



Assessment of Yield Performance of Cluster Bean cultivars in *Melia dubia*-based Agroforestry Systems

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10.18805/LR-5428

ABSTRACT

Background: *Melia dubia* is a promising tree species in industrial agroforestry and plantation systems across southern India and is popular for its fast growth and economic potential. Choosing a suitable intercrop for an agroforestry system determines the longevity and viability of the system. This study was carried out to explore the feasibility of cluster bean cultivars as an intercrop in *Melia dubia* -based agroforestry system.

Methods: A trial was conducted by comparing three cluster bean varieties such as, Sonali, Pusa Navbahar and MDU 1, under *Melia dubia* with three treatment conditions representing: open field conditions, as an understorey in three-year-old *M. dubia* and six-year-old *M. dubia* plantations.

Result: In three-year-old *Melia dubia* plantation, the light intensity recorded by cluster beans was reduced to 78.12% (65,000 lumen per square metre) for MDU 1, 76.44% (63,600 lumen per square metre) for Pusa Navbahar and 74.51% (62,000 lumen per square metre) for Sonali when compared to the control and the pod yields for the three varieties were recorded as 10.15 t/ha, 9.28 t/ha and 7.86 t/ha, respectively. The benefit cost ratios of cluster bean varieties in three-year-old plantations were 1.43, 1.38 and 1.21, respectively. Overall, the yield attributing parameters such as flowers/cluster, pods/cluster, number of pods, pod length were greater in the MDU1 variety than in the other two varieties. Thus, intercropping cluster bean cv. MDU1 as an understorey in *M. dubia* plantations can maximize land utilization and yield the greatest returns.

Key words: BCR, Cluster bean, *Melia dubia*, Yield.

INTRODUCTION

Agroforestry aims to enhance overall land productivity by integrating crops and livestock with trees and shrubs on the same area of land, either concurrently or sequentially. Planting trees on agricultural lands can help address numerous challenges in agricultural systems, including sustainable biological production, large-scale of deforestation, diminishing soil fertility, drought occurrence and the increasing application of hazardous chemicals (Arya *et al.*, 2018). In order to achieve a higher return on investment, farmers in recent years have increasingly preferred fast-growing, short-rotation highly valuable tree species. In this sense, *Melia dubia* has proven to be a commercially viable species that, commands a high price on the market. *M. dubia* (Malabar neem) is a rapidly expanding native species of industrial wood within the Meliaceae family. One of the primary notable multiutility trees has a straight, cylindrical trunk that can reach a height upto 25 meters; with a crown spread and a straight bole ranging up to 9 meters in length; and a girth ranging from 1.2 to 1.5 meters. It is a multipurpose, short-rotation tree primarily used as a raw material for manufacturing plywood, pulp and paper, as well as for packing cases and match splints (Parthiban *et al.*, 2009; Priyanka *et al.*, 2019 and Sarvade *et al.*, 2014).

Legumes have considerable potential in agroforestry systems because of their many uses, being functional either as a growing crop or as crop residue (Bhatt *et al.*, 2017). In India, the cultivation of cluster beans, also known

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How to cite this article: Hemalatha, P., Ravi, R., Krishnamoorthi, S., Boominathan, P., Selvanayagi, S., Radha, P., Baranidharan, K. and Divya, M.P. (2025). Assessment of Yield Performance of Cluster Bean cultivars in *Melia dubia*-Based Agroforestry Systems. Legume Research. 1-5. doi: 10.18805/LR-5428.

Submitted: 19-09-2024 **Accepted:** 07-01-2025 **Online:** 30-01-2025

as guar gums [*Cyamopsis tetragonoloba* (L.) Taub.], as an annual legume during the *Kharif* (June-October) season for use as a vegetable, gum and fodder is predominant. Due to its drought tolerance compared to other legumes, it is also grown in Pakistan, Indonesia, Myanmar, parts of Central Africa and the arid southwestern United States. With a market share of 80%, India is a significant producer and exporter of cluster beans and their derivatives. A total of 3,41,813.63 metric tonnes of guar were exported from India from 2023-2024 (DGCIS, 2024). As a leguminous crop, guar fixes 25-30 kg/ha of atmospheric nitrogen in soil, besides serving as a green manure in improving soil quality by contributing 40-50 kg/ha of nitrogen (DPD, 2020) through biomass. It is also grown as a cover crop in general, as well as a shade crop for ginger, due to its many uses. Cluster beans are typically grown in combination

with pearl millet, mung beans and sesame in rainfed areas of Rajasthan, India.

