Mango Based Agroforestry Systems in Degraded Foothills of North-western Himalayan Region

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ABSTRACT

The investigation (1995 - 1998) indicated that even on degraded land (>68 per cent gravels /boulders) the mango plantation can be established successfully by adopting site specific agrotechniques. The vegetative vigour of mango plantation was better with groundstorey crops as compared to sole planted mango. The effect of mango trees was apparent on *Rabi* season crop (toria) at the age of fourth year when tree's canopy was about 25 per cent. Among various groundstorey crops tried during *Kharif* season; urd, cowpea and sesame had given good response while arhar was affected by adverse weather conditions during second year, though it has given maximum dry matter yield (75.97 q/ha) followed by cowpea (27.71q/ha), urd (17.88q/ha) and minimum in sesame (12.05 q/ha). The average grain yield of urd, arhar and sesame were 5.78, 3.56 and 2.23 q/ha, respectively. In case of cow pea, 14.49 q/ha green pod yield was recorded. Whereas, during *Rabi* season, >11 q/ha dry matter and >3 q/ha grain yield of toria was recorded. Economic evaluation of groundstorey component with mango under degraded land suggested that urd - toria was the best combination followed by cowpea-toria and sesame-toria and given B:C ratio of 3.89, 2.69 and 2.50, respectively.

Key words: *Canopy cover, drymatter, degraded land, economics, groundstorey crops, overstorey component, Mangifera indica.*

1. INTRODUCTION

Mango (*Mangifera indica* L.) is indigenous to India and known as 'King of fruits' due to its wide edaphoclimatic adaptability, rich biodiversity, high nutritive value, excellent flavour, attractive appearance and popularity among masses. It is grown over an area of 1.23 million hectare in the country and producing 10.99 million tonnes of fruits which accounts for 22.1 per cent of total area (5.57 m ha) and 22.9 per cent of total fruit production (47.94 million tonnes). In foothills of north-western Himalayan region, popularly known as *Doon valley,* mango is most liking woody component of various fruit based agroforestry systems and mango based agroforestry systems (AFS) were adopted largely by the farmers as remunerative enterprise due to its multiple utility (Saroj and Arora, 1994). Almost each part of the plant is used for one or the other purpose like; wood as timber, green leaves as fodder, dried twigs as fuel and fruit is consumed raw and ripe both (Rocheleau et al., 1998 and Saroj and Dadhwal, 1997). Raw fruits are used for making chutney, powder, pickle and drink while ripe fruits besides fresh consumption are used for making jam, squash, slice, pulp, juice, nectar, mango leather, etc. The seed kernel is used in soap industry.

In India, the mango is an integral component of homestead gardening and now a days there is high demand of dwarf hybrids for kitchen gardening. However, based on agroclimatic suitability and management systems, growing of annual crops in association with mango is an age old practice in different agroclimatic zones of the country (Saroj and Dadhwal, 1997). The tree has long gestation period, particularly those raised from seedlings, hence at prebearing stage the practice of intercropping in order to utilize interspaces and generation of some income is very common (Chundawat, 1993) but without much scientific consideration. There are some findings, where mango based AFS were found promizing (Rajput et al., 1989; Randhawa, 1990; Reddy and Sudha, 1990; Kanwar et al., 1993; Gill et al., 1995 and Singh et al., 1996) whereas, there are several combinations where detrimental response have also been noticed (Singh et al., 1963; Singh, 1967; Anon., 1969; Ram and Rajan, 1985 and Taeotia, 1989). A vivid account of mango based AFS in Zimbabwe and India have been given by Musvoto and Campbell(1995) and Saroj and Dadhwal (1997), respectively.

