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Assessment of the growth and yield attributes of different intercrops under Mahogany based Agroforestry system

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Abstract
The experiment was conducted during the year 2024-25 at farmer's field located at Kusur village of Mundgod taluk, Uttara Kannada district. Total area of field is one acre. The average annual rainfall is 2200 mm. To study Tree-Crop performance of Mahogany based Agroforestry system the experiment was laid out in Factorial Randomized Block Design with 7 treatments and three replications with two environments (Mahogany and open). Seven intercrops are selected viz., Cowpea, Blackgram, Greengram, Horsegram, Chickpea, Mothbean and Lentil. Various growth and yield parameters were recorded for both trees and crops. The performance of intercrops grown under Mahogany were recorded. The performance of seven pulses under open conditions and in association with *Swietenia macrophylla* (Mahogany) in an Agroforestry system. In the Mahogany-based Agroforestry system, Cowpea (7.59 q/ha, HI 36.90 percent, RGYI 12.38 percent) and Blackgram (7.48 q/ha, HI 35.88 percent, RGYI 15.24 percent) emerged as the most productive and shade-tolerant intercrops. Overall, these pulses Cowpea and Blackgram, are the most suitable options for sustaining yield, harvest efficiency, and adaptability in *Swietenia macrophylla*. Based on the findings of the study, it can be concluded that all seven pulse varieties demonstrated superior performance under open field conditions when compared to their growth under the Mahogany-based Agroforestry system. However, within the constraints of the agroforestry environment and intercrops such as cowpea and blackgram emerged as the most promising options. These crops showed comparatively higher seed and biological yields than the other varieties evaluated, making them suitable candidates for cultivation under tree-based systems like *Swietenia macrophylla*.

Keywords: Mahogany, agroforestry system, intercrops, yield, shade tolerant, efficiency, adaptability

Introduction
Agroforestry systems based on trees offer distinct advantages across diverse climatic regions, both arid and humid. In dry and semi-arid landscapes, planting trees on farmland improves crop growth by regulating the local microclimate through lowering air temperature and minimizing evaporative water loss (Bunderson *et al*., 1990) [5]. Many tree species develop deep root systems that extract water and nutrients from lower soil layers, providing resilience during drought periods. Intercropping, a significant element of agroforestry, refers to raising multiple crops simultaneously or sequentially within the same land unit during a growing season. Though this approach enhances the efficient use of available resources, it may also cause competition for light, water, and nutrients between species. As a result, yields of some crops in tree-based systems may be relatively lower than those in monocropping systems, due to shared resource limitations.

Given the rising demand for quality hardwood in India, *Swietenia macrophylla* (Mahogany) presents a promising and profitable venture within the forestry industry. Renowned for its high market value and desirability, mahogany thrives particularly well in tropical climates. Its adaptability to the conditions of India's central dry zone makes it a strong candidate for large-scale cultivation, offering excellent prospects for commercial forestry and sustained financial returns over time.

Swietenia macrophylla, commonly referred to as Mahogany, is a reddish-brown, straight-grained tropical hardwood from the Meliaceae family.

Originally native to regions of Central and South America, it has been extensively introduced and cultivated across Southeast Asia and the Pacific, including nations such as India, Indonesia, the Philippines, and Sri Lanka. Alongside *Swietenia macrophylla*, *Swietenia mahagoni* and *Swietenia humilis* are also considered true mahoganies. The species was first brought to India in 1795 from the West Indies and planted at the Royal Botanical Garden in Kolkata. Since then, it has gained popularity, particularly in southern parts of the country (Akhilraj and Inamati, 2023) [1-2]. Mahogany trees can attain heights exceeding 30 meters and reach up to 150 cm in diameter at breast height. While the species is tolerant of various soil types and climatic conditions, it performs best in deep, fertile, and well-drained soils with a pH of 6.5 to 7.5. Ideal growing conditions include annual rainfall between 1000 and 2500 mm, a dry spell lasting around four months, elevations from sea level to 1500 meters, and temperatures ranging from 20 °C to 28 °C (Krisnawati *et al*., 2011) [12]. Mahogany requires full sunlight, is vulnerable to frost, but can withstand fire and shows moderate ability to coppice. However, it does not grow well in waterlogged soils. The timber is prized for its superior quality and is widely utilized in the manufacture of furniture, doors, windows, marine products, sports equipment, and musical instruments. Additionally, its fruit commonly known as sky fruit is valued in traditional medicine for its potential to help regulate blood sugar and cholesterol levels, as well as to support cognitive health, including conditions like Alzheimer's disease (Akhilraj, 2023) [1-2]. In this investigation, *Swietenia macrophylla* (Mahogany) will serve as the central tree species, paired with selected intercrops to assess system compatibility and productivity. The study is structured around specific objectives aimed at evaluating the effectiveness and potential of this agroforestry approach.

