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Economic feasibility of *Melia composite* - radish based agrisilviculture systems

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Abstract
The present study was undertaken to assess the economic feasibility of *Melia composita* (8m × 5m, 8m × 4m) - radish based agrisilviculture and sole radish cropping systems. Among different cropping systems [*M. composita* (8m × 5m)-radish, *M. composita* (8m × 4m) - radish, and sole radish], the highest net returns of Rs. 2,92,364 per hectare and benefit-cost ratio (3.60) were obtained from *M. composita* (8m × 5m) - radish based system followed by sole cropping system while the lowest net returns of Rs. 2,19,918 ha^{-1} were obtained from closer spacing (8m × 4m) of *M. composita*. The present study pointed out that, intercropping of radish with *M. composita* at the spatial arrangement of 8m × 5m contributed the highest net returns even in later growth of tree development (up to 12 years). It indicates that *M. composita* - radish based agrisilviculture system can give better economic returns compared to the sole cropping system.

Keywords: Agroforestry, *Melia composita*, radish, economics, net returns

Introduction
Agroforestry is an agriculture technique of growing food crops and trees on the same land and has been labeled as “the future of agriculture”. It is widely practiced in the Himalayan region particularly; the Indian Himalayas represent 18% of India’s land area. The Indian Himalayas occupy a special place in the mountain ecosystems of the world. This region is not only important from the standpoint of climate and as a provider of life, giving water to a large part of the Indian subcontinent, but it also harbours a rich variety of flora, fauna, human communities, and cultural diversity. Agroforestry plays a vital role in the Indian economy by way of tangible and intangible benefits. In fact, agroforestry has high potential for simultaneously satisfying three important objectives *viz.*, protecting and stabilizing the ecosystems, producing a high level of output of economic goods, and improving income and basic materials to the rural population. It has helped in the rehabilitation of degraded lands on one hand and has increased farm productivity on the other. At present agroforestry meets almost half of the demand of fuelwood, 2/3 of the small timber, 70-80 per cent wood for plywood, 60 per cent raw material for paper pulp, and 9-11 per cent of the green fodder requirement of livestock, besides meeting the subsistence needs of households for food, fruit, fiber, medicine, etc. It is also realized that agroforestry is the only alternative to meet the target of increasing forest cover to 33 per cent from the present level of less than 25 per cent (Dhyani *et al*., 2013) [4].
M. composita Willd. (Syn. *M. dubia* Cav.), commonly known as Malabar neem, is an indigenous, fast-growing, multipurpose, short rotation, and valuable timber species that emerged as one of the most suitable tree species for different agroforestry systems. It is being planted in the agroforestry system either in block plantation or along the farm boundary. It occurs mostly in tropical moist deciduous forests of the Sikkim, Himalayas, north Bengal, upper Assam, Khasi Hills, north circle, Deccan, and the Western Ghats at an altitude of 1200 to 1800 meters. It is valued for its high-quality fungus and termite resistant timber for furniture, agricultural implements (Suprapti *et al*., 2004) [14], as substitute pulpwood species, fuelwood, and leaf used as a fodder. The flowers are said to provide excellent bee forage. The industrial and ecological significance of *M. composita* has encouraged the farmers to take large scale plantations with different intercrops (Parthiban *et al*., 2009) [10].

In the mid- Himalayan range, it is being preferred by the farmers to meet for fodder in scarcity, fuel, charcoal, tool handles, and making agricultural implements.
Radish (*Raphanus sativus* L.) belongs to the genus *Raphanus*, family Brassicaceae or Cruciferae, originated from the Central and Western China and India. It is one of the most ancient vegetables. Radish is a good source of vitamin A and vitamin C and minerals like calcium, potassium, iron, and phosphorus. The most popular eating part of radish is the tuberous roots although the entire plant is edible and the tops can be used as a leafy vegetable. It is a popular root vegetable in both tropical and temperate regions. It is a fast-growing winter crop and produces large bio-mass in a short time. It can be cultivated undercover for early production but large scale production infield is more common in India. It is invariably suggested that the adoption of any agroforestry technology is believed and adopted if it is economically viable (Bhusara *et al.*, 2016, Mohanty *et al.*, 2017) [1, 8]. Therefore, a combination of Radish - *M. composita* was evaluated for its economic feasibility in the mid-Hill zone of Himachal Pradesh.

