Original Research Article

A Growing Prosperity of Okra Cultivation (*Abelmoschus esculentus* L.) underMahaneem (*Ailanthus excelsa*) basedAgro-Silviculture System in a Semi-Arid Region of India

Abstract

Production of food to feed the rapidly growing population of India is the current challenge. To overcome such global issues of food security and climatechange, there is need to develop a good economically feasible agroforestry systems in the tropics.Beside that, Indian farmers also facing the effect of climate change on monocropping system and lack of optimum land utilization for their economic sustainability.Hence, the economic feasibility of okra cultivation in theagri-silviculture system of mahaneem (*Alianthusexcelsa*) in the arid zone was conducted at the Regional Research Station in Bawal, Haryana, Indiaduring two consecutive rainy seasons from July 2020 to October 2020 and July 2021 to October 2021. To create an economically prosper agro-forestry system, okra varieties Varsha Uphar and Hisar Naveen was planted under various planting density of Mahaneem in agri-silvicultural system. Nevertheless, agroforestry is a compelling alternative that encourages social, economic, ecological and agricultural sustainability in response to these challenges.The ratio of net return to cultivation cost was used to compute the benefit-cost ratio for test of economic feasibility to the proposed agroforestry system in the semi-arid zone climate of India. The present study revealed that 10 x 10 m planting spacing with the Hisar Naveen okra variety calculated the highest net return (108528 Rs./ha & 123884 Rs./ha in the consecutive years) and benefit-cost ratio(1.90 & 1.86 in the consecutive years) which was highest profitable for farmers to get economic and ecological security.Hence, it is recommended that the Mahaneem-based agro-silviculture system, specifically incorporating the Hisar Naveen variety, proves to be economically more feasible compared to sole cropping which offers practical guidance for farmers and policymakers seeking effective strategies to enhance agricultural productivity amidst evolving environmental conditions.

Keywords: Agro-silviculture, Mahaneem, Okra, Agroforestry, Economic feasibility,Arid Zone Agricultural Sustainability.

INTRODUCTION

India is facing the challenge of population that is rapidly increasing, with a current count of approximately 1.39 billion people and growing at an alarming rate (Conway, 2012). In light of global issues like food security and climate change, the pursuit of efficient and sustainable farming practices has become crucial. Due to the increased demand for necessities like food, fuel and fodder put due to this population expansion, the natural ecological systems of arid and semi-arid regions that include water, land and vegetation are under tremendous strain. Ahmad *et al*. (2019) highlighted that agroforestry is a compelling alternative that encourages social, economic and ecological sustainability in response to these challenges. Growing ofagricultural crops under tree-based systems has been widely promoted in the tropical regions of the world as a natural resource managementstrategy that attempts to sustainable goals of agriculturaldevelopment with the conservation of soils,water, climate and biodiversity(Schroth *et al.* 2004). Nevertheless, agroforestry also provides direct and indirect benefits such as alternative sources of income and employmentto the rural poor (Balooni2003; Puri and Nair 2004; Samra *et al.* 2005; Handa*et al.* 2016; Mehta and Kaushik 2023). Therefore, an exciting opportunity to increase agricultural output is present by the convergence of commercially significant crop cultivation with new agro-silviculture systems in the Arid Zone Region of India. The climatic conditions in arid region of India are critical to grow tree crop and agricultural crops.

Agriculture crop *i.e.*Okra (*Abelmoschus esculentus* L.), cultivation under shade of Mahaneem (*Ailanthus excelsa* L.) in the semi-arid region of India, is a prime example of one such potential combination in action (Bhuyan *et al.*, 2021).Okra develops in a healthy environment because of the special properties of Maheeem, which include its ability to replenish the soil and provide a substantial amount of shade. When analysing the complexities of this mutually beneficial relationship, it becomes apparent that the MahaneemAgro-Silviculture concept improves the resilience of the agro-ecosystem overall in along with making okra production cheaper.