Material and Methods

The present study was carried out in farmer's field located in Hilly Zone (Zone-9) of Agro-climatic zone of Karnataka. The site is geographically positioned at 14°59'20.59" N latitude and 74°59'9.89" E longitude, with an elevation of 550 meters above mean sea level (MSL). This zone is predominantly characterized by hilly terrain. The experiment was carried out in a well-established, four-year-old mahogany plantation, following a Factorial Randomized Block Design (RBD) with three replications and seven treatments. Each experimental plot measured 2.5 x 2.5 meters and included mahogany trees spaced at 3 x 3 meters. Seven pulse crops namely, cowpea, blackgram, greengram, horsegram, chickpea, mothbean, and lentil were sown as intercrops within the mahogany plantation.

Intercrops were sown using a spacing of 10 cm between plants and 15 cm between rows (10 × 15 cm). Seeds were sown by dibbling. All intercrop seeds were sown on 13th February 2025. The initial irrigation of the experimental plots was carried out immediately after sowing. During the first fifteen days, flood irrigation was applied once every three days. Thereafter, the frequency was reduced to three times per month until harvest. No fertilizers were applied to either the intercrops or the sole crops throughout the study period. Seven days after sowing, gap filling was carried out to maintain a uniform intercrop population and ensure even distribution of plants across the plots. Manual weeding was performed 20 days after sowing and continued as needed throughout the following two months. The initial harvest of the pulse crops was done when approximately 80 percent of the pods had matured. The remaining pods were harvested later, once they fully ripened. After drying, the pods were threshed to separate the grains. Harvesting took place on 23rd May 2025, and the collected grains were weighed and converted into grain yield, expressed in quintals per hectare (q/ha^{-1}).

Results and Discussion

Plant height

At harvest, plant height was significantly affected by the interaction of cropping system and intercrop species, ranging from 33.80 cm (T_5 Chickpea) to 52.50 cm (T_2 Blackgram). In sole cropping, T_2 Blackgram (52.50 cm) was significantly taller, followed by T_1 Cowpea (44.23 cm), while the remaining species (T_3 Greengram, T_6 Mothbean, T_7 Lentil, T_5 Chickpea, and T_4 Horsegram) were on par. Under mahogany, T_1 Cowpea (43.20 cm) and T_2 Blackgram (41.30 cm) recorded higher values, with T_4 Horsegram (37.40 cm) being intermediate, whereas the others (T_3, T_6, T_7, T_5) showed lower but statistically similar heights. The reduction in height under the tree canopy can likely be linked to factors such as shading, competition for resources, and the influence of leaf litter, all of which may limit optimal growth. Overall, the results demonstrated that plant height benefited significantly from the more favourable growing conditions in the open field, as opposed to the limitations imposed by the shaded environment of the mahogany system.

The present findings align with earlier studies (Bhaskar *et al*., 2019; Chauhan *et al*., 2019; Kaur *et al*., 2020; Khare *et al*., 2011) [4, 8, 10, 11], which reported reduced plant height of intercrops under tree-based agroforestry systems compared to open-field conditions. Similar trends were observed by Tripathi *et al*. (2018) [21] under Eucalyptus, and by Chaturvedi and Jha (1998) [6] and Pandey and Tewari (2004) [16], who noted suppressed vegetative growth of pulses under increasing shade, supporting the current Mahogany-based results.

Number of pods

At harvest (90 DAS), pod number per plant showed clear variation across intercrops and environments. In sole cropping, Blackgram (57.90) produced the most pods, closely followed by Cowpea (56.90), Greengram (56.20), and Horsegram (55.40), while Lentil (54.00) and Mothbean (52.30) yielded moderately fewer. Chickpea (50.40) recorded the lowest. Under mahogany, Cowpea (52.10) again ranked highest, with Horsegram (44.90) and Greengram (43.00) performing next best. Lentil (39.80) and Mothbean (40.20) showed moderate values, whereas Chickpea (38.20) remained the lowest under shade.

Tripathi *et al*. (2018) [21] reported reduced pod production in greengram and blackgram under Eucalyptus-based agroforestry due to limited light and competition, while Pooja A.P. (2021) [17] similarly found fewer pods per plant in blackgram grown under coconut shade compared to open conditions.

