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Sericulture-based agroforestry systems for hilly areas of north-east India

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Abstract. Sericulture-based agroforestry systems (AFS) have great potential for higher returns in the north-eastern region with sloping and valley-land conditions. A field investigation was initiated in November, 1992 at Research Farm, Barapani (980 m above msl, 26°N and 92°E and average rainfall 2428 mm/year) on acid Alfisol. Seven mulberry (*Morus alba* L.) varieties, seven silkworm breeds and rearing performance of a bivoltine breed, NB-18 were evaluated in different trials. Three sericulture-based AFS viz. sericulture with 1. fruit trees and fodder grasses, 2. field (upland) crops, and 3. lowland rice were developed at the Research Farm. Mulberry varieties TR-4, S-1635 and TR-10, and NB-18 – a bivoltine silkworm breed were found better suited for this region. Sericulture with field crops (French bean-groundnut-mustard/vegetables) for valley land, with fruit plants (guava, pineapple) and grasses for mid-hill situations, and with rice for low lands were found suitable at the Farm and for possible adoption in the north-eastern hill region of India.

Introduction

Shifting cultivation and deforestation are major constraints in developing sustainable food-production systems in the north-eastern hill region, due to their detrimental effects on soil and water resources (Borthakur et al., 1985; Singh et al., 1994). At the same time the region has some excellent indigenous resource-based land use systems. Most of them are tree based, having unique fertility restoration capacity by preventing soil loss, improving soil organic matter status and replenishing the nutrients through effective recycling mechanism (Chauhan and Dhyani, 1989; Dhyani and Chauhan, 1994; Singh and Dhyani, unpublished). Sericulture is yet another vocation being practised since time immemorial as a part time occupation in this region (Gargi et al., 1994). This is mainly because the farmers lack systematic block plantation of mulberry, and also crop production for self consumption is their first priority. Moreover, farmers continue to rear multivoltine silkworm breeds which are hardy, but inefficient than the frailer but more productive bivoltine strains. Considering agroforestry as a viable solution to tackle the problem of shifting cultivation (Dhyani and Singh, 1995), sericulture could

be combined as one of its component. Hence, nine AFS as models, including three sericulture-based systems, were designed and evaluated for their productivity and sustainability. The paper evaluates three sericulture-based systems for their suitability under identical soil and climatic conditions and possible adoption in this region.

Materials and methods

A collaborative project between the Indian Council of Agricultural Research (ICAR), Research Complex for north-eastern Hill Region and Central Silk Board was initiated in May 1993. The experiments were laid out at ICAR Research Farm, Barapani (980 m above msl, 26°N and 92°E) in Meghalaya, India on acid Alfisol. The area receives an average rainfall of 2428 mm yr^{-1}. The systems were developed in 3 ha area distributed on foot hills (2 ha) with 30–48% slope and in valley land situations (1 ha). The project aims at the development of land use technologies based on sericulture under different AFS for this region.

To find out suitable varieties of mulberry (*Morus alba* L.) for hills, six high yielding varieties (HYV) viz. TR-4, TR-10, BC-259, S-1635, C-763, Kanva-2(K-2) and one local were planted at 0.9 × 0.9 m spacing in 3 replications during May 1993. There were 51 plants in gross plot and 15 in net plot. Growth parameters such as plant height, number and length of primary and secondary branches, and leaf yield (fresh weight) were recorded at the time of leaf harvests during November 1993, April, June, August and November 1994.

'Voltinism' or the natural breeding frequency of the worm varies from twice a year in the case of bivoltines, found only in temperate climates, to several times a year with multivoltines. Bivoltines produce yarn of greater uniformity and neatness and is thus preferred. With the advent of artificial hatching and improved rearing techniques, a number of bivoltine strains well acclimatized to different agro-climatic regions are now available (Datta, 1992). In the present study, seven improved breeds comprising bivoltine and $B_1 \times B_1$ hybrids viz. NB-18, KPG(A), KPG(B), P_5, J-112, NB-18 × P_5 and P_5 × KPG(B) were evaluated. The first four breeds are pure bivoltine races of Indian origin, and NB-18 × P_5 and P_5 × KPG(B) are the hybrids developed at Regional Extension Centre, Shillong (Meghalaya). J-112 is a Japanese race. KPG(A) and KPG(B) races were developed at Regional Sericulture Research Station, Kalimpong (West Bengal). Hatching percentage of silkworm eggs, effective rate of rearing (ERR/10,000 larvae) by number and weight, and silk ratio were calculated by using the following formulae;