Hence, MahaneemAgro-Silviculture based agro-system is important because it can help with the immediate issue of food security. In addition to directly supplying food, Quandt *et al*. (2018) have said that this integrated method shows the ability to improve soil fertility and produce revenue for food purchases. India is confronted with a range of agricultural and environmental challenges, including deforestation, soil erosion, increasing livestock and human population pressure and a declining land-to-man ratio. Fast-growing tree species, especially *Ailanthus excelsa* (Roxb.), popularly called "Ardu" or "Mahaneem," must be incorporated in order to increase the nation's tree coverwhich is now less than 20% and meet the raw material requirements of wood-based industries (Mehta and Kausik, 2023). Kaushik *et al*. (2017) highlight *Ailanthus excelsa* as a key element in agroforestry systems and show the sustainability and economic potential of growing trees alongside crops.

The establishment of Mahaneem plants in agroforestry systems that extend across community land, farm boundaries and road avenues is essential to maintaining the stability of ecosystems because it reduces the fluctuations in climate parameters carried on by climate change (Jat et al. 2011). In order to meet the needs of human and livestock populations in a sustainable manner without depleting land or natural resources, *Ailanthus excelsa* integration into farming systems is especially well-suited for the degraded soils of arid and semi-arid agro-ecosystems (Kaushik *et al*., 2017).

Nevertheless, *Ailanthus excelsa* L.acknowledged for its economic significance due to gained popularity in sustainable development, improving the standard of living for resource-poor farmers in semi-arid areas. Mahaneem is a great addition to sustainable practices because to its fast growth, adaptability, and tolerance to diverse pressures. Its wood is used in industries, and its leaves provides valuable feed for tiny ruminants. In order to further support, sustainable agricultural practices in the area, the current study focuses on identifying appropriate combinations of various arable crops under the *Ailanthus excelsa*-based agroforestry system in the semi-arid zones of India. Hence, the present research studyprovides the economic feasibility of okra under the agro-silviculture system in complex relationships between the semi-arid climate of Haryanato insight into the sustainable practices that propel the increasing wealth of the farmers.

MATERIALS AND METHODS

Experimental Site: The present study was conducted at the Regional Research Station of the College of Agriculture, Bawal, Haryana, India which isgeographically is situated at 28.1°N latitude and 76.5°E longitude. The trial was conductedtwo consecutive rainy seasons *i.e.*, from July 2020 to October 2020 and July 2021 to October 2021.

Experimental Design and Details: Nine-year-old plantations of*Alianthusexcelsa* served as the tree component of this experiment which planted four distinct spacing configurations (10 × 20 m, 10 × 10 m, 10 × 6.5 m, and 10 × 5 m) with six-month-old *Alianthusexcelsa* seedlings. In order to established an agri-silvicultural system in agro-forestry, the second component of the system involved intercropping, especially the okra variety *i.e.*, Varsha Uphar and Hisar Naveen, sowed in conjunction with Mahaneem in all the spacings.

Cost-Benefit Ratio Analysis: The agroforestry system based on Ailanthus underwent a multi-step economic evaluation. The entire cost of cultivation was computed, including labour pay (for clearing land, planting seeds, weeding, watering, harvesting intercrops, and pruning trees), as well as costs for seeds, fertiliser, marketing, and other miscellaneous expenses. The gross return was expresses in rupees per hectare of the intercrop yield at various Mahaneem planting fourspacing. The cost of cultivation was then reducing from the gross return per hectare to arrive at the net return. The ratio of net return to cultivation cost was then use to compute the benefit-cost ratio.

Statistical Analysis:A two-factorial randomised block design with ten treatment combinations used in the experiment. Standard errors (S.Em.±) computed for each situation based on ten treatment combinations that used. Using the Panse and Sukhatme (1967) method, a crucial difference (CD) at a 5 percent probability level was calculate to compare treatment means when the treatment effects considered significant.Data presented in the Bar Diagram in the graphical form were prepared using MS Excel Spreadsheet.

RESULTS AND DISCUSSION

Evaluating the economic feasibility of cultivation and intercropping is pivotal for the judicious utilization of new agroforestry models. In this study, we conducted a comparative analysis of a Mahaneem (*Ailanthus excelsa* L.) based agroforestry systems with okra inter cropping under different planting spacing of mahaneem.The economic information of okra-based agroforestry systems showed in Table 1 that maximum cost of cultivation & gross return was foundin 10 x 10 m planting of mahaneemagro-siliviculture system whereas, least cost of cultivation and gross return was calculated in control (without tree). In case of higher net return and B:C ratio was observed 10 x10 m planting spacing while lease in control (without tree) in the year 2020-21 and 2021-22 (Table 1). When compared okra varieties, maximum gross return, net return and benefit cost ration was observed okra variety Hisar Naveen as compared to okra variety Varsha Uphar in both year (Table 1).

