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Unleashing the Potential of Industrial Agroforestry: A Success Story in Bundelkhand Region

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Introduction

Industrial agroforestry in Bundelkhand holds immense potential for revitalizing the agricultural landscape, empowering local farmers, and fostering economic resilience. By incorporating agroforestry into industrial and farming practices, the region can create a balanced, sustainable ecosystem that supports both environmental health and economic growth. Considering the shortage of suitable raw material, the wood based industries have to establish plantation of suitable species to achieve maximum yield within a short rotation period. There are some of the species suitable for various industrial uses such as timber, plywood pulpwood, pencil making, match splints, dendro energy, packing cases, flooring & construction and other utilities.

Considering the potential of trees in the economy of the rural population of the region, RLBCAU initiated integration of fast growing trees on these marginal agriculture lands with legumes. The trees viz. Melia (*Melia dubia*), Kadamb (*Neolamarckia cadamba*), Khamer (*Gmelina arborea*) & Ardu (*Ailanthus excelsa*) were integrated on agricultural lands. Due to high value in wood industry, environment amelioration and use for scalable produce properties these species have been selected in present agroforestry trials. The experiments were conducted at H-12, H-13 blocks of the university. Further, under FLD on Agroforestry, Ronija village of Jhansi district was adopted to develop industrial agroforestry model. The training programme was also conducted to the end userson "Improved Techniques of Agroforestry" aimed at promoting Agroforestry for enhancing farmers' income.

Problems addressed

The Industrial Agroforestry initiative undertaken by Rani Lakshmi Bai Central Agricultural University (RLBCAU), Jhansi, addresses critical challenges faced by the Bundelkhand region, such as deteriorating soil health, water scarcity, low agricultural returns, and lack of raw material supply for wood-based industries. Traditional agriculture on marginal lands was proving to be economically unviable, pushing farmers toward unsustainable practices. To resolve these issues, RLBCAU initiated a comprehensive industrial agroforestry model by integrating fast-growing, high-value tree species such as *Melia dubia*, *Neolamarckiacadamba* (Kadamb), *Gmelina arborea* (Khamer), and *Ailanthus excelsa* (Ardu) with rabi-season legume crops like lentil, chickpea, and grass pea. These species were chosen for their industrial demand (timber, pulp, match splints, and energy), adaptability, and environmental benefits.

Technology implemented

The technology implemented involved structured plantation at different spacings (5m × 3m, 5m × 4m, 5m × 5m) to assess the optimal growth performance of trees and intercrops. Scientific trials were conducted at RLBCAU's experimental blocks and extended to farmer fields under the FLD (Frontline Demonstration) program in Ronija village, Jhansi. This included the introduction of intercrops during the tree's juvenile phase, maximizing land use and income in the initial years. In addition, hands-on training, awareness programs, and exposure visits were organized to empower farmers with knowledge on agroforestry practices, water conservation, and soil health management.

Development of *Gmelina arborea* based industrial agroforestry system

Khamer (*Gmelina arborea*) was planted in the year July 2020 at three spacings (5m × 3m, 5m × 4m and 5m × 5m) accommodating 168 plants of Gmelina in an area of 3000 m^2. The different legumes were grown in rabi season under Gmelina in three years (Table 1).The area between the rows was inter-cropped with lentil (*Lens culinaris*), grass pea (*Lathyrus sativus*) and chick pea (*Cicer arietenum*) in Rabi 2021-22 & 2022-23 and only lentil (*Lens culinaris*) in 2023-24. Spacing S_2 (5m × 4m) exhibited maximum height and basal girth for *Gmelina arborea* in Quarter 12 than S_1 (5m × 3m) and S_3 (5m × 3m) spacings (Fig. 1).

