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Comparative effect of NPK levels, organic manures and biofertilizer on growth & yield of wheat (*Triticum aestivum*) under chironji (*Buchanania lanzan spreng.*) based agroforestry system

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Abstract

A field experiment was carried out to assess the comparative effects of NPK levels, organic manures, and biofertilizers on the growth and yield of wheat under Chironji-based agroforestry at the Forestry Nursery, Research Farm, College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, U.P. The study was conducted using wheat variety DBW 187 in a randomized block design with three replications, involving thirteen treatments that combined inorganic fertilizers (NPK), organic manures (FYM, vermicompost, poultry manure), and biofertilizer (Azotobacter) at 75%, 50%, and 25% levels. The findings revealed that the integrated application of 75% NPK+ 25% vermicompost significantly enhanced both growth and yield parameters. Among pre-harvest traits, this treatment recorded the maximum plant height, number of tillers, and leaf length, while post-harvest attributes such as panicle length, grains per panicle, test weight, grain yield, straw yield, and harvest index were also highest. Economic analysis indicated that this treatment was the most profitable, providing superior returns relative to input costs. The study suggests that partial substitution of chemical fertilizers with organic amendments like vermicompost, in combination with biofertilizers, can effectively improve wheat productivity and economic returns under Chironji-based agroforestry systems.

Keywords: Agroforestry, inorganic, wheat, organic fertilizers, chironji

1. Introduction

Agroforestry is a dynamic and ecologically oriented land-use system that integrates trees and other woody perennials into farms and rangelands to diversify production while ensuring environmental, social, and economic benefits (Handa *et al.*, 2016) ^[21]. By combining trees, shrubs, crops, and sometimes livestock, agroforestry aims to enhance productivity, profitability, and sustainability of ecosystems (National Agroforestry Policy, 2014) ^[28]. Globally, approximately 43% of agricultural land (over one billion hectares) has more than 10% tree cover, with 160 million hectares exceeding 50% tree coverage (Zomer *et al.*, 2009). The presence of trees in agricultural landscapes has been shown to improve nutrition, income, housing, health, energy security, and environmental sustainability, forming the basis of “evergreen agriculture” promoted by the World Agroforestry Centre (ICRAF, 2008) ^[22, 36].

The primary objective of agroforestry is to optimize production and economic returns per unit area while maintaining sustainability. To achieve this, several agroforestry models have been developed, combining tree-crop-livestock systems to maximize economic returns either simultaneously or sequentially. Such models are designed to be technologically feasible, ecologically sustainable, economically viable, and socially acceptable.

Buchanania lanzan, commonly known as Chironji, Cuddapah almond, or Char, is a valuable tree species native to India and widely distributed across Madhya Pradesh, Chhattisgarh, Jharkhand, Southeast Uttar Pradesh, Gujarat, Rajasthan, Orissa, Andhra Pradesh, Karnataka, and Maharashtra. Its timber is moderately termite-resistant and is used for furniture, boxes, crates, and agricultural implements, while the gum and lac support the livelihoods of tribal communities, especially in Sonbhadra District of Uttar Pradesh.

Despite its socioeconomic importance, over-exploitation and indiscriminate harvesting have caused a decline in Chironji populations, posing a threat to its survival (Kumar *et al.*, 2012; Chauhan *et al.*, 2012). Additionally, insect pests such as the stem borer *Placaederus obesus* further threaten its productivity (Malik *et al.*, 2012; Meshram & Soni, 2011) [19, 24, 26, 27].

Wheat, an annual crop of the Gramineae family, is extensively cultivated in India over 27.92 million ha, producing approximately 80.71 million tons at an average productivity of 2,891 kg/ha (Anonymous, 2009-2010) [17]. India contributes roughly 12% of the world's wheat production. Over the last 35 years, wheat production has increased by more than 600%, with nutrient consumption rising from 3 kg/ha in 1961 to 91 kg/ha in 2009 (The Hindu Survey of Indian Agriculture, 2012) [34].

While wheat requires adequate nutrition for optimum growth, organic manures alone are insufficient to meet its nutrient demands, resulting in lower yields (Sheoran *et al.*, 2017). Timely application of chemical fertilizers significantly enhances wheat productivity (Lewis *et al.*, 1938). Studies have shown that combining mineral fertilizers with organic manures improves plant growth, field efficiency, and water use efficiency (Zhang *et al.*, 2016). Inoculation with biofertilizers further enhances crop growth, tiller survival, and yield (Ahmed *et al.*, 2011; Singh *et al.*, 1986) [16, 24, 30, 31, 35].

