Yield Advantages and Economic Returns from Pigeonpea/Cotton Strip Intercropping Rotations on a Vertisol in the Indian Semi-Arid Tropics

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Abstract

Pigeonpea (Cajanus cajan (L.) Millsp.) is an important component of several cropping systems of the semi-arid tropics (SAT). In a 4-year field study (1990 to 1994), a medium duration pigeonpea, cultivar ICPL 87119 was strip-intercropped with hybrid cotton, cultivar NHH 44 in five replacement series of four strip widths (1.5, 3, 4.5, and 6-m strip) under three land-configuration systems [flat, ridge and furrow (RF at 0.75-m), and broadbed and furrow (BBF at 1.5-m)] on a Vertisol under rainfed conditions at ICRISAT Asia Center (IAC), Patancheru, India. A strip plot design was used with land configuration treatments allocated to vertical plots and cropping systems to horizontal plots with three replications. Each crop strip was rotated with an associated intercrop in a 2-year rotation cycle. Land configuration treatments remained unchanged during the four years.

Individual crop yields (grain or seed cotton and stem dry matter) were significantly influenced by the cropping system but not by land configuration or treatment interactions. Seed cotton yields were higher than pigeonpea grain yields. Pigeonpea dry stem yields were higher than cotton stem yields during all four years. Sole pigeonpea grain yield varied from 0.49 to 1.57 t ha^{-1}, whereas sole seed cotton yield varied from 1.45 to 2.04 t ha^{-1}. Crop yields decreased as strip size was reduced, with greater yield reductions in cotton than in pigeonpea. Sole pigeonpea produced more total dry matter (TDM) (6.51 t ha^{-1}) than sole cotton (4.95 t ha^{-1}). Cropping system TDM production increased as pigeonpea strip size was increased. Land equivalent ratio (LER) and monetary value equivalent ratio (MVER) indicated that strip intercropping was always superior to sole cropping. A strip intercropping combination of 4.5-m pigeonpea and 1.5-m cotton gave the maximum mean LER value (1.4) and MVER value (1.19). Averaged over four years, sole cotton had the maximum gross (Rs. 19.87 thousands ha^{-1}) and net monetary returns (Rs. 14.25 thousands ha^{-1}), and sole pigeonpea had the lowest gross (Rs. 12.41 thousands ha^{-1}) and net monetary returns (Rs. 7.24 thousands ha^{-1}). All strip intercropping systems were more profitable than sole pigeonpea with maximum net returns (Rs. 9.97 thousands ha^{-1}) obtained from a strip intercropping combination of 1.5-m pigeonpea and 4.5-m of cotton. Benefit:cost ratio varied widely among cropping systems and between years. However, sole cotton gave the maximum benefit:cost ratio of 2.57, followed by sole pigeonpea with a value of 2.18. Results of combined yield analysis of each rotation cycle, indicated the sole pigeonpea -

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sole cotton rotation as the most profitable system when compared with strip intercropping combinations.

Introduction

Intercropping is a widespread practice in tropical developing countries. This system of cropping can offer potential advantages over sole cropping. Intercropping is the growing of two or more crop species simultaneously on the same field (Andrews and Kassam 1976). There are several types of intercropping systems including mixed, row, strip, and relay (Francis 1986). Strip intercropping is a system in which two or more crops are grown simultaneously in different strips narrow enough to develop inter-crop interference, yet with the advantage of facilitating independent crop management. There has been renewed research interest in strip intercropping in Canada (Fairey and Lefkovitch 1990), China (Zhongmin and Guang 1990), and the U.S.A. (Cruse 1990; Putnam and Allan 1992; West and Griffith 1992).

Vertisols are potentially the most productive soils in India and contribute significantly to the national economy (Murthy 1988). However, large amounts of the available 73 million ha of Vertisols are underutilized primarily because of inherent management and nutrition-related constraints. Vertisols are traditionally fallowed during the rainy season because these soils are non-trafficable when wet and non-workable when dry (El-Swaify et al. 1985). For such soils, the "watershed-based cropping systems approach" developed at ICRISAT allows cropping both during the rainy season (kharif) and the following dry and cool postrainy season (rabi). Improved cropping systems, graded broadbeds and furrows (BBF), and improved soil fertility are the main components of this Vertisol technology. The BBF system improves drainage and soil workability in such soils (Kampen 1980). Use of different land configuration systems (e.g., ridge or raised beds) have been found beneficial for several crops grown on poorly drained soils (Kumar et al. 1987; Mascagni and Sabbe 1990a and 1990b; Mascagni et al. 1991). However, little is known about the possible advantages of strip intercropping under different land configuration systems on Vertisols.