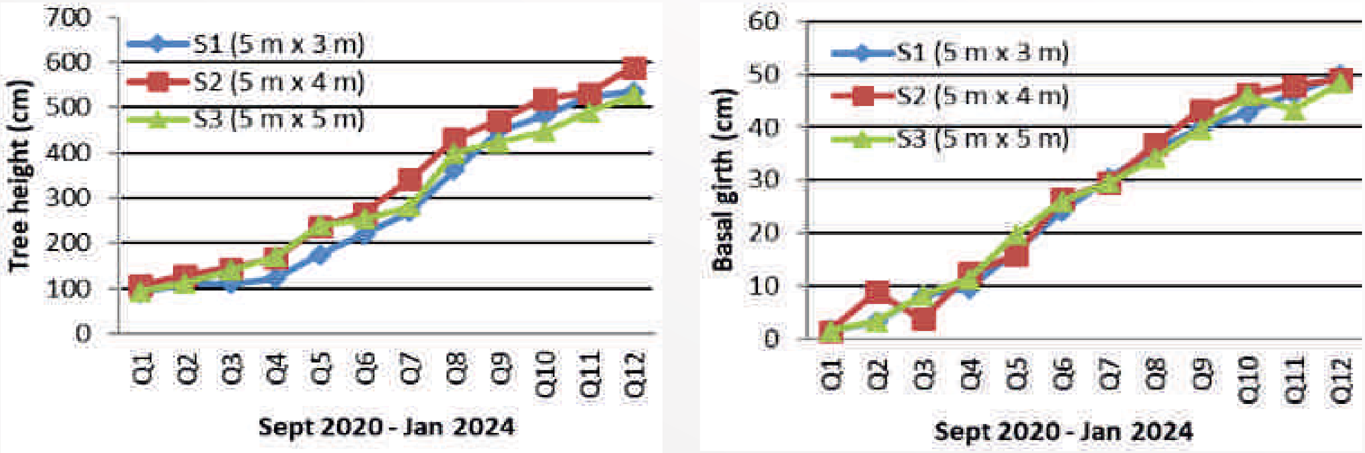
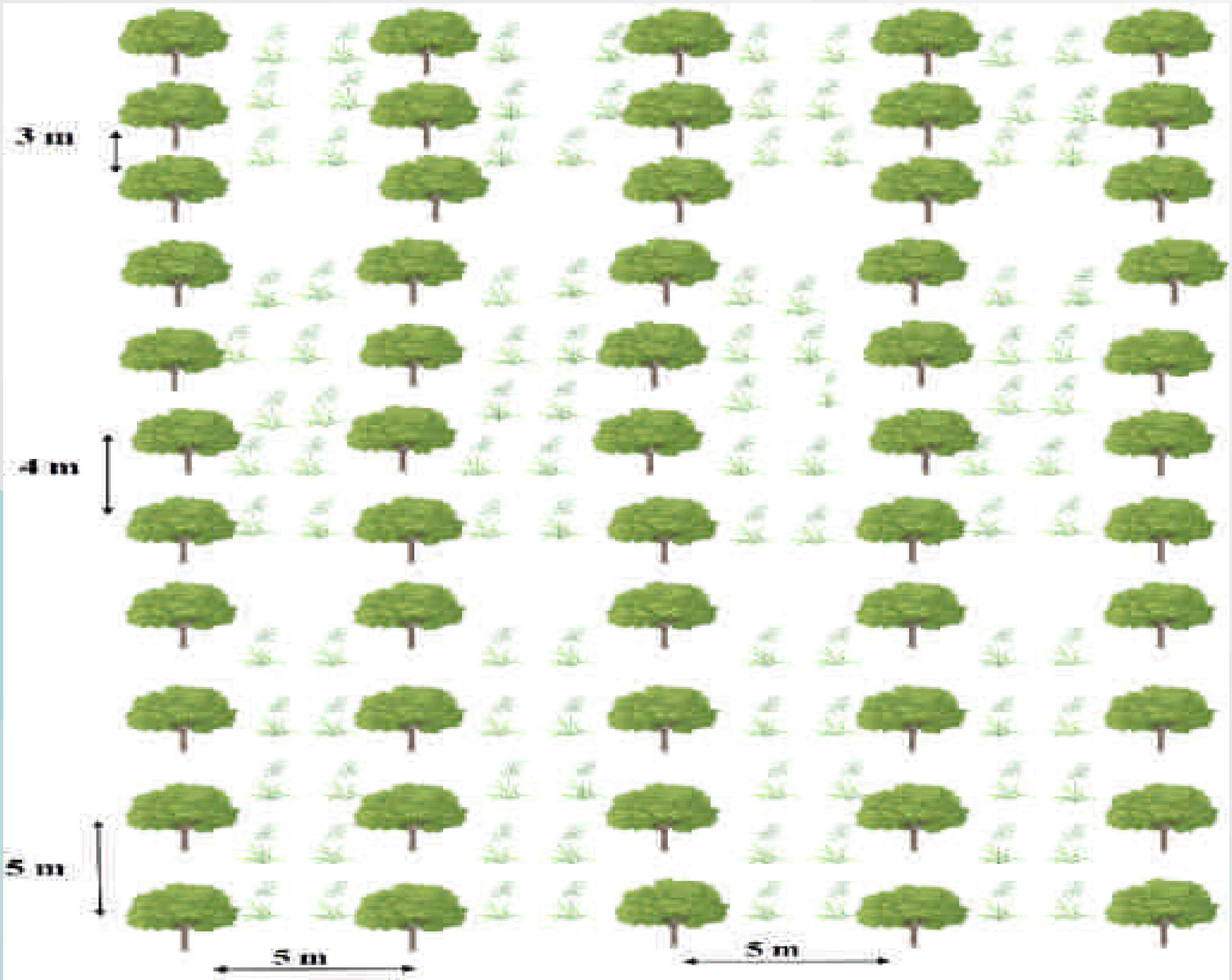


