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PERFORMANCE OF DIFFERENT LEGUMES UNDER BAMBOO-BASED AGROFORESTRY IN BUNDELKHAND

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ABSTRACT

Bamboo based agroforestry models offer farmers greater economic benefits, enhance soil health, address the decrease in national forest coverage (33%), and supply raw materials for both industries and the rural community's domestic needs. During the research, spacing of *Bamboo* spp. were examined was 8 m × 6 m with two different growing conditions, namely sole cropping and intercropping. The data analysis indicates that different intercrops cultivated in open conditions had superior development and production characteristics compared to those produced under agroforestry. An analysis was conducted on various growth and yield characteristics of lentil, chickpea, lathyrus, jack bean and broad bean revealing a notable impact of growing conditions on both plant growth and production. The findings indicate that parameters such as plant height, number of branches, dry matter accumulation, number of pods per plant, number of root nodules per plant at 50 DAS, number of days taken to physiological maturity, number of days taken to 50% flowering, straw yield, grain yield and biological yield were greater in sole cropping compared to agroforestry. The grain yield of pulse crops in agroforestry was 1179 kg/ha for lentil, 1237 kg/ha for chickpea, 715 kg/ha for lathyrus, 917 kg/ha for jack bean, 829 kg/ha for broad bean. The growth performance of bamboo under agroforestry was also good in terms of height, girth of 3rd internode, length of 3rd internode and culm diameter in comparison to sole bamboo.

***Keywords*:** Intercropping, Bamboo, Agroforestry, Different intercrops, sole cropping

Introduction

The phenomenon of anthropogenic climate change is being observed worldwide and has led to a rise in global surface temperature by 0.85 °C in the last century. The temperature is projected to rise by a minimum of 1.5 °C by the end of the 21st century (Wuebbles, 2018). The prevalence of poverty is increasing as a result of recent global warming and is expected to continue rising for various groups when the global mean temperature rises by 1 °C to 1.5 °C and beyond (Lomborg, 2020). The Bundelkhand region, located in central India spans a total area of 2.94 million hectares. Out of this, 69% is used for agriculture, 8% (0.236 million hectares) is covered by forests, and the remaining land is used for non-agricultural purposes, is barren or cultivable waste. The region has a hilly and uneven landscape, with highly eroded soils that have low fertility. Groundwater resources are scarce, and rainfall is unpredictable, leading to inadequate irrigation facilities and frequent droughts and crop failures. Bundelkhand is a region highly prone to water scarcity and land degradation, making it susceptible to fluctuations in climate (Gupta *et al.*, 2014). The climate in this region is semi-arid and subtropical, with an average annual rainfall of 867 mm. Approximately 90% of the total precipitation is concentrated within a three-month interval, notably from July to September (Tewari *et al.*, 2016; Singh *et al.*, 2014). The intense ecological stress exerted on forests and communal lands, combined with the reduction in vegetation cover, has led to a shortage of both fuelwood and fodder in the region. This scarcity had a detrimental impact on the security of people's livelihoods (Dev *et al.*, 2016, 2018).

Agroforestry is an achievable approach in this scenario to address climate change and alleviate global warming. It achieves this by absorbing greenhouse gases (CO_2) by the technique of carbon sequestration. Agroforestry, a type of Climate Smart Agriculture, offers a hopeful solution for small-scale farmers in poor countries as an effective adaptation strategy.

Bamboo, a highly resilient plant species, continues to thrive in the present day and is sometimes referred to as "The Green Gold". Bamboo is an exceptional and distinctive plant on planet Earth due to its rapid growth rate and the ability to be harvested annually if maintained intensively. Bamboo is a highly productive, sustainable, and adaptable plant that is considered a significant Non-Wood Forest Product (NWFP). It serves as a source of food, shelter, and raw materials and can thrive in a varied range of climatic and soil conditions.

Bamboo is widely raised worldwide in a forest plantation due to its rapid growth cycle and its versatile applications in construction, furniture making, panel manufacturing, pulp production and flooring. (Partey *et al.*, 2017). In India the bamboo is cultivated on an estimated area of 1,49,443 square kilometres, primarily in forest regions (FSI report, 2021). Nevertheless, there has been a lack of substantial efforts to include bamboo into existing farming practices across various agro-ecological regions, particularly in the semi-arid regions that comprise roughly 15% of the Earth's geography (Huang 2016).