Test weight

Test weight at harvest was notably affected by crop type, environment, and their interaction, ranging from 4.44 g in Mothbean to 9.13 g in Chickpea. Sole cropping averaged higher (6.54 g) than the mahogany system (6.14 g). In sole crops, Chickpea (9.32 g) was the heaviest, followed by Cowpea (8.52 g), with Blackgram (6.73 g) and Greengram (6.21 g) being similar. Horsegram (5.21 g) and Lentil (5.12 g) were lower, while Mothbean (4.67 g) was the least. Under mahogany, Chickpea (8.94 g) and Cowpea (8.03 g) remained highest, Blackgram (6.25 g) and Greengram (5.95 g) were intermediate, Horsegram (4.82 g) and Lentil (4.81 g) were lower, and Mothbean (4.22 g) the minimum.

Kumar *et al*. (2013) [13] observed reduced wheat test weight under Eucalyptus-based agroforestry, while Rani *et al*. (2015) [19] reported lower growth and yield traits of wheat and toria under poplar compared to open fields. Similarly, Rahangdale *et al*. (2014) [18] noted decreased seed weights in several kharif crops under bamboo shade due to limited light and nutrient availability.

Seed yield

At harvest (90 DAS), seed yield differed significantly across intercrops and environments, ranging from 6.26 q/ha in Chickpea to 8.06 q/ha in Cowpea. In sole cropping, Blackgram (8.62 q/ha), Cowpea (8.53 q/ha), and Greengram 8.46 q/ha, produced the highest and comparable yields, while Chickpea 7.32 q/ha remained lowest. Under mahogany, Cowpea 7.59 q/ha recorded the maximum yield, followed by Blackgram 7.48 q/ha and Horsegram 7.02 q/ha, whereas Greengram, Lentil, Mothbean, and Chickpea were significantly lower. Shade reduced yields more in Lentil, Chickpea, and Mothbean, moderately in Blackgram and Greengram, and least in Cowpea and Horsegram.

Chauhan *et al*. (2011) [7] documented a significant decline in wheat grain yield under poplar plantations, with the reduction becoming more pronounced as the trees aged. Sarvade *et al*. (2014) [20] reported maximum wheat grain yield of 36.0 q/ha in open field environments. In a related study, Verma and Rana (2014) [22] analyzed the performance of rice and wheat intercropped with *Eucalyptus tereticornis*, observing that grain production under tree-based systems (1.49 t/ha) was lower than in sole cropping. Consistent with these results, Sarvade *et al*. (2014) [20] also found reduced wheat yields under Poplar plantations compared to open plots, attributing this to the aggressive growth habit of poplar trees, which exacerbates competition and diminishes intercrop performance.

Harvest index

The harvest index among intercrops ranged from 33.46 percent in Chickpea to 38.33 percent in Blackgram. Blackgram recorded the highest index, followed by Cowpea (38.20 percent) and Greengram (35.61 percent), while Chickpea remained the lowest. In open conditions, Blackgram (40.78 percent) and Cowpea (39.51 percent) were superior, with Chickpea (35.71 percent) at the minimum. Under mahogany, Cowpea (36.90 percent) led, while Chickpea (31.22 percent) was the lowest. On average, the harvest index was higher in open fields (37.78 percent) than under shade (33.49 percent), indicating reduced partitioning efficiency under canopy cover.

The harvest index was generally higher in open conditions than under mahogany-based agroforestry. Similar findings were reported by Bijalwan (2011) [3], who observed seasonal and crop-wise variation in harvest index under agri-horticultural systems. Gawali *et al*. (2015) [9] noted reduced harvest index with closer poplar spacing, while Lakshmamma and Subba Rao (1996) [14] and Mohammed (2012) [15] reported a decline in blackgram and other crops with increasing shade. Likewise, Sarvade *et al*. (2014) [20] found that wider tree spacing improved wheat's harvest index, indicating that shading limits assimilate allocation to grains.