It is also essential to mention that so far, almost all the works on mango based AFS have been done on good land with assured input supply (Saroj et al., 1996) but meagre information is available either on resource conservation (Raturi and Chadha, 1993) or on utilization of degraded lands (Saroj et al., 1994). However, further extension of area under mango on good land is least possible due to reduction in land:man ratio, fast urbanization and industrialization. The alternative only seems to utilize degraded lands by accommodating suitable tree-crop combinations on the same piece of land for fulfilling the basic need of man and animals (Saroj et al., 1994 and Dadhwal et al., 1995). In foothills of north-western Himalayan region, large area (35 % of total geographical area of *Doon valley*) is either lying underutilized or left unutilized (Singh, 1985). Therefore, present study was planned with the objectives; i) to utilize and rehabilitate

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degraded gravely land for mango based AFS, ii) to select compatible groundstorey crops at prebearing stage of mango and iii) to workout economic viability of the systems.

2. MATERIALS AND METHODS

2.1. The Experimental Site

The investigation was carried out at Research Farm-Selakui (altitude 30^0 20' 4" N and longitude 72^0 52' 12" E, latitude about 680 m above .m.s.l), Central Soil and Water Conservation Research and Training Institute, Dehradun, from 1995-1998. The climate of the locality is humid subtropical with average rainfall of 1636 mm annum^{-1}. During experimental period, the mean maximum and minimum temperature ranged from 19.0 - 37.6 ^{0}C and 3.6- 24.0 ^{0} C, respectively. In general, May- June were the hottest months while December-January were coldest months of the year.

The experimental site was gravely riverbed land formed by debris deposition eroded from adjoining hills. The soil and stone ratio was 31.3:68.7 by weight based on 1 m^3 profile analysis. Average workable top soil depth mixed with some gravels was less than even one feet (24.45 cm). The size and amount of gravels/ boulders increased with increasing depth of soil profile. The mechanical analysis of soil particles (<2 mm) indicated that the fraction of coarse sand alone was more than 45 per cent, hence infiltration rate was very high (2,92 cm hr^{-1}). Overall fertility status was very poor (Table 1).

2.2. Tree Establishment

To establish mango plantation, the pits of 1 m^3 were dug out during month of May, 1995 at a spacing of 8 X 8 m after removing the bushes from the experimental site. The gravels/ boulders bigger than 5 cm diameter were sorted out from the excavated materials by sieving. Rest of the materials (soil mixed with smaller gravels) plus 1 feet^3 of well rotten FYM were mixed thoroughly and filled in the pits as filling mixture in the middle of June, 1995. About 100 g of BHC dust was also added during planting to control attack of termite. The grafted plants of mango cultivar 'Mallika' (a hybrid between Neelam and Dashehari) were planted in the last week of July, 1995. Only 2 plants dried up after planting which were replaced in August, 1995 itself. Regarding management, the drip system has been installed with a provision of four drippers per plant in four directions for irrigating mango plants during stress months only (April to middle of June in summer and November to January in winter season) if there were no rains. Recommended dose of fertilizers (100:50:100 g NPK plant^{-1} year^{-1}) were applied in two split doses, first half in first week of July and second half in last week of February to promote vegetative growth. During monsoon season, 20 kg FYM per plant was also given every year. During summer, 20 kg fresh leaves of subabul (*Leucaena leucocephala*) was applied in the basin of every plant as mulch material. In the initial two years, thatching of plants was also done in order to protect them against frost during winter.

Table 1. Physico-chemical properties of experimental site (< 2mm fractions)

Parameter		Profile depth (cm)			Mean
		0-30	30-60	60-100	
A.	Soil:Gravel*	60.3:39.7	28.8:79.2	13.1:86.9	31.3:68.7
B.	Mechanical				
	Coarse sand (%)	32.08	51.60	51.72	45.13
	Fine sand (%)	35.72	27.10	26.28	29.73
	Silt (%)	18.40	10.50	12.40	13.74
	Clay (%)	13.80	10.80	9.60	11.40
C.	Chemical				
	pH	6.90	7.20	7.40	7.20
	OC (%)	0.80	0.57	0.21	0.52
	N (%)	0.09	0.06	0.03	0.06
	P_2O_5 (ppm)	11.34	11.47	10.54	11.13
	K_2O (ppm)	94.92	43.43	20.42	52.92
	Ca (%)	0.20	0.18	0.19	0.19
	Mg (%)	0.17	0.15	0.11	0.14