Many of the cluster bean varieties have varying maturity periods, branching habits and seed yield qualities and quantities, making them suitable for cultivation in arid and semiarid regions. For instance, the varieties HG 365, HG 563, RCG 1066 and RCG 1003 are grown for seed gum, whereas Pusa Sadabahar, Durga Bahaar and Pusa Navbahar are grown for vegetables (both summer and rainy season crops). Furthermore, some cultivars, such as HFG 119 and HFG 156, are raised only for animal feed (DPD, 2020). The variety, MDU 1 has a cluster bearing nature (7-9 fruits/node) with long attractive green coloured fruits measuring 13-14 cm. The crop matures in 90-100 days after sowing and has more number of fruits / plant (150-175 fruits). The yield potential of this variety is 13t/ha and the fruits are rich in fibre content (4.5g/100g of the fruit). The plants possess tolerance capacity towards powdery mildew incidence. With this background, this study was carried out with an objective of determining the economic feasibility of growing cluster beans under a *Melia dubia* - based agroforestry system. In addition, we assessed how light intensity under three-and six-year-old *M. dubia* impacts the productivity of cluster beans.

MATERIALS AND METHODS

This investigation was conducted at the Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam (11°19' and 11°20'N, 76°56' and 76°57'E and 300 m above MSL), during 2019 - 2022 with three treatment combinations such as control (open field condition) (T1), intercropping cluster bean with three (T2) and six-year-old *M. dubia* plantations (T3). The soil at the experimental site is an Inceptisol (Typic Ustropept-Irugur soil series), sandy loam in texture, red, non-calcareous, neutral in reaction, non-saline, low in available and soil organic carbon and medium in available phosphorus and potassium. Three cluster bean varieties namely, Pusa Navbahar (released by Indian Agricultural Research Institute, New Delhi), MDU 1 (released by Tamil Nadu Agricultural University, Coimbatore) and Sonali (released by a private firm, Mangaldev Agritech Pvt. Ltd., Agra) were grown as intercrops under *M. dubia* plantations as per treatments. In control plot, cluster bean was raised as monocrop under open field condition. The experiment was set up in a randomized block design with three replications.

The impact of the tree canopy on the light intensity available to the intercrop was evaluated to choose the suitable cluster bean variety for intercropping in *M. dubia* plantation with a focus on growth parameters and light interception. Light intensity was measured using a lux meter (Make: LI-COR made in USA, Model: LI-1500), positioned at the crop's canopy level to ensure accurate readings. The readings were allowed to stabilize and the lux values displayed on the meter were recorded. The light intensity between 11.30 am and 12.00 noon was measured by a lux meter to estimate the light availability for the crops under three-year-old (T2) and six-year-old (T3) *M. dubia* trees and also in open field. The data were examined using appropriate statistical procedures for ANOVA to ensure accuracy and reliability in the interpretation of the results (Panse and Sukhatme, 1985). The benefit-cost ratio (BCR) is a metric used to summarize the overall correlation between the relative costs and benefits of a proposed project. When the BCR exceeds 1.0, the project is expected to generate a positive Net Present Value (NPV), indicating profitability for the firm and its investors. The BCR is calculated as the ratio of total income to the total cost of production within the system.

RESULTS AND DISCUSSION

Generally, cluster bean is a sun-loving crop that requires 7-8 hours of direct sunlight. The results related to its biological and yield parameters are discussed here.

Number of flowers/clusters

Considering the interaction with varieties and field condition, a significantly maximum number of flowers/clusters was observed in T1V1 (11.63) followed by T1V2 (10.20) whereas the minimum was recorded in T3V3 (6.60), owing to increased light availability and reduced competition from other plants (Table 1). The recorded variation in the number of flowers per cluster in cluster beans may also be attributed to the open field condition and genetic differences among the various cultivars. Similar findings have been reported by Heindl and Brun (1983), who noted flower abscission in soybeans under shaded conditions and by Bhusara *et al.* (2018), who observed fewer green gram flowers in intercropped plots with *Melia composita* compared to open plots.

Number of pods/clusters

The number of pods/ cluster in different ecosystems varied remarkably at harvest as this parameter is highly influenced

Table 1: Effect of the *Melia dubia* ecosystem on the number of flower clusters of cluster bean varieties.

Treatments	Number of flower clusters/plant		
	MDU 1 (V1)	Pusa Navbahar (V2)	Sonali (V3)
Open condition (T1)	11.63 ^a	10.20 ^a	8.90 ^a
Three years old <i>Melia dubia</i> (T2)	9.10 ^b	8.27 ^b	7.43 ^a
Six years old <i>Melia dubia</i> (T3)	8.53 ^b	7.20 ^b	6.60 ^a

Letters indicate statistical significance at $p < 0.05$.; a,b,c indicates variation in treatments.

by the genetic make-up of the crop cultivars and the light conditions. Among the treatments, T1V1 recorded the significantly higher number of pods per cluster (31.82), likely due to increased light availability enhancing the net assimilation rate in open conditions. In contrast, T3V3 had the lower number of pods per cluster (25.79), attributed to increased shading from larger crowns and genetic differences among the varieties. These results closely align with those quoted by Patel (1995), George and Nair (1987) in cowpea, Mahajan (2001) in *Trigonella foenum-graecum*, Sreerekha and Dhurua (2009) in pigeon pea and soybean and Ahir *et al.* (2019) in various pulse crops, including green gram, cowpea, black gram, Indian bean and pigeon pea.

