Indian Journal of Agricultural Sciences **81** (7): 616–21, July 2011

A modified alley cropping system of agroforestry in South Andaman Islands: an analysis of production potential and economic benefit

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Received : 22 March 2010; Revised accepted: 15 April 2011

ABSTRACT

A study was conducted during 2001–07 to know production potential and economic benefit of a modified alley-cropping system of agroforestry in humid climate of South Andaman Island of India. In the modified alley cropping system highly remunerative perennial crop black pepper *(Piper nigrum* L.) was grown on the double hedgerows (20 m long) of *Gliricidia sepium* (Jacq.) Walp. whereas maize *(Zea mays* L.) and okra *(Abelmoschus esculentus* L.) in the alleys (4 m wide) during rainy season (June–August) and post-rainy season (September–November) during the second respectively for seven consecutive years. Dimensions of the double hedgerows in the modified alley cropping system were: height 2.5 m and canopy width 3.0 m. Yields in maize and okra were maximum (5.04 tonnes/ha and 7.47 tonnes/ ha, respectively) for the first cropping year, which declined to 2.14 tonnes/ha and 5.89 tonnes/ha, respectively during the sixth cropping year. On the contrary, production in black pepper was the lowest (0.21 tonnes/ha) during the second and the highest (2.38 tonnes/ha) during the seventh cropping year. Investment in maize (₹19 581/ha) and okra (₹30 179/ ha) did not differ among the cropping years. But, in black pepper, investment was maximum (₹44 to 32 thousand / ha) for two cropping years in the beginning and declined to ₹11 880 to ₹15 675/ha from the third year onwards. Economic analysis revealed that net profit from the black pepper was negative for the first and second cropping year (₹44 399 and ₹6 630 / ha, respectively) in the beginning, but okra alone compensated it. From the third cropping year black pepper alone not only compensated its establishment cost, but also earned a reasonably good income for ₹97 082 / ha. Moreover, net return in black pepper over the seven cropping years of the experiments were ₹12 97 292 that not only compensated the negative returns from the system, but also made the alley cropping system 4.46 times more profitable than without the black pepper.

Key words: Black pepper, Cost:benefit ratio, Double hedgerows, Economics, *Gliricidia sepium*

Agroforestry studies started in the late 20th century with high expectations to eliminate hunger and poverty and reduce deforestation and environmental degradation and enhance fuel and fodder supply. However, these goals remained basically the same today as they were more than two decades before (Sanchez *et al.* 2010). Unfortunately, agroforestry studies were made without taking the principles of competition and socio-economic benefits into account (Casey 2004). And agroforestry practices were advocated with rigid cropping systems, fixed design, definite mixture of species, which required high levels of management skill and labour investment. As a result, the modern agroforestry could not make dent in farmer's fields.

Beneficial effects of trees in nutrient build-up (Pandey *et al.* 2007a), microclimate changes (Chen *et al.* 2002) and soil erosion control (Pandey and Chaudhari 2010) have been well documented. But, these tree benefits are beyond the perception of farmers because they are intangible in nature. Nevertheless farmers follow either age-old traditional agroforestry like *Acacia nilotica* L. based system in central India, *Prosopis cineraria* (Sw.) DC. and *Acacia nilotica* systems in north and western India (Tejwani 1994), coconut–arecanut-based homegarden agroforestry in southern part of India (Pandey *et al.* 2007b) or modern industry–linked highly remunerative poplar *(Populus deltoids* Bartr.) based agri-silviculture model in north-western India which feeds to match box industry (Gill *et al.* 2009). The traditional systems fulfill primarily the basic needs of farmers, whereas the modern industry-linked system provides high income to household. These clearly indicate that to make agroforestry farmers friendly, it should be made highly remunerative either by developing industry-linked models or by adding value on the existing agroforestry systems. Value-added agroforestry systems might be designed either incorporating highly remunerative trees along with annual crops like poplar +