$$\text{Hatching } \% = \frac{\text{Total number eggs hatched during brushing}}{\text{Total number of eggs in layings}} \times 100$$

$$\text{ERR (by number)} = \frac{\text{Number of cocoon produced}}{\text{Number of silkworm larvae brushed}} \times 10{,}000$$

$$\text{ERR (by weight)} = \frac{\text{Total weight of cocoon produced}}{\text{Number of silkworm larvae brushed}} \times 10{,}000$$

$$\text{Silk ratio (\%)} = \frac{\text{Single shell weight}}{\text{Single cocoon weight}} \times 100$$

Where ERR is effective rate of rearing.

In order to study the rearing performance of silkworm race NB-18, three rearings during May–June, July–August and October–November, 1994 were conducted.

Three sericulture-based agroforestry systems (AFS) (Figure 1) viz. sericulture with 1. fruit trees and fodder grasses, 2. field (upland) crops, and 3. lowland rice were also initiated at the same time as part of agroforestry research at the Farm. Each AFS developed in a sort of model with emphasis on sustained productivity and more frequent returns.

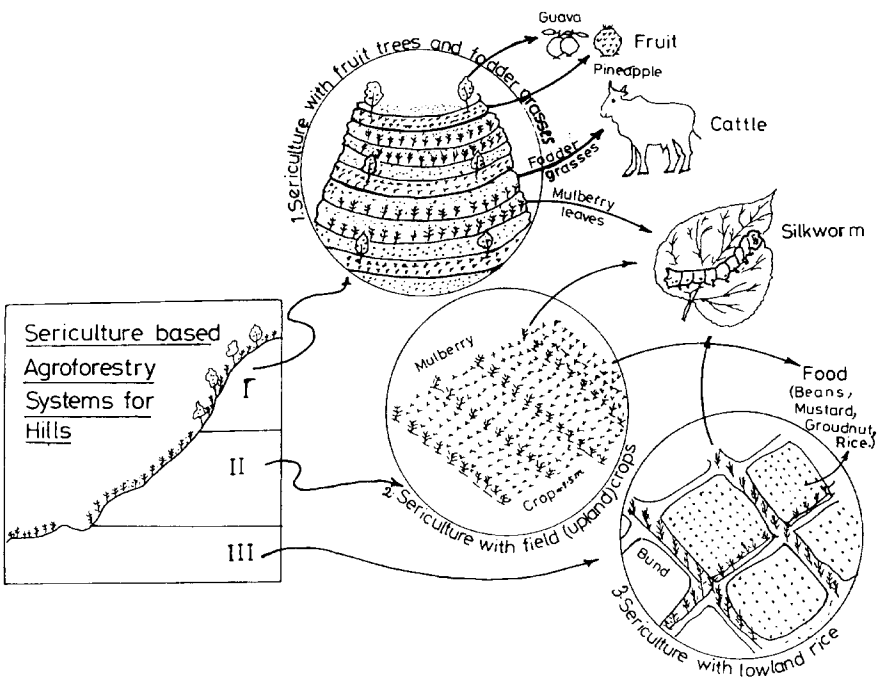

Figure 1. Schematic representation of the sericulture based AFS for north eastern hill region of India.

I. The sericulture with fruit trees and grass system [Figure 1(I)] comprised of guava cv. Allahabad safeda (6 m row to row along the slope × 4 m plant to plant across the slope) with pineapple (60 × 30 cm spacing) planted in paired rows on contours of 90 cm to 1.2 m width. The slope of the experimental area was 30–48%. Two rows of mulberry (TR-4) 90 cm apart were planted between two rows of guava. The inter-terraced area under risers was not disturbed. Local grasses dominated by *Arundinella bengalensis, Setaria palmifolia, Imperata cylindrica* and *Panicum maximum* were allowed to grow on risers and harvested for cattle fodder. Thus, in one hectare, there were 416 guava, 3,333 mulberry, 16,667 pineapple plants and about 3,333 m^2 area were grasses.