Materials and methods

The present study was conducted at the experimental farm of Agroforestry, Dr. Y S Parmar University of Horticulture and Forestry, Nauni. The area is located at 30º 51' N latitude and 76º 11' E longitude, with an elevation of 1200 m above mean sea level and slope of 7-8 per cent, which falls in the sub-tropical, sub-humid agro-climatic zone of Himachal Pradesh, India. Radish (Var. Japanese white) was intercropped in 5.4 m^2 plots size at 30 cm × 10 cm spacing under 13-year old *M. composita* spaced at 8m × 5m and 8m × 4m and as sole cropping systems. The experiment was conducted in a randomized block design with three replications and the treatments were; T_1- *M. composita* (8m × 5m) + Radish, T_2- *M. composita* (8m × 4m) + Radish, and T_3- (Sole Radish).
The radish crop was harvested and cumulative yield was considered in economic analysis. In the case of *M. composita*, standing biomass at the age of 12 years was taken into account. Stem wood biomass of *M. composita* was computed following the standard formula: $ff = \frac{2h_1}{3h}$ where, ff - form factor, h_1 - height at which diameter is half of dbh, which was measured manually by climbing on trees, h - total height of the tree (Pressler, 1865 and Bitterlich, 1984) [12]. The volume of standing trees was calculated by Pressler's formula (1865) [12] and expressed in cubic meters. V = ff × h × g, where, V – volume, ff - form factor, h - total tree height, g - basal area. The volume per hectare was calculated by multiplying the mean volume with the number of trees per hectare. Biomass = average specific gravity of stem wood × volume. The specific gravity used for *M. composita*, 0.93 (Ranot and Sharma, 2013) [13].
The branch wood biomass of *M. composita* was estimated as per following procedure; the total numbers of branches irrespective of size were counted on each of the sample tree, and then these were categorized on the basis of basal diameter into three groups, *viz.*, < 6 cm, 6-10 cm and >10 cm. The fresh weight of two sampled branches from each group was recorded separately in the field and representative samples were taken to the laboratory for moisture and dry weight determination.
The dry weight of branches was determined using following formula;

$$moiture\ per\ cent = \frac{\text{Fresh weight} - \text{oven dry weight}}{\text{oven dry weight}} \times 100$$

$$\text{Total green biomass} = \text{Average fresh weight of sample} \times \text{number of branches},$$

$$\text{Total dry biomass} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \times \text{Total fresh weight of branches/ leaves and twigs.}$$

Total branch biomass per sample tree was determined as given by:

$$Bbt = n_1bw_1 + n_2bw_2 + n_3bw_3 = S\ nibwi$$

Where, Bbt - Branch biomass (fresh/dry) per tree, n_i - Number of branches in the i^{th} branch group, bw_i - average weight of branch of i^{th} group, i - 1, 2, 3,---------------- refers to branch group.