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wheat or introducing highly remunerative crops on the existing agroforestry systems itself. In the present study the second approach was followed and a modified version of alley cropping system was developed where the hedgerows of *Gliricidia sepium* (Jacq.) Walp. were used as standards (support) for growing black pepper (*Piper nigrum* L.), a highly remunerative crop, and the alleys were grown with annual crops like miaze *(Zea mays* L.) and okra *(Abelmoschus esculentus* L.) during rainy season and post-rainy season, respectively. Generally hedgerows in alley cropping is cut to 50 cm height from ground so that light travels to intercrops and pruning biomass is used as a supplement for nitrogen. But, in the modified alley cropping hedgerows are allowed to grow up to 2.5 m and canopy expansion up to 3 m so that they provide greater space to the pepper vines to spread with and also make harvesting of pepper berries easy, and ultimately to make the alley cropping system highly remunerative. Traditionally, the black pepper is grown on arecanut palm which is a tall tree (12 m height) having thin cylindrical bole (15 cm dia.). The pepper vines trail on the palm tree as high as 8–9 m and make harvesting of the pepper berries difficult and labour-intensive and ultimately the pepper cultivation uneconomical. The present study describes the structural design, production potential and profitability of the modified alley-cropping system in the South Andaman Islands of India.

Fig 1 Lay-out of the modified alley cropping system. (a) Double hedge rows of *Gliricidia*, (b) black pepper grown in space between hedge rows, (c) maize sown as an intercrop in the alley, (d) okra sown as an intercrop in the alley

MATERIALS AND METHODS

Study site

The study was conducted at a research farm of Central Agricultural Research Institute located at Sipighat, South Andaman (10°30'–13°42'N lat. and 92°14'–94°14'E long.) of India. The site lies 315 m above mean sea level. Soils are entisols; well-drained, gravelly-sandy-loamy in texture, slightly acidic in reaction and moderate to poor in nutrients (Pandey *et al.* 2007a). The climate is an equatorial humid tropical. Temperature varies from 23.1°C to 30.1°C being maximum in May and minimum in December. Average annual rainfall is 3000 mm, distributed over 8–9 months. Humidity ranging from 71% to 85% is maximum in September and minimum in February.

Experimental design of modified alley cropping and management

Lay-out of the modified alley-cropping is given in Fig 1, a, b, c, d. Four-year-old alley cropping system with six double hedgerows of *Gliricidia sepium*, each 20 m in length and planted 4 m apart from one another, were selected for the study. Hedgerow to hedgerow distance in a double hedgerow was 1 m, and plant-to-plant distance within a hedgerow was 50 cm. Thus, there were six double hedgerows and five alleys. At one extreme end of the each alley, a plot without hedgerows, equal in width and 5 m in length, was present. A galvanized iron sheet was put 1 m deep at the interface between the hedgerows and the plots (alley) to keep them free from root competition. The plots served as controls for the crops grown in the alleys. Pits, 30 cm × 30 cm in size were dug at 50 cm interval in the centre (1m space) of the double hedgerows. Soils and FYM in 2:1 ratio were filled in the pits. Four rooted cuttings of black pepper *(Piper nigrum*) var. 'Panniyur1' were planted in the each pit. Two pepper vines from each pit were trailed on one hedge plant in one hedgerow and remaining two on a hedge plant in the opposite hedgerow. Pepper vines were thinned to best one later on when it was well established. Bordeaux mixture (1%) was spread fortnightly to the vine during the rainy season and at one-month interval during rest of the months in the beginning for two years and thereafter only during the rainy season. A 10 cm thick mulch of FYM: soil and *Gliricidia* leaves mixed in 4:2:1 proportion was filled in the space (1 m) in the double hedgerows in January 2001 for soil-moisture conservation during dry months. The double hedgerows were pruned four times in a year, ie April, July, September and November for three consecutive years, and in March from the fourth year onwards. Pruning was done at 1 m during the first cropping year, at 2 m during the second cropping year and at 2.5 m from third year onwards. The pruning biomass production (oven dry) was estimated on per hectare basis by multiplying the number of the hedge plants (D) in a hectare with the weight of pruning biomass (leaf + stem) produced by a hedge plant. The number of hedge plants was calculated following Pandey *et al.* (2001) as follows:

D = Area (100 × 100 m) / alley width (m) × plant-to-plant distance (m) in a hedgerow

All the alleys including their corresponding control plot were grown for maize during rainy months (early June to mid August) and okra during post-rainy months (September to November) for seven consecutive cropping years, i e 2001 to 2007. Hybrid maize ('Ganga 5') was grown at 50 cm × 50 cm distance. Fertilizer N,P,K was applied at the rate of 120:100:80 kg / ha. Okra (hybrid Arkanamica) was sown at 50 cm × 50 cm distance and fertilizer N,P,K was applied at the rate of 100:80:60 kg / ha. Urea was applied in two split doses to both the crops. Half at the time of sowing and remaining half after weeding. Weeding was performed after 15 days in maize and 20 days in okra. Okra was irrigated to field capacity generally one to two times as and when required during dry spell in November. Three random alleys and their corresponding control plots were sampled for the estimation of yields in maize as well as okra.