Intercropping and sequential cropping that involve short-duration and high yielding crop cultivars are the main components of the improved cropping systems. Although these cropping systems are characterized as highly productive and more efficient than traditional cropping systems, the focus in their development has been ICRISAT mandate crops in food-oriented production systems. There has been relatively little effort made to develop cash-oriented production systems involving crops like cotton - the most important cash crop grown on Vertisols by Indian farmers.

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is an important component of several cropping systems of the semi-arid tropics (SAT). In India, pigeonpea is the most widely grown legume (3.62 million ha) next to chickpea (7.41 million ha), and contributes about 90% of the world production. Cotton (*Gossypium* spp.) is one of the most important cash crops grown in India. It is grown over an area of 7.36 million ha, with a production of about 9.76 million bales lint (each bale is 180 kg) annually. Traditionally, 80-90% of pigeonpea in India is intercropped with cereals (maize, sorghum, rice, and pearl millet), short-duration legumes (green gram, black gram, and cowpea), oilseeds (groundnut, sesame, and castor), cotton, and cassava (Aiyer 1949). Pigeonpea/cotton intercropping is a major cash cropping system widely practiced on black cotton soils (Vertisols) of the Deccan Plateau in India. Farmers in this area usually plant several rows of cotton with a strip of sorghum or pigeonpea, either in distinct rows or in mixed cropping (Rao 1986). The average productivity of these cropping systems in farmers' fields is relatively low [pigeonpea = 0.66 t ha^{-1} grain and cotton = 0.65 t ha^{-1} seed cotton (Fertilizer Association of India (FAI) 1994)] when compared with yields obtained in experimental fields [pigeonpea = 2.5 t ha^{-1} grain (ICRISAT 1989) and cotton = 3 t ha^{-1} seed cotton (Basu et al. 1992)]. The primary reasons for these poor on-farm yields are: pest and disease susceptible cultivars, occurrence of intermittent drought and waterlogging conditions, and poor agronomic practices. The availability of high yielding disease and pest tolerant crop genotypes have improved the scope for pigeonpea/cotton intercropping.

Experimental

To evaluate the agronomic performance and economic returns of pigeonpea/cotton strip intercropping rotations under different land configuration systems, a field study was undertaken at ICRISAT Asia Center (IAC), Patancheru, India (17°N, 78.5°E and 500 m altitude) on a Vertisol during four cropping seasons (1990 to 1994) under rainfed conditions. Five strip-intercropping rotations with pigeonpea and cotton were evaluated under three land-configuration systems: flat, ridge and furrow (RF at 0.75-m), and broadbed and furrow, (BBF at 1.5-m). A medium-duration (180-200 days), high yielding pigeonpea, cultivar ICPL 87119, was strip-intercropped with a widely adapted hirsutum hybrid cotton, cultivar NHH 44, in five replacement series (4:0, 3:1, 2:2, 1:3, and 0:4) of four strip-widths (1.5, 3, 4.5, and 6-m strips). Each crop strip was rotated with the associated intercrop in a 2-year rotation cycle. A strip-plot design was used with land configuration treatments allocated to vertical plots and cropping systems to horizontal plots with three replications. Land configuration treatments remained constant during all four years. In each year, crops were grown with recommended crop management practices and insecticide sprays. Soil at the experimental site was low in mineral nitrogen (19.2 mg kg^{-1} NO_3^- + NH_4^+ N) and available phosphorus (6.5 mg kg^{-1} available Olsen P) and rich in exchangeable potassium (135.9 mg kg^{-1} exchangeable K). Exchangeable K was estimated by using the method of Thomas (1982), mineral N by the method of Keeney and Nelson (1982), and available Olsen P by the method of Olsen and Sommers (1982). Total rainfall during each experimental period was 692 mm in 1990/91, 709 mm in 1991/92, 709 mm in 1992/93, and 776 mm in 1993/94. Rainfall was well distributed in all the cropping periods, except in 1992/93 where most rainfall occurred before August. Severe waterlogging did not occur in any of the cropping seasons. *Helicoverpa armigera* was the major pest, with high infestation observed in 1990/91 and 1992/93 cropping seasons. At maturity, each crop was harvested from a plot area (6 m × 4 m) and the dry yields recorded. Total crop duration varied from 213 days in 1993/94 to 259 days in 1990/91 for pigeonpea, and 216 days in 1990/91 to 269 days in 1993/94 for cotton.

