Impact of Tree Geometry on the Growth and Yield performance of Black Gram (*Vigna Mungo* L.) under Kadam (*Neolamarckia Cadamba*Roxb.) based Agroforestry System

Abstract

Agroforestry is an environmentally conscious and comprehensive method of land management that entails cultivating agricultural crops, forest trees, and/or animals in conjunction on the same parcel of land through the implementation of suitable management strategies. The present study entitled "Impact of tree geometry on the growth and yieldperformance of Black Gram (*Vigna mungo* L.) under Kadam (*Neolamarckia cadamba* Roxb.) based Agroforestry System" was conducted during the *Kharif* season of 2022-23 within an already established 2-year-old plantation situated at Forestry research farm, RLBCAU, Jhansi. The study encompasses three different spacings, *i.e.*,S_1- 5 m x 5 m, S_2- 5 m x 4 m and S_3- 5 m x 3. A randomized block design having four treatments each replicated five times was laid out. Outcomes of research revealed that sole cropping of black gram exhibited higher plant height (77.44 cm), leaf and branch numbers (6.38 and 5.32, respectively), dry matter accumulation(17.05 g/plant for above-ground and 2.12 g/plant for below-ground), leaf area (2183.06 cm^2), root nodules (11.54), shorter phenological duration *viz*., 50% flowering, 50% pod setting and maturity (40.11 days, 54.49 days, and 70.84 days, respectively).It also demonstrated significantly higher yield attributes such as number of pods and seeds per pod(27.28), number of seeds per pod (5.82),test weight(36.73 g),grain yield (0.79 t ha^{-1}), straw yield (1.78 t ha^{-1}), biological yield(2.57 t ha^{-1}), harvest index (30.63 %), and grain-to-straw ratio(0.44) compared to the intercropped. Among all the agroforestry treatments *Neolamarckia cadamba* at 5 m × 5 m with *Vigna mungo*, found to perform better than closer spacing (*i.e.*,5 m x 4 m and 5 m x 3 m) spatial arrangements. Hence, wider spacing must be adopted for higher economic returns than closer spacing. Overall, current research provided valuable insights for optimizing tree-crop interactions in agroforestry systems to enhance productivity and sustainability.

Keywords: Agroforestry, Central India, Kadam, Industrial plantation, Intercropping, Black Gram, Tree geometry

Introduction

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In a world with limited land resources, agroforestry emerges as a promising solution to tackle the challenges of feeding a rapidly growing global population(Buringh, 1989). With only 22% of the Earth's land suitable for farming, and even smaller portions offering high production capacity for intensive crop cultivation, farmers confront numerous hurdles, including floods, droughts, and erratic rainfall in regions with scarce precipitation. In response, many rely on rainfed agriculture and focus on cultivating a single crop.However, the pressing need to maximize outputs from available land while minimizing soil damage necessitates a shift towards sustainable land management practices (Singh *et al*., 2024).

"Agroforestry, an innovative approach that integrates agricultural crops, forest trees, and animals within the same land parcel through effective management strategies, offers a holistic solution to optimize resource utilization and foster ecological balance" (Lasco*et al.*,2014).The strategic arrangement and spacing of trees in agroforestry systems play a crucial role in their success and sustainability. By careful planning and tree placement, farmers can maximize access to vital resources like water, light, and nutrients, leading to enhanced growth and higher crop yields (Choudhary *et al*., 2024). Moreover, the spatial arrangement of trees provides microclimatic advantages such as shade and wind protection, benefiting both trees and crops(Rathod *et al*., 2024). This fosters biodiversity, reduces pest and disease pressure, and creates habitats for beneficial insects and animals, contributing to the overall ecological balance (Chavan *et al.,* 2015).

In context of India, where nearly 70% of the population resides in rural areas and relies on agriculture and animal husbandry for livelihood, agroforestry plays a pivotal role in meeting food security and nutritional needs. India's status as the largest producer and consumer of black gram (*Vigna mungo* L.), a pulse crop rich in essential nutrients, underscores its critical role in addressing protein demands (Panhwar, 2005). However, the challenge of limited land resources, particularly in the face of an expanding population, calls for intensified farming practices and sustainable land management.Among many trees utilized in agroforestry, *Neolamarckiacadamba*, a versatile species, stands out for its prolific wood production and ecological benefits. With adaptability to diverse climatic conditions, including ample sunlight, frost resistance, and tolerance to varying rainfall and temperature, *Neolamarckiacadamba* becomes a valuable resource for plywood and furniture manufacturing. Its capacity to deliver ecological services such as carbon sequestration, nitrogen cycling, and soil protection further highlights its importance in fostering environmental balance (King, 1969).