For economic analysis, the time spent by the labourers for sowing of maize and okra and their cultural operations and raising black pepper and its management was recorded. Labour data were converted to man-day (8 hr work/day) /ha. Cost of seed, fertilizer and fungicide were obtained from local market for the respective year. Products of maize, okra and black pepper were valued at the price farmers sell to local vendors.

Data were subjected to analysis of variance test using SPSS statistical package. Treatment included crops (three) and year of cropping (seven), replicated three times. LSD ($P<0.05$) was used to compare the means. Regression technique was applied to know the relationship between the parameters.

RESULTS AND DISCUSSION

Hedgerows dimensions

Height of the double hedgerows of the modified alley cropping system was maintained to 1 m during the first cropping year, 2 m the second cropping year and 2.5 m from the third cropping year onwards by pruning as described in the materials and methods section (Table 1). Dimensions of the double hedgerows were manipulated according to the growth and the spreading of the black pepper vines. First year, the hedgerows were pruned to 1 m to facilitate light to the vines. Shading is known to increase humidity (Pandey *et al.* 2007b), which causes foot-rot, a dreaded fungal disease to the vines. As the vines trailed high, the hedgerows height was increased to provide them cover to spread with on the one hand, and avoid shading to the vines, on the other. The pruning caused tillering in the *Gliricidia* hedge that resulted into widening of the hedgerows canopy. The pepper vines, however, grew quickly and covered the hedgerows up to 2.5 m within three years that subdued the lateral expansion of the hedgerows. Ultimately, the hedgerows canopy was stabilized to 3 m within three years (Table 1). The hedgerows produced maximum pruning biomass in the beginning for two consecutive cropping years, and then declined from the fourth cropping year onwards. However, the top of the hedgerows when pruned over the vines after third year, it grew further, which was evident from the low amount of the pruning biomass after the fourth year. It indicates that the hedgerows can be manipulated to any desired height. Decline in the pruning biomass with passage of time may be a disadvantage of growing black pepper on the hedgerows in the alley cropping system. Pruning biomass production is regarded one of the major objectives of the alley cropping system. In our study, some amount of pruning biomass was produced every year. Pruning of the hedgerows is essentially required to maintain the vigour of the hedgerows. Pandey and Venkatesh (2007) have found that seven-year-old *Gliricidia* standards, when not pruned shed their leaves and commenced flowering in dry months and became stunted in growth within two years at the study site.

Table 1 Height and canopy width of *Gliricidia sepium* double hedgerows and pruning biomass production in the modified alley cropping system in the South Andaman Islands

Cropping year	Double hedgerows of *Gliricidia*		Biomass production (tonnes/ha/year)
	Height (m)	Canopy width (m)	
1	$1.01^a \pm 0.05$	$1.11^a \pm 0.04$	$12.02^a \pm 1.20$
2	$2.02^b \pm 0.08$	$2.53^b \pm 0.07$	$10.01^b \pm 1.50$
3	$2.51^c \pm 0.06$	$3.02^c \pm 0.05$	$5.04^c \pm 1.0$
4	$2.52^c \pm 0.05$	$3.01^c \pm 0.04$	$2.11^d \pm 0.50$
5	$2.53^c \pm 0.07$	$3.02^c \pm 0.08$	$2.12^d \pm 0.08$
6	$2.52^c \pm 0.06$	$3.02^c \pm 0.90$	$2.11^d \pm 0.06$
7	$2.51^c \pm 0.05$	$3.03^c \pm 0.10$	$2.10^d \pm 0.04$

Values of a parameter in a column with different superscripts are significant at $P<0.05$.