Proper plant nutrition using organic manures is fundamental for sustainable agriculture, improving both the quality and quantity of agricultural produce while enhancing soil health (Jat *et al.*, 2015). Organic fertilizers increase soil biological activity, improve nutrient availability, maintain soil structure, and enhance the growth of beneficial microorganisms (Chew *et al.*, 2019) [20, 23].

Vermicompost is a nature-friendly biotechnological process that converts organic waste into nutrient-rich fertilizer. Its

application increases soil micronutrient content, particularly zinc and copper, while improving soil health (Thakur *et al.*, 2021). Azotobacter, a free-living nitrogen-fixing bacterium, contributes 25-30 kg N/ha, enhancing wheat yield and quality (Sharma *et al.*, 1987; Bhattacharyya *et al.*, 2000) [18, 29, 33]. Integrating organic manures and biofertilizers with chemical fertilizers not only sustains soil fertility but also reduces dependence on chemical inputs, supporting long-term crop productivity.

Despite the recommended doses of chemical fertilizers, wheat productivity is plateauing due to soil degradation and depletion of organic matter and nutrients. Therefore, it is essential to explore integrated nutrient management practices combining organic manures, biofertilizers, and chemical fertilizers to maintain soil fertility, improve crop growth, and enhance yield sustainably under Chironji-based agroforestry systems.

2. Materials and Methods

2.1 Study Area

The research work will be carried out during the year 2023-2024 in the research and nursery of the College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, situated at south of river of Yamuna and Rewa road at a distance of 6 km from Prayagraj city. Geographically Prayagraj city is located at an elevation of 98 m amsl 25.28° N latitude and 81.54° E longitudes. The area of Prayagraj district comes under subtropical belt in the south-east UP of India. Atmospheric temperature widely varying from 40°C or even less during winter to 46°C in summer. Annual rainfall is 1100 mm, major part of which is received i.e. during monsoon season in the middle of July to end of September after which the intensity of rainfall decreases. However, occasional precipitation is also not uncommon during winter.