Number of seeds/pods

The data on the number of seeds/pods at harvest are illustrated in Fig 1. Among the treatments, the maximum number of seeds per pod in cluster bean was observed in T1V1 (8.83), followed by T1V2 and T2V1 (8.40), likely due to high light interaction and high photosynthesis rate in open-field conditions while the minimum seed set was recorded in T3V3, possibly due to reduced shade tolerance, which negatively impacted seed production. Similar findings were reported by Sreerekha and Dhurua (2009). The seed counts in T1V2 and T2V1 were comparable at

8.40, with T1V1 outperforming T3V3. Comparable results were also recorded by Lal *et al.* (2014) and Ahir *et al.* (2019).

Pod length (cm) and pod width (cm)

The pod length and width of cluster beans were measured at harvest and were significantly influenced by the three ecosystems (Table 2). On comparing the different treatments of cluster bean, the maximum pod length and pod width was recorded in the T1V1 (16.80 and 1.10 respectively) compared to other treatments. In contrast, Sharma *et al.* (2023) found significantly higher pod length and pod width in aonla-based agroforestry systems with soybean compared to open cropping, likely due to the compatibility between aonla and soybean, which creates favourable growing conditions. The results align with Bhutia *et al.* (2015) in *Pisum sativum* under peach trees and Haitham *et al.* (2017) in pea plants under *Sesbania sesban*.

Yield / ha

Among the different treatments for growing cluster bean, the highest yield of cluster bean was recorded in T1V1 (11.58 tonnes), followed by T1V2 (10.61 tonnes) compared to other treatments (Table 3). When water and nutrients are sufficient, plant production mainly depends on the radiant energy intercepted by leaves. In three-year-old *Melia*

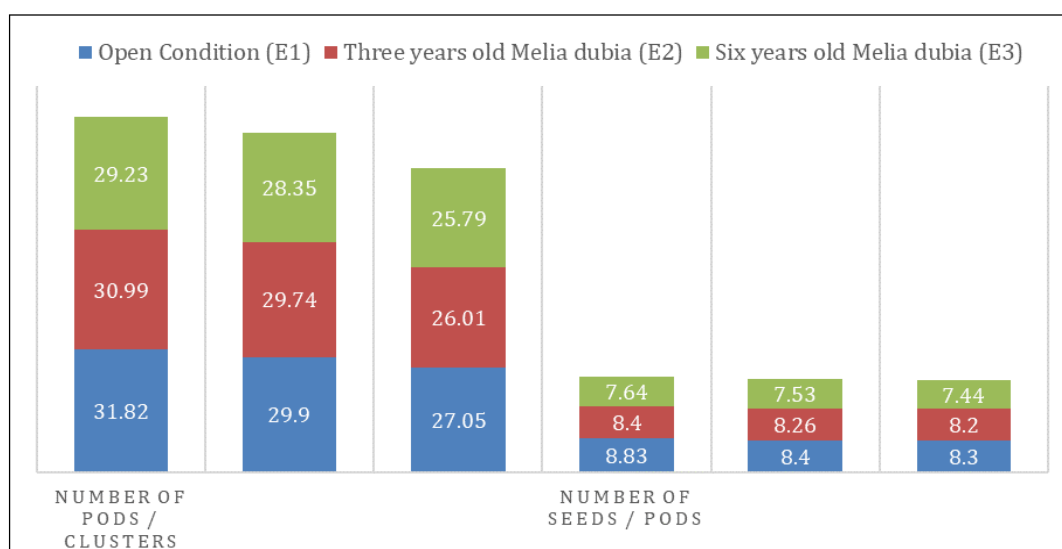


Fig 1: Effect of the *Melia dubia* ecosystem on the number of pods/clusters and the number of seeds/pods of cluster bean varieties.

Table 2: Effects of *Melia dubia* ecosystem on the pod length (cm) and pod width (cm) of cluster bean varieties.

Treatments	Pod length (cm)			Pod width (cm)		
	MDU1 (V1)	Pusa navbahar (V2)	Sonali (V3)	MDU1 (V1)	Pusa navbahar (V2)	Sonali (V3)
Open condition (T1)	16.80	15.30	14.53	1.10	1.03	0.97
Three years old <i>Melia dubia</i> (T2)	14.80	13.77	13.83	1.03	1.03	0.97
Six years old <i>Melia dubia</i> (T3)	14.37	14.27	13.83	1.00	0.97	0.93

There is no significance between the treatments.