Crop production

Yields of the maize (5.04 tonnes/ha for first year, 2.82 tonnes/ha the second year, 2.41 tonnes/ha the third year, 2.24 tonnes/ha the fourth year and 1.99 tonnes/ha from fifth year onwards up to the seventh cropping year) and okra (7.47 tonnes/ha for first year, 6.53 tonnes/ha the second year, 6.22 tonnes/ha the third year, 5.87 tonnes/ha the fourth year and onwards up to the seventh cropping year) declined significantly in the alleys compared to controls in all the cropping years. Decline in the yields of both the crops were the lowest during the first cropping year, increased thereafter up to third cropping year, and stabilized from the fourth cropping years onwards. Total decrease in the maize yield over the seven cropping years was 54%. But, total decline in the okra yield, over the seven cropping years, was 18% lower than maize. Decline in the yield in maize during the first cropping year could primarily be due to competition for nutrients because the hedgerows were pruned to 1 m and the soil-water was in plenty during the rainy season. However, subsequent cropping years when the hedgerows grew taller, reduction in the yields of the maize was due to competition for both light and the nutrients. Delayed pruning in alley cropping is reported to reduce crop yields, because of increased competition (Pandey *et al.* 2001). Maize yield is reported to decline in alley cropping system in humid climate of Andaman (Pandey and Venkatesh 2007). However, in okra yield reduction was mainly due to competition for soil- water and partly due to competition for light. During late rainy season, dry spells occur frequently. High inter-annual coefficient of variation (58%) in rainfall occurred in November across the cropping years. Eleven-year-data (1996 to 2007) revealed that evaporation in November was, on an average, 103 mm (Pandey and Venkatesh 2007), whereas average rainfall across the experiment years was 118 mm in November. Pandey and Venkatesh (2007) reported that whenever, rainfall is less than 150 mm/month in the growing season and evapotranspiration 4 mm / day, soil-water becomes limiting to crops. Black pepper started production from the second cropping year, increased linearly and recorded maximum yield (Y, tonnes/ha) from the sixth cropping year onwards (x, year) as: $Y = -1.124 + 0.76\ x$, ($r^2 = 0.998$, $P<0.01$). Early bearing in the black pepper in our study may be attributed to mulching with high amount of organic matter. Black pepper is reported to start bearing generally from third cropping year (Sivaraman *et al.* 2002).

Economic analysis

Cost of cultivation, net profit and benefit:cost ratio differed significantly due to the crops ($P<0.001$) and cropping years ($P<0.001$). Cost of cultivation was highest for the black pepper-followed by the okra and the maize for two cropping year in the beginning (Tables 2, 3, 4). Thereafter the pattern was reversed and cost of cultivation was the highest in okra, followed by maize and black pepper. Net profit from black pepper was negative for the two cropping years in the beginning. But, benefit started from the third cropping year and was maximum from the sixth cropping year. The intercrop okra earned profit invariably in all the cropping years, with maximum in the beginning for three cropping years. But, the net returns from the maize became negative from the second cropping year and persisted until the last year. For the two cropping years in the beginning, net returns from the improved alley cropping system (across all the crops) were 40% lower than the traditional system (Table 5). However, from the third year net returns were many folds (3.89 to 10.24) greater than traditional system.

Negative net returns from black pepper for the first and

Table 2 Cost of cultivation and benefit in maize in the modified alley cropping system in the South Andaman Islands

Cropping year	Cost (₹/ ha)					Total	Benefit	Benefit:
	Labour	Fertilizer	Seed	Fungicides	Total	returns (₹)	(₹)	cost ratio
1	6,930[a]±225	8,244[a]±113	850[a]±47	NAP	16,024[a]±193	25,200[a]±976	+9,176[a]±317	+0.57[a]±0.11
2	6,720[a]±222	8,244[a]±104	875[a]±53	NAP	15,839[a]±207	14,100[b]±864	–1,739[b]±187	–0.11[b]±0.08
3	9,700[b]±817	8,244[a]±113	915[ab]±78	NAP	18,859[b]±976	12,050[c]±891	–6,809[c]±167	–0·36[bc]±0.05
4	10,400[b]±914	8,244[a]±98	927[ab]±84	NAP	19,571[b]±987	11,200[c]±854	–8,371[c]±201	–0.43[c]±0.08
5	10,300[b]±634	9,635[b]±135	945[ab]±101	NAP	20,880[b]±964	17,600[d]±864	–3,280[d]±198	–0.16[d]±0.06
6	12,840[c]±1103	9,635[b]±65	1,012[b]±94	NAP	23,487[c]±1074	15,920[d]±671	–7,567[e]±167	–0.32[d]±0.07
7	11,760[c]±943	9,635[b]±55	1,014[b]±96	NAP	22,409[c]±1026	17,120[d]±861	–5,289[e]±176	–0.24[d]±0.07
Average	[A]9,807±801	[B]8,840±260	[C]934±22	NPA	19,581±1031	16,170±1632	–3,411±211	–0.15±0.1