Agroforestry systems that utilize bamboo can significantly contribute to the improvement of sustainability and the conservation of resources. Bamboos has several advantages compared to trees, including a very short time span from planting to harvest, a growth rate three times faster than Eucalyptus, and the release of 35% more oxygen than equal strands of other trees. The growth cycle of bamboos typically spans four to five years before they can provide their initial harvest. Bamboo thrives in a variety of soil types, including fertile alluvial soil, compact lateritic soil, and sandy saline soil found along the coast. The agricultural community would benefit greatly from engaging in bamboo cultivation, since it offers the potential for consistent revenue from well-maintained plantations. In light of the information provided, a study was conducted with the aim of creating and establishing a bamboo-based agroforestry that is well-suited for semi-arid regions.

Material and Methods

Study Site

The research was carried out in the year 2023-24 on a 4-year-old Bamboo plantation at the Forestry Research Farm Bhojla, situated at Rani Lakshmi Bai Central Agricultural University in Jhansi. The location is located at an altitude of 284 metres above the average sea level and is classified under agro-climatic zone-VIII (Figure 1). The yearly rainfall in this area varies from 870 to 1000 mm, while the mean annual temperature is 25.80 °C. The soil is dry, stony, shallow, and mostly consists of granite, gneiss, and white sandstone. It possesses a little amount of organic material. The research region is primarily distinguished by two primary soil types: red soil and black soil.

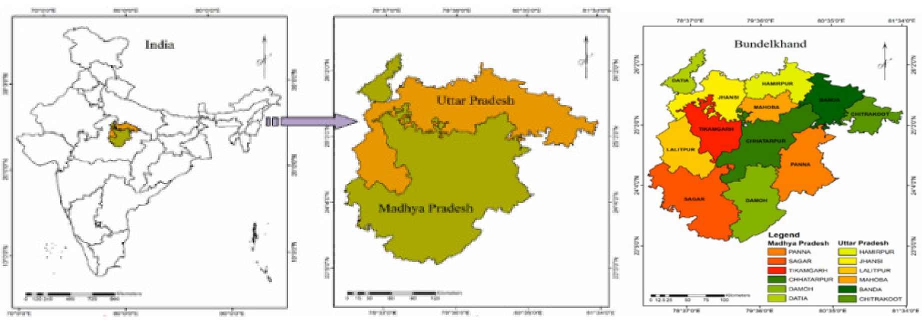

Fig. 1 : Location Map of study site

Experimental Details

The study was conducted using a randomized complete block design (RBD) consisting of ten treatment combinations., i.e., T_1 = *Bamboo spp.* + *Lens culinaris*, T_2 = *Bamboo spp.* + *Cicer arietinum*, T_3 = *Bamboo spp.* + *Lathyrus sativus*, T_4 = *Bamboo spp.* + *Canavalia ensiformis*, T_5 = *Bamboo spp.* + *Vicia faba,* T_6 = *Lens culinaris* sole crop, T_7 = *Cicer arietinum* sole crop, T_8 = *Lathyrus sativus* sole crop, T_9 = *Canavalia ensiformis* sole crop and T_{10} = *Vicia faba* sole crop. Each treatment combination was replicated three times. The crops were cultivated using the prescribed set of techniques and practices. Additionally, T_0 = sole bamboo tree; was also considered one treatment for evaluating the growth parameters of bamboo.

Statistical Analysis

The experiment involved the evaluation of various crop growth and yield parameters, and the resulting data was analysed using statistical techniques. For each variable, the average values were determined, and then analysis of variance (ANOVA) was done to evaluate the impact of the treatments. The least significant difference (LSD) test was used to compare the means of various treatments, with a significance threshold of $p<0.05$.

Results and Discussions

Effect of bamboo-based agroforestry on growth parameters of different intercrops

Height of plant and no. of branches at harvest

The highest height of intercrops observed was in T_9 as compared to T_4 in case of *Canavalia ensiformis*. For *Vicia faba,* T_{10} was the best treatment as a compared to T_5. Similarly, for *Lens culinaris, Cicer arietinum* and *Lathyrus sativus* the height was greater in case of sole cropping as compared to bamboo-based agroforestry. The maximum number of branches of intercrops observed was in T_8 as compared to T_3 in case of *Lathyrus sativus*. For *Vicia faba* T_{10} was the best treatment as compared to T_5(Table 1). It was observed that number of branches were highest in sole cropping of all intercrops as compared to intercropping. These findings align with previous studies reporting negative effects of tree density on the growth of intercropped crops like paddy, soybean, green gram and sesame (Rahangdale *et al*., 2014). The leaf leachates of *Dendrocalamus stocksii* have an inhibitory effect on the growth attributes of groundnut (Rawat *et al*., 2018) Similarly, the leaf leachates of *Dendrocalamus strictus* inhibit the growth of soybean and wheat (Nema and Reddy, 2016).