Table 3: Light intensity and pod yield of cluster bean varieties in various ecosystems.

Treatments	Light intensity (lux)			Pod Yield		
	MDU 1 (V1)	Pusa navbahar (V2)	Sonali (V3)	MDU 1 (V1)	Pusa navbahar (V2)	Sonali (V3)
Open condition (T1)	83,200 ^a	83,200 ^a	83,200 ^a	11.58 ^a	10.61 ^a	9.34 ^a
Three years old <i>Melia dubia</i> (T2)	65,000 ^b	63,600 ^b	62,000 ^b	10.15 ^a	9.28 ^a	7.86 ^b
Six years old <i>Melia dubia</i> (T3)	31,900 ^c	30,000 ^c	29,200 ^c	7.10 ^b	6.89 ^b	6.09 ^b

Letters indicate statistical significance at $p < 0.05$; a,b,c indicates variation in treatments.

Table 4: BCR of cluster bean varieties intercropped with *Melia dubia* plantations at different ages.

Treatments	Benefit - cost ratio		
	MDU 1 (V1)	Pusa navbahar (V2)	Sonali (V3)
Open condition (T1)	1.83	1.68	1.48
Three years old <i>Melia dubia</i> (T2)	1.61	1.47	1.24
Six years old <i>Melia dubia</i> (T3)	1.12	1.09	0.96

dubia plantation, the light intensity recorded by cluster beans was reduced to 78.12% (65,000 lumen per square metre) for MDU 1, 76.44% (63,600 lumen per square metre) for Pusa Navbahar and 74.51% (62,000 lumen per square metre) for Sonali when compared to the control. In agroforestry systems, factors such as Photosynthetically Active Radiation (PAR), temperature, species combinations, canopy structure, tree age, height and leaf area influence biomass growth (Jose *et al.*, 2004). This trend may be reflected in this study. The similar yield reduction peculiarity recorded in pulses intercropped with trees was recorded by Bhusara *et al.* (2018), Pandey *et al.* (2019) and Ajaykumar *et al.* (2022). Jia *et al.* (2021) and Zhang *et al.* (2019) also reported a similar yield decrease in wheat when intercropped under walnut (*Juglans regia*) and ber (*Ziziphus jujuba*) trees respectively.

However, the yield performance of cluster bean under the treatment T2V1 and T2V2 is comparable with T1V1 and T1V2. This is due to trait plasticity, which helps crops adapt to shaded conditions while sustaining light absorption and biomass productivity similar to monocultures (Arenas-Corraliza *et al.*, 2018).

Benefit cost ratio (BCR)

The BCR for cluster bean cultivation under the *M. dubia* agroforestry system was evaluated to assess the economic viability of this system, with the results are shown in Table 4. As expected, higher BCR (1.83 for MDU 1 and 1.68 for Pusa Navbahar) values were recorded under open field conditions without tree component. Ashalatha *et al.* (2015) reported similar findings in their study to develop *M. dubia*-based agroforestry model for yield enhancement. However, the BCR (1.61) recorded in MDU 1 under three-year-old *M. dubia* plantation was comparable with the higher BCR recorded in MDU 1 and Pusa Navbahar under open field conditions. Agroforestry systems may create a beneficial microclimate, promote nutrient recycling and enhance topsoil organic matter through *M. dubia* leaf fall, which likely minimized differences between open-field and intercropping conditions. This is because MDU1 offers the

best option for intercropping with *M. dubia*. The local origin of MDU1 may have provided it with an advantage, allowing it to outperform other varieties even under shaded conditions and also maximum light interception and photosynthetic activity as reported by Miah *et al.* (2001) and Hossain *et al.* (2020).

CONCLUSION

Melia dubia is emerging as a key species in industrial agroforestry plantations in southern India, provide opportunities for large-scale intercropping with various agricultural crops. The findings of the current study suggest that cluster beans can be successfully cultivated under *Melia dubia* plantations during the early stages of tree growth to achieve optimal yields. The cluster bean variety MDU1 is ahead of the other two varieties. As tree ages, the light intensity reaching the understorey decreases, resulting in lower pod yield of the cluster bean. Even though, the yield penalty was not drastic, the short- rotation practiced for *Melia* (8-year rotation) offers the best possible option for incorporating cluster bean as an intercrop. There are few areas where clarity is needed, such as the nitrogen fixed by cluster bean and its impact on the growth of fast-growing trees such as *Melia dubia*. This paper clearly shows the age limit (three years) at which cluster bean can be used as an intercrop followed by shade tolerant crops such as turmeric and ginger. Therefore, the introduction of cluster bean-based intercropping patterns can help maximize land use for *Melia*-based agroforestry systems with the highest yields. In addition, future studies need to focus on evaluating the intercropping ability of cluster beans in other agroforestry models to meet farmers' needs.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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