* > 2mm fraction

2.3. The Crops

The crops were introduced from *Rabi* season 1996. Short duration oilseed crop toria (*Brassica campestris* var. Toria) variety Pant - 303 was grown uniformly in all the plots except control. Whereas, during *Kharif* season, five crops viz., cowpea (*Vigna sinensis*) variety - Komal, clusterbean (*Cyamopsis psoralioides*), arhar (*Cajanus cajan*), sesame (*Sasamum indicum*) and urd (*Phaseolus vulgaris*) variety - T9 were grown as groundstorey crops. All the *Kharif* crops were leguminous in nature except sesame (oilseed crop). During both the seasons, groundstorey crops were grown on rainfed basis and also without any fertilizer application. Plant protection measures and interculture operations were done as and when desired for both the components.

2.4. The Methods

The experiment was laidout in randomized block design with three replications. The plant unit per treatment was four and plot size per treatment was 16 X 16 m. Provision of border rows was also made. The data on vegetative character of plants i.e., plant height, canopy spread, stock and scion diameter, number of primary and secondary branches and canopy volume were recorded every year. In case of crops, dry matter and grain yield were recorded except for cowpea. Cowpea was grown for vegetable purpose, hence tender pods were picked up time to time. The effect of direction (North, South, East and West) and distance from tree basin (0-1, 1-2, 2-3 m and in-between rows) on grain yield of toria were also recorded every year. The grain/ pods were sold while crop residue was incorporated in the plots from where they were harvested. The B:C ratio was also computed by considering the cost of all inputs and gross output by selling the produce at farm itself on prevailing local market rate.

3. RESULTS AND DISCUSSION

3.1. Survival and Growth of Perennial Component

After three year of observation, there was cent per cent plant survival under both the systems i.e. sole planted mango and mango with annual crops (Table 2). The results suggested that for survival of mango plants under degraded land, the initial management play vital role rather than system of land utilization. At this stage, the average plant height, stock diameter, scion diameter, canopy spread, canopy volume and number of primary branches were 1.9m, 7.9 cm, 6.28 cm, 2.11m, 3.57m^3 and 3.50, respectively under degraded riverbed land, where top soil depth was less than 30 cm. Overall plant growth was better except scion:stock ratio, where annual crops were introduced as groundstorey component than those of sole planted mango and marked differences were noticed particularly in case of canopy volume. Infact, intercultural operations in annual crops influenced positive response on the vegetative growth of mango plants at initial stage (Saroj et al.,1999).

The scion:stock ratio is an indicator to assess vegetative incompatibility between rootstock and scion of a component plant. In present investigation, there was no indication of incompatibility at this stage and thus resulted better union and growth of mango plants. The canopy cover reflect the area covered by the foliage of the tree component on the ground. In this investigation, canopy cover increased with increasing age of the tree and at fourth year of observation about 1/4th of the area was covered by the overstorey component (Table 3). However, the per cent increase of canopy cover followed a sigmoid trend by reflecting higher percentage increase in 1997 than 1996 and 1998 in both the cases i.e. with and without crop. The phenomenon indicated clear shift in veg-

Table 2. Comparision of survival and growth of mango plants with and without groundstorey crops at 3-years

Growth parameter	With crops (Mango+Annual crops)	Without crop (Sole mango)	Average	Differences*
Plant survival (%)	100	100	100	± 0.00
Plant height (m)	1.91	1.87	1.90	+ 2.14
Stock diameter (cm)	7.92	7.87	7.90	+ 0.64
Scion diameter (cm)	6.30	6.22	6.28	+ 1.29
Scion:Stock	0.79	0.79	0.79	± 0.00
Canopy height (m)	1.45	1.41	1.44	+ 2.84
Canopy spread (m)	2.13	2.05	2.11	+ 3.90
Canopy volume (m^3)	3.64	3.20	3.57	+ 13.75
No. of primary branches	3.53	3.35	3.50	+ 5.37
No. of secondary branches	30.15	28.50	29.88	+ 5.79