II. Sericulture with field crops system [Figure 1(II)] comprising mulberry (K-2) with intercrops [French bean (*Phaseolus vulgaris* L.)-contender, groundnut (*Arachis hypogaea* L.)-JL-24 and mustard (*Brassica campastris* L.)-M 27] was laid out with 15 spacing combinations (row to row: 90, 120, 150, 180, 210 cm, and plant to plant: 60, 90, 120 cm) in three replications. Farm Yard Manure @ 40 t in two doses and NPK @ 150:60:50 kg ha^{-1} yr^{-1} in equal split doses after each harvest were applied for mulberry plants. Recommended technique for rearing and feeding of silkworm (Datta, 1992) and standard cultural practices for intercrops were followed during the study. The details are depicted in Figure 2.

The rearings and crop schedule is synchronised in such a manner that there is least a shade or competition between mulberry and crop plants. This is done by following pruning schedules after every harvest e.g. as soon as the mulberry leaves are harvested for the 1st rearing (March–April), the plants were pruned at 40–60 cm (middle pruning) above the ground level. This helps to expose the crop seedlings to the sunshine for better growth during early stages. A thorough digging is given to the field before sowing. Seeds are sown by keeping 30 cm distance from mulberry plants.

III. A system of sericulture with rice cultivation was established in 0.2 ha in lowlands [Figure 1(III)]. Mulberry (K-2 and C-763) plants were planted on raised bunds (0.75 m height) at 90 cm apart. Two rice crops (March to July, and July to October) and four silkworm rearings were carried out each year. To judge the effectiveness of intercrop in this system, Land Equivalent Ratio (LER) (Mead and Wiley, 1980) was worked out as shown below:

$$\begin{aligned} LER &= RY_{rice} + RY_{mulberry} \\ &= P_{rice}/M_{rice} + P_{mulberry}/M_{mulberry} \end{aligned}$$

Where, RY = relative yield, P = intercrop, and M = sole crop

Economic analysis

An economic analysis was done by expressing the yields in cash units based on the ruling price (@ Rs. kg^{-1}, cocoon = 60, French bean, green pod = 4,

SERICULTURAL OPERATIONS	MONTHS	AGRICULTURAL OPERATIONS
Ist rearing: Brushing date(B.D.): March 25, Harvesting: April 20, Middle pruning, 60 cm height: May Ist wk	March- April- May	FRENCHBEAN Sowing : April Ist wk Harvesting: May 3rd wk
IInd rearing: B.D. : June 10, Harvesting : July 5, Ground pruning, 30 cm height: July 3rd wk	June- July	GROUNDNUT Sowing : June Ist wk
IIIrd rearing B.D. : August 15, Harvesting: Sept.12, Tipping: Sept. 2/3rd wk	August- September- October	GROUNDNUT Harvesting: September 3rd wk/ October Ist wk
IVth rearing B.D. : October 20, Harvesting: Nov. 19, Middle pruning: (December- January)	October- November- December- January- February	MUSTARD Sowing : October Ist fortnight Harvesting: February IInd fortnight OR VEGETABLES : (November-February)

Figure 2. Calender of events for cocoon rearing and crop raising in the hilly areas of north east India.

fuelwood = 0.20, groundnut = 12, mustard = 15, rice = 3.75, rice straw = 1.60; where 1 $ = Rs. 35.00) of the nearby (Umroi) market at which the exchange of produce between farmers and middlemen takes place. These prices are far below than the official rates.

Opinion survey

In order to find out preference for the models, a first hand survey involving 128 farmers and 88 officials from extension departments, trainees and other officers visiting the Research Farm was conducted during 1994–95.

