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Productivity and economics of banana (*Musa species AAA*)-based crop sequences

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ABSTRACT

In a field experiment performance of 7 banana (*Musa sp., AAA)*-based crop sequences was assessed in terms of their productivity, economic returns and impact on soil fertility. The crop, whose combinations constituted the sequences were banana, papaya (*Carica papaya* L.), pigeonpea [*Cajanus cajan* (L.) Millsp.], wheat (*Triticum aestivum* L. emend. Fiori & Paol.), maize (*Zea mays* L.), cowpea [*Vigna unguiculata* (L.) Walp.], okra (*Hibiscus esculentus L.),* greengram (*Phaseolus radiatus* L.) and lentil (*Lens culinaris* Medikus). The sequence of banana PC (PC, plant crop) – papaya (2 crop cycles)–banana PC–banana R_1 (R_1, first ratoon) gave the highest banana-equivalent yield (78.57 tonnes/ha/year), net return (Rs 78.414/ha/year) as well as return/rupee investment (Rs 1.99/Re). Another sequence (banana PC–banana R_1–lentil-pigeonpea–papaya 1 crop) where banana and papaya were seperated by growing pulses proved to be comparable with the best treatment with a return rate of Rs 1.88/rupee investment. The above 2 sequences did not show any adverse impact on soil-fertility status. Crop sequence without banana was least profitable. Banana monoculture for 4 crop cycles [banana PC–banana R_1– banana R_2 (R_2, second ratoon)–banana PC] showed yield decline in third and fourth cycles, registering a lower net return of Rs 1.4/Re/year.

Key words : Banana-based cropping systems, Productivity, Economics

Banana is a major fruit crop in Koshi and Vaishali regions of North Bihar. Usually it is grown as a perennial monoculture. Once the plantation is established, it occupies the land for 4 to 5 years. Older plantations of 6 years or more age can also be seen in Vaishali belt. The degree of sustainability of banana or any other crop is strongly dependent on soil health. The long-duration monoculture often leads reduction in productivity due to nutritional imbalances (Dalvaux *et al.*, 1990) and biological, i.e. insect pests, nematode, bacterial and fungal, activities (Lescot, 1996; Lin, 1993). Short-duration crops lower in their demand for nutrients are, therefore, needed to be introduced in the cropping system. Pulses are more important in this regard, owing to their beneficial effect on soil health. Since the improved location-specific crop sequences greatly help in maintaining productivity of the field in face of its changing demands (Palaniappan and Sivaraman, 1996), the present work was undertaken to find a suitable banana-based crop sequence for calcareous sandy-loam soil of North Bihar.

MATERIALS AND METHODS

The experiment was conducted at Horticultural Research Station, Birauly, (25.4°N, 84.6°E, and 52.8 m above mean sea-level) during 1991–97. The soil of the experimental plot was calcareous sandy loam with pH 8.4, EC 8.4, EC 0.36 dS/m, organic carbon 0.21%, available N 126 kg/ha, P_2O_5 14.5 kg/ha and K_2O 129.6 kg/ha and free $CaCO_3$ 27.3%. The crops of banana, pigeonpea, wheat, lentil, maize, cowpea, greengram and okra constituted different treatments of cropping sequences. The treatments were replicated 4 times in randomized complete-block design with a plot size of 4.5 m × 6.0 m.

Plant crop of banana was sown in first week of July. Other crops were sown as per their recommended sowing time and managed with recommended package of practices (Table 1). If required, pre-sowing irrigation was applied to ensure good germination of the pulse or cereal crop. Fertilizer application was made following the area-specific recommendation for the individual crop ignoring residual effect of the previous crop on the succeeding crop. Different sequences spanned over the period of 4 years and 3 months to 6 years and 3 months. Crop yields were recorded

Table 1. Variety, sowing time, spacing, seed rate and duration of component crops grown under different sequences