Moreover, *Neolamarckiacadamba's* ability to fix atmospheric nitrogen enhances soil fertility, reducing reliance on artificial fertilizers and promoting sustainable agricultural practices. This, combined with the financial benefits and therapeutic properties valued in traditional and cultural practices, supports rural development and sustainable agriculture (ICRAF, 1983).

To maximize the land utilization, an agroforestry trial was laid out to investigate the performance of black gram under different spatial arrangements ofKadam plantation.

Materials and Methods

Details of the experimental site

The current research was conducted at the Forestry Research Farm, Rani Lakshmi Bai Central Agricultural University, Jhansi, during the *Kharif* season 2022-23.The designated research site is geographically located at a latitude of 25.515257° N and a longitude of 78.563506° E, with an elevation of 284 m above the mean sea level. Situated within the semi-arid region of the Bundelkhand area in Uttar Pradesh, India, this location falls under the Agroclimatic Zone VIII (Central Plateau and Hills Region Zone) of Uttar Pradesh in India.It is characterized by a subtropical climatic pattern, featuring extremely hot summers and cold winters, along with semi-humid climatic conditions. The average temperature in this area is approx. 25.80°C and mean annual precipitation typically ranges from 850 to 1000 mm. The soil in the study area is characterized by its dryness, stony texture, and shallow depth, predominantly composed of granite, gneiss, and white sandstone formations. It contains minimal organic matter. The region is primarily defined by two dominant soil types: red soil and black soil.

Experimental details

The study aimed to investigate the impact of different tree spacing configurations on the growth and yield performance of Black Gram. The plantation area encompassed three different tree spacings, *i.e.*5×5 m, 5×4 m, and 5×3 m along with sole. The experiment was designed in a Randomized Block Design (RBD) with four treatments and five replications. The treatmentsare as follows:

T_1 - *Vigna mungo* sole crop

T_2–*Neolamarckia cadamba*(5 m × 5 m) +*Vigna mungo*

T_3 – *Neolamarckia cadamba* (5 m × 4 m) + *Vigna mungo*

T_4 – *Neolamarckia cadamba* (5 m × 3 m) + *Vigna mungo*

The selected Black Gram variety, IPU 13-1, was used for sowing, and various growth parameters, including emergence count, plant height,leaves and branch numbers per plant, above and below dry matter accumulation per plant, leaf area, and root nodules per plant. Additionally, the phenological duration, encompassing days taken to reach 50% flowering, pod setting, and maturity, were also evaluated. Moreover, the yield attributes of Black Gram, such as pod and seed numbers, test weight, grain and straw yield, biological yield, harvest index, and grain-to-straw ratio, were analysed.The data obtained from experiment was subjected to statistical analysis using Fisher's analysis of variance techniques Gomez & Gomez (1984).

Results and Discussion

1. Growth attributes of black gram under different tree geometry of *Neolamarckia cadamba* in agroforestry system

The current study investigates the growth attributes of black gram under different treatments of *Neolamarckia cadamba* based agroforestry systemas shown in table no.1& figure 01. The emergence count (36.60 per sq. m), plant height(77.44 cm), number of leaves and branches per plant (12.27 and 12.66, respectively), above-ground and below-ground dry matter accumulation(17.05 g/plant for above-ground and 2.12 g/plant for below-ground), leaf area per plant(2183.06 cm^2) and number of root nodules per plant(11.54)was found highest, in sole crop (T1). Among different agroforestry treatments, denser tree spacing (T4) having the lowest value. In terms of phenological parameters, T1 exhibited the shortest duration for 50% flowering, 50% pod setting, and physiological maturity (40.11 days, 54.49 days, and 70.84 days, respectively). The agroforestry treatments had longer durations, with T4 *Neolamarckia cadamba* (5 m × 3 m) + *Vigna mungo* showing the longest duration (46.76 days, 62.75 days, and 75.21 days). Among the geometry treatment, T2 (*Neolamarckia cadamba* + *Vigna mungo* at 5m x 5m spacing) performs better than T3 and T4 treatments.