Results and discussion

In the north-east region sericulture is practised since time immemorial (Gargi et al., 1994). All the four commercially known varieties of silk viz. mulberry, eri, muga and tasar are produced here (Prasad et al., 1996). The silkworm pupae are regarded as delicious food and are in high demand in local markets (Roychoudhury and Joshi, 1995). But in most of the situation sericulture is still a part time occupation. This is mainly because the farmers lack in systematic block plantation of mulberry and depend on the foliage available from plants in farm forestry. The major constraint is the non-availability of high land for mulberry plantation as most of it is under tea or shifting cultivation. With the launching of National Sericulture Project in 1989–90 efforts are on to boost the production of bivoltine silk in both traditional and non-traditional areas. In view of this more than 2,800 ha area is being brought under mulberry cultivation within two years (RSRS, 1995).

The agro-climatic condition and slightly acidic soils were found to be advantageous for good growth of mulberry. The high yielding varieties (HYV) favourably responded to the inputs and cultural practices and thereby produced about 60% more leaf and cocoon yield than the local variety (Table 1). Similar results were reported from hilly areas of South India (Narasimhanna et al., 1987). In addition the HYV produced nutritious leaves with high moisture content. This is a desirable attribute as the leaf moisture content of 70% is

Table 1. Varietal performance[1] of mulberry and net returns from the sale of cocoon.

Mulberry variety	Plant height (m)	Moisture (%)	Yield (t ha^{-1} yr^{-1})			Net returns from cocoon (Rs)
			Leaf	Cocoon	Fuelwood	
TR-4	1.70	75.9	19.1	0.81	6.4	33,449.00
TR-10	1.69	76.5	16.6	0.70	6.3	27,125.00
BC-259	1.44	76.5	15.2	0.65	5.7	23,627.00
S-1635	1.51	75.0	18.2	0.77	6.1	31,085.00
C-7635	1.52	75.2	16.5	0.70	5.6	26,865.00
Kanva-2	1.43	73.9	14.1	0.60	5.7	21,715.00
Local	1.28	62.1	9.1	0.39	4.1	8,215.00

[1] On the basis of 5 harvests in October 1993, April, May–June, August and October–November, 1994.

1 $ = RS. 35.00

obligatory for good development of late age silkworm (Datta, 1992). It was observed that first leaf harvest for silkworm rearing could be done within six months of planting. The six HYV viz. TR-4, S-1635, TR-10, C-7635, BC-259 and K-2 were found to be high leaf yielder. The yield potential was 19, 18, 16.6, 16.5, 15 and 14 t ha^{-1} yr^{-1}, thereby high cocoon yield (0.6–0.8 t ha^{-1} yr^{-1}), as against 9 t ha^{-1} yr^{-1} leaf and 0.39 t ha^{-1} yr^{-1} cocoon yield from local variety. The yields are slightly lower than reported from Assam (RSRS, 1995). The HYV also provided 5.6 to 6.4 t ha^{-1} yr^{-1} fuelwood from prunings. Overall HYV recorded 2.5 to 4 times more income than local variety. Therefore, the six varieties could be recommended as suitable HYV for the region. The effective rate of rearing and silk ratio with the silkworm race NB-18 were almost same among the HYV (Table 2).

The five bivoltine races recorded a cocoon yield of 13 to 17.6 kg/10,000 larvae. But hybrids $P_5 \times$ KPG(B) and NB-18 $\times$ P_5 produced higher cocoon yield (18.6–19.8) (Table 3). These yields are 22–41% higher than reported

Table 2. Rearing performance[2] of silkworm race NB-18 on mulberry varieties.

Mulberry variety	Weight of 10 larvae (g)	ERR/10,000 larvae		Silk ratio (%)
		No.	Kg	
TR-4	46.8	8700	18.29	19.0
TR-10	46.8	8657	18.19	18.5
BC-259	46.8	8766	18.44	18.9
S-1635	46.2	8629	17.19	18.3
C-763	45.6	7972	15.44	17.6
Kanva-2	44.8	8272	17.06	19.3

[2] On the basis of 3 rearings during May–June, August and October–November, 1994.
ERR – Effective rate of rearing.

Table 3. Rearing performance[3] of silkworm races on mulberry leaves.