Crop	Variety	Sowing time	Spacing	Seed rate (kg) or plants/ha	Fertilizer rate (kg/ha)			Average crop duration (months)
					N	P_2O_5	K_2O	
Banana	'Basrai (AAA)'	Jun.-Jul.	1.5 m × 1.5 m	4,444 plants	888	222	888♣	14-16
Papaya	'Pusa Delicious'	Sep.-Oct.	1.8 m × 1.5 m	3,703 plants	740	370	740	16-18 (1st cycle) @
Pigeonpea	'Bahar'	Jun.	60 cm × 25 cm	20 kg	20	0	0	9-10
Lentil	'C 35'	Oct.	22.5 cm × 5 cm	30 kg	15	40	0	4.5
Wheat	'HP 1209'/'UP 262'	Nov.	In rows 20 cm apart	150 kg	80	40	20	5.5
Maize	'Swan'/'Laxmi'	Jun.*	75 cm × 25 cm	20 kg	110	75	50**	6.0**
		Oct.**	75 cm × 25 cm	20 kg	100	60	40*	4.0*
Greengram	'Pusa Baisakhi'	Apr.	30 cm × 10 cm	20 kg	20	40	0	2.5
Okra	'Prabhani Kranti'	Jun.	50 cm × 45 cm	10 kg	100	60	60	3.0
Cowpea	'Pusa Komal'	Jul.	45–60 cm × 45 cm	15 kg*/25 kg**	30	40	40	3.0

**Kharif*; ***rabi*; @ 2nd cycle takes only 10–12 months; ♣fertilizer application in banana and papaya were made in 2–3 splits on plant basis, i.e. 200 g N, 50 g P_2O_5 and 200 g K_2O/plant/year in case of banana and 200 g N, 100 g P_2O_5 and 200 g K_2O/plant/year in case of papaya and economics of production was worked out for each sequence at prevalent market rates of inputs and outputs to arrive at the return per rupee invested. For the sake of comparison, yields of all component crops in a sequence were converted into banana equivalent on price basis. The sustainability-yield index (SYI) was calculated based on the banana-equivalent yield applying the formula suggested by (Reddy and Kumar, 1999).

$$SYI = \frac{\mu - \delta}{Y_{max}}$$

where, μ = mean of particular treatment, δ = standard deviation of particular treatment, and Y_{max}= potential maximum yield over the years. After harvesting all the crops in a sequence, soil samples were drawn and analysed following standard procedures for organic carbon, available N, P_2O_5 and K_2O to see the change in fertility status under that sequence.

RESULTS AND DISCUSSION

Crop productivity and economics

Among all crop sequences, the sequence having 3 crops of banana and 2 of papaya (T_2) gave the highest banana-equivalent yield, which was significantly higher than the corresponding values of the other sequences (Table 2). The higher productivity of this combination compared to the crop sequences without banana was attributed to inherent higher yield potentials of the crops like banana and papaya. In fact, growing plant crop of banana and then papaya for 2 fruiting cycles had depressing effect on the succeeding banana crop, but heavy tonnage (i.e. total harvested yield) gave the maximum return on the investment masking the effect of yield depression (Table 3). Growing 4 crops of banana in succession (T_6) was found to be the next best yielder but economic analysis revealed that return/rupee investment was notably lower in this case (Table 3). This was mainly due to decline in the yield of banana in the 3rd and 4th crop cycles. N'Guessan and Ganry (1990) and Lin (1993) also reported decline in yield due to prolonged monoculture. Interruption of monoculture with pulses (T_5) showed improvement in yield of the following banana crop as compared to T_6. This resulted into better net return/rupee investment with T_5 than T_6 (Table 3).

The sequence without banana gave the lowest yield and was economically least remunerative. Although banana yielded better under the sequence having 3 plant crops of banana separated intermittently with a pulse crop (T_1), the total output in terms of banana-equivalent yield was significantly lower. This was due to lower yield potential of pigeonpea compared to that of banana, ultimately resulting in lower profitability. The sequence having 2 crops of banana (PC+R_1), 2 of pulses (lentil and pigeonpea) and 1 of papaya (T_3) was economically as viable as the best treatment (T_2). Papaya as one of the component crops in both the sequences (T_2 and T_3) proved more paying owing to its heavy yield potential. Its better selling rate also helped in income maximization of these sequences.