Table 1: Plant height (cm) of different legumes in sole and under Mahogany based Agroforestry system at 30 and 60 DAS

Treatments	30 DAS			60 DAS			At harvest (90 DAS)		
	Sole crops	Intercrops	Mean	Sole crops	Intercrops	Mean	Sole crops	Intercrops	Mean
T_1- Cowpea	17.50	12.00	14.75	37.70	34.90	36.30	44.23	43.20	43.71
T_2- Blackgram	18.30	16.90	17.60	40.60	30.50	35.55	52.50	41.30	46.90
T_3- Greengram	14.80	12.60	13.70	34.50	24.20	29.35	41.20	35.80	38.50
T_4- Horsegram	13.50	13.20	13.35	33.40	28.70	31.05	38.50	37.40	37.95
T_5- Chickpea	13.20	9.23	11.21	29.60	20.40	25.00	38.77	33.80	36.28
T_6- Mothbean	14.13	10.56	12.34	31.23	22.30	26.76	40.11	34.30	37.20
T_7- Lentil	13.40	10.02	11.71	30.50	21.60	26.05	39.60	33.90	36.75
Mean	14.97	12.07		33.93	26.09		42.13	37.10	
	SE(m) ±	CD at 5%		SE(m) ±	CD at 5%		SE(m) ±	CD at 5%	
Cropping system (E)	0.05	0.17		0.06	0.17		0.06	0.17	
Crops (C)	0.11	0.32		0.11	0.33		0.11	0.32	
Interaction (E× C)	0.15	0.45		0.16	0.47		0.15	0.46	

DAS = Days After Sowing; E = Growing condition

Table 2: Number of pods of different legumes under sole and Mahogany based Agroforestry system at harvest

Treatments	At harvest (90 DAS)		
	Sole crops	Intercrops	Mean
T_1- Cowpea	56.90	52.10	54.50
T_2- Blackgram	57.90	42.00	49.95
T_3- Greengram	56.20	43.00	49.60
T_4- Horsegram	55.40	44.90	50.15
T_5- Chickpea	50.40	38.20	44.30
T_6- Mothbean	52.30	40.20	46.25
T_7- Lentil	54.00	39.80	46.90
Mean	54.72	42.88	
	SE(m) ±	CD at 5%	
Cropping system (E)	0.10	0.31	
Crops (C)	0.20	0.59	
Interaction (E× C)	0.28	0.84	

DAS = Days after sowing

E = Growing condition

Table 3: Test weight of seed (g) of different legumes under sole and Mahogany based Agroforestry system at harvest

Treatments	At harvest (90 DAS)		
	Sole crops	**Intercrops**	**Mean**
T_1- Cowpea	8.52	8.03	8.27
T_2- Blackgram	6.73	6.25	6.49
T_3- Greengram	6.21	5.95	6.08
T_4- Horsegram	5.21	4.82	5.01
T_5- Chickpea	9.32	8.94	9.13
T_6- Mothbean	4.67	4.22	4.44
T_7- Lentil	5.12	4.81	4.96
Mean	6.54	6.14	
	SE(m) $\pm$	CD at 5%	
Cropping system (E)	0.01	0.03	
Crops (C)	0.01	0.05	
Interaction (E× C)	0.02	0.07	

DAS = Days After Sowing
E = Growing condition

Table 4: Weight of seed yield (q/ha) of different legumes under sole and Mahogany based agroforestry system at harvest

Treatments	At harvest (90 DAS)			Percentage yield reduction (%)
	Sole crops	**Intercrop**	**Means**	
T_1- Cowpea	8.53	7.59	8.06	12.38
T_2- Blackgram	8.62	7.48	8.05	15.24
T_3- Greengram	8.46	6.36	7.41	33.01
T_4- Horsegram	8.02	7.02	7.52	14.24
T_5- Chickpea	7.32	5.21	6.26	40.49
T_6- Mothbean	7.57	5.56	6.56	36.15
T_7- Lentil	7.82	5.32	6.57	46.99
Mean	8.04	6.36		
	SE(m) $\pm$	CD at 5%		
Cropping system (E)	0.04	0.11		
Crops (C)	0.08	0.27		
Interaction (E× C)	0.11	0.35		

DAS = Days After Sowing
E = Growing condition

Table 5: Harvest index of different legumes under sole and Mahogany based Agroforestry system at harvest

Treatments	At harvest (90 DAS)		
	Sole crops	**Intercrops**	**Mean**
T_1- Cowpea	39.50	36.89	38.20
T_2- Blackgram	40.77	35.87	38.32
T_3- Greengram	38.03	33.17	35.60
T_4- Horsegram	37.38	33.50	35.44
T_5- Chickpea	35.70	31.21	33.46
T_6- Mothbean	36.18	32.15	34.17
T_7- Lentil	36.86	31.61	34.23
Mean	37.78	33.49	
	SE(m) $\pm$	CD at 5%	
Cropping system (E)	0.01	0.04	
Crops (C)	0.01	0.05	
Interaction (E× C)	0.03	0.11	