Silkworm races	Hatching (%)	ERR/10,000 larvae		Silk ratio (%)
		No.	Kg	
NB-18	86.5	8103	17.49	19.3
KPG(B)	89.2	8354	17.62	17.9
P_5	78.4	8200	17.30	18.6
KPG(A)	79.3	8173	13.43	17.8
NB-18 $\times$ P_5	61.7	8679	19.85	20.3
$P_5 \times$ KPG(B)	67.3	8713	18.63	21.8
J-112	89.3	–	14.20	16.0

[3] On the basis of 4 harvests in April, May–June, August and October–November, 1994.
ERR – Effective rate of rearing.

from elsewhere (RSRS, 1995). This indicates the potential of the races under identical agro-climatic conditions.

Sericulture with field crops such as French bean-groundnut-mustard/vegetables was found to be profitable crop sequence. The combination would help in augmenting income as well as suppress the weed growth. The data indicated that 210 × 120 cm spacing for intercrops, and 90 × 60 cm for cocoon recorded the highest yield (Table 4) although 150 × 60 cm proved to be the best spacing as it balances the returns from cocoon as well as intercrops (Figure 3). It provided a net return of Rs. 41,380 ha^{-1}, which is highest, except the 90 × 60 cm spacing. Low temperature and deciduous habit of mulberry would not allow rearing during winter, although intercrops could be grown easily between mulberry rows. Vegetables like cabbage, knol khol, cauliflower could be grown (Gargi et al., 1994) in place of mustard as they have shorter gestation period. Hence the crop sequence for rainfed situation would be french bean-groundnut followed by mustard/vegetables.

Sericulture with fruit plants and grasses is an ideal system for the mid-hill situations. Yield (Table 5) from such a system could be very high from second

Table 4. Cocoon, intercrop yield and net returns as influenced under varied spacings of mulberry.

Spacing (cm × cm)	Yield (t ha^{-1} yr^{-1})					Total net returns (Rs.)
	Cocoon	French-bean	Ground-nut	Mustard	Fuel-wood	
90 × 60	1.2	0.6	–	–	6.4	51,300.00
90 × 90	0.8	0.8	0.7	0.2	5.6	35,150.00
90 × 120	0.5	1.0	0.9	0.2	4.2	9,670.00
120 × 60	0.8	1.0	0.9	0.3	6.3	30,680.00
120 × 90	0.5	1.5	1.0	0.3	4.2	16,162.00
120 × 120	0.4	2.6	1.0	0.4	3.2	16,380.00
150 × 60	0.7	3.2	1.3	0.5	5.1	41,380.00
150 × 90	0.5	3.7	1.4	0.5	3.4	30,835.00
150 × 120	0.4	5.1	1.5	0.5	2.5	30,150.00
180 × 60	0.5	4.9	1.5	0.5	4.2	38,300.00
180 × 90	0.4	3.7	2.0	0.5	2.8	34,500.00
180 × 120	0.3	3.9	1.9	0.6	2.1	26,900.00
210 × 60	0.5	4.6	1.8	0.6	2.1	37,650.00
210 × 90	0.4	4.8	2.3	0.7	2.4	37,300.00
210 × 120	0.3	5.5	2.1	0.7	1.8	36,100.00
Mulberry (Sole)	0.8	–	–	–	5.9	33,980.00
Frenchbean-groundnut-mustard	–	5.8	2.4	0.8	–	35,450.00
Sole groundnut[a]	–	–	1.3	–	–	9,150.00

[a] Farmer's practice (one crop yr^{-1}).
1 $ = RS. 35.00.

Figure 3. Intercropping french bean with mulberry under sericulture with field (upland) crops.

Table 5. Yield from sericulture with fruit trees and fodder grasses during the initial years of establishment.

Components	Yield (t ha^{-1} yr^{-1})		
	1st yr	2nd yr	3rd yr
Guava fruits	–	–	4.4
Pineapple fruits	–	7.0	9.0
Mulberry leaves	1.2	6.1	6.4
(= cocoon)[1]	(0.7)	(0.3)	(0.3)
Fuelwood	0.5	0.9	1.0
Grasses (green fodder)	12.1	19.9	24.0

[1] One rearing in first year, thereafter 4 rearings yr^{-1}.

year onwards. The system has great potential for employment generation, conservation of hill soils and production of enough grasses to feed $1\,^1/_2$ cattle unit ha^{-1} yr^{-1}. Guava on the contours could be substituted by fruit plants such as Assam lemon, pear and amla. Planting high yielding nutritious grasses e.g. Nandi (*Setaria sphacelata*), thin napier (*Panicum polystachon*), broom (*Thysanolaena agrostis*) and legumes viz. stylo (*Stylosanthes guyanensis*) in the inter-terraced area will help in increasing fodder production. Broom

plantation proved advantageous in even less than 0.25 m soil depth, as it restores and maintains soil fertility and fetches high returns (Dhyani and Singh, 1995).