Pigeonpea seed yield response

Pigeonpea seed yield responded significantly to strip widths but not to land configuration or treatment interaction (Table 1). Sole pigeonpea seed yields varied from 0.49 t ha^{-1} in 1992/93 to 1.57 t ha^{-1} in 1991/92. Intercropped pigeonpea consistently yielded better than expected yield of sole pigeonpea because of reduced intraspecific competition among pigeonpea plants. The yield from strip intercropping combination of 4.5-m pigeonpea and 1.5-m cotton produced seed was similar to that from sole pigeonpea grown in a 6-m strip. These results suggest that medium-duration pigeonpea is an ideal crop for intercropping. A comprehensive review by Ahlawat et al. (1985) indicated that pigeonpea-based cropping systems are always superior to sole cropping in cases when pigeonpea is grown as an intercrop or sequential crop with other crop species. These benefits were attributed to

Table 1. Mean pigeonpea seed yield for different pigeonpea/cotton strip intercropping systems grown under three land-configuration systems on a Vertisol at ICRISAT Asia Center during the 1990 to 1994 cropping seasons.

	Seed yield (t ha^{-1})				
Teatment	1990/91	1991/92	1992/93	1993/94	Pooled mean
Land configuration(LC)					
Flat	0.68	1.04	0.40	0.83	0.74
Ridge and furrow(RF)	0.69	1.08	0.32	0.83	0.73
Broadbed and furrow(BBF)	0.70	1.01	0.42	0.81	0.74
SE	±0.032	±0.081	±0.051	±0.044	-
F test	NS[1]	NS	NS	NS	-
CV%	8.1	13.4	23.3	9.2	-
Cropping system (CS)					
Pigeonpea:cotton strip size[m]					
6.0 : 0	0.84	1.57	0.49	1.02	0.98
	(100)[3]	(100)	(100)	(100)	(100)
4.5 : 1.5	0.91	1.20	0.49	0.98	0.98
	(0.63)	(1.18)	(0.37)	(0.77)	(0.74)
3.0 : 3.0	0.67	0.88	0.37	0.79	0.68
	(0.42)	(0.79)	(0.25)	(0.51)	(0.49)
1.5 : 4.5	0.35	0.52	0.19	0.50	0.39
	(0.21)	(0.39)	(0.12)	(0.26)	(0.25)
SE	±0.042	±0.125	±0.115	±0.064	-
F test	**[2]	**	NS	**	-
CV%	10.6	20.8	52.1	13.5	-
Interaction (LCxCS)					
SE	±0.065	±0.161	±0.134	±0.097	-
F test	NS	NS	NS	NS	-
CV%	14.6	15.4	32.6	18.7	-

1 NS is not significant.
2 ** is significant at P<0.01 level.
3 Figures in parentheses indicate the "expected yield" which was calculated as:

$$Ye_{ij} = Y_{ii} \times Z_{ij}$$

where Ye_{ij} =Expected yield of species i grown in association with species j.
Y_{ii}=Actual yield of species i in sole cropping
Z_{ij}=Sown proportion of species i grown in association with species j.

improved spatial and/or temporal complementarity among the component crops in the pigeonpea-based cropping systems. In addition, intercropping pigeonpea with sorghum resulted in significant reduction in wilt incidence in pigeonpea (Natarajan et al. 1985). An insignificant interaction between cropping system and land configuration system suggests that future cropping system studies with cotton and pigeonpea can be undertaken on any of the three land-configuration systems.

Seed cotton yield response

Seed cotton yield response to land configuration or cropping system by land configuration interaction was similar to that for pigeonpea seed yield. Seed cotton yield was significantly reduced by intercropping in all four years (Table 2). Intercropping pigeonpea with cotton resulted in significant yield losses in cotton. This yield reduction in cotton was mainly related to better competitive ability of pigeonpea than cotton. This was evident by a more luxuriant growth of intercropped pigeonpea than sole pigeonpea (data not shown). Yield reduction in cotton and various associated short-duration legumes and cereals have been reported in Orissa (Padhi et al. 1993) and in West Bengal (Mandal et al. 1987), which are states of India. Seed cotton yield in sole crop varied from 1.45 t ha^{-1} in 1990/91 to 2.04 t ha^{-1}

Table 2. Mean seed cotton yields for different pigeonpea/cotton strip intercropping systems grown under three land-configuration systems on a Vertisol at ICRISAT Asia Center during the 1990 to 1994 cropping seasons.