Fig. 1. Influence of different plant spacing's on *Gmelina arborea* height and basal girth

Table 1. Yield of intercrops under *Gmelina arborea*

Tree Spacing	Average yield of intercrops (Kg ha^{-1})			
	2021-22 and 2022-23			2023-24
	Chickpea	Lentil	Grass pea	Lentil
5m × 3m	1266	854	849	861
5m × 4m	1290	869	853	874
5m × 5m	1301	881	858	910



***Gmelina arborea* based industrial agroforestry model layout**

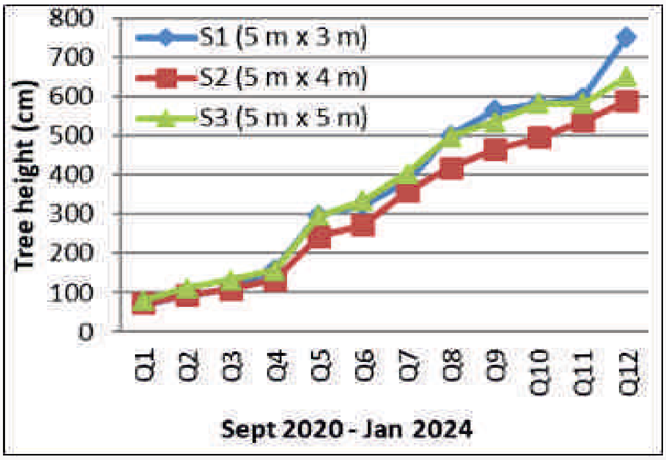
Field view of Gmelina based agroforestry model

Visits of dignitaries in the established industrial agroforestry model in RLBCAU field

Electronic media coverage of successful Industrial Agroforestry Model

Development of *Neolamarckia cadamba* based industrial agroforestry system

Kadamb (*Neolamarckia cadamba*) was planted in the year July 2020 at three spacings (5m x 3m, 5m x 4m and 5 m x 5m) accommodating 148 plants of Kadamb in an area of 3000 m^2. The different legumes were grown in rabi season under Kadamb in three years (Table 2). The area between the rows was inter-cropped with lentil (*Lens culinaris*), grass pea (*Lathyrus sativus*) and chick pea (*Cicer arietenum*) in Rabi 2021-22 & 2022-23 and ginger (*Zingiber officinale*) in 2023-24. *Neolamarckia cadamba* attained maximum height at S_1 (5mx3m) spacing and basal girth at S_3 (5m x 5m) spacing in quarter 12 compared to S_2 (5m x 4m) & S_3 (5mx5m) and S_1 (5m x 3m) & S_2 (5mx 4 m) spacings, respectively (Fig. 2).