The highest profitability in terms of gross return (250232 & 294111 Rs./ha) was observed when Hisar Naveen variety of okra was sown with densely planted Mahaneem (10 × 5 m spacing)which was depicted in figure 2. The highest net return (108528 & 123884 Rs/ha) was obtained under 10 × 10 m spacing with the variety Hisar Naveen. In contrast, sole planted Varsha Uphar was the least profitable in terms of gross return (124273 & 130588 Rs/ha) and net returns (25207 & 19776 Rs/ha). Despite variations in net and gross returns, the Benefit-Cost ratio was maximum at 10 × 10 m with Hisar Naveen (1.89 & 1.86), while the lowest ratio was recorded in sole Varsha Uphar cropping (1.25 & 1.18) which was shown in figure 1. Notably, net returns and the Benefit-Cost ratio decreased in the second year of the experiment compared to the first, whereas the cost of cultivation and gross returns increased. When compare to agroforestry systems, sole okra growing shown the lowest cultivation costs (99066 & 110812 Rs/ha) in 2020–21 and 2021–22 (figure 1).Our results show that when compared to solo cropping, the agroforestry system based on *Ailanthus excelsa* produced greater net returns. In various planting spacings, a rise in the number of trees per hectare has resulted in an increase in the cost of cultivation, gross return, and net return, with or without trees. In okra variety Hisar Naveen, the maximum benefit-to-cost ratio was note with 10 × 10 m plant spacing in all systems. A higher number of trees per hectare, which would result in more wood and fodder production, could be the cause of the improved net returns (123884 Rs) for okra var. Hisar Naveen with 10 × 10 m plant geometry. In agreement with Banerjee *et al*. (2010), pruning and lopping of *A. excelsa* also contributed to greater wood yield.Pratap and Pant (2020) revealed that the net returns (Rs. 177672 ha^{-1}) were higher under wider spacing (8 × 5 m) of *Melia composita* based agroforestry system when okra intercropped as compared to the sole cropping system.

The increased crop productivity and accompanied rise in market prices are responsible for the improved returns under agroforestry systems. Kaushik *et al*. (2014) reported observed that horticultural systems with optimum returns are gain to field and vegetable crops. Furthermore, research conducted in North-West India's dry region showed that agri-silvi-horti systems produced higher net returns than solo cropping (Kaushik *et al*., 2017). These results have been supported by Ahlawat *et al*. (2021), who conclude that under an agroforestry system based on *Ailanthus excelsa*, the highest net returns were achieved in the wheat crop, followed by the onion crop, during the Rabi season of 2014–15.

CONCLUSION

The findings reveal that Mahaneem planting at a spacing of 10 × 10 m, particularly when coupled with the Hisar Naveen variety of Okra, yields the highest net realization and benefit-cost ratio. This outcome suggests that the Mahaneem-based agro-silviculture system, specifically incorporating the Hisar Naveen variety, proves to be economically more feasible compared to sole cropping. Consequently, this study offers practical guidance for farmers and policymakers seeking effective strategies to enhance agricultural productivity amidst evolving environmental conditions.

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Table 1: Economicsof Planting Spacing of Mahaneemunder Agri-Silviculture System (2020-21 & 2021-2022)