	Seed cotton yield (t ha^{-1})				
	1990/91	1991/92	1992/93	1993/94	Pooled
Treatment					mean
<u>Land configuration(LC)</u>					
Flat	0.78	1.20	0.83	0.55	0.84
Ridge and furrow(RF)	0.75	1.10	0.69	0.62	0.79
Broadbed and furrow(BBF)	0.80	1.11	0.88	0.59	0.85
SE	±0.026	±0.066	±0.075	±0.061	-
F test	NS[1]	NS	NS	NS	-
CV%	5.7	10.1	16.3	18.1	-
<u>Cropping system(CS)</u>					
Pigeonpea : cotton strip size[m]					
4.5 : 1.5	0.20	0.32	0.15	0.12	0.20
3.0 : 3.0	0.56	0.77	0.53	0.25	0.53
1.5 : 4.5	0.89	1.42	0.87	0.49	0.92
0 : 6.0	1.45	2.04	1.65	1.46	1.65
SE	±0.073	±0.121	±0.118	±0.048	-
F test	**[2]	**	**	**	-
CV%	16.4	18.1	25.6	14.7	-
<u>Interaction(LCxCS)</u>					
SE	±0.085	±0.148	±0.153	±0.107	-
F test	NS	NS	NS	NS	-
CV%	12.0	12.5	20.8	34.3	-

1 NS is not significant.
2 **is significant at $P<0.01$ level.

in 1991/92. Cotton was a more productive and stable crop than pigeonpea as indicated by consistently higher yields in cotton with lower coefficient of variation values (6 to 26%) when compared with pigeonpea yields (8 to 52%). The higher coefficient of variation values for pigeonpea when compared to cotton were attributed to infestation of *Helicoverpa armigera.*

The beneficial effects of land configuration on crop yields depend upon the crop species used and the severity of waterlogging. Therefore, the crop yield response to land configuration has varied greatly (Kumar et al. 1987; Rweyemamu and Boma 1990; Gupta and Sharma 1994). In the present study, the use of the raised land configurations RF and BBF did not improve yields for any of the crops because waterlogging was not a severe constraint during any of the four years.

Total dry matter production

The total dry matter (TDM) yields were not significantly affected by either land configuration treatments or treatment interactions (Table 3) during any of the years. The TDM yields decreased significantly as the strip size of pigeonpea was reduced. Averaged over 4 years, sole pigeonpea gave the highest TDM yields (6.5 t ha^{-1}), and sole cotton gave

Table 3. Total dry matter (TDM) production for different pigeonpea/cotton strip intercropping systems grown under three land-configuation systems on a Vertisol at ICRISAT Asia Center during the 1990 to 1994 cropping seasons.

	TDM yield (t ha^{-1})				
Treatment	1990/91	1991/92	1992/93	1993/94	Pooled mean
Land configuration(LC)					
Flat	5.5	6.9	5.4	6.4	6.1
Ridge and furrow(RF)	5.5	6.8	5.1	6.5	6.0
Broadbed and furrow(BBF)	5.6	6.5	5.2	6.3	5.9
SE	±0.13	±0.07	±0.10	±0.12	-
F test	NS[1]	NS	NS	NS	-
CV%	4.2	1.9	3.2	3.3	-
Cropping system(CS)					
Pigeonpea : cotton strip size [m]					
6.0 : 0	6.2	7.3	5.3	7.3	6.5
4.5 : 1.5	6.3	6.9	5.5	7.2	6.5
3.0 : 3.0	5.7	6.2	4.6	5.5	5.5
1.5 : 4.5	5.2	6.1	4.3	4.5	5.0
0 : 6.0	4.0	5.8	4.1	5.9	5.0
SE	±0.20	±0.27	±0.14	±0.29	-
F test	**[2]	**	**	**	-
CV%	6.4	6.8	4.6	7.7	-
Interaction(LCxCS)					
SE	±0.32	±0.41	±0.27	±0.38	-
F test	NS	NS	NS	NS	-
CV%	8.2	10.2	9.0	7.9	-