Root nodules per plant at 50 DAS and Dry matter at harvest (g m^{-2})

The maximum number of root nodules was observed in T_7 as compared to T_2 in case of *Cicer arietinum*. For *Lathyrus sativus*, the maximum root nodules were observed in intercropping, T_3 (8.6) as compared to sole cropping T_8(7.6). Whereas in all other intercrops the maximum no. of root nodules per plant at 50 DAS was observed in sole cropping as compared to intercropping. The maximum dry matter at harvest was observed in *Cicer arietinum* in agroforestry (T_2), followed by T_7. For *Vicia faba* T_{10} was the best treatment as compared to T_5. In case of *Lens culinaris* the highest dry matter at harvest was found in T_6 as compared to T_1. For *Canavalia ensiformis* the highest dry matter at harvest was observed in T_4 as compared to T_8. For *Lathyrus sativus* highest dry matter at harvest was observed in T_8 as compared to T_3. Prior research has had a substantial influence on the formation of dry matter in various intercrops within bamboo-based agroforestry systems (Manasa *et al.,* 2024).

Days to 50 % flowering and days to physiological maturity

The days to 50% flowering was firstly observed in *Lathyrus sativus* in T8 followed by T3. Similarly, in case of all the intercrops the days to 50% flowering was observed firstly in sole cropping as compared to intercropping. The similar trend was followed for days to physiological maturity. The study also found that the number of days it takes for plants to reach 50% flowering and physiological maturity has a substantial effect on the total yield of intercrops (Swarnkar *et al.,* 2023).

Effect of bamboo-based agroforestry on yield parameters of different intercrops

No. of pods per plant, no. of seeds per pod and 100 seed weight

The maximum no. of seeds per pod, 100 seed weight was observed at time of harvest was in T_9 followed by T_4. At harvest the highest no. of seeds per pod was observed in *Cicer arietinum* in sole cropping (T_7), followed by T_2. For *Vicia faba*, T_{10} was the best treatment as compared to T_5. No. of pods per plant was highest was sole cropping as compared to cropping under the tree. In case of 100 seed weight for *Lens culinaris*, the largest weight was of T_1 as compared to T_6. For other all intercrops the highest seed weight was in sole cropping compared to agroforestry (Kumar *et al*., 2013; Dev *et al*., 2016).

Grain Yield, Straw Yield, Biological Yield, Harvest Index and Grain to straw ratio

The highest grain yield for *Cicer arietinum and Lens culinaris* was observed in T_7 followed by T_6, T_2, and T_1. The lowest grain yield was observed in *Lathyrus sativus.* The highest straw yield was observed in T_3 followed by T_8, T_{10}, and T_4. The highest biological yield for was observed in T_7 followed by T_6, T_2, T_1. The highest harvest index for *Cicer arietinum and Lens culinaris* was observed in T_7 followed by T_6, T_1, T_2. The grain to straw ratio was observed highest in T_7, T_1, T_2, T_6 followed by T_9, T_4, and T_5 & T_{10}. Possible factors contributing to this phenomenon include the availability of light, nutrients, and moisture, which may be affected by the competition between trees and crops. The reduction in yield of pulse crops in intercropping was earlier reported by Mishra *et al*., (2010), Osman *et al*., (2011), Burman *et al*., (2009), Pandey *et al*., (2002), Kumar *et al*., (2013), Dev *et al*., (2020), Bhol and Nayak, (2014), Parasriya *et al*., (2022), Nema and Reddy (2016). As bamboo and other agroforestry species grow older, they become more competitive and, as a result, reduce crop yields (Ahlawat *et al*., 2008)

Principle Component Analysis- Biplot for growth and yield attributes of different intercrops

Principle Component Analysis- Biplot based on growth and yield attributes of different intercrops under bamboo and sole cropping were worked out for different treatments (Figure 2.) Two axes were extracted in Principle Component Analysis axis 1 gave 41.9 % of variation and axis 2 gave 26.9 % of variation. This accounts for total variation of 68.8 %. PCA shows that the growth parameters were higher in T_4, T_9, T_5, $T_{10;}$ days to physiological maturity and 100 seed weight were observed highest in T_9 and T_4. whereas the yield attributes like grain yield, biological yield, harvest index, grain to straw ratio were highest in T_7, T_2, T_6, and T_1. The straw yield was observed highest in T_8 and T_3.