Staver (1987) has noted that papaya can be a good preceeding crop for banana, provided sufficient care is taken for adequate fertilization of both the crops. Rooting habit of banana differs from that of papaya. Ability of papaya to extract nutrients from deeper soil layers might have reduced the competitive abilities of the 2 crops. Similarly, introduction of pulses between banana and papaya (T_3) resulted in sustaining yield of papaya owing to their ability to fix atmospheric N. Also, legumes are less demanding on soil resources like water and nutrients and easily adaptable to varying environments (Palaniappan and Sivaraman, 1996).

Net return and yield sustainability

Cost of cultivation and return analysis clearly revealed that banana monoculture (T_6) was more paying than growing cereals and pulses (T_7). Sequences having papaya as a component crop (T_2) offered 31.8% greater returns than the prevalent monocropping in T_6 (Table 3). This 31.8% increase in the net return seems to be lucrative particularly when the farmers are bent on monoculture and reluctant to change the traditional cropping pattern. This crop combination (T_2) provides a good alternative to have a change-over with perennial crops. This sequence also recorded the highest sustainability index in terms of yield (Table

Table 2. Performance of crops grown under banana-based sequential cropping*

Treatment	Crop sequence (yield, tonnes/ha)	Sequence duration (year)	Banana-equivalent yield** (tonnes/ha/year)	Sustainability yield index (%)
T_1	Banana PC (84.3)–pigeonpea (1.7)–banana PC (70.5)–pigeonpea (1.2)–banana PC (70.0)	6.25	41.22	50.60
T_2	Banana PC (79.6)—papaya FC (96.6) papaya SC (80.4)–banana PC (52.4)–banana R_1 (60.6)	5.83	78.57	90.98
T_3	Banana PC (81.7)–banana R_1 (86.6)–lentil (0.28)–pigeonpea (1.32)–papaya FC (70.8)	5.25	55.61	60.41
T_4	Banana PC (89.2)–wheat (20.4)–maize (1.71)–wheat (2.28)–okra (5.73)–lentil (0.32)–banana PC (67.5)	5.25	35.46	37.90
T_5	Banana PC (81.5)–banana R_1 (89.9)–cowpea (6.3)–lentil (0.27)–banana PC (70.9)	4.25	61.53	54.42
T_6	Banana PC (86.5)–banana R_1 (78.5)–banana R_2 (67.2)–banana PC (56.4)	4.25	67.91	57.02
T_7	Cowpea (8.4)–wheat (2.4)–greengram (0.83)–pigeonpea (1.04)–maize (1.85)–wheat (1.97)–pigeonpea (0.72)–maize (3.6)–wheat (2.70)	4.66	19.41	18.06
	LSD ($P = 0.05$)		3.76	21.24

*PC, plant crop; R_1, first ratoon; R_2, second ratoon; FC, first crop; SC, second crop

**Based on following market rates (Rs/100 kg) : Banana bunches 150; papaya 225; pigeonpea 1,700; lentil 1,350; wheat 500; maize 400; okra 200; cowpea 400; greengram 1,600.

Table 3. Economics of banana-based cropping systems

Treat-ment	Crop sequence	Gross income (Rs/ha/year)	Cost of cultivation (Rs/ha/year)	Net income (Rs/ha)	Net return* (per rupee/ year)
T_1	Banana PC–pigeonpea–banana PC–pigeonpea–banana PC	61,840	25,920	35,920	1.38
T_2	Banana PC–papaya FC–papaya SC–banana PC–banana R_1	117,864	39,450	78,414	1.99
T_3	Banana PC–banana R_1–lentil–pigeonpea–papaya FC	83,423	28,952	54,471	1.88
T_4	Banana PC–wheat–maize–wheat–okra–lentil–banana PC	53,194	26,476	26,718	1.01
T_5	Banana PC–banana R_1–cowpea–lentil–banana PC	92,305	34,180	58,125	1.70
T_6	Banana PC–banana R_1–banana R_2–banana PC	101,859	42,390	59,469	1.40
T_7	Cowpea–wheat–greengram–pigeonpea–maize–wheat–pigeonpea–maize–wheat	28,745	15,630	13,115	0.84
	LSD (P = 0.05)	7,863	2,742	4,533	0.15