* Per cent increase (+)/ equal (±) the growth parameters of mango with crops over without crop

etative growth rate of mango plant. The canopy volume, which is an indicator of overall plant vigour followed similar trend as canopy cover and the percent increase in canopy volume was also more in 1997 as compared to 1996 and 1998. Almost all the plants came in fruiting in second year of plantation as the variety Mallika is a early bearing hybrid but the blossom alongwith fruits at pea stage were removed to provide enough strength to the plants at initial years.

Table 3. Per cent canopy cover of mango with and without groundstorey crops in succeeding years

Treatment	Year			
	1995	1996	1997	1998
With crop	4.88	8.13	17.00	26.63
	-	(66.60)	(109.10)	(56.64)
Without crop	4.38	8.13	15.88	25.63
	-	(85.61)	(95.35)	(61.40)
Mean	4.63	8.13	16.44	26.13

Values in parenthesis are percentage increase over previous year

3.2. Reciprocal Response of Components

Data presented in table-4 revealed that there was no significant influence of groundstorey component on the growth parameters of mango like plant height, stock and scion diameter, scion: stock ratio and number of primary branches but it was significant for canopy height, canopy spread, canopy volume and number of secondary branches. The maximum plant vigour was obtained in those plots where sesame was grown as groundstorey crop while minimum was with cowpea. The poor crop stand of sesame under high rainfall zone might be conducive for better growth of mango plants. Even in control plots (sole mango plantation), the growth of mango was better than those of cowpea plots. Meanwhile, with rest of the crops (arhar and urd) the growth parameters of mango were in between sesame and control. In general, growing of leguminous crops inside the orchard had better effect on checking erosion, improving and maintaining soil structure, keeping down weeds and resource conservation (Russell,1950 and Lyon et al., 1952) than cereals and oilseed crops, resulting better growth and yield responses. However, in the present investigation, contrary results were obtained particularly with cowpea, though the differences in most of the cases were non-significant. Therefore, to see the influence of groundstorey crops on perennial component, some more data will be required.

Similarly, the vegetative growth of groundstorey crops was also least affected by mango plants particularly during *Kharif* season but there was some adverse effect on reproductive phase of crops upto one meter lateral distance from tree basin. During *Kharif* season, rainfall was in plenty, hence no moisture stress, owing to least adverse effect on vegetative growth of *Kharif* season crops. In case of arhar, outward bending of arhar plants was observed in the vicinity of mango tree. The shading effect of mango plants on vegetative and reproductive growth of rainfed toria crops was very apparent during *Rabi* season due to moisture stress in the vicinity of the mango tree.

3.3. Yield of Groundstorey Crops

3.3.1. Drymatter Yield

In this investigation, rehabilitation of experimental site was one of the basic objective, therefore, the drymatter obtained from various crops was incorporated in the same plots every year from where they had been harvested. However, in case of arhar only 50 percent drymatter in form of thinner stalks and straw was incorporated in the field and that too after minor chopping in order to proper

Table 4. Growth of mango plants as influenced by groundstorey crops

Growth parameter	Groundstorey crops					Control	SEm (±)	CD(p=0.05)
	Cowpea	Clusterbean	Arhar	Sesame	Urd	(No crop)		
Plant height (m)	1.78	1.91	1.92	2.03	1.93	1.87	0.201	NS
Stock diameter (cm)	7.70	7.99	7.69	8.03	8.17	7.87	0.568	NS
Scion diameter (cm)	6.04	6.06	6.32	6.60	6.49	6.22	0.256	NS
Stock : Scion	0.79	0.77	0.82	0.81	0.80	0.79	0.034	NS
Canopy height (m)	1.36	1.39	1.41	1.53	1.48	1.41	0.049	0.109
Canopy spread (m)	1.99	2.03	2.13	2.27	2.21	2.05	0.111	0.248
Canopy volume (m³)	3.02	3.13	3.68	4.43	3.93	3.20	0.426	0.950
Number of primary branches	3.50	3.52	3.50	3.56	3.57	3.35	0.033	NS
Number of secondary branches	30.07	30.14	30.31	29.05	31.18	28.50	0.558	1.243