Perusal of yield (Table 6) data on cocoon, fuelwood and intercrop revealed that the two mulberry varieties (K-2 and C-763) performed equally good in lowland. The sericulture with rice in lowland was found viable as there is regular income at frequent intervals from rice and cocoon crops. Annually four cocoon and two rice crops could be harvested from the system. The land equivalent ratio (LER) also indicated that the intercropping system of rice + mulberry was more advantageous than sole crop.

Opinion survey

The agroforestry models developed here showed visitors' keen interest for fruits, food, fuel and fodder. Cash inflow from cocoon and fruits was another important factor. Sericulture with fruit plants and grass model was highly preferred by the farmers, followed by sericulture with field (uplands), crops, whereas extension and other officials ranked sericulture with field (uplands) crops as the first choice followed by sericulture with lowland rice (Table 7).

Feeding schedule

It was found that there was no significant difference in the cocoon yield between 3 or 4 times per day feeding of mulberry leaves. Moreover, 3 times a day feeding could easily be adjusted with farmers' daily schedule (Table 8). At the same time the rearing of 50 dfls (disease free layings) at a time can be carried out by an average farmer family (4.5 members/family) in this region.

Table 6. Yield potential and net returns from sericulture with lowland rice.

Treatments	Yield (t ha^{-1})			LER	Net returns (Rs)
	Cocoon	Fuelwood	Rice		
Intercrop					
Mulberry (Kanva-2)	0.23	1.72	3.1	1.26	26,450.00
Mulberry (C-762)	0.21	1.70	3.1	1.25	25,840.00
Monoculture					
Rice	–	–	3.6	1.00	12,640.00
Mulberry	0.60	5.1	–	1.00	20,970.00

1 $ = Rs. 35.00.

Table 7. Preference for sericulture based AFS developed at Research Farm.

Agroforestry system	Preference and rank	
	Farmers	Officials
Sericulture with		
i) field (upland) crops	Highly preferred(II)	Extremely preferred(I)
ii) fruit trees and fodder grasses	Extremely preferred(I)	Preferred(III)
iii) lowland rice	Preferred(III)	Highly preferred(II)

Table 8. Feeding schedule of mulberry leaves and farmers' day to day activities.

Feeding	Time	Farmer's routine
I	5 to 6 a.m.	Farmer go for agricultural operations in the field (Main feeding)
II	12 a.m.	Lunch time after returning from field
III	6 p.m.	Dinner (final feeding)

Nutrients considerations

According to one estimate, production of 100 kg mulberry leaves takes away 1 kg of nitrogen from soil (Datta, 1992). Obviously to ensure optimum returns this has to be replaced immediately. Hence timely application of adequate quantities of nutrients and manure as described earlier is essential.

Conclusions

The mountainous hill slopes of north-east India enjoy salubrious climate for growing HYV of mulberry. The varieties are ideally suited for rearing bivoltine silkworm races producing high cocoon yield and superior quality of silk. Although the cost of cocoon production is high, the returns are significantly enough. The study also revealed that returns to family labour and management (the gross returns minus all the costs except cost of family labour and management) were quite remunerative. The cost/benefit ratio was found to be 1.58, 1.54, 1.31 and 1.13 for sole mulberry, mulberry intercropping, sole crop (improved practices) and sole crop (farmer's practice). The findings are in agreement with other similar reports (Gargi et al., 1994; Kerutagi and Shankara Murthy, 1996). Thus the result indicated the potential of sericulture-based agroforestry systems. It provides multiple output, generates income as well as employment, and also protects the soil. Its large scale adoption in

shifting cultivation areas will achieve conservation-linked sustainable production goals.

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