1 NS is not significant.
2 **is significant at $P < 0.01$ level.

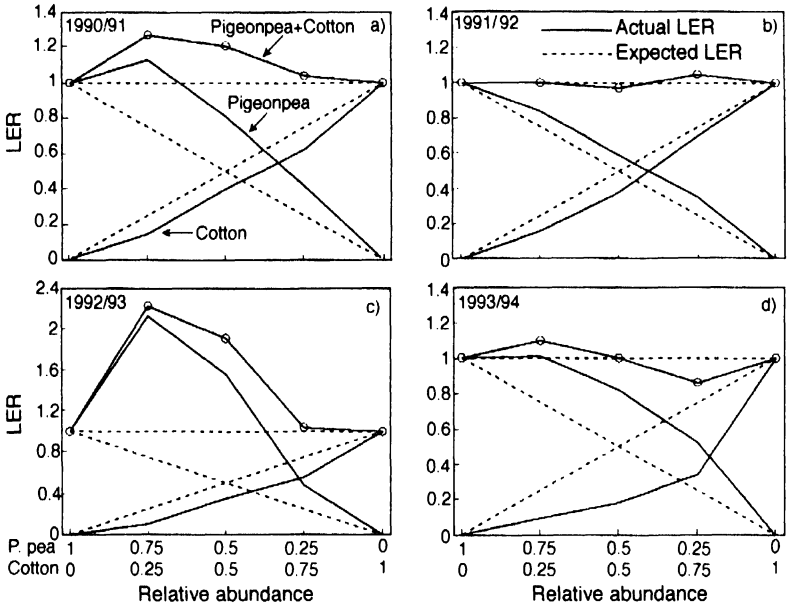

Fig. 1. Mean land equivalent ratio (LER) values for different pigeonpea/cotton strip intercropping systems on a Vertisol at ICRISAT Asia Center during the 1990 to 1994 cropping periods.

the lowest (5 t ha^{-1}). The TDM yields were generally higher in 1991/92 and 1993/94, possibly because of well distributed rainfall in these seasons.

Yield advantage of intercropping

Yield advantage of intercropping was measured by a land equivalent ratio, LER (Willey 1979) and a monetary value equivalent ratio, MVER. Mean LER values for each species and total LER values for cropping systems are presented as a replacement diagram (Fig. 1). The cropping system treatments strongly affected the mean LER values for individual species and the total LER values for cropping systems. The effects of land configuration or the interaction of land configuration and cropping system were not significant. The LER values for pigeonpea were always higher than the expected LER values in all strip intercropping combinations during the study. In contrast, cotton always gave lower than expected LER values in the corresponding strip intercropping combinations. The LER values varied from 0.35 to 2.13 for pigeonpea, and from 0.10 to 0.70 for cotton. The convex LER curves for pigeonpea and the concave LER curves for cotton indicate that pigeonpea is the most competitive species in this system. Total LER values for intercropping generally exceeded unity (Fig. 2a), indicating a yield advantage in strip intercropping. A strip combination of 4.5-m pigeonpea and 1.5-m cotton gave the highest LER value of 2.23 in 1992/93 (Fig. 2a), indicating a 123% yield advantage over either sole cropping. The observed trend in MVER values across intercropping treatments (Fig. 2b) was similar to LER trends (Fig. 2a) except

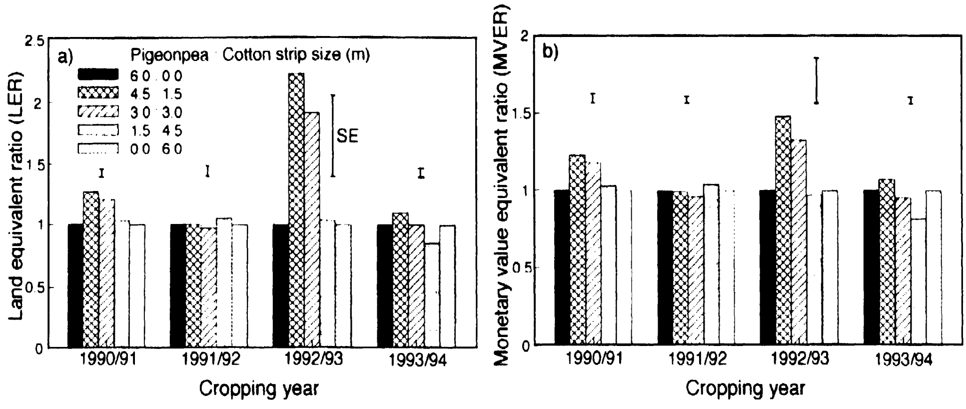

Fig. 2. Pooled land equivalent ratio (LER) and monetary equivalent ratio (MVER) values for different pigeonpea/cotton strip intercropping systems on a Vertisol at ICRISAT Asia Center during the 1990 to 1994 cropping periods.