mixing in the soil while remaining 50 per cent thicker stalks were utilized as fuel wood. Among various *Kharif* crops, the maximum drymatter was obtained by growing of arhar (75.97 q/ha) followed by cowpea (27.71 q/ha), urd (17.88 q/ha) and minimum in sesame (12.05 q/ha) (Table 5). There was complete failure of clusterbean crop during both the years. The seeds of cluster bean did not germinate and some seeds that did germinate, were rotten at seedling stage under high rainfall conditions.

During *Rabi* season, only toria crop was grown in all the combinations. So far, there was no effect of *Kharif* crops on drymatter yield of toria but differences were very clear under different years of cropping (Table 5). The maximum dry matter yield was recorded in 1997 followed by 1996 and minimum in 1998. The variation in drymatter yield of toria was mainly due to distribution of rainfall during crop growing season (October-December).

3.3.2. *Grain/Pod Yield*

In all the groundstorey crops, grain yield was recorded after threshing and subsequent drying, but in case of cowpea, green pod yield was recorded, which had been grown for vegetable purpose. It is obvious from the data (Table 6) that though the average green pod yield of cowpea was 14.49q/ha but there was great variation in pod yield of 1997 (8.45 q/ha) and 1998 (20.52 q/ha). Meanwhile, there was not much differences in crop stand during both the years. Infact, in 1997, there was heavy infection of leaf mossaic after first pickings of pods and remaining two picking had given very low pod yield. This was mainly due to infected seed material. In 1998, source of seeds was changed and excellent performance of crop was noticed. In this year, picking was done six times resulting not only higher yield but also increased period of availability of green pods. The arhar crop yielded 3.56 q/ha seeds during 1997 but there was no grain formation in 1998 due to uncongenial weather conditions, though the crop stand was very good. There was heavy flowering in arhar crop but due to rain, frost and prevailing foggy atmosphere for a week during seed formation stage, flowers were dropped off followed by blackening of foliage, resulted no grain formation. In case of urd and sesame sustained performance was obtained by giving average yield of 5.78 q/ha and 2.23 q/ha, respectively.

During *Rabi* season, even under rainfed condition, the toria crop had given good performance even under degraded rainfed condition. The data presented in table 6 indicated that there was very low differences in the grain yield of toria under different combinations but there was high variation in different years. The yield varied from

Table 5. Drymatter yield (q/ha) of groundstorey crops grown with mango

Kharif season				Rabi season				
Groundstorey crop	1997	1998	Mean	Groundstorey crop	1996	1997	1998	Mean
Cowpea	26.50	28.92	27.71	Toria	11.15	13.50	10.15	11.60
Clusterbean*	-	-	-	Toria	11.20	13.62	10.25	11.69
Arhar**	77.42	74.52	75.97	Arhar	-	-	-	-
Sesame	12.35	11.75	12.05	Toria	11.10	13.55	10.10	11.58
Urd	17.50	18.25	17.88	Toria	11.24	13.26	10.35	11.62

* Crop failure, **Arhar grown year the round

Table 6. Grain yield (q/ha)of groundstorey crops grown with mango

Kharif season				Rabi season				
Groundstorey crop	1997	1998	Mean	Groundstorey crop	1996	1997	1998	Mean
Cowpea*	8.45	20.52	14.49	Toria	3.16	4.15	2.42	3.24
Clusterbean**	-	-	-	Toria	3.17	4.32	2.40	3.30
Arhar***	3.56	-	3.56	Arhar	-	-	-	-
Sesame	2.10	2.35	2.23	Toria	3.09	4.30	2.50	3.30
Urd	5.20	6.36	5.78	Toria	3.18	4.10	2.68	3.32

* Green pod yield, **Crop failure, ***No grain formation in second year

2.5 q/ha (1998) to 4.21 q/ha (1997). The trend was similar to that of drymatter yield. The main factor responsible for variation in grain yield of toria was rainfall distribution during crop growing season. The influence of rainfall distribution on the yield is depicted in fig 1. It is concluded from the figure that the grain yield of toria during 1998 was less than 1997 despite higher total rainfall in 1998 (280 mm) as compared to 1997 (159 mm) during crop growing season (October to December).