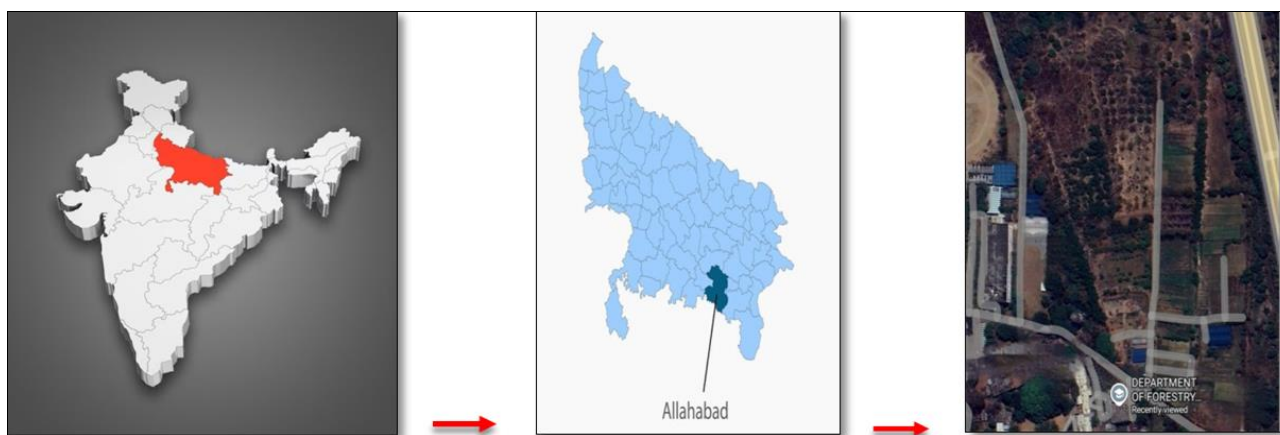


Fig 1: Study Area, College of Forestry, SHUATS, Prayagraj, Uttar Pradesh

The experiment was conducted using a Randomized Block Design (RBD) with 13 treatment combinations, each replicated three times, resulting in a total of 39 plots. The wheat variety DBW 187 was used, and treatments were randomly allocated within each replication. The treatments included combinations of inorganic fertilizers (NPK), organic manures (FYM, vermicompost, poultry manure), and biofertilizer (Azotobacter) at different proportions: T₀-Absolute Control; T₁-25% NPK + 75% FYM; T₂-50% NPK + 50% FYM; T₃-75% NPK + 25% FYM; T₄-25% NPK + 75% Vermicompost; T₅-50% NPK + 50% Vermicompost; T₆-75% NPK + 25% Vermicompost; T₇-25% NPK + 75% Poultry Manure; T₈-50% NPK + 50% Poultry Manure; T₉-75% NPK + 25% Poultry Manure; T₁₀-25% NPK + 75% Azotobacter; T₁₁-50% NPK + 50% Azotobacter; and T₁₂-

75% NPK + 25% Azotobacter. The soil at the experimental site was sandy loam, with baseline characteristics varying slightly under open conditions and under Chironji trees. Under open conditions, the soil pH was 6.9, organic carbon 0.28%, electrical conductivity 0.12 dS/m, nitrogen 248 kg/ha, phosphorus (P₂O₅) 14 kg/ha, and potassium (K₂O) 170 kg/ha, whereas under Chironji, the respective values were 6.6, 0.38%, 0.16 dS/m, 231 kg/ha, 20 kg/ha, and 187 kg/ha (KVK, Allahabad, 2025). This experimental setup allowed assessment of integrated nutrient management using inorganic, organic, and biofertilizer sources in wheat under Chironji-based agroforestry systems.

3. Results and Discussion: The pre-harvest data on the plant height, number of tillers, leaf length are presented in Table 1 and

Figure 2 under open and under Chironji based Agroforestry System which revealed that there were significant differences

between organic and combination of inorganic and organic fertilizers on the growth parameters.

Table 1: Effect of NPK levels, organic manures and bio fertilizer on growth attributes of wheat under Chironji based Agroforestry System

T. No.	Plant Height (cm) (120 DAS)		Number of Tillers (120 DAS)		Leaf length (cm) (120 DAS)	
	Open Condition	Agroforestry System	Open Condition	Agroforestry System	Open Condition	Agroforestry System
T ₀	64.33	59.62	5.86	4.06	22.67	21.38
T ₁	92.1	85.54	7.93	6.64	27.83	26.6
T ₂	102.9	100	9.4	7.91	29.76	27.6
T ₃	108.8	106.7	11.2	10.01	31.2	29.12
T ₄	91.63	84.1	7.33	6.06	27.63	26.55
T ₅	101.9	96.46	9.06	7.46	28.93	27.23
T ₆	110.3	107.7	12.16	10.1	32.43	30.11
T ₇	91.16	83.3	7.26	5.67	26.06	25.14
T ₈	96.33	93.23	8.9	7.14	28.43	27.17
T ₉	104.7	103.8	10.66	9.08	30.06	28.26
T ₁₀	91.03	83.16	6.6	5.03	24.66	23.38
T ₁₁	94.73	91.96	8.2	7.03	27.96	27.13
T ₁₂	107	104.4	11.14	9.93	30.1	28.4
F-test	S	S	S	S	S	NS
C.D. at 0.5%	3.335	5.567	0.688	1.153	4.318	-
S.Ed. (+)	1.606	2.681	0.331	0.556	2.08	-