NAP, Not applied; NA, not applicable
Values of a parameter in a column with different superscripts are significant at $P<0.05$
Values of parameters in a row with different superscripts are significant at $P<0.05$

Table 3 Cost of cultivation and benefit in okra in the modified alley cropping system in the South Andaman Islands

Cropping year	Cost (₹/ ha)					Total return (₹)	Benefit (₹)	Benefit: cost ratio
	Labour	Fertilizer	Seed	Fungicides	Total			
1	11,410[a]±463	7,245[a]±103	4,800[a]±260	875[a]±55	24,330[a]±511	89,640[a]±870	+65,310[a]±1431	+2.68[a]±0.80
2	11,690[a]±454	7,245[a]±99	4,800[a]±251	875[a]±67	24,610[a]±687	78,360[b]±814	+53,750[b]±1308	+2.18[b]±0.70
3	16,000[b]±670	7,870[a]±98	5,000[a]±224	900[a]±97	29,770[b]±741	74,640[b]±712	+44,870[c]±1178	+1.51[c]±0.61
4	15,900[b]±530	7,870[a]±67	6,300[b]±261	930[a]±118	31,000[b]±1241	70,920[c]±610	+39,920[d]±1161	+1.29[d]±0.21
5	15,600[b]±481	8,630[b]±115	6,300[b]±254	1051[b]±124	31,581[b]±1130	70,440[c]±589	+38,859[c]±1098	+1.23[d]±0.22
6	18,600[c]±612	8,630[b]±108	6,700[c]±263	1051[b]±136	34,981[c]±1180	71,160[c]±728	+36,179[c]±980	+1.03[d]±0.20
7	18,600[c]±608	8,630[b]±116	6,700[c]±260	1051[b]±130	34,981[c]±1100	70,680[c]±718	+35,699[c]±670	+1.02[d]±0.11
Average	[A]15,400±1,018	[B]8,017±220	[C]5,800±312	962±30	30,179±1,526	75,120±2,460	44,941±3,825	1.56±0.2

Values of a parameter in a column with different superscripts are significant at $P<0.05$
Values of parameters in a row with different superscripts are significant at $P<0.05$

Table 4 Cost of cultivation and benefit in black pepper in the modified alley cropping system in the South Andaman Islands

Cropping year	Cost (₹/ ha)					Total return (₹)	Benefit (₹)	Benefit: cost ratio
	Labour	Fertilizer	Seed/ seedling	Fungicides	Total			
1	39,830[a]±2416	NAP	3819±123	750[a]±31	44,399[a]±2628	0	–44,399[a]±1217	–1.0[a]±0.1
2	31,080[b]±2214	NAP	NA	750[a]±28	31,830[b]±2071	25,200[a]±876	–6,630[b]±817	–0.21[b]±0.5
3	12,800[c]±1870	NAP	NA	750[a]±34	13,850[c]±2076	1,23,600[b]±1214	+1,10,050[c]±3876	+8.12[c]±1.8
4	10,900[c]±2014	NAP	NA	980[a]±36	11,880[c]±1981	2,08,800[c]±1861	+1,96,920[d]±4531	+16.58[d]±4.31
5	11,500[c]±1876	NAP	NA	1,270[b]±87	12,770[c]±1761	2,29,200[d]±5414	+2,16,430[e]±4891	+16.95[d]±3.81
6	14,040[d]±1878	NAP	NA	1,272[b]±71	15,312[d]±1810	2,79,600[e]±6727	+2,64,288[f]±5976	+17.26[d]±2.91
7	14,400[d]±1761	NAP	NA	1,275[b]±61	15,675[d]±1641	2,85,600[e]±7318	+2,69,925[f]±6227	+17.22[d]±2.87
Average	[A]19,221±4,004	NAP±	[B]3,819±123	[C]1,007±92	20,817±4,350	1,92,000±37,491	1,43,798±44,655	+10.7±3

Values of a parameter in a column with different superscripts are significant at $P<0.05$
Values of parameters in a row with different superscripts are significant at $P<0.05$

Table 5 Benefit from the modified and traditional alley cropping system in the South Andaman Islands