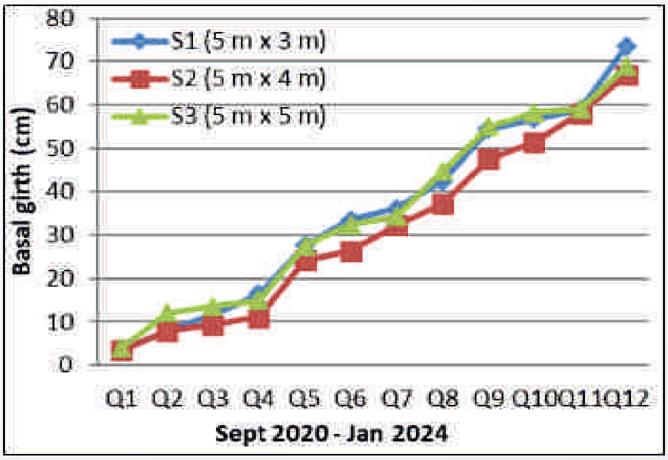
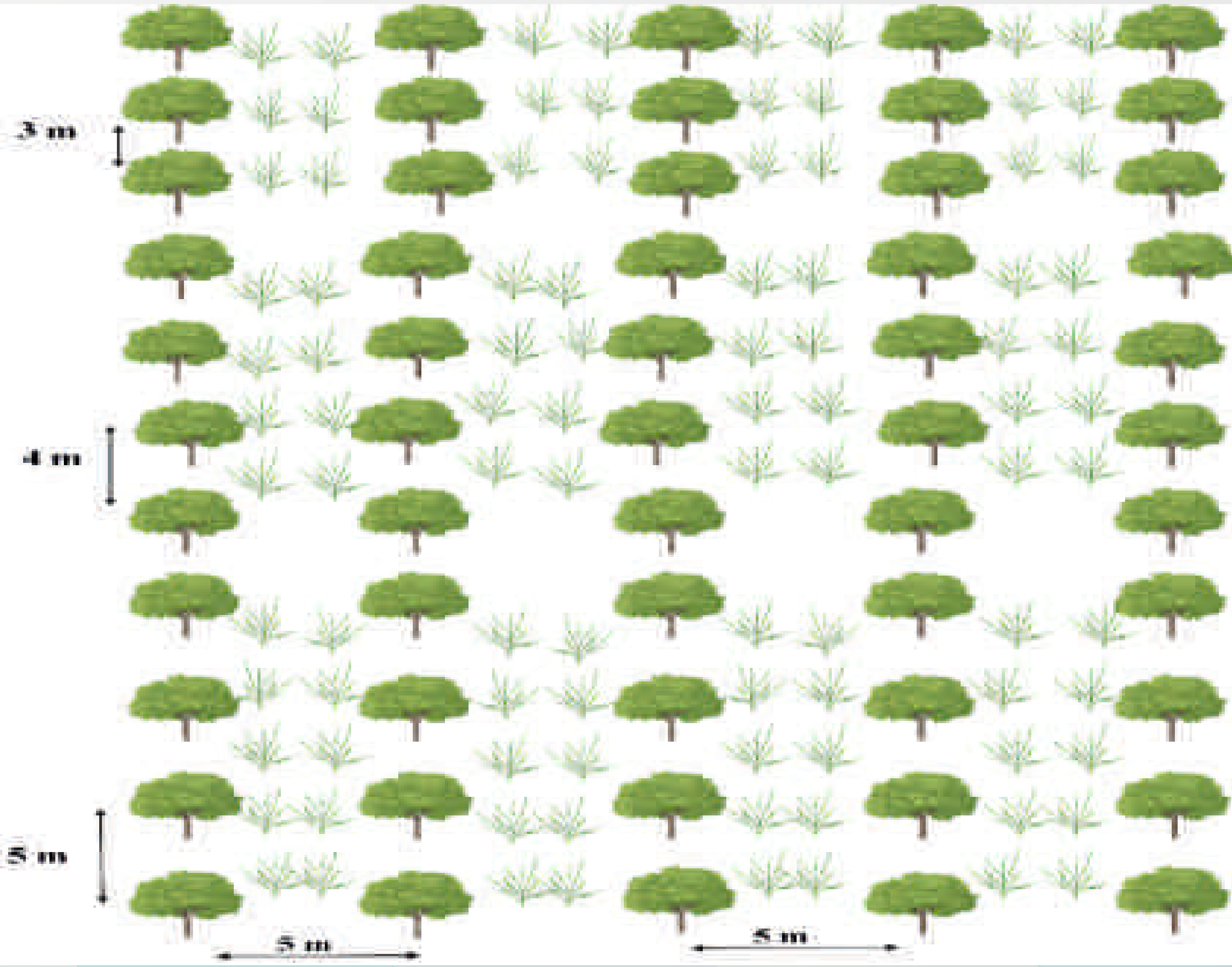


Fig. 2. Influence of different plant spacing's on *Neolamarckiacadamba*height and basal girth

Table 2. Yield of intercrops under *Neolamarckia cadamba*

Tree Spacing	Average yield of intercrops			
	2021-22 and 2022-23 (Kg ha^{-1})			2023-24 (t ha^{-1})
	Chickpea	Lentil	Grass pea	Ginger
5m × 3m	1240	870	854	5.4
5m × 4m	1250	882	863	5.6
5m × 5m	1268	889	864	6.3