It may be likely due to increased competition for light, water, and nutrients from trees with higher density as compared to wider spacing and open condition. The results of this study are consistent with findings of previous studies conducted by Meena *et al.* (2021), Singh *et al.*(2022), Sharma *et al.*(2016), Khan *et al.*(2009), Yadav *et al.*(2008),Narayana *et al.*(2013), Gowsalya*et al.*(2016)and Subramaniyan *et al.*(2021)who alsoreported similar outcomes which may be due to negative effects of tree competition on the growth and yield

of black gram in agroforestry systems. Also, Ajaykumar *et al*. (2022)found that the sole crop of black gram had better growth compared to the intercropped treatments with Malabar neem (*Melia dubia*) trees at different spacings.

Similarly, Dalvi *et al*. (2020) reported that black gram performed better in open conditions and its growth decreases when the spacing decreases. These studies suggest that black gram is sensitive to the competition from trees for light, water, and nutrients, and requires adequate spacing and management practices to optimize its productivity in agroforestry systems.

2. Yield attributes of black gram under different tree geometry of *Neolamarckia cadamba* in agroforestry system

The yield attributes (Figure 02 &table no. 2) showed that the sole crop treatment (T1) performed significantly better than the intercropped treatments in terms of all parameters. The sole crop treatment (T1) recorded highest values for number of pods per plant (27.28), number of seeds per pod (5.82), test weight (36.73 g), grain yield (0.79 t ha^{-1}), and straw yield (1.78 t ha^{-1}).

Among the intercropped treatments, the combination of *Neolamarckia cadamba*with a spacing of 5m x 5m (T2) and black gram achieved the highest values for these parameters, number of pods per plant (26.37), number of seeds per pod (5.48), test weight (35.22 g), grain yield (0.74 t ha^{-1}), and straw yield (1.64 t ha^{-1}) while the treatment 5m x 3m (T4) showed the lowest values. The results indicated that the various yield attributes of black gram decreased with increasing tree density in the agroforestry system.

The biological yield, harvest index and grain to straw ratio was assessed and the results revealed that the sole crop treatment (T1) had the highest values for biological yield (2.57 t/ha), harvest index (30.63 %), and grain to straw ratio (0.44), which significantly higher than the intercropping. Among all the intercropping treatments, T2*Neolamarckia cadamba*(5 m × 5 m) + *Vigna mungo*had the highest values for biological yield (2.38 t ha^{-1}), harvest index (31.25 %), and grain to straw ratio (0.45), while T4 had the lowest values for all these parameters.

The reason could be better light, nutrition and moisture availability due to lesser competition between trees and crop in wider spacing as compared to closer spacing. The yield reduction in intercropping are consistent with prior research highlighting the advantages of sole cropping over intercropping.This is in line with earlier findings of Parasriya *et al*.

(2022), Hossain *et al.*(2019), Narayana *et al.* (2013),Bhanu *et al.*(2019). Similarly, Bhusara*et al.*(2018),Dalvi *et al.*(2020), Sureshbhai*et al.*(2017).Osman *et al*. (2011)reported that black gram yield was higher under sole cropping than Casuarina-based agroforestry system. Also, Dai *et al*. (2016)and Meena *et al.* (2021), reported higher harvest index and grain to straw ratio of black gram under increased plant density as compared to lower plant density.