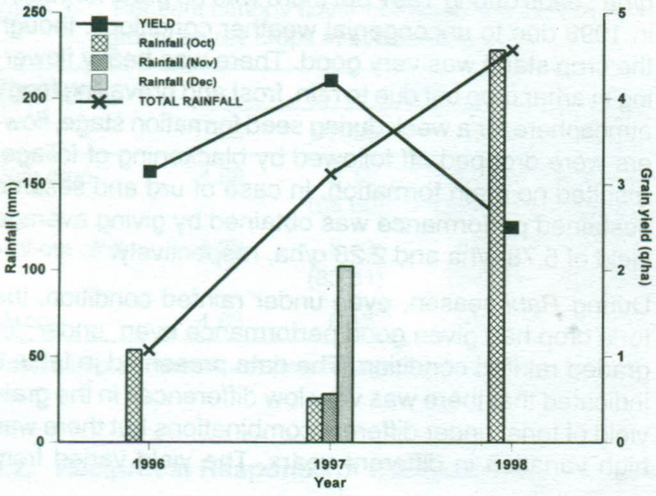

Fig.1 Grain yield of toria as influenced by rainfall distribution during growing season (Oct.-Dec.)

3.3.3. *Effect of Direction and Distance on Yield of Toria*

The effect of overstorey component (mango) on the yield of *Kharif* season crops was not prominent but significant variation was observed on the grain yield of toria in different years. During second year (1996) of cropping, yield was neither affected by directions nor by distance from tree basin, as the tree canopy cover was very low at this stage. The yield was also not much affected by directions during third (1997) and fourth year (1998) but slightly better yield was obtained in north and west directions during both the years, due to better soil moisture regime in those directions. Infact, sun rises in the north-east and sets in the west by moving clock-wise direction, hence sunny hours are more in east and south directions, which lead to reduction in soil moisture regime in those directions, owing to poor yield response. Under similar agroclimatic conditions, the non-significant effect of direction on the yield of groundstorey crops with forest trees have already been reported by Saroj et al. (1999).

The yield was also recorded at different lateral distances from tree basin and it was observed that the yield was lower in the vicinity of tree and it was increased with increasing lateral distances form tree basin as depicted in fig.2. Reduction in yield in the vicinity of tree was due to shading effect of overstorey component. The results are in conformity with those of Bhuva et al., 1989; Forell, 1990; Ralhan et al., 1992; Saroj and Arora, 1994 and Saxena et al., 1990, where they reported inverse relationship between yield and canopy cover of mango based AFS during *Rabi* season. During third year (1997), the yield reduction at 0-1 and 1-2 m lateral distances were about 12 and 6 per cent, respectively over yield in-between tree rows while there was least difference between 2-3 m and in-between tree rows. The reduction was further increased with increasing canopy cover during 1998. In this year, at 0-1 and 1-2 m lateral distances the yield reduction was to the tune of 18 and 11 per cent, respectively over yield in-between rows.