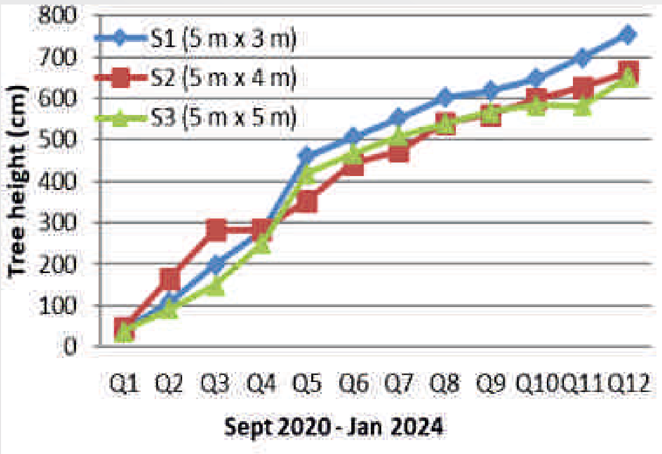


***Neolamarckia cadamba* based Industrial Agroforestry Model layout**

Field view of Kadamb based agroforestry model

Development of *Melia dubia* based industrial agroforestry system

Melia or Malabar Neem (*Melia dubia*) was planted in the year August 2020 at three spacings (5m x 3m, 5m x 4m and 5 m x 5m) accommodating 144 plants of Melia in an area of 2500 m^2. The different legumes were grown in rabi season under Melia in three years (Table 3). The area between the rows was inter-cropped with lentil (*Lens culinaris*), grass pea (*Lathyrus sativus*) and chick pea (*Cicer arietenum*) in Rabi 2021-22 & 2022-23 and lentil (*Lens culinaris*) in 2023-24. *Melia dubia* attained maximum height and basal girth at S_1 (5m x 3m) spacing in quarter 12 compared to S_2(5m x 4m) & S_3(5m x 5m) spacings, respectively (Fig. 3).



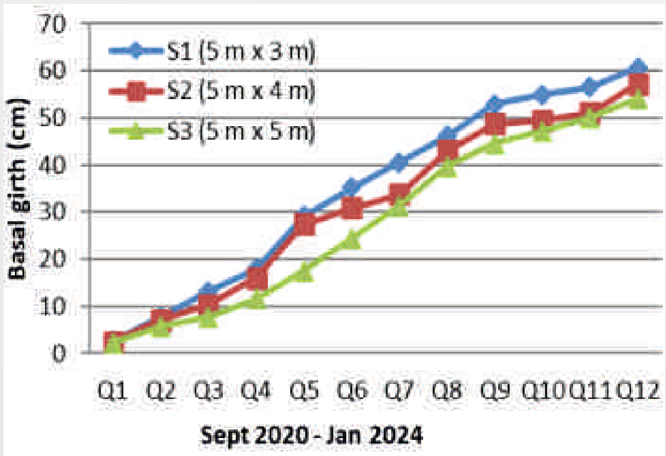
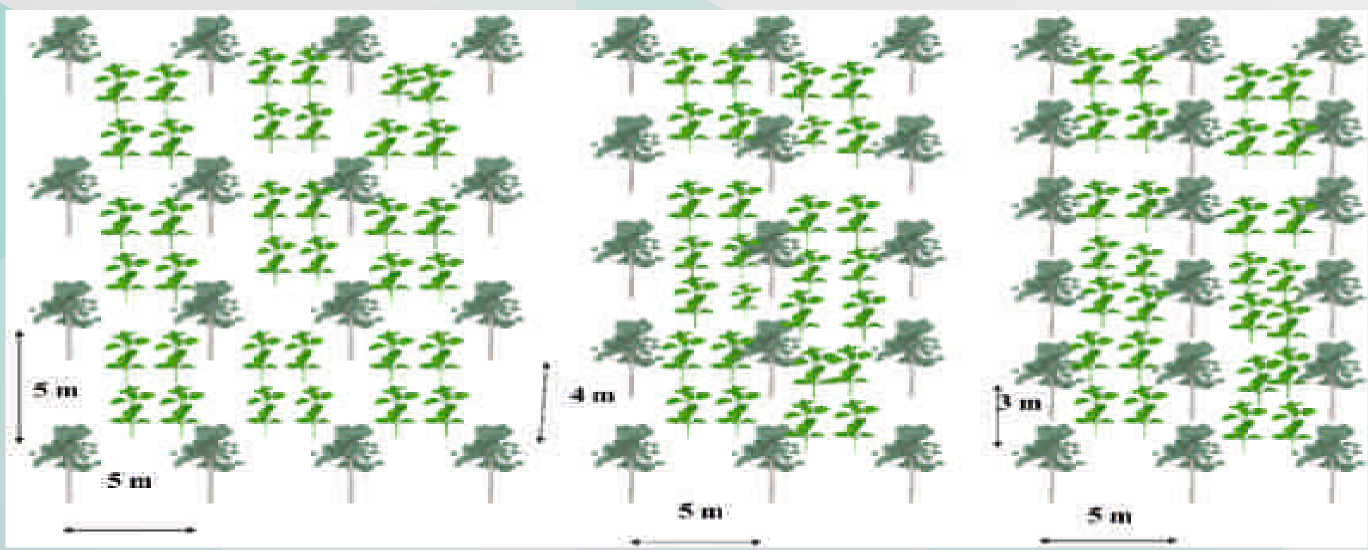


Fig. 1. Influence of different plant spacing's on *Melia dubia* height and basal girth



