paired row planting) + sorghum	1.00	11.61	12.36	24.97	86.37	3.46	6.64
Greater yam (paired row planting) + pigeonpea	1.02	11.61	10.85	23.48	84.25	3.59	7.36
Greater yam (skipped row planting) + maize	0.86	5.91	10.49	17.26	64.56	3.74	6.16
Greater yam (skipped row planting) + sorghum	0.85	5.91	9.10	15.86	54.66	3.45	5.98
Greater yam (skipped row planting) + pigeonpea	0.87	5.91	6.48	13.26	53.83	4.06	7.94
Greater yam (sole crop)	0.95	11.53	9.86	22.34	63.16	2.83	6.13

Energy equivalents are given under Materials and Methods energy input through manures and fertilizer energy. Padhi and Panigrahi (2006) also opined the same. The next higher amount of energy input was utilized by sorghum and pigeonpea in normal as well as paired row cropping. The energy input used in skipped row planting irrespective of intercrops was lower than in greater yam sole cropping. This was mainly due to less greater yam seed energy apart from manure and fertilizer energy. The output energy however is dependent on yield. Intercropping with normal and paired row planting irrespective of intercrops produced higher output energy due to higher greater yam tuber yield apart from intercrop yield (Table 1). Energy output in skipped row planting irrespective of intercrops was lower than energy output of sole greater yam cropping. Lesser greater yam population led to lower tuber yield in skipped row planting. The maximum amount of energy output was observed with greater yam + maize (normal row planting) followed by greater yam + maize (paired row planting).

Energy output : input ratio and energy-use efficiency may be considered for energy relationships. All the intercropping systems and planting patterns recorded higher energy output : input ratio and energy-use efficiency than sole greater yam. The maximum energy output : input ratio and energy-use efficiency was found with greater yam + pigeonpea (skipped row planting) due to its lower seed as well as manures and fertilizer energy inputs. Greater yam + maize (normal row planting) intercropping system was the next best in energy output : input ratio due to higher output energy from the yields (Table 2). Sharma and Chander (2006) and Padhi and Panigrahi (2006) reported similar findings in other crops and cropping systems.

It can be concluded that maize was the best intercrop with greater yam planted at normal rows (90 cm × 90 cm), as this treatment gave higher tuber-equivalent yield, land-equivalent ratio, production efficiency and energy output: input ratio.

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