that MVER values were generally lower than LER values. Averaged over 4 years, a strip combination of 4.5-m pigeonpea and 1.5-m cotton gave a maximum LER value of 1.4 and a maximum MVER value of 1.19. Our results are similar to studies carried out in West Bengal (Mandal et al. 1987) and in Orissa (Padhi et al. 1993) states of India, using other short-duration legumes (greengram, blackgram, peanut, soybean) and cereals (finger millet, rice) grown in intercropping systems with cottton.

Yield advantages in intercropping can be maximized by improving the degree of `complementarity' between crop components and by minimizing inter-crop competition (Willey 1979). In the present study, there was strong inter-crop competition (Fig. 1). To maximize biological efficiency of this system, use of compatible genotypes would be required. In intercropping, temporal complementarity is more important than spatial complementarity (Willey 1979). Therefore, the component crops should have large maturity differences so as to have better temporal use of resources. In the present study, the maturity difference between pigeonpea and cotton was only about 10 days. Baker and Yusuf (1976) have quantified that there should be at least a 30- to 40-day maturity difference in component crops to capture the advantages of intercropping.

Monetary advantages of intercropping

During all four years, data on cash and labor inputs used in each cropping systems were recorded. Total cost of production for each cropping system was estimated based on the input used and the current market prices. Gross economic returns for each cropping system were estimated based on actual crop yields (stem and grain or seed cotton) and the annual average commodity prices from the primary markets in Andhra Pradesh. The total

Table 4. Total gross economic returns for different pigonpea/cotton strip intercropping systems grown under three land-configuration systems on a Vertisol at ICRISAT Asia Center during the 1990 to 1994 cropping seasons.

	Gross economic returns (Rs.'000ha^{-1})				
Treatment	1990/91	1991/92	1992/93	1993/94	Pooled mean
Land configuration(LC)					
Flat	9.52	18.62	12.67	14.94	13.94
Ridge and furrow(RF)	9.40	18.00	11.38	15.31	13.52
Broadbed and furrow(BBF)	9.45	17.14	12.43	14.75	13.44
SE	±0.199	±0.426	±0.436	±0.399	-
F test	NS[1]	NS	NS	NS	-
CV%	3.6	4.1	6.2	4.6	-
Cropping system(CS)					
Pigeonpea : cotton strip size[m]					
6.0 : 0	7.51	16.82	6.07	12.41	10.70
4.5 : 1.5	9.82	17.11	7.78	13.53	12.06
3.0 : 3.0	10.98	19.34	10.52	12.80	13.41
1.5 : 4.5	11.38	23.74	12.49	12.63	15.04
0 : 6.0	13.29	26.37	19.15	20.66	19.87
SE	±0.537	±1.303	±1.168	±1.054	-
F test	**[2]	**	**	**	-
CV%	9.8	12.6	16.6	12.2	-
Interaction(LCxCS)					
SE	±0.707	±1.633	±1.478	±1.457	-
F test	NS	NS	NS	NS	-
CV%	9.8	11.2	14.7	13.9	-

1 NS = Not significant.
2 ** = Significant at $P < 0.01$ level.

Table 5. Total net economic returns for different pigeonpea/cotton strip intercropping systems grown under three land-configuration systems on a Vertisol at ICRISAT Asia Center during the 1990 to 1994 cropping seasons.