***Melia dubia* based Industrial Agroforestry Model layout**

Table 3. Yield of intercrops under *Melia dubia*

Tree Spacing	Average yield of intercrops (Kg ha^{-1})			
	2021-22 and 2022-23			2023-24
	Chickpea	Lentil	Grass pea	Lentil
5m × 3m	1235	886	854	890
5m × 4m	1295	895	862	923
5m × 5m	1320	903	882	940



Field view of Melia based agroforestry model

Development of *Ailanthus excelsa* based industrial agroforestry system

Ailanthus or Mahaneem (*Ailanthus excelsa*) was planted in the year July 2021 at two spacings (5m x 3m, 5m x 4m) accommodating 44 plants in an area of 1000 m^2. The different legumes were grown in rabi season under Ailanthus in three years (Table 4). The area between the rows was inter-cropped with lentil (*Lens culinaris*), grass pea (*Lathyrus sativus*) and chick pea (*Cicer arietenum*) in Rabi 2021-22 & 2022-23 and lentil (*Lens culinaris*) in 2023-24. *Ailanthus excelsa* attained maximum height and basal girth at S_1 (5m x 3m) spacing in quarter 7 compared to S_2 (5m x 4m) spacing, respectively (Fig. 4).

Table 4. Yield of intercrops under *Ailanthus excelsa*

Tree Spacing	Average yield of intercrops (Kg ha^{-1})			
	2021-22 and 2022-23			2023-24
	Chickpea	Lentil	Grass pea	Lentil
5m × 3m	1185	849	840	882
5m × 4m	1203	867	872	907

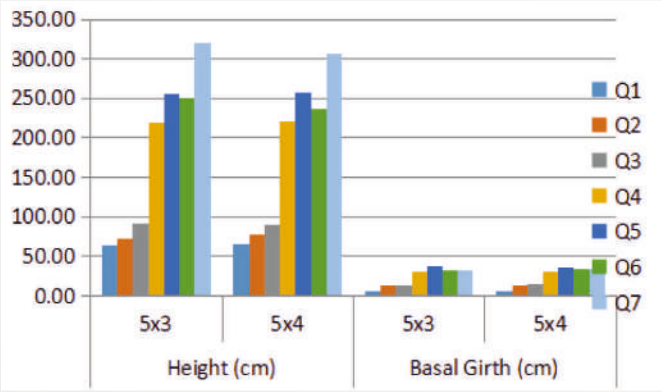
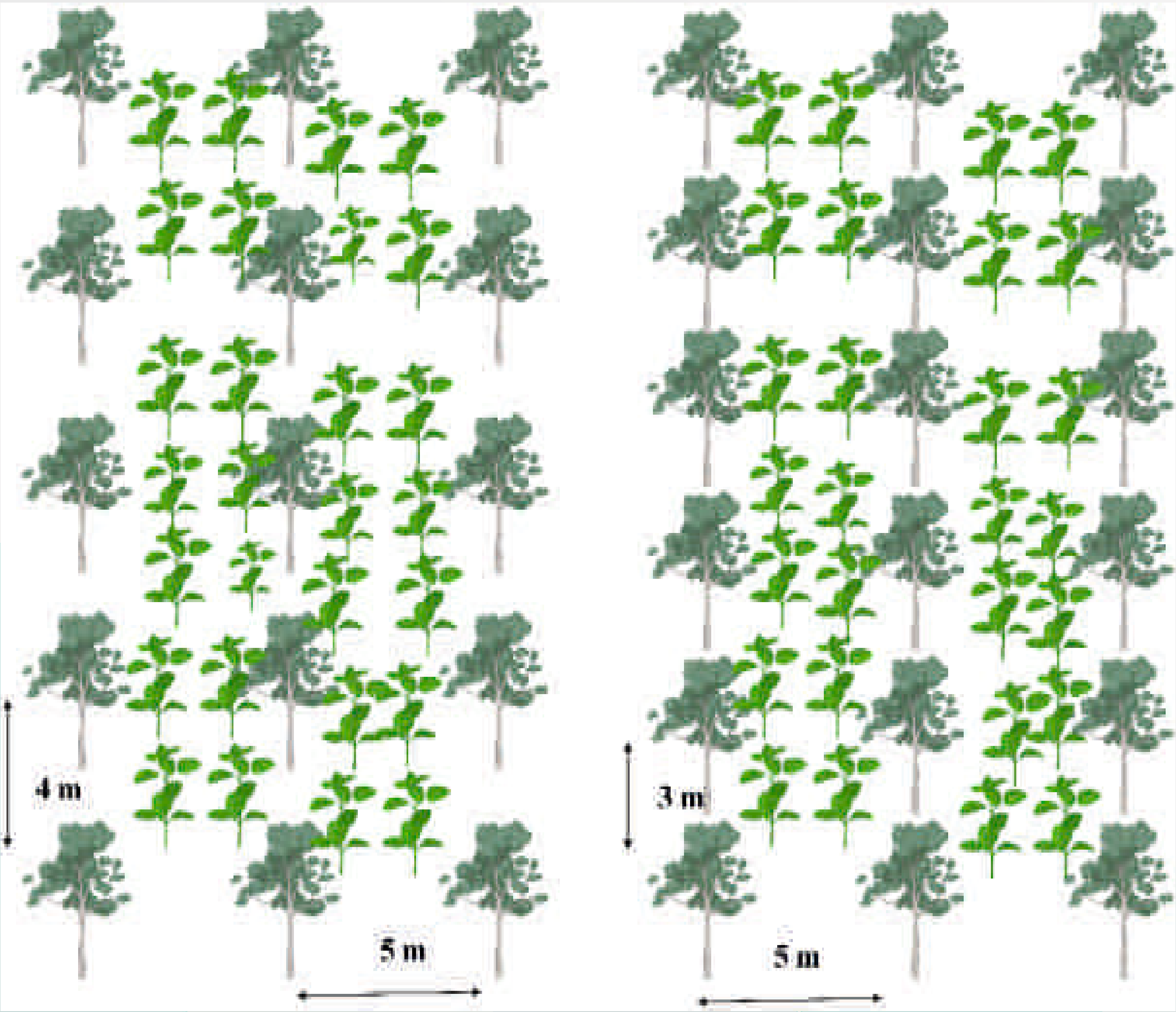