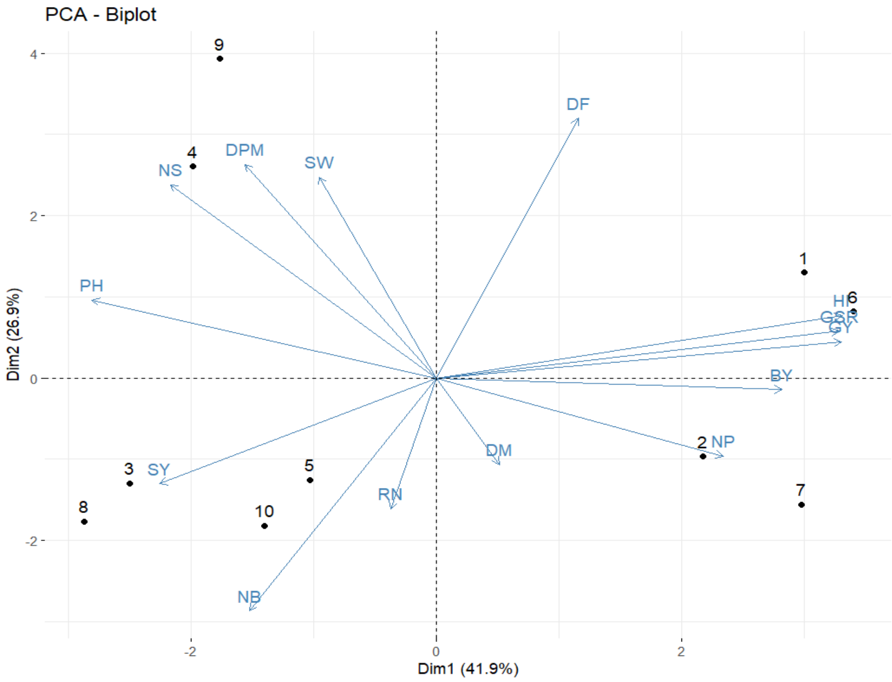

Fig. 2 : PCA- Biplot Analysis for growth and yield attributes of different intercrops

(In Figure, PH* = Plant height, NB* = No. of branches, RN* = Root nodules, DM* = Dry matter, DF* = Days to 50% flowering, DPM* = Days to physiological maturity, NP* = No. of pods per plant, NS* = No. of seeds per pod, SW* = 100 Seed weight, GY* = Grain Yield, SY* = Straw Yield, BY* = Biological Yield, HI* = Harvest Index, GSR* = Grain to straw ratio, whereas numbers 1 to 10 indicate treatments from T_1 to T_{10})

Growth performance of bamboo under different growing condition

The growth parameters of Bamboo tree differed significantly in intercropping as compared to sole bamboo tree. The growth parameters of bamboo like height of the tree (7.88 m), crown spread (5.45 m), girth of 3rd internode (17.75 cm) and diameter of 3rd internode (5.65 cm) was observed highest in T_1(*Bamboo spp*. + *Lens culinaris*) followed by T_2(*Bamboo spp*. + *Cicer arietinum*). Length of 3rd internode was highest in T_2(*Bamboo spp*. + *Cicer arietinum*. The higher growth of *Bambusa balcoa* and *Bambusa tulda* was observed in agroforestry system as compared to sole bamboo trees (Banerjee *et al*., 2009). The disintegration of bamboo leaf litter releases nutrients that are advantageous for both bamboo tree and intercrops (Baruah and Borah 2019). The culm height of bamboo was observed highest under agroforestry (Dhanyashri *et al*., 2020). The crown spread of a tree has significant impact on production of intercrops and soil properties (Kittur *et al*., 2016). The growth parameters like girth of bamboo culm was highest in intercropping as compared to sole cropping (Behera *et al*., 2016); whereas intercropping benefitted the bamboo tree as increase in length and diameter of bamboo was observed under intercropping as compared to sole tree (Dev *et al*., 2020).