Year	Modified system				Traditional		
	Maize (₹)	Okra (₹)	Black pepper (₹)	Total (₹)	Maize (₹)	Okra (₹)	Total (₹)
1	+9,176[a]±317	+65,310[a]±1431	–44,399[a]±1217	+30,087[a]±	+9,176[a]±317	+65,310[a]±1431	+74,486
2	–1,739[b]±187	+53,750[b]±1308	–6,630[b]±817	+45,381[b]±	–1,739[b]±187	+53,750[b]±1308	+52,011
3	–6,809[c]±167	+44,870[c]±1178	+1,10,050[c]±3876	+1,48,111[c]±	–6,809[c]±167	+44,870[c]±1178	+38,061
4	–8,371[c]±201	+39,920[d]±1161	+1,96,920[d]±4531	+2,28,469[d]±	–8,371[c]±201	+39,920[d]±1161	+31,549
5	–3,280[d]±198	+38,859[c]±1098	+2,16,430[e]±4891	+2,52,009[e]±	–3,280[d]±198	+38,859[c]±1098	+35,579
6	–7,567[e]±167	+36,179[c]±980	+2,64,288[f]±5976	+2,92,900[f]±	–7,567[e]±167	+36,179[c]±980	+28,610
7	–5,289[e]±176	+35,699[c]±670	+2,69,925[f]±6227	+3,00,335[f]±	–5,289[e]±176	+35,699[c]±670	+30,410
Total	–23,879 ±2,110	+3,14,587 ±3,825	+10,06,584 ±44,655	[A]+12,97,292 ±39,429	–23,879 ±2,110	+3,14,587 ±3,825	[B]+2,90,706 ±5,774

Values of a parameter in a column with different superscripts are significant at $P<0.05$
Values of parameters in a row with different superscripts are significant at $P<0.05$

second cropping years were probably due to its long gestation period, a characteristic of most tree / perennial crop production systems and requirement of high number of labourers (569/ha) for the first cropping year. Labour requirement declined from third year onwards to 108/ha. Maize and okra together compensated the cost incurred in the establishment of the black pepper during the first and second cropping year. Maize did not earn income from the second cropping year, but okra always earned income mainly because of its high price. Labour requirement in these crops was relatively low 97 and 159/ha, respectively every year. The Island is always in deficit in vegetable, hence it is costly. Third year, black pepper alone not only compensated its cumulative establishment cost, but also earned a reasonably good income for ₹ 97082 /ha. Comparing the cumulative net benefit with and without black pepper from the system across the seven cropping years of the experiments, it was estimated that black pepper introduction on the hedgerows increased the tangible profit 4.46 times greater from the modified alley cropping than the traditional system, which made the alley cropping system highly remunerative. Pruning biomass, though an important product of the alley cropping system, is not considered for the economic analysis of the modified system because it is not a marketable item. Shi *et al.* (2005) are of the view that establishment costs are a major disincentive to adopt the tree/perennial-based production system like hedgerow intercropping in the short term. Black pepper is known to yield for 20 years, if managed properly (Sivaraman *et al.* 2002). Hence, economic life of black pepper for 20 years seems sufficient to earn farmers a handsome income from the improved system.

The improved alley cropping system appears quite attractive as it increases the yield of black pepper about three times compared to that on arecanut standard in the traditional black pepper cultivation system in the Island, and makes the harvesting of pepper berries easy due to shorter height of the hedgerows that saves labour input and ultimately reduces the cost of cultivation. Pepper production is reported an average 0.3 kg / standard on the arecanut in the Island (Pandey and Venkatesh 2007), 0.6 kg / vine in Kerala and 303 kg / ha across the pepper growing states of India (Sivaraman *et al.* 2002). Black pepper growers plant arecanut at 2.7 m × 2.7 m spacing in their homegardens in the Islands. Therefore, the modified alley cropping system seems comparatively more profitable and socially desirable as it requires no additional land and crop management inputs, but provides high returns relative to small investment, once it is established.

Thus, it is concluded that black pepper vines trail on the double hedgerows of *Gliricidia* of the modified alley cropping system quickly and starts bearing, though learning stage, from the second cropping year. Maximum production occurs from the sixth cropping year. Net returns from the black pepper are negative in the beginning for two csropping years, but maize–okra crop rotation in the alleys offsets the negative returns from the system. Net returns in black pepper, averaged across the seven cropping years of the experiments, not only compensate the total investment incurred for its establishment, and reduction in the yields of maize but make the system tangibly profitable by 4.46 times greater than without the black pepper. It indicates that introduction of black pepper on the hedgerows in the alley cropping on the long term will make the system highly remunerative and most attractive to farmers.

ACKNOWLEDGEMENT

Author is thankful to Indian Council of Agricultural Research, New Delhi, for funding the study in the form of AP Cess Fund Project.

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