Fig. 4. Influence of different plant spacing's on *Ailanthus excelsa* height and basal girth



***Ailanthus excelsa* based Industrial Agroforestry Model layout**

Field view of Ailanthus based agroforestry model

Technology transfer

Development of industrial agroforestry model at Ronija Village in Jhansi District

Under FLD on Agroforestry, Ronija village of Jhansi district was adopted to develop industrial agroforestry model and training programme was also organized on "Improved Techniques of Agroforestry" aimed at promoting Agroforestry and enhancing farmers' income.Ronija village in Jhansi district is emerging as a model agroforestry village by the university initiatives. With the joint efforts of agricultural scientists, government agencies, and local farmers, the village is witnessing a transformation in modern farming techniques, agroforestry development, and sustainable agricultural practices. Scientists and experts from RLBCAU, Jhansi are actively involved in establishing the models at farmers field and training to farmers for guiding them in adopting new-age farming methods.

Awareness creation and training to the farmers

The farmers are provided with hands-on training, workshops, and exposure visits. They are learning about water conservation methods, soil health management, and the use of technology in farming. Progressive farmers like MrGulab Chand and MrNand Ram Yadav have become role models by implementing industrial Agroforestry model in their land. The impact of these efforts is evident in the improved yield, increased income levels, and enhanced livelihood opportunities for the rural community. Women farmers, too, are playing a crucial role in agroforestry activities, contributing to household income and economic stability. Based on the consideration of local environmental conditions, soil health, and compatibility with existing crops three fast-growing tree species viz. *Neolamarckiacadamba, Melia dubia and Gmelina arborea*, are promoted for plantation at a Spacing of 5x5 m^2, 2x3 m^2, 4X5 m^2, 8x8 m^2along with *Tectona grandis* at boundary plantation.

Establishment of Agroforestry Models at the farmer's field

Initiation to the establishment of successful Agroforestry Models at farmer's field

Facilitating pit digger, quality planting materials, regular monitoring carried out by the team of scientists of RLBCAU, Jhansi. Due to these technological intervention farmers successfully adopted agroforestry system in their landscape. This initiative showcases a collaborative approach towards sustainable agroforestry, where scientific expertise, combined with farmer participation, contributes to a resilient and productive farming system that benefits both the environment and the rural economy. The success of Ronija village serves as an inspiration for other rural communities looking to modernize agriculture. Officials from the agriculture department are keen to replicate this model in neighboring villages to ensure holistic rural development. With continued support from government schemes, scientific institutions, and farmer participation, Ronija is well on its way to becoming a benchmark for sustainable and profitable farming in Uttar Pradesh.