Conclusion

During the course of research, a significant effect of growing condition was reported on various plant growth and yield parameters. T_7 (*Cicer arietinum* sole cropping) showed highest grain yield followed by T_2 (*Bamboo spp*. + *Cicer arietinum),* whereas highest straw yield was observed in T_8 (*Lathyrus sativus* sole cropping) followed by T_3 (*Bamboo spp*. + *Lathyrus sativus.* It was observed that all growth and yield attributes were higher in sole cropping of all crops as compared to intercropping. Intercropping showed significant increase in tree height, crown spread, diameter at 3rd internode, and girth at 3rd internode. Bamboo based agroforestry can be advantageous if proper intercultural operations are done to avoid competition between crop and tree component. Agroforestry known for improve multi-level production, here in bamboo-based agroforestry, the intercrops can be successfully taken because the yearly production will be continued of intercrops and bamboo.

Table 1 : Effect of bamboo-based agroforestry on growth parameters of different intercrops

Treatments	Height of Plant at Harvest (cm)	No. of branches at harvest	Root nodules per plant at 50 DAS	Dry matter at harvest (g m^{-2})	Days to 50 % flowering	Days to physiological maturity
T_1	33.3	3.6	4.3	207.1	82.6	125.6
T_2	38.7	6.3	10.6	336.4	71.6	122.3
T_3	62.2	6.3	8.6	227.9	60	134
T_4	95.6	4.3	7.3	269.6	86.3	155
T_5	83.5	7.3	7.6	274.5	60.6	112
T_6	40.8	4	4.6	230.8	83.3	120.6
T_7	42.5	6.6	11.3	354.1	66.6	112.6
T_8	67.3	9	7.6	260.1	59.3	132.6
T_9	98.5	4.3	7.6	276.5	87	151.6
T_{10}	95.2	7.6	8.3	293.6	63.6	106.6
SE.m$\pm$	0.88	0.48	0.6	6.41	0.94	1.51
CD (0.05)	2.83	1.56	1.93	20.51	3.03	4.83
CV (%)	2.33	14.16	13.3	4.06	2.27	2.05

Table 2 : Effect of bamboo-based agroforestry on yield parameters of different intercrops

Treatments	No. of pods per plant	No. of seeds per pod	100 seed weight (g)	Grain Yield (Kg ha^{-1})	Straw Yield (Kg ha^{-1})	Biological Yield (Kg ha^{-1})	Harvest Index (%)	Grain to straw ratio
T_1	92.3	1.3	2.68	1179	1585	2765	42.6	0.73
T_2	55.3	1.6	15.5	1237	1682	2919	42.3	0.73
T_3	49.3	2.6	5	715	1919	2634	27.1	0.37
T_4	25.6	9.3	127.6	917	1797	2715	33.7	0.5
T_5	66.3	3.3	32.8	829	1638	2467	33.5	0.5
T_6	95	1.6	2.6	1348	1721	3069	43.9	0.7
T_7	56.3	2	17.3	1403	1727	3131	44.8	0.8
T_8	49.3	4.3	5.8	723	1907	2630	27.4	0.37
T_9	30.6	9.6	1301	953	1685	2638	36.1	0.56
T_{10}	69.3	3.6	33.2	851	1827	2678	31.7	0.46
SE.m$\pm$	0.89	0.33	0.39	7.67	13.14	12.58	0.26	0.008
CD (0.05)	2.87	1.06	1.27	24.5	42.03	40.24	0.85	0.02
CV (%)	2.64	14.47	1.85	1.3	1.3	0.78	1.27	2.38

Table 3 : Growth performance of bamboo under different growing condition

Treatments	Culm height (m)	Crown Spread (m)	Length of 3rd internode (cm)	Girth of 3rd internode (cm)	Diameter of 3rd internode (cm)
T_0	7.58	5.36	23.60	16.3	5.19
T_1	7.88	5.45	24.1	17.75	5.65
T_2	7.68	5.32	24.15	17.63	5.61
T_3	7.45	5.10	22.43	15.5	4.93
T_4	7.78	5.35	23.83	16.98	5.4
T_5	7.63	5.25	23.70	16.45	5.23
SE.m±	0.106	0.13	0.28	0.64	0.204
CD (0.05)	0.31	0.39	0.85	1.92	0.61
CV (%)	2.76	4.99	2.409	7.66	7.66

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