Tree Spacing (m) / Okra varieties	*Cost of cultivation (Rs./ha)*			*Gross return (Rs./ha)*			*Net return (Rs./ha)*			*B:C Ratio*		
	Varsha Uphar	*Hisar Naveen*	*Mean*	*Varsha Uphar*	*Hisar Naveen*	*Mean*	*Varsha Uphar*	*Hisar Naveen*	*Mean*	*Varsha Uphar*	*Hisar Naveen*	*Mean*
2020-21												
10 × 20	113022	113022	113022	161233	167901	164567	48211	54879	51545	1.43	1.49	1.46
10 × 10	121922	121922	121922	224227	230450	227339	102305	108528	105417	1.84	1.90	1.87
10 × 6.5	132574	132574	132574	225931	238224	232078	93357	105650	99504	1.71	1.80	1.75
10 × 5	142917	142917	142917	236084	250232	243158	93167	107315	100241	1.65	1.75	1.70
Control	99066	99066	99066	124273	128382	126328	25207	29316	27262	1.26	1.30	1.28
Mean	121900	121900		194350	203038		72449	81138		1.58	1.65	
C.D. (5%)												
Tree Spacing	2258			4340			5301			0.053		
Varieties	NS			2745			3353			0.033		
Tree Spacing × Varieties	NS			NS			NS			NS		
2021-22												
10 × 20	129518	129518	129518	182000	189044	185522	52482	59526	56004	1.41	1.46	1.43
10 × 10	144081	144081	144081	262013	267965	264989	117932	123884	120908	1.82	1.86	1.84
10 × 6.5	159966	159966	159966	268211	281217	274714	108245	121251	114748	1.68	1.76	1.72
10 × 5	175541	175541	175541	279289	294111	286700	103748	118570	111159	1.59	1.68	1.63
Control	110812	110812	110812	130588	135044	132816	19776	24232	22004	1.18	1.22	1.20
Mean	143984	143984		224420	233476		80437	89493		1.53	1.59	
C.D. (5%)												
Tree Spacing	2354			7252			8049			0.06		
Varieties	NS			4587			5091			0.038		
Tree Spacing × Varieties	NS			NS			NS			NS		