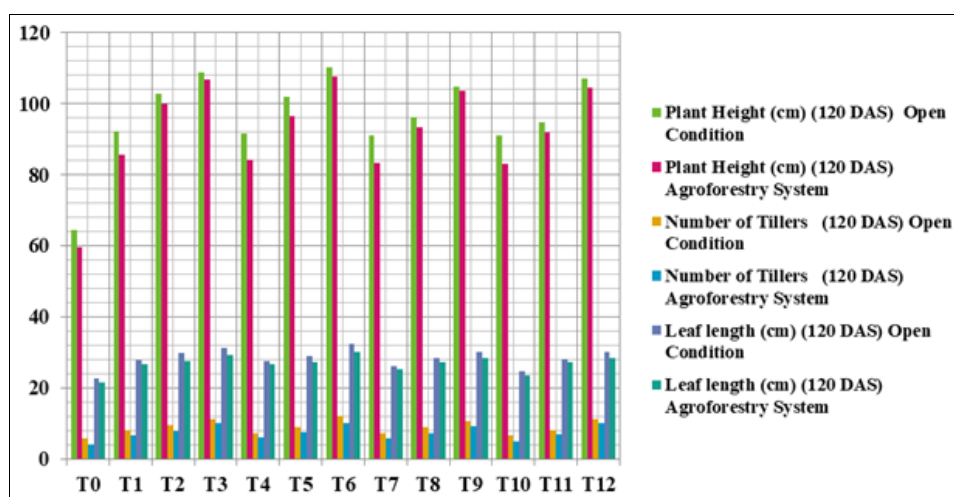


Fig 2: Effect of NPK levels, organic manures and bio fertilizer on growth attributes of wheat under Chironji based Agroforestry System

3.1 Growth Attributes

At 120 days after sowing (DAS), plant growth parameters showed significant variation among treatments under both Chironji-based agroforestry and open field conditions. The maximum plant height under Chironji was recorded in T₆ (75% NPK + 25% Vermicompost) at 107.7 cm, followed closely by T₃ (75% NPK + 25% FYM) at 106.73 cm, while the minimum height was observed in the absolute control T₀ (59.62 cm). Similarly, in the open field, the highest plant height was observed in T₆ (110.3 cm), followed by T₃ (108.8 cm), with the lowest in T₀ (64.33 cm). These results are consistent with findings reported by Santhosh and Mehera (2022) [32].

The number of tillers per plant at 120 DAS also showed maximum values in T₆, recording 10.10 tillers under Chironji and 12.16 tillers under open field, followed by T₃ (10.01 and 11.2 tillers, respectively). The minimum tiller number was observed in T₀ (4.06 under Chironji; 5.86 in open field), aligning with results by Satish *et al.* (2022) [9].

Similarly, leaf length was greatest in T₆ (30.11 cm under Chironji; 32.43 cm in open field), followed by T₃ (29.12 cm; 31.2 cm), while the shortest leaves were recorded in T₀ (21.38 cm; 22.67 cm). Overall, the combination of 75% NPK + 25% Vermicompost (T₆) consistently promoted superior vegetative growth under both agroforestry and open field conditions.

Table 2: Effect of NPK levels, organic manures and bio fertilizer on yield attributes of wheat under Chironji based Agroforestry

T. No.	Length of Panicle (cm)		Number of Grains Panicle ⁻¹		Test Weight (g)	
	Open Condition	Agroforestry System	Open Condition	Agroforestry System	Open Condition	Agroforestry System
T ₀	10.7	9.63	22.63	20.2	45.27	44.67
T ₁	12.35	11.32	27.43	25.43	46.4	46.33
T ₂	13.6	12.61	29.5	27.59	47.67	46.83
T ₃	14.73	14.3	31.2	29.6	50.47	48.93
T ₄	11.93	11.2	27.3	25.28	46.2	45.3
T ₅	13.33	12.44	29.4	27.54	47.47	46.7
T ₆	15.03	14.4	32.63	30.41	51.17	49.47

T ₇	11.26	10.6	27.1	24.99	45.9	45.27
T ₈	13.23	12.33	28.46	26.43	47.33	46.67
T ₉	14.36	13.28	30.53	28.23	48.73	47.83
T ₁₀	11.23	10.2	25.5	23.2	45.43	45.18
T ₁₁	13.1	11.79	28.1	26.07	47.03	46.18
T ₁₂	14.56	14.22	30.9	29.12	49.9	48.37
F-test	S	S	S	S	S	S
C.D. at 0.5%	1.479	1.482	0.947	2.044	2.438	2.469
S.Ed. (±)	0.712	0.714	0.456	0.984	1.174	1.189

The post-harvest data on the Length of Panicle (cm), Number of Grains Panicle⁻¹, Test Weight (g) are presented in Table 2 and

Figure 3 under open and under Chironji based Agroforestry System.