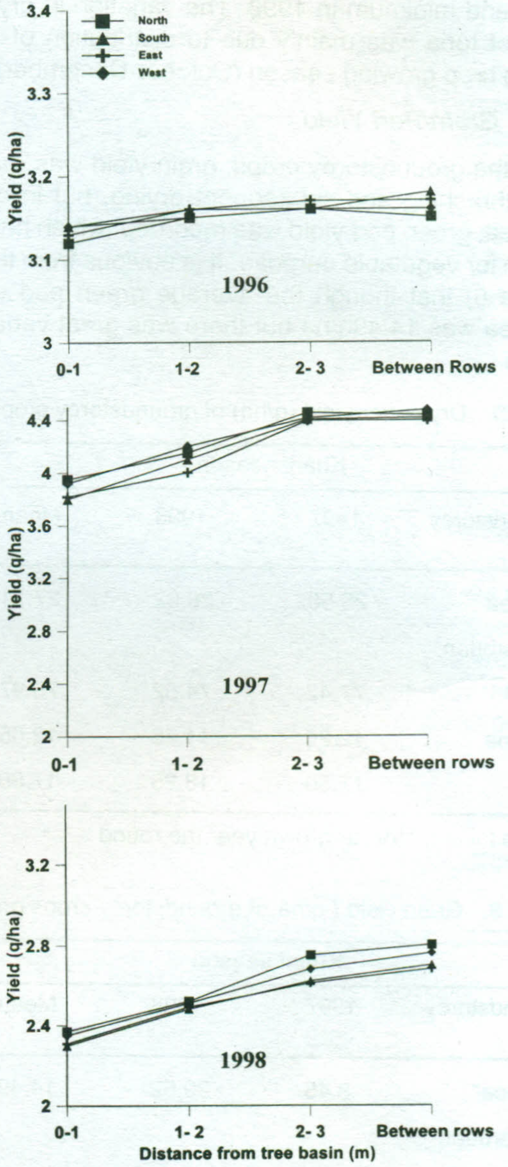

Fig.2 Effect of Distance and direction on yield of toria with mango plantation

3.4. Economics of Groundstorey Crops

Besides other, economic viability is one of the essential consideration for adoption of any technology under farmers field. Data given in table 7 revealed that maximum net return per year was obtained with urd-toria rotation (Rs. 8658.00/ha) followed by cowpea-toria (Rs. 6387.00/ ha), sesame-toria (Rs. 4652/ha), respectively under degraded rainfed conditions. The clusterbean crop was completely failed. Arhar was grown year the round and very susceptible to adverse weather conditions, hence it was also not considered as good groundstorey crop with mango. The maximum B:C ratio was also recorded with urd-toria rotation (3.89) followed by cowpea-toria (2.69) and sesame-toria (1.72), respectively. It is also important to point out that there was very low yield of cowpea in 1997 as compared to 1998 but this rotation ranked on second place from economic viability point of view. This indicated that apart from urd-toria, the cowpea-toria rotation may be one of the profitable combinations in association with mango in the initial year.

4. CONCLUSION

It is obvious that mangoes are an integral component of various agroforestry systems on good land but present investigation revealed that mango based AFS can be practiced even on degraded land in north-western Himalayan region by adopting site specific management practices. Introduction of groundstorey crops at initial stage of mango plantation have positive influence on the vegetative vigour of perennial component. Among various groundstorey crops, urd-toria followed by cowpea-toria and sesame-toria rotation had given good yield and economic return without any adverse effect to mango plantation under degraded land.

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Table 7. Economics of groundstorey crops grown with mango

Kharif crops				Rabi crops					Gross output (Rs/ha)	Gross input (Rs/ha)	Net income (Rs/ha)	B.C ratio
	Income (Rs/ha)				Income (Rs/ha)							
Crops	1997	1998	Mean (a)	Crop	1996	1997	1998	Mean (b)	(a+b)			
Cowpea	4225	10260	7243	Toria	2844	3735	2178	2919	10162	3775	6387	2.69
Clusterbean	—	—	—	Toria	2853	3888	2168	2968	2968	1730	1238	1.72
Arhar	4984	—	2492	Arhar	—	—	—	—	2492	2350	142	1.06
Sesame	4620	4950	4785	Toria	2781	3870	2250	2967	7752	3100	4652	2.50
Urd	7800	9540	8670	Toria	2862	3690	2412	2988	11658	3000	8658	3.89

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