Visit of dignitaries to witness successfully implemented technology at farmer's field

Agricultural Profile of Ronija Village

Ronija village, located in Jhansi district, encompasses a total geographical area of 417.77 hectares, of which 343.34 hectares are under cultivation and 55.31 hectares are under non-agricultural use. The village exhibits a typical semi-arid agricultural pattern characteristic of the Bundelkhand region, where farming is largely dependent on the seasonal monsoon. During the kharif (monsoon) season, most farmers practice rainfed cropping due to erratic and uneven rainfall. The major crops cultivated include pigeon pea (arhar), groundnut, black gram (urdbean), green gram (mungbean), and paddy, the latter being grown only in limited pockets where water availability permits. In contrast, the rabi (winter) season is primarily supported by groundwater irrigation through wells and tube wells, allowing cultivation of wheat, chickpea (Bengal gram), lentil (masoor), and mustard (rapeseed).

Before the intervention, the traditional cropping system generated limited returns due to low soil fertility and rainfall variability. The introduction of industrial agroforestry models in such landscapes has transformed the local farming system by integrating tree-based systems with traditional crops, enhancing land productivity, improving soil health, and providing sustainable income diversification to the farming community.

Income Diversification through Industrial Agroforestry Models

Under the Frontline Demonstration (FLD) program, a total of 8 hectares of farmland in Ronija village were brought under industrial agroforestry models, directly benefiting 12 progressive farmers, namely Mr. Gulab Chandra, Mr. Ramesh Chandra Tiwari, Mr. Jugal Kishor Tiwari, Mr. Kishori Pal, Mr. Praveen, Mr. Mathura Prasad, Mr. Atar Singh Ahirwar, Mr. Balveer Tiwari, Mr. Komal Singh Pal, Mr. Asharam, Mr. Ram Newaj, and Mr. Rajkumar. These farmers successfully adopted tree-based cropping systems integrating high-value intercrops with fast-growing industrial tree species.The integration of fast-growing industrial tree species such as *Melia dubia*, *Gmelina arborea*, and *Neolamarckia cadamba* with high-value intercrops like turmeric, ginger, and colocasia has significantly enhanced household income. These intercrops provided short-term cash returns while trees contributed to long-term asset creation, ensuring economic resilience. Additionally, the inclusion of medicinal and aromatic crops such as Ashwagandha, Tulsi, and Aloe vera further diversified the production system, offering new income streams and reducing climatic and market risks.

Through this integrated approach, farmers experienced an average income rise of 45–60%, with net returns annually, compared to conventional monocropping. Beyond economic benefits, the system improved soil organic carbon, reduced input costs, and increased on-farm biodiversity. The success of these 12 beneficiaries has motivated neighbouring farmers to adopt similar models, demonstrating the strong replicability and scalability of industrial agroforestry as a climate-resilient and income-enhancing land-use system in the Bundelkhand region.

Benefits of Technology

The initiative has yielded multiple benefits for the rural population. The combination of trees and crops enhanced income stability, optimized land utilization, and improved soil fertility and microclimatic conditions. Farmers experienced increased yield from both trees and intercrops, while the integration of species like Ginger with *Neolamarckia cadamba* further diversified income sources. This model also supports climate resilience. Trees act as carbon sinks, contribute to biodiversity, and mitigate the adverse effects of climate change, such as drought and erratic rainfall, which are common in Bundelkhand. Moreover, the model enhances water-use efficiency through better infiltration and reduced surface runoff, addressing one of the region's most persistent problem i.e. water scarcity. Socially, the program has created entrepreneurial opportunities for rural youth and encouraged the active participation of women farmers. Women involved in nursery management, intercrop cultivation, and farm planning have gained income and confidence, contributing to gender empowerment in agriculture. Farmers like Mr. Gulab Chand and Mr. Nand Ram Yadav have reported notable increases in income, and their success stories are now motivating other communities.

Spread of the Technology

The spread of the industrial agroforestry model in Bundelkhand has been strategic and farmer-centric. Initially implemented as a pilot demonstration at RLBCAU's research farm, the project was expanded to farmer fields in Ronija village, Jhansi, under the FLD (Front Line Demonstration) program. Through continuous engagement, this village has become a lighthouse for agroforestry practices in the region. Key to this spread has been the training and capacity-building programs organized by RLBCAU. These included classroom sessions, on-farm demonstrations, and field visits that enabled knowledge transfer and hands on experience for farmers. A total of five training programs were conducted, covering tree planting techniques, nursery management, crop integration, and post-harvest management. The university also facilitated the supply of quality planting material, fertilizers, and other inputs, reducing the entry barrier for marginal farmers.

With strong support from RLBCAU scientists, the agriculture department, and local governance, the initiative is now being replicated in neighboring villages. The development of infrastructure, including planting pits, supply of quality saplings, and regular scientific monitoring, ensured smooth adoption. The collaborative approach of linking scientific research with local knowledge and farmer participation has led to the successful establishment of agroforestry as a sustainable and profitable model for rural transformation in the region. This initiative stands as a benchmark for future agroforestry expansion in Uttar Pradesh and beyond.

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