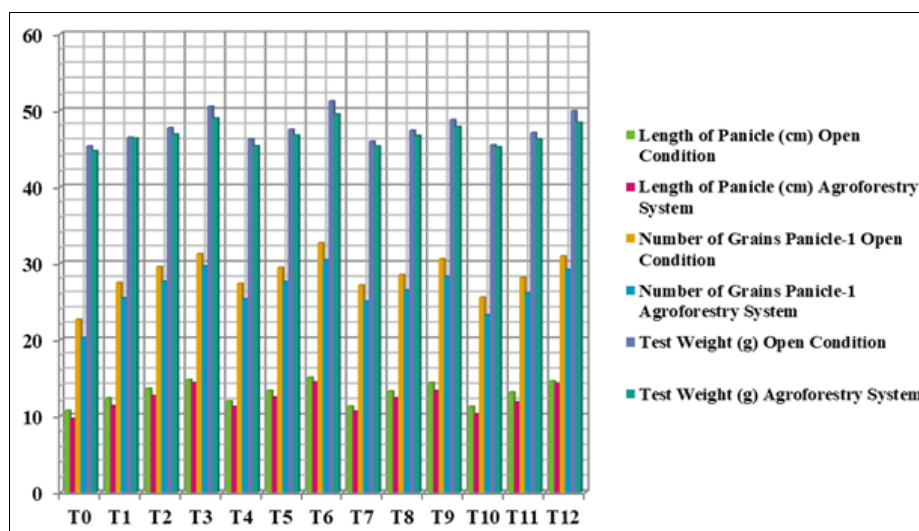


Fig 3: Effect of NPK levels, organic manures and bio fertilizer on yield attributes of wheat under Chironji based Agroforestry

At harvest, yield attributes of wheat showed significant differences among the treatments under both Chironji-based agroforestry and open field conditions. The maximum panicle length under Chironji was observed in T₆ (75% NPK + 25% Vermicompost) at 14.40 cm, followed closely by T₃ (75% NPK + 25% FYM) at 14.30 cm, while the shortest panicles were recorded in the control T₀ (9.63 cm). In the open field, the highest panicle length was noted in T₆ (15.03 cm), followed by T₃ (14.73 cm), with the minimum in T₀ (10.7 cm), corroborating the findings of Santhosh and Mehera (2022) [32].

The number of grains per panicle was also highest in T₆ (30.41 under Chironji; 32.63 in open field), followed by T₃ (29.60; 31.2), whereas T₀ recorded the lowest values (20.2; 22.63). Similarly, test weight reached its maximum in T₆ (49.47 g under

Chironji; 51.17 g in open field), followed by T₃ (48.93 g; 50.47 g), with the minimum observed in T₀ (44.67 g; 45.27 g), aligning with results reported by Prajapati *et al.* (2022) [8]. Overall, the treatment T₆ (75% NPK + 25% Vermicompost) consistently resulted in superior yield attributes, highlighting the effectiveness of integrating chemical fertilizers with organic manures for enhancing wheat productivity under both agroforestry and open field systems.

3.2 Yield Attributes

The yield data on the Grain Yield (t/ha), Straw Yield (t/ha), Harvest Index (%) are presented in Table 3 and Figure 3 under open and under Chironji based Agroforestry System.

Table 3: Effect of NPK levels, Organic manures and biofertilizer on yield attributes of wheat under Chironji based Agroforestry System

T. No.	Grain Yield (t/ha)		Straw Yield (t/ha)		Harvest Index (%)	
	Open Condition	Agroforestry System	Open Condition	Agroforestry System	Open Condition	Agroforestry System
T ₀	1.79	1.73	1.91	1.88	45.4	43.11
T ₁	3.51	3.3	3.7	3.36	48.01	46.79
T ₂	3.7	3.54	3.91	3.59	49.16	48.19
T ₃	4.02	3.99	4.4	4.28	50.9	48.55
T ₄	3.41	3.13	3.43	3.15	47.93	46.6
T ₅	3.69	3.52	3.89	3.67	48.72	47.97
T ₆	4.36	4.08	4.6	4.4	51.02	49.35
T ₇	3.16	3.06	3.18	3.08	47.82	46.52
T ₈	3.68	3.4	3.82	3.63	48.2	47.72
T ₉	3.82	3.55	4.1	3.71	49.76	48.3
T ₁₀	2.94	2.61	3.07	2.9	47.19	46.07
T ₁₁	3.65	3.33	3.74	3.53	48.17	47.15
T ₁₂	3.92	3.76	4.23	4.05	50.84	48.4
F-test	S	S	S	S	S	S
C.D. at 0.5%	0.775	0.706	0.559	0.686	2.43	2.53
S.Ed. (±)	0.373	0.34	0.269	0.331	1.174	1.23