DAS = Days After Sowing
E = Growing condition

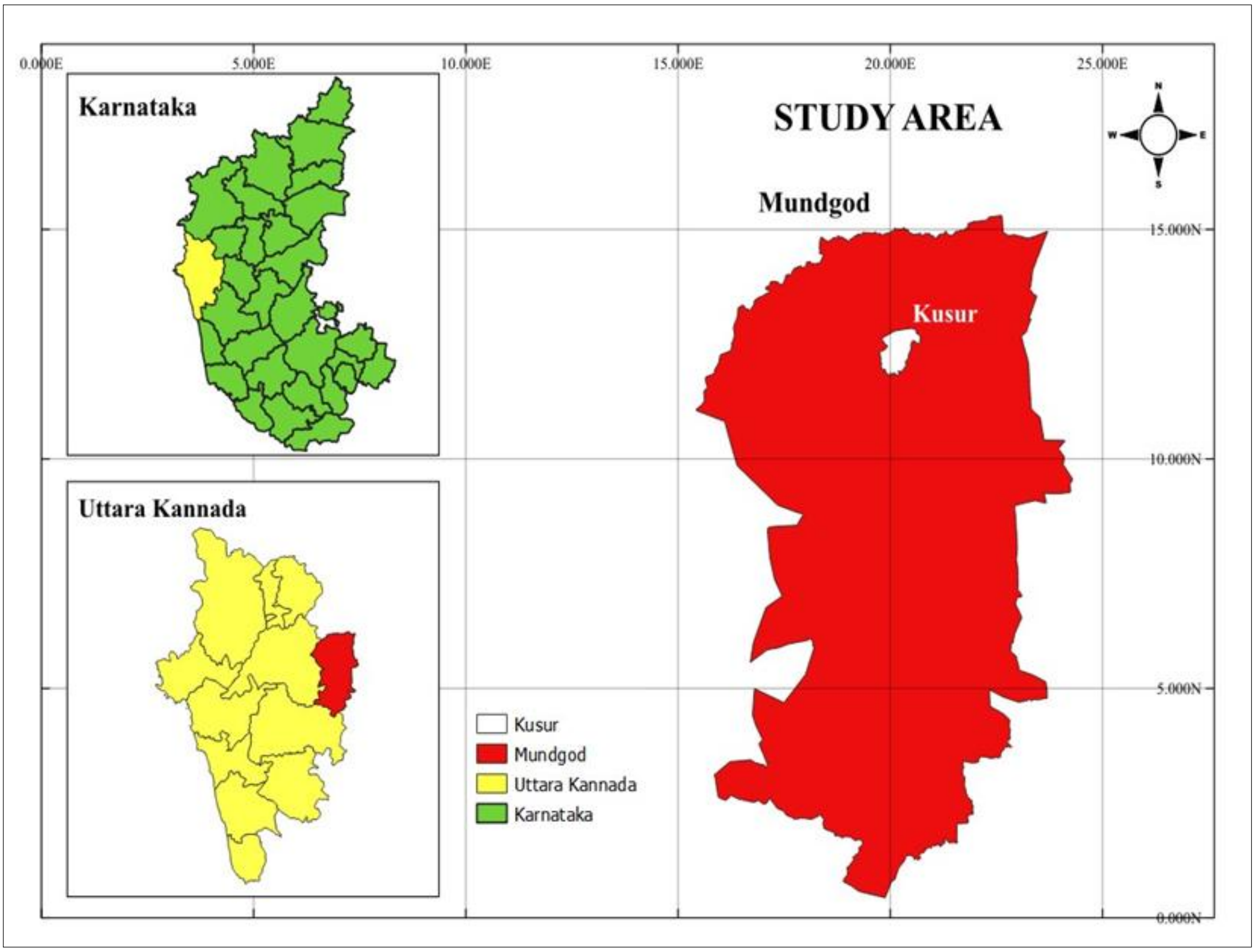

Fig 1: Location of Experimental area