Note: NS= non-significant

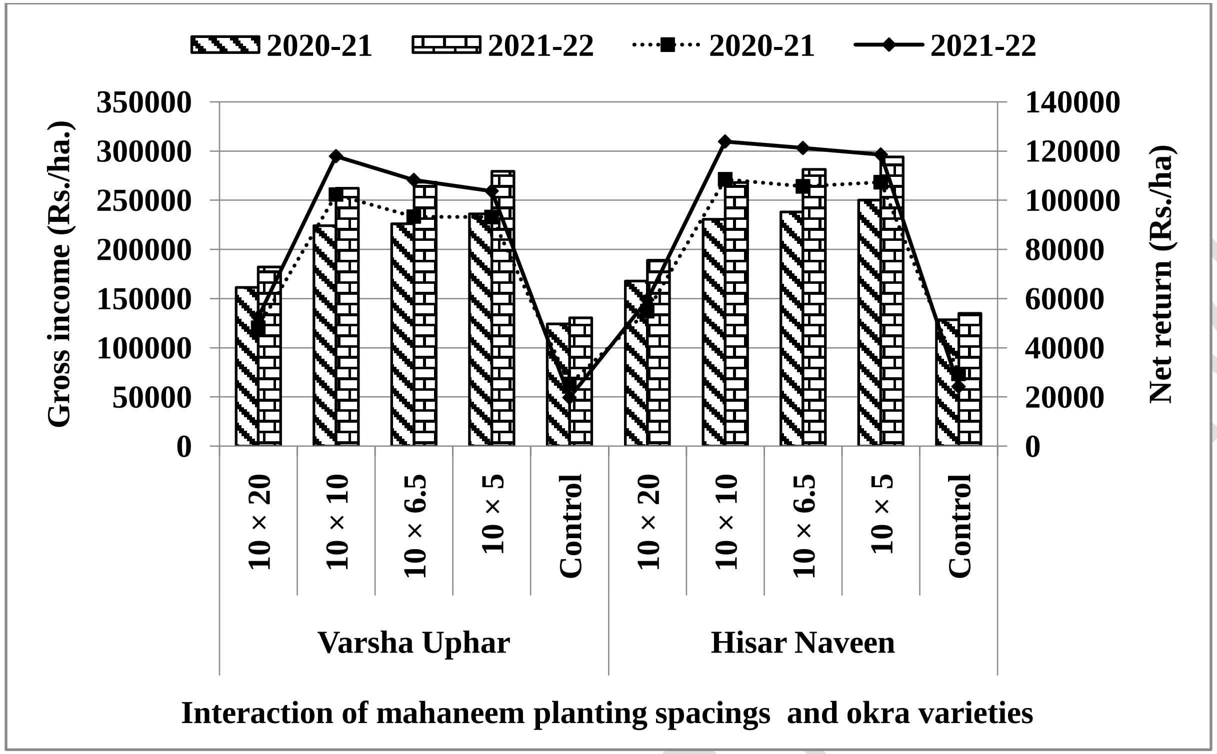

Fig. 1: Gross Return and Net Return of Interaction of Planting Spacing of Mahaneem and Intercrop Okra Varieties under Agri-Silviculture System and Okra Sole Cropping System (2020-21 & 2021-2022)

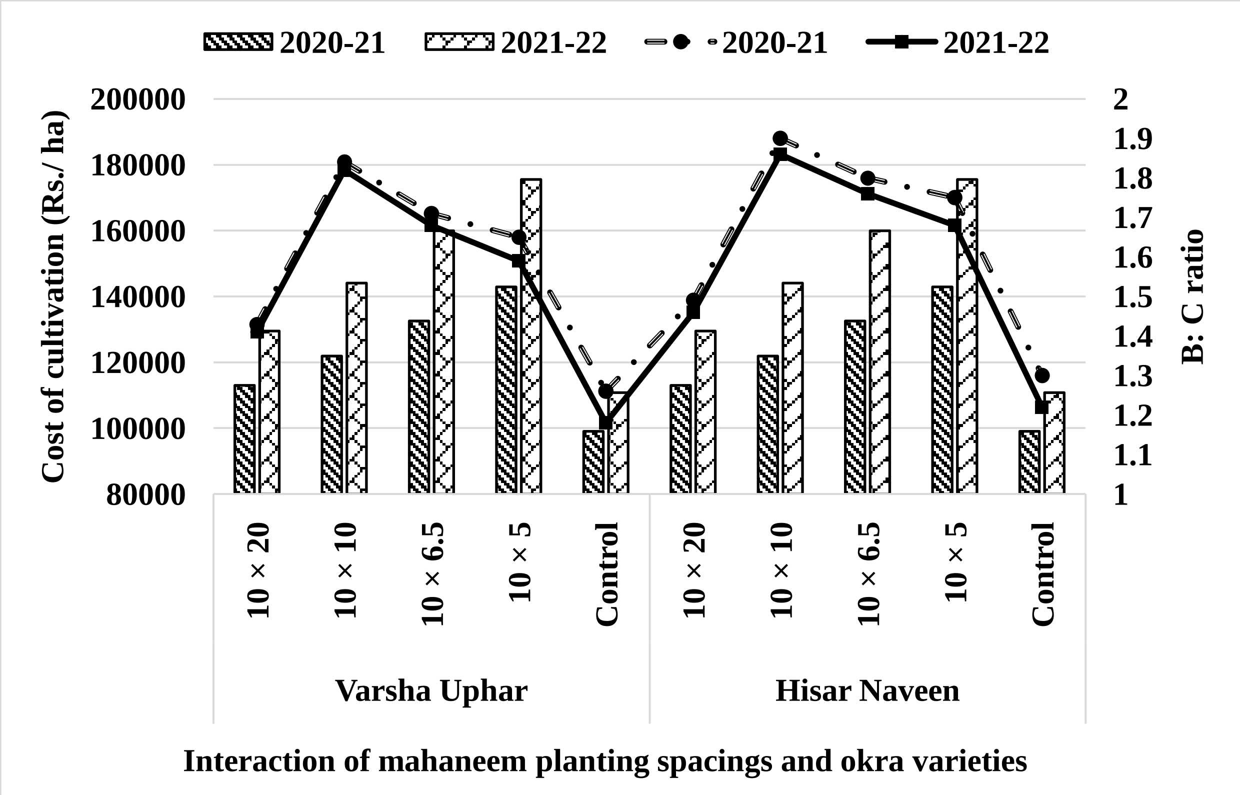

Fig. 2: Cost of Cultivation (Rs/ha) and B:C ratio of Interaction of Planting Spacing of Mahaneem and Intercrop Okra Varieties under Agri-Silviculture System and Okra Sole Cropping System (2020-21 & 2021-2022)