Results and discussion

The prices of inputs and cost of cultivation of *M. composita* + radish based agrisilviculture and as sole cropping systems are given in Tables 1 and 2. The gross and net returns from radish and wood biomass production (per hectare under each land-use system) was worked out on the basis of prevailing market rates of radish and *M. composita* wood (Table 1). The net returns from agrisilviculture systems are based on the annual standing biomass of *M. composita* up to the age of 12 years.
The outcomes introduced in Table 3 pointed out that, among *M. composita* - radish based agrisilviculture and sole radish cropping systems, on account of radish production, the most noteworthy net returns of Rs. 244689 ha^{-1} were gained from the sole cropping system followed by *M. composita* (8m × 5m) + radish and minimum (Rs. 160454 ha^{-1}) were acquired from *M. composita* (8m × 4m) + radish based agrisilviculture system. This is ascribed to the higher production of radish in sole cropping. Slightly lower production under trees is attributed to competition and low light under trees in the early stage of the growth of radish. On the other hand, on account of the stem and branch wood biomass (annual average of 12 years) of *M. composita*, the highest (Rs. 59464 ha^{-1} yr^{-1}) net returns were accrued from closer spacing of *M. composita* (8m × 4m) while, least (Rs. 50039 ha^{-1} yr^{-1}) were acquired from wider spacing of *M. composita* (8m × 5m). The higher net return from closer spacing is ascribed to the fact that closer spacing accommodates more numbers of trees per hectare.
Data introduced in Table 4 revealed that, overall, *M. composita* (8m × 5m) - radish based system provided the maximum net returns to the tune of Rs. 292364 ha^{-1} yr^{-1} followed by sole cropping system (Rs. 244689 ha^{-1} yr^{-1}) while *M. composita* (8m × 4m) - radish based agrisilviculture system provided the most reduced net returns (Rs. 219918 ha^{-1} yr^{-1}). Dutt and Thakur, (2004) [5] detailed that net returns were relatively more under agroforestry systems by combining *Ocimum sanctum* and *Tegetes minuta* with poplar at various spacing in contrast with mono-cropping. Similarly, Prajapati *et al.* (2020) [11] revealed the most elevated net returns of Rs. 164135 ha^{-1} from *M. dubia* - Sorghum Sudan grass-based silvipasture system. Jilariya *et al.* (2019) [6] reported net returns of Rs. 336360 ha^{-1} from *M. dubia* - Aloe vera based silvi-medicinal systems, which are higher contrasted with the present study. Chandana *et al.* (2020) [3] in rainfed conditions of Hyderabad have revealed net returns (Rs. 166775 ha^{-1}) from 6 years of old *M. composita* and Rs. 169732 ha^{-1} from *M. composita* - Pearl millet-based agri-silviculture system. Meena (2015) [7] has reported average net

returns of Rs. 79,652 ha from ber based horti-pasture system. Verma and Thakur (2011) [15] have reported returns ranging from Rs. 20286 to 58614 per hectare from agroforestry systems. The variation in net returns from various agroforestry systems might be because of nature, age, and prevailing market rates of outputs.

Results on the economic feasibility of *M. composita* + radish based agrisilviculture and as sole radish cropping on BCR, NPV and IRR pointed out that, among *M. composita* - radish based agrisilviculture and sole cropping systems, the maximum BCR (3.60) and IRR (24 %) were estimated from *M. composita* (8m × 5m) - radish based agrisilviculture system followed by sole radish cropping system with BCR (3.21) however, it showed higher NPV (222444.7) compared to tree-based land-use systems. The economic feasibility analysis expressed that wider (8m × 5m) spacing of *M. composita* is more viable compared to sole cropping. Among all the systems under study, higher net returns were obtained from *M. composita* (8m × 5m) - radish based agrisilviculture system hence, found economically superior compared to the rest of the land-use systems in the study. Nandal and Kumar (2010) [9] gained the highest NPV (67326), B: C ratio (1.75:1), and IRR (55%) from *M. azedarach* based agroforestry system involving dhaincha barseem as intercrop. The economics of agroforestry systems vary with the nature of components, prevailing edpho-climatic conditions, and market rates of outputs derived.

Conclusion

The economic returns from agroforestry systems are well documented by earlier researchers however, most of them are only up to 5 to 6 years of plantation and have suggested intercropping in the early stage of tree growth. The present study pointed out that, intercropping of radish with *M. composita* at the spatial arrangement of 8m × 5m contributed the highest net returns even in later growth of tree development (up to 12 years). It indicates that *M. composita* -radish based agrisilviculture system can give better economic returns compared to the sole cropping system. The IRR and BCR analysis likewise expressed that wider spacing (8m × 5m) of *M. composita* when intercropped with radish could be the most economically viable system. Consequently, wider spacing (8m × 5m) of *M. composita* is proposed for intercropping of radish even in the later stage of tree growth and development.

Table 1: Prevailing of inputs prices (Rs.) used and outputs from land use systems

S. No.	Commodity	Price (Rs.)
I.	**Cost of per unit inputs**	
	Radish seeds	1000 kg^{-1*}
	M. composita seedlings	5 $seedling^{-1*}$
	Farmyard manure	250 $quital^{-1*}$
	Urea	6.5 kg^{-1*}
	Single super phosphate	10 kg^{-1*}
	Murate of potash	18 kg^{-1*}
	Labour wages	300 day^{-1*}
	Tractor charges per hour	600 hr^{-1*}
II.	**Per unit output price**	
	Fresh Radish (leaves + root)	10 kg^{-1*}
	M. composita stem wood	4500 t^{-1**}
	M. composita branch wood	2000 t^{-1*}

*Price used as per local retailer in Nauni, Solan. **https://www.indiamart.com/sriraghavendranurseries-plantations.