	Net economic returns (Rs.'000ha^{-1})				
Treatment	1990/91	1991/92	1992/93	1993/94	Pooled mean
Land configuration(LC)					
Flat	6.44	14.42	7.93	10.35	9.79
Ridge and furrow(RF)	6.23	13.70	6.53	10.51	9.24
Broadbed and furrow(BBF)	6.48	12.84	7.58	9.95	9.21
SE	±0.199	±0.426	±0.436	±0.399	-
F test	NS[1]	NS	NS	NS	-
CV%	5.4	5.4	10.3	6.7	-
Cropping system(CS)					
Pigeonpea : cotton strip size[m]					
6.0 : 0	5.09	13.32	1.87	8.69	7.24
4.5 : 1.5	6.99	13.13	2.90	9.25	8.07
3.0 : 3.0	7.71	14.84	4.97	7.99	8.88
1.5 : 4.5	7.59	18.73	6.26	7.29	9.97
0 : 6.0	9.15	20.82	12.25	14.80	14.25
SE	±0.536	±1.303	±1.168	±1.054	-
F test	**[2]	**	**	**	-
CV%	14.6	16.5	27.5	17.8	-
Interaction(LCxCS)					
SE	±0.707	±1.633	±1.478	±1.457	-
F test	NS	NS	NS	NS	-
CV%	14.6	14.6	24.4	20.3	-

1 NS is not significant.
2 ** is significant at $P < 0.01$ level.

production cost for sole pigeonpea grown on a flat land configuration varied from Rs. 2377 ha^{-1} in 1990/91 to Rs. 4138 ha^{-1} in 1992/93. The total production costs for sole cotton grown on a flat land form ranged from Rs. 4097 in 1990/91 to Rs. 6840 ha^{-1} in 1992/93. An average additional cost of Rs. 85 ha^{-1} was required for making both RF and BBF land forms for each species. The higher total production cost in sole cotton was mainly due to additional cost involved in seed, manual planting, plant protection, and cotton picking. Total production cost for different intercropping species varied proportionally with strip size.

Total gross and net economic returns (Tables 4 and 5) were not significantly influenced by land configuration or the interaction between land configuration and cropping system over the four years. However, total gross and net economic returns responded significantly to cropping system treatments. Sole cotton always gave higher gross and net returns when compared to sole pigeonpea or any pigeonpea/cotton strip intercropping system. A strip combination of 1.5 m pigeonpea and 4.5 m cotton system was as profitable as the sole cotton system in 1990/91 and 1991/92. Gross and net economic returns increased as the strip size of cotton increased. Economic returns were higher in 1991/92 and 1993/94 because of higher yields from both species when compared to other years. Averaged over 4 years, sole cotton gave the highest gross return (Rs. 19.87 thousands ha^{-1}) and net return (Rs. 14.25 thousands ha^{-1}). The lowest gross return (Rs. 10.7 thousands ha^{-1}) and net return

Table 6. Benefit : Cost(BC) ratio values for different pigeonpea/cotton strip intercropping systems grown under three land-configuration systems on a Vertisol at ICRISAT Asia Center during the 1990 to 1994 cropping seasons.

	Benefit : Cost ratio				
Treatment	1990/91	1991/92	1992/93	1993/94	Pooled mean
<u>Land configuration(LC)</u>					
Flat	2.10	3.43	1.70	2.27	2.38
Ridge and furrow(RF)	1.96	3.19	1.40	2.20	2.19
Broadbed and furrow(BBF)	2.05	2.98	1.57	2.08	2.17
SE	±0.067	±0.096	±0.084	±0.078	-
F test	NS[1]	NS	NS	NS	-
CV%	5.7	5.2	9.3	6.2	-
<u>Cropping system(CS)</u>					
Pigeonpea : cotton strip size[m]					
6.0 : 0	2.10	3.81	0.45	2.34	2.18
4.5 : 1.5	2.47	3.30	0.59	2.16	2.13
3.0 : 3.0	2.36	3.30	0.90	1.66	2.06
1.5 : 4.5	2.05	3.73	1.01	1.37	2.04
0 : 6.0	2.21	3.76	1.78	2.53	2.57
SE	±0.177	±0.319	±0.228	±0.225	-
F test	NS	NS	**[2]	**	-
CV%	15.0	17.2	25.4	17.8	-
<u>Interaction(LCxCS)</u>					
SE	±0.229	±0.395	±0.288	±0.303	-
F test	NS	NS	NS	NS	-
CV%	14.3	14.9	22.4	19.4	-

1 NS is not significant.

2 ** is significant at P <0.01 level.

(Rs. 7.24 thousands ha^{-1}) were obtained by sole pigeonpea.