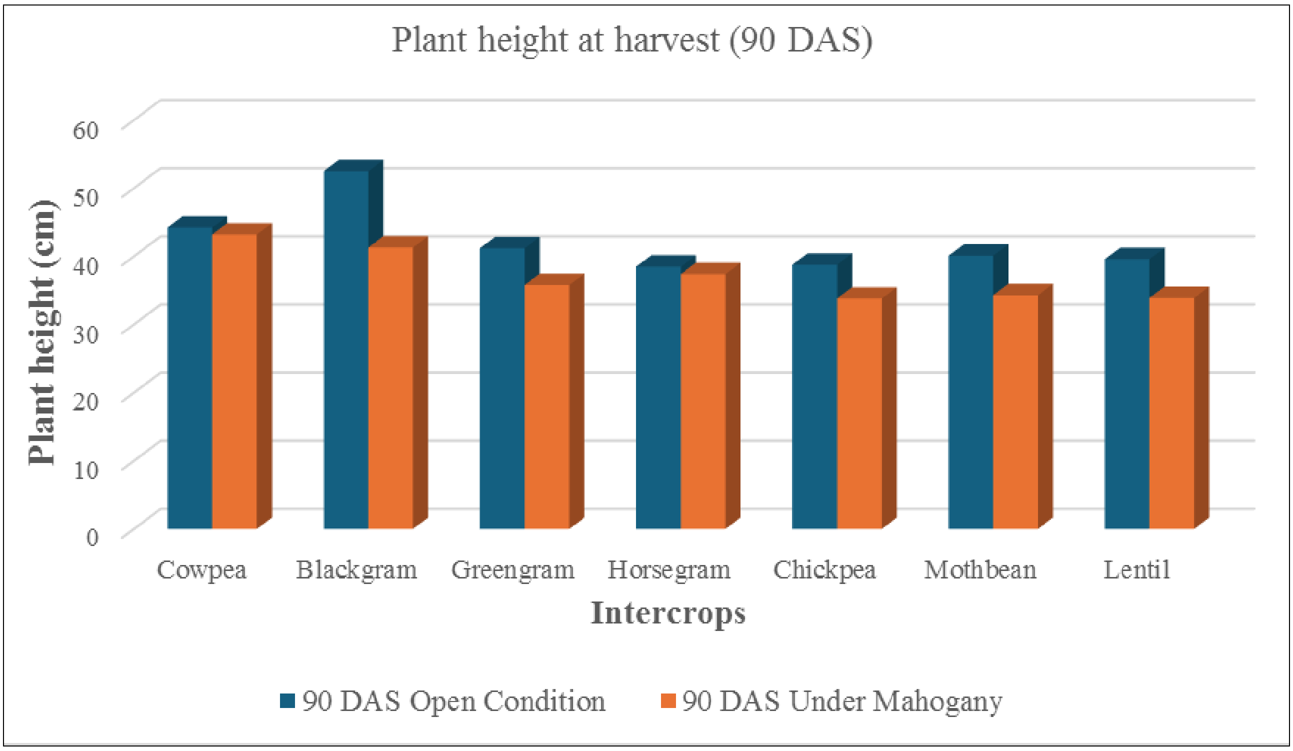

Fig 2: Plant height (cm) of different legumes under sole and Mahogany based Agroforestry system at harvest