Figure 01: Growth attributes of black gram

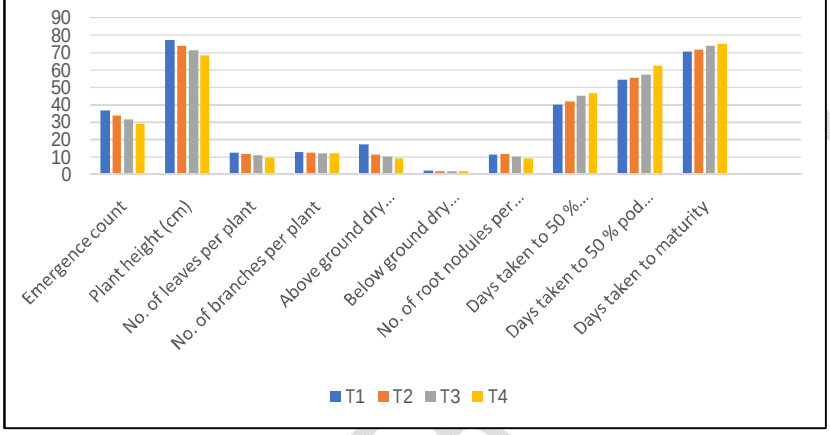

Figure 02: Yield attributes of black gram

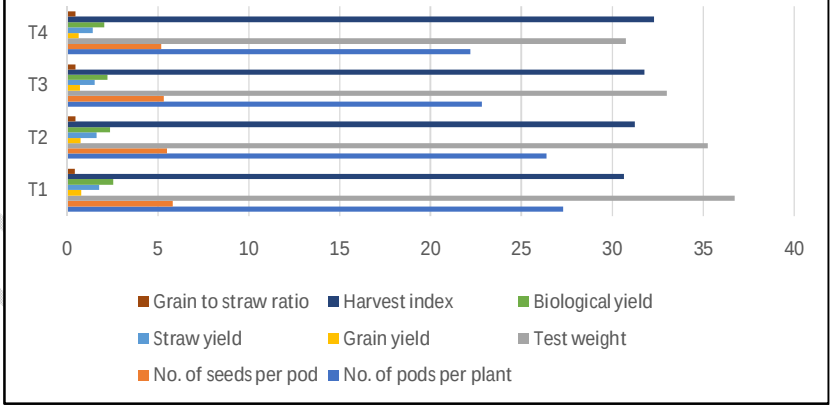

Table 1: Growth attributes of black gram under different tree geometry of *Neolamarckiacadamba*in agroforestry system

Treatment	Emergence count (per sq. m.)	Plant height (cm)	No. of leaves per plant	No. of branches per plant	Above ground dry matter accumulation (g)	Below ground dry matter accumulation (g)	Leaf area per plant (cm^2)	No. of root nodules per plant	Days taken to 50 % flowering	Days taken to 50 % pod setting	Days taken to maturity
T1	36.60	77.44	12.27	12.66	17.05	2.12	2183.06	11.54	40.11	54.49	70.84
T2	33.80	74.06	11.75	12.25	11.36	1.90	1973.38	11.82	41.74	55.62	72.02
T3	31.60	71.34	10.91	12.03	10.21	1.86	1800.13	10.20	45.02	57.43	73.98
T4	29.00	68.60	9.62	11.91	9.08	1.74	1529.18	8.93	46.76	62.75	75.21
SEm±	0.77	1.99	0.61	0.15	0.53	0.08	103.51	0.35	1.60	1.93	1.02
CD @ 5%	2.36	6.14	1.88	0.46	1.62	0.24	318.90	1.08	4.92	5.94	3.14
C.V. (%)	5.23	6.12	12.24	2.73	9.85	9.31	12.37	7.39	8.23	7.49	3.12

Table 2: Yield attributes of black gram under different tree geometry of *Neolamarckiacadamba* in agroforestry system

Treatment	No. of pods per plant	No. of seeds per pod	Test weight (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)	Grain to straw ratio
T1	27.28	5.82	36.73	0.79	1.78	2.57	30.63	0.44
T2	26.37	5.48	35.22	0.74	1.64	2.38	31.25	0.45
T3	22.82	5.33	32.99	0.71	1.53	2.25	31.75	0.47
T4	22.17	5.17	30.75	0.67	1.41	2.08	32.26	0.48
SEm±	0.44	0.15	0.65	0.02	0.04	0.06	0.24	0.01
CD @ 5%	1.36	0.45	2.00	0.06	0.13	0.19	0.74	0.02
C.V. (%)	4.00	5.97	4.27	5.72	6.16	5.91	1.72	2.48

Conclusion

The study observed that intercropping of black gram with Kadam plantations in different spacing resulted in the highest growth and yield attributes under sole cropping conditions. Intercropping pulses with fast-growing trees proved to be financially more rewarding for farmers as compared to sole cropping. The average maximum seed yield of black gram with intercropping in the *Neolamarckia cadamba* (5 m × 5 m) + *Vigna mungo* combination was reported to be 0.74 t ha^{-1}, with a marginal reduction when compared to sole cropping (0.79 t ha^{-1}). Therefore, the wider spacing of (5 x 5 m) can be suggested for intercropping in *Neolamarckia cadamba* plantations during initial years. Considering the economic returns from the trees at the harvesting stage, it may be concluded that the financial benefits were higher in the intercropping systems than sole cropping systems. Also,it mitigates the risk of crop failure and compensate for returns from the trees. The interaction between trees and crops can be maximized through technological interventions and good agricultural practices to achieve optimal gains. Overall,the findings suggest that integration of kadam trees with black gram at appropriate spacing offers an advantageous approach to optimize growth and yield attributes, making agroforestry systems a profitable and sustainable alternative to traditional sole crop cultivation.

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