Table 2: Cultivation and maintenance cost (Rs. /ha) of Radish and *M. composite*

A	radish	Land use systems		
		T_1	T_2	T_3
1	**Material Cost**			
A	Cost of seeds	8000	8000	8000
B	FYM	25000	25000	25000
C	Urea	1413.03	1413.03	1413.03
D	Single super phosphate	3000	3000	3000
E	Murate of potash	1080	1080	1080
2	**Labour Cost**			
a)	Ploughing	2400	2400	2400
b)	Preparation of beds	4500	4500	4500
c)	Sowing	3000	3000	3000
d)	Manures application	3000	3000	3000
e)	Weeding/Hoeing/earthing up	15000	16500	16500
f)	Irrigation	6000	6000	6600
g)	Picking/Harvesting	13500	12900	13500
h)	Transportation	3000	3000	3630
	Sub- Total	83400	84300	86130
3	Miscellaneous cost (2% of sub-total)	1668	1686	1722.6
4	Interest on working capital (7% of sub-total)	5838	5901	6029.1
	Total Variable Cost	90906	91887	93881.7
5	**Fixed Cost**			
	Land rent	10000	10000	10000
	Depreciation	250	250	250
	Land revenue	31.25	31.25	31.25
	Interest on fixed capital (7% of sub-total)	719.68	719.68	719.68
	Total Fixed Cost	11000.93	11000.93	11000.938
	Total Cost	101906.94	102887.94	104882.64
B	***M. composita* (up to 12 years)**			
	Items	**T_1**		**T_2**
1	Site Preparation	1000		1000

	Digging of pits	1000	1300
	Planting and Filling of pits	833	1200
	Cost of seedling	1250	1565
	Cost of FYM	750	937.5
	Weeding	1000	1350
	Pruning	3750	4800
	Extraction of pruned Material	3750	4800
	Miscellaneous (2% on total working capital)	266.66	339.05
	Interest on working capital (7%)	933.31	1186.675
	Land rent	41600	41600
	Depreciation and maintenance	246.66	308.91
	Total	56379.63	60387.14

T_1 - *M. composita* (8m × 5m), T_2 - *M. composita* (8m × 4m) and T_3 - Sole Radish

Table 3: Gross and net returns (Rs. /ha) from *Melia composita* – Radish based Agrisilviculture and sole cropping systems

Land use systems	**Radish**				***Melia composita***							**Total net returns from land use systems**
	Total radish yield (t/ha)	**Cost of cultivation**	**Gross Returns**	**Net returns**	**Wood biomass (t /ha)**			**Cost of Cultivation (Rs. /ha)**	**Gross Returns (Rs. /ha)**	**Net Returns (Rs. /ha)**	**Net returns (Rs. /ha/yr)**	
					Stem wood	**Branch wood**	**Pruning Material**					
T_1	350.22	107895	350220	242325	124.18	44.02	5	56380	656850	600470	50039	292364
T_2	269.33	108876	269330	160454	152.08	38.80	6	60387	773960	713573	59464	219918
T_3	355.56	110871	355560	244689	-	-	-	-	-	-	-	244689

Table 4: Overall economic feasibility of *Melia composita* – Radish based Agrisilviculture and sole cropping systems

Land use Systems	**Total Cost (ha^{-1} yr^{-1})**	**Gross returns (ha^{-1} yr^{-1})**	**Net returns (ha^{-1} yr^{-1})**	**Benefit cost ratio (BCR)**	**Net present value (NPV)**	**Internal rate of return (IRR)**
M. composita (8 × 5) + Radish	112593	404958	292364	3.60	189759.9	24%
M. composita (8 × 4) + Radish	113908	333827	219918	2.93	188487.8	23%
Sole Radish	110871	355560	244689	3.21	222444.7	-

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