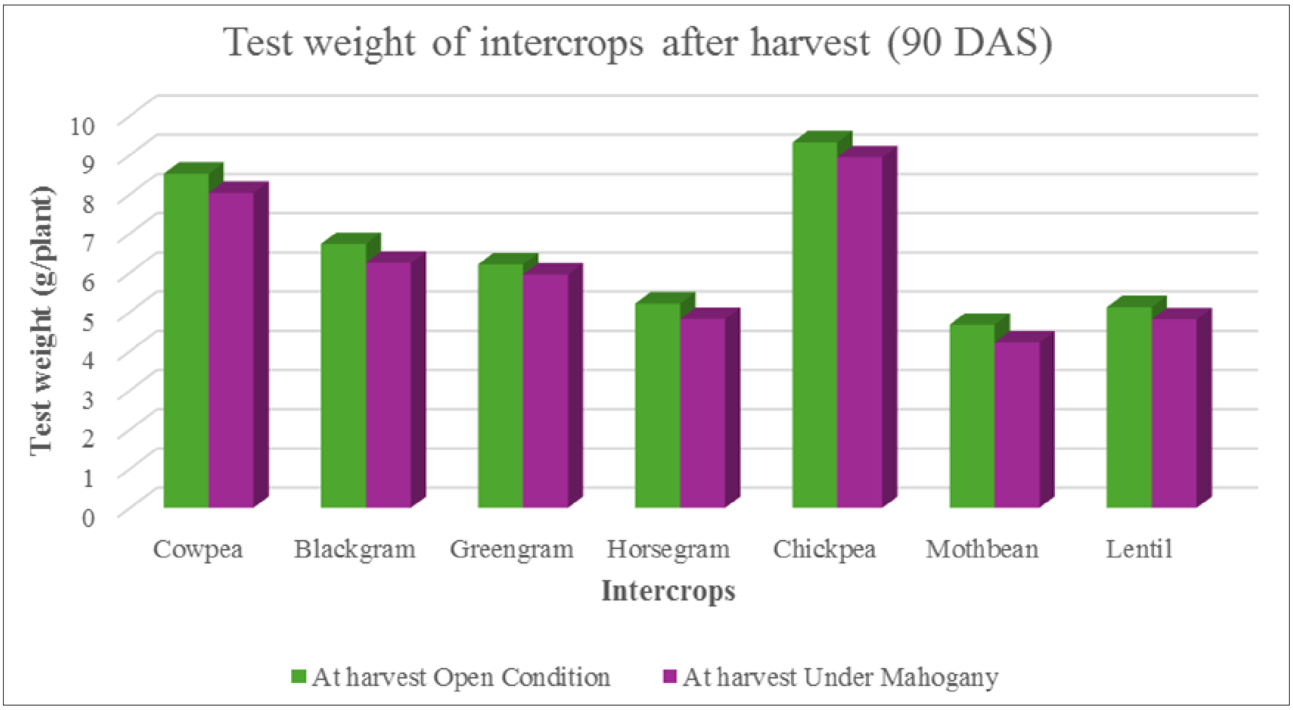

Fig 3: Test weight of the seed (g) of different legumes under sole and Mahogany based agroforestry system at harvest

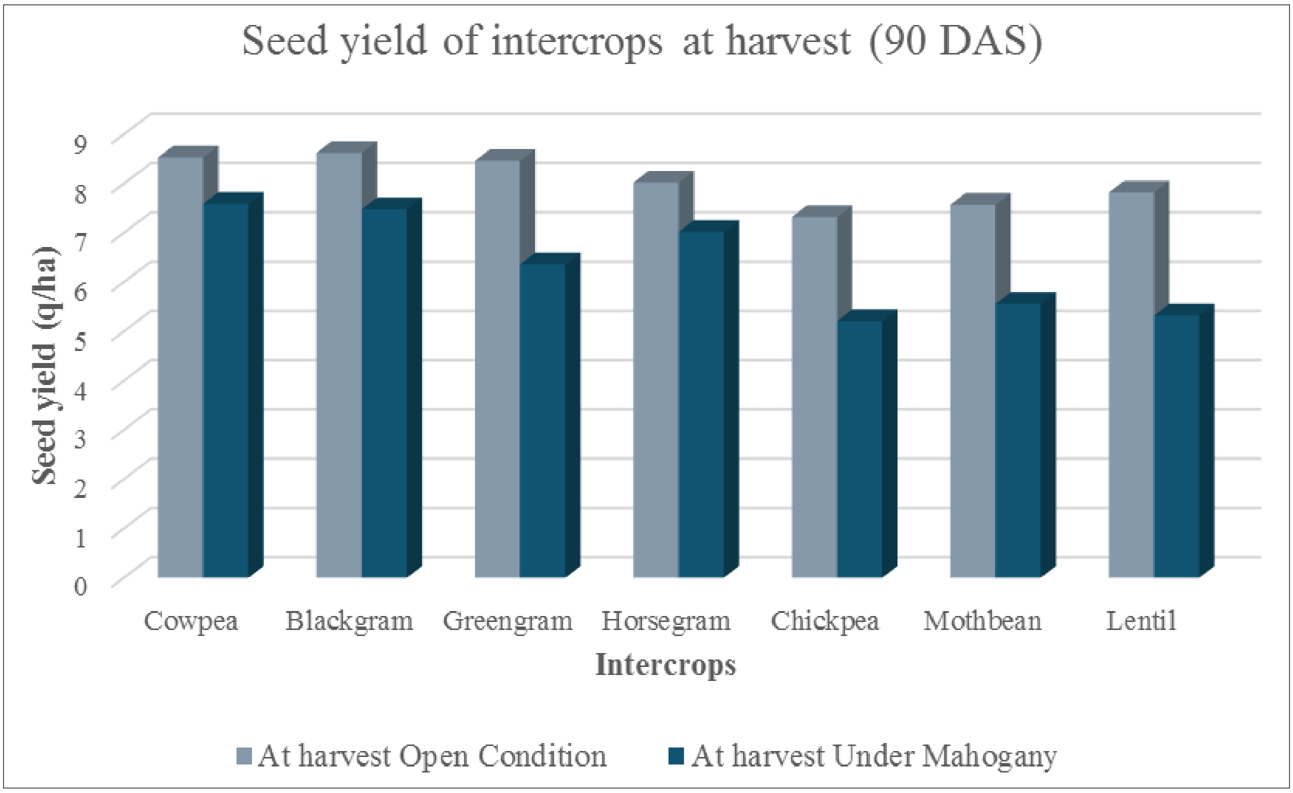

Fig 4: Weight of seed yield (q/ha) of different legumes under sole and Mahogany based agroforestry system at harvest