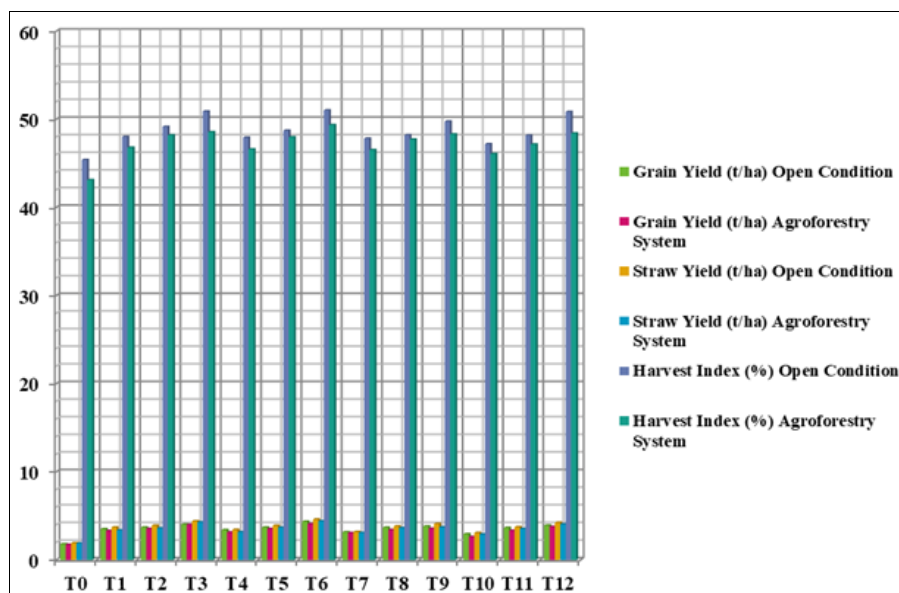


Fig 4: Effect of NPK levels, Organic manures and biofertilizer on yield attributes of wheat under Chironji based Agroforestry System

The grain yield of wheat varied significantly among treatments under both Chironji-based agroforestry and open field conditions. Under Chironji, the highest grain yield was recorded in T₆ (75% NPK + 25% Vermicompost) at 4.08 t/ha, followed by T₃ (75% NPK + 25% FYM) at 3.99 t/ha, while the lowest yield occurred in the control T₀ (1.73 t/ha). In the open field, grain yield was similarly highest in T₆ (4.36 t/ha), followed by T₃ (4.02 t/ha), with the minimum in T₀ (1.79 t/ha), consistent with observations reported by Satish *et al.* (2022) [9].

The straw yield exhibited a similar trend, with T₆ producing the maximum straw yield (4.40 t/ha under Chironji; 4.60 t/ha in open field), followed by T₃ (4.28; 4.40 t/ha), and T₀ showing the lowest values (1.88; 1.91 t/ha). Likewise, the harvest index was highest in T₆ (49.35% under Chironji; 51.02% in open field), followed by T₃ (48.55%; 50.90%), while the lowest was observed in T₀ (43.11%; 45.40%). These results indicate that integrating 75% NPK with 25% Vermicompost (T₆) consistently enhanced both grain and straw yields as well as the harvest index, demonstrating the benefits of combined chemical and organic nutrient management under both agroforestry and open field systems.

Conclusion: Based on the field experiment, among the 13 treatments evaluated under both open field and Chironji-based agroforestry systems, Treatment T₆ (75% NPK + 25% Vermicompost) consistently performed best, recording the highest grain yield, straw yield, and harvest index. T₆ also showed the highest benefit-cost (B:C) ratio, with 2.97 under open conditions and 2.74 under Chironji trees. The study further indicated that, at present, wheat (or garlic, depending on your crop context) grown in open conditions performed better than under Chironji trees, as the trees are still young and not yet producing fruits. However, in the long term, Chironji-based agroforestry is expected to generate higher income once the trees start yielding fruits after 3-4 years, with Chironji kernels fetching ₹600-2,000 per kilogram in the Indian market. Consequently, the B:C ratio of the agroforestry system is likely to increase, making it more profitable than monoculture cultivation. It is therefore recommended that further long-term research be carried out on this agroforestry model to validate its economic potential and to encourage adoption by farmers for sustained productivity and profitability.

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