The benefit:cost (BC) ratio values varied significantly among cropping systems (Table 6), but not among land configurations or treatment interactions. The BC ratio values varied widely among cropping systems and between years (1.78 - 3.76 for sole cotton, 0.45 - 3.81 for sole pigeonpea, and 0.59 - 3.73 for strip intercropping). Higher BC ratio values for sole cotton suggest sole cotton as the most remunerative cropping system when compared with sole pigeonpea or pigeonpea/cotton strip intercropping. Averaged over 4 years, sole cotton gave the maximum BC ratio of 2.57, with the lowest BC ratio (2.04) obtained by a strip combination of 1.5-m pigeonpea and 4.5-m cotton. Sole pigeonpea gave a BC ratio of 2.18. These positive BC ratio values suggest that all cropping systems were profitable on Vertisols under rainfed conditions.

Monetary advantages of intercropping rotations

The net economic returns and BC ratio values for each 2-year sole cropping or strip intercropping rotations are given in Table 7. Strip intercropping rotations differed significantly for net economic returns and BC ratio values in both rotation cycles. However, the net returns and BC ratio values for different rotation treatments were substantially higher in the first rotation cycle (1990/1991) than in the second cycle (1992/1993). The BC ratio values for strip intercropping rotations varied significantly only in the second rotation cycle. Averaged over 2 rotation cycles, sole pigeonpea - sole cotton or sole cotton - sole pigeonepa rotation gave maximum net returns (Rs. >21 thousands ha^{-1}) and maximum BC ratio of 2.46.

Table 7. Total net economic returns and benefit : cost (BC) ratio values for different pigeonpea/cotton strip intercropping systems rotation on a Vertisol at ICRISAT Asia Center during the 1990 to 1994 cropping seasons.

	Net economic returns (Rs.'000 ha^{-1})			Benefit : cost (BC) ratio		
Strip intecropping rotation	Cycle 1 1990 to 92	Cycle 2 1992 to 94	Mean	Cycle 1 1990 to 92	Cycle 2 1992 to 94	Mean
<u>Strip size(m)</u>						
6 pp[1] - 6 Cot[1]	25.91	16.67	21.29	3.25	1.66	2.46
4.5 pp / 1.5 Cot- 4.5 Cot/1.5 pp	25.70	10.19	17.95	3.27	1.00	2.14
3 pp/3 Cot- 3 Cot/3 pp	22.55	12.96	17.76	2.90	1.25	2.08
1.5 pp/4.5 Cot- 1.5 Cot/4.5 pp	20.72	15.51	18.12	2.70	1.48	2.09
6 Cot - 6 pp	22.48	20.94	21.71	2.94	1.97	2.46
SE	1.50	1.77	-	0.198	0.185	-
F test	*[2]	**[2]	-	NS[3]	*	-
CV%	12.9	17.4	-	12.7	17.1	-

1 PP is pigeonpea and Cot is cotton.

2 *, ** is significant at P <0.05 and 0.01 level, respectively.

3 NS is not significant.

Conclusion

The results from this 4-year field study indicate that pigeonpea/cotton strip intercropping is a potential system for Vertisols in the Indian SAT. Total LER and MVER values for intercropping generally exceeded unity, indicating a better biological efficiency of strip intercropping when compared with either species as sole crop. A strip combination of 4.5-m pigeonpea and 1.5-m cotton gave a maximum mean total LER value of 1.4, indicating a 40% yield advantage over a sole cotton or sole pigeonpea system. Cotton proved to be a more stable and higher yielding crop than pigeonpea. Intercropping pigeonpea had a better yield than cotton, suggesting that medium-duration pigeonpea is an ideal crop for improving complementarity in intercropping. However, pigeonpea was a more competitive crop than cotton and depressed cotton yields significantly when they were intercropped. In contrast, economic analysis indicated that sole cotton was more remunerative than sole pigeonpea or all strip intercropping combinations, and that sole pigeonpea was always inferior to strip intercropping. Results of the combined analysis of each 2-year rotation cycle showed that sole pigeonpea - sole cotton or sole cotton - sole pigeonepa rotation was the most remunerative system when compared with the other strip intercropping rotations. However, from the food security point of view and by considering the additional benefits of intercropping farmers should opt for strip intercropping rotations under low input situations and for sole crop rotations under high input situations. For increasing pigeonpea or cotton yields or monetary returns under Indian SAT conditions, use of different land configuration systems (RF or BBF) was not advantageous over the graded flat system. Future strip intercropping studies should compare the performance of crop genotypes with wider crop maturity durations.

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