*Benefit : cost ratio; PC, plant crop; R_1 and R_2, 1st and 2nd ratoon; FC, first fruiting cycle; SC, second fruiting cycle

Table 4. Available N, P, K status of soil under banana-based sequential cropping*

Treatment	Crop sequence	Total nutrients applied (kg/ha)			Available soil nutrients (kg/ha)			Organic C (%)
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	
T_1	Banana PC–pigeonpea–panana PC–pigeonpea–banana PC	2,704	746	2,664	140.0	14.1	120.6	0.27
T_2	Banana PC–papaya FC–papaya SC–banana PC–banana R_1	4,144	1,406	4,144	136.7	17.2	127.7	0.28
T_3	Banana PC–banana R_1–lentil–pigeonpea–papaya FC	2,551	894	2,516	147.2	15.2	140.2	0.33
T_4	Banana PC–wheat–maize–wheat–okra–lentil–banana PC	2,151	684	1,916	149.4	16.8	134.2	0.25
T_5	Banana PC–banana R_1–cowpea–lentil–banana PC	2,709	746	2,704	140.8	18.7	121.8	0.30
T_6	Banana PC–banana R_1–banana R_2–banana PC	3,552	888	3,552	134.7	16.5	110.5	0.24
T_7	cowpea–wheat–greengram–pigeonpea–maize–Wheat–pigeonpea–maize–wheat	530	400	180	130.4	15.6	136.8	0.22
	LSD (P = 0.05)				11.7	2.7	11.1	0.049
	Initial status				126.0	14.5	129.6	0.21

*Evaluated after harvesting all the crops under the sequence

2). Separating 2 crops of banana ($PC+R_1$) and 1 of papaya by growing pulses (T_3) proved to be at par with T_2 in respect of benefit : cost ratio. However, sustainability-yield index (SYI) of this sequence (T_3) was lower than T_2 owing to lower yield potential of pulse crops in comparison with banana or papaya. The rate of net return was lower in T_6 mainly because the sequence, though showed higher gross return, had higher production cost per unit area. Lin (1993) also noted higher production cost limiting the margin of profit in case of perennial banana culture in Taiwan. Crop sequence without banana produced the lowest return on the investment, as yield potentials of the component crops were markedly lower than banana.

Impact on soil ertility

Soil analysis after harvesting the last crop of the sequences showed that fertility status was maintained in majority of the cases in spite of growing heavy demanding crops like banana and papaya (Table 4). The experimental soil was calcareous sandy loam, rated low in available N, P_2O_5 and K_2O. It is evident that in all the sequences there was a positive balance for nutrients like N and P_2O_5 (Table 4). This reflected that uptake of these nutrients did not exceed their addition to the soil. Monocropping of banana, however, showed an appreciable decline in the K_2O content of the soil. Similarly, depletion in K_2O content was also evident in the sequences having 3 crops of banana (T_1, T_2 and T_5). Such a depletion was attributed to exceedingly heavy consumption of K by banana crop. A banana stand yielding 50 tonnes/ha removes as high as 1,438 kg K from the soil (Lahav, 1995).

The positive balance for nitrogen and phosphorus may be owing to application of fertilizers on the individual crop basis, ignoring the residual effect of the previous crop. This might have caused excessive addition of nutrients during the course of experimentation. Legumes are known from nitrogen-fixing ability. They have also been reported to be able to extract insoluble forms of soil P (Palaniappan and Sivaraman, 1996). Their inclusion in the sequence thus contributed towards maintenance of the soil fertility. Higher P_2O_5 content in T_3 may be due to carry-over effects of fertilizers applied to the preceeding crop.

On the basis of above results it was concluded that banana can be grown in a sequence like banana PC–papaya FC–papaya SC–banana PC–banana R_1 or banana PC–banana R_1–lentil–pigeonpea–papaya FC. Such a combination is more sustainable and will not pose a serious problem of nutrient deficiency in the soil if all the component crops are adequately fertilized following their recommended doses. Monocropping of banana for 4 crop cycles needs to be discouraged, as it can adversely influence the soil fertility.

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