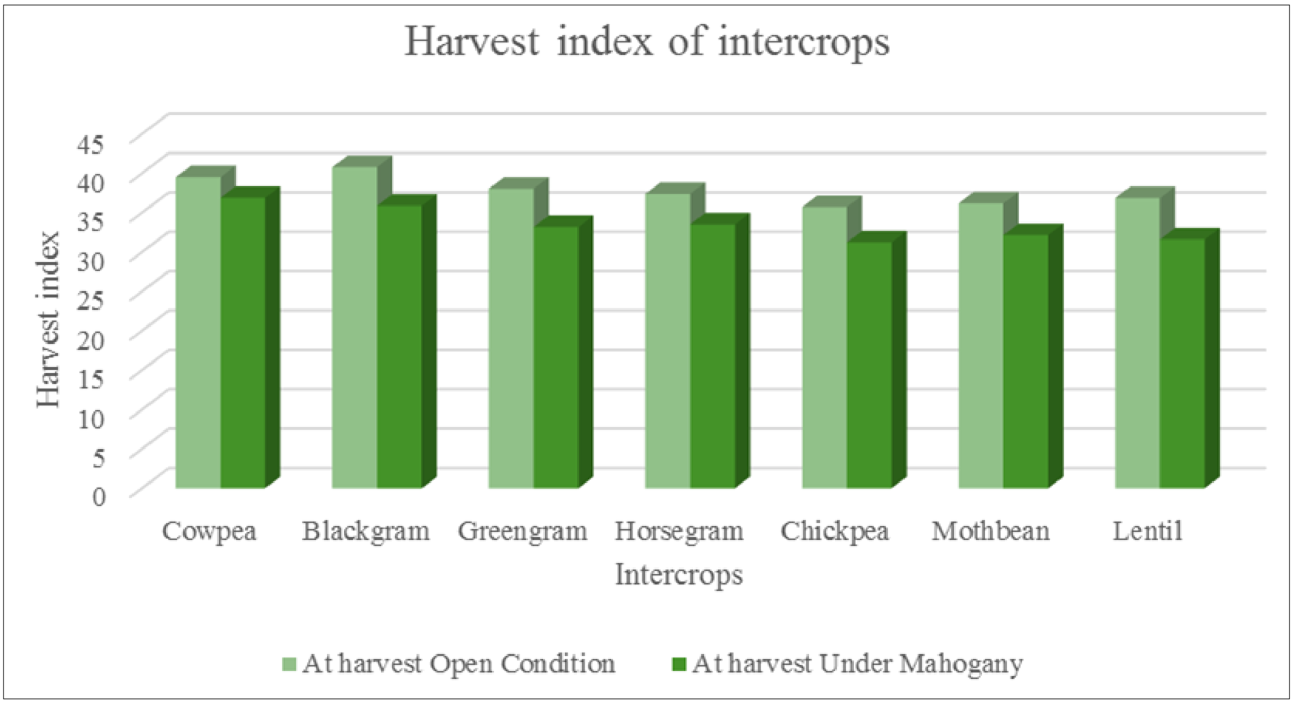

Fig 5: Harvest index of different legumes under sole and mahogany based Agroforestry system at harvest

Conclusion

Based on the findings of the study, it can be concluded that all seven pulse varieties demonstrated superior performance under open field conditions when compared to their growth under the mahogany-based agroforestry system. However, within the constraints of the agroforestry environment and intercrops such as cowpea and blackgram emerged as the most promising options. These crops showed comparatively higher seed and stover yields than the other varieties evaluated, making them suitable candidates for cultivation under tree-based systems like *Swietenia macrophylla*.

To effectively harness the benefits of crop-environment interactions in agroforestry systems, especially under rainfed conditions, the cultivation of cowpea and blackgram as intercrops is recommended. These pulses consistently recorded higher seed yields in the study. Furthermore, the highest tree volume was observed in *Swietenia macrophylla* when intercropped with cowpea, blackgram, and greengram. Although the differences in tree volume were statistically non-significant, the consistent trend suggests that these intercrops can be considered compatible and beneficial for growth alongside mahogany.

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