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PERFORMANCE OF SORGHUM AND BARLEY INTERCROPPED WITH KADAM BASED AGROFORESTRY SYSTEM IN SEMI-ARID ECOSYSTEM OF HARYANA

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SUMMARY

The present study was carried out to evaluate the performance of sorghum and barley intercropped with 3-year-old kadam based agroforestry system at a spacing of 7m × 3m. The growth observations of kadam tree like dbh (12.46 cm) and basal diameter (18.24 cm) were recorded during the study. The growth, physiological parameters, yield attributes and yield of sorghum and barley were also recorded. The plant height of sorghum and barley showed significant variation under kadam based agroforestry system (AFS) and open (sole crop). Significant variation was observed in the physiological parameters (chlorophyll, photosynthesis, transpiration and stomatal conductance) of sorghum and barley crops with kadam plantation as well as sole crop (devoid of trees). The plant height, leaf area, fresh leaf and stem weight, and green fodder yield in sorghum showed highly significant variation in kadam as well as sole sorghum. The fodder yield of sorghum varied from 32.24 (with kadam) to 40.90 (control) t/ha. The per cent yield reduction in kadam plantation was 21.16 %, respectively over control. Significant variations were also observed in spike length, number of grains per spike, grain and straw yield of barley under kadam based AFS as well as sole barley (devoid of trees). The grain yield of barley varied from 2.21 (kadam) to 3.91 (control) t/ha. The per cent yield reduction in kadam plantation was 43.43 %, respectively over control.

Key words: Agroforestry, kadam, sorghum, fodder yield, barley, grain yield

India is home to 536 million livestock, constituting about 16% of the global livestock population. Livestock play a crucial role in the rural economy, comparable to agriculture. In the 2019 livestock census, Haryana contributed approximately 1.3% to the country's total livestock population. According to the 2015-16 Land Use Statistics database from the Ministry of Agriculture, the state accounts for nearly 8% of the country's land area dedicated to fodder crops (Handa *et al.,* 2020). However, India faces a significant shortage, with only 224.08 million tons of green fodder available against a requirement of 611.99 million tones. To support the 416 million cattle, sheep and goats, only 4.4% of cropped area is allocated to fodder cultivation in India. This scarcity leads to undernourished livestock that do not reach their full potential (Ravi *et al.,* 2009). To overcome this scarcity, adoption of agroforestry systems across a wide range of land in the country and the integration of multipurpose trees into existing farming and cropping systems appear to be suitable options (Kaushik and Kumar, 2003). Additionally, the presence of trees enhances crop productivity by improving soil fertility (Young, 1989) and providing a beneficial shade effect in arid and semi-arid regions. Shading effect of trees under agroforestry reduces under storey temperature and helps mitigate evapotranspiration (Bunderson *et al.,* 1990).

Anthocephalus cadamba, commonly known as kadamb, is one of the fast-growing indigenous tree species with a broad crown and a straight cylindrical bole. In favorable climatic conditions, it can grow taller, reaching heights of 20 m or more, with a clean bole of about 9 m and a diameter ranging from 40 to 60 cm (Bijalwan *et al.,* 2014). It is an ingredient of southern tropical semi evergreen forests, secondary north Indian tropical moist deciduous forest and tropical fresh water swamp forest (Champion and Seth,

1968). Due to its heavy leaf shading during autumn-spring and the easy decomposition of its leaves, *Anthocephalus cadamba* is a suitable alternative for agroforestry system in most parts of India. The species is in high demand for the pencil industry, plywood and match splints, making it a viable option for farm forestry in humid tropics for industrial and income generation purposes. While *Casuarina equisetifolia*, *Acacia mangium* and *Tectona grandis* are commonly used in agroforestry in humid tropics, *Anthocephalus cadamba* shows more potential in terms of growth, yield and economics. Additionally, *Anthocephalus cadamba* is sporadically used as a shade tree in tea and coffee plantations and is resistant to insect pests even in humid tropical conditions (Bijalwan *et al.,* 2014). It has minimal shade effect and does not exhibit allelopathic effects on agricultural crops, making it highly suitable for agroforestry purposes. Its wide adaptability, ranging from semi-arid to humid tropics and foothills of the Himalayas, makes it a preferred option for adoption in various agroecological zones across India. It is known to improve organic matter contents, total nitrogen, available phosphorus as well as DTPA extractable micronutrients (Sarkar and Das, 2022).

Sorghum (*Sorghum bicolor)* is a major food crop in Africa, South Asia, and Central America. It is one of the main food staple for millions of people in Asia. Sorghum is the world's fifth most important and widely farmed cereal crop, following maize, wheat, rice, and barley (Yahaya *et al.,* 2023). Global reports exist for several strains of sorghum, including grain, sweet, and forage sorghum (used for animal feed), and the purpose of cultivation extends from human consumption to the production of animal feed (Hariprasanna and Rakshit, 2016). As per the 2020 statistics report by the Food and Agricultural Organization (FAOSTAT), the leading countries that cultivate sorghum are the United States, India, Nigeria, and Mexico. According to Sharan *et al.* (2018), sorghum is an ideal crop for addressing global food security since it can tolerate high salinity environments, flourish in the face of biotic and abiotic stressors, and become dormant in unfavorable environmental conditions (Labuschagne, 2018). Barley (*Hordeum vulgare* L.) is an important crop widely used as feed for livestock and malt in the brewing and distilling industries (Newton *et al.,* 2011). Furthermore, it's excellent nutritional content and health advantages are drawing more attention for human consumption. Barley is widely produced globally because to its versatility and adaptability to different environmental conditions (Ko *et al.,* 2019). Crop residues, cultivated fodder, and fodder from community resources like permanent pastures and grazing lands are the three main sources of fodder in India. There is a significant disparity in fodder availability and demand due to the variety of forage crops grown in different seasons and areas, as well as the production of forage with little inputs on degraded and marginal land (Ghosh *et al.,* 2016). Therefore, there is an urgent need to increase the area planted with fodder crops since the major causes of animals' low productivity at the moment are the stresses of an ever-increasing animal population and a vast imbalance between the supply and demand of high-quality fodder. Keeping in view, the present study was conducted to evaluate the performance of sorghum and barley under a kadamb based AFS in Haryana, with a specific emphasis on growth, physiological parameters, yield attributes and economic viability.

MATERIALS AND METHODS

The present study was conducted at research area of the Department of Forestry, CCS Haryana Agricultural University, Hisar (290 10′ N lat.,750 46′ E long., alt. 215 m msl). In this study, about six-month-old seedling of kadamb was transplanted in the research field during first week of July, 2020 at a spacing of 7 m × 3 m. During *Kharif* season sorghum (HJ 541) was sown in June, 2022 and during *Rabi*, 2022-23 barley (BH 393) was sown. The standard package of practices as recommended by CCS HAU, Hisar was followed. The growth, physiological parameters, yield attributes and yield of intercrops were recorded during the study period.

RESULTS AND DISCUSSION

Tree growth parameters and soil properties

During *Kharif* season sorghum (HJ 541) was sown in June, 2022 and during *Rabi*, 2022-23 barley (BH 393) was sown in November, 2022. The growth, physiological parameters, yield attributes and yield of intercrops were recorded during the study period. The growth parameters (basal diameter and DBH) of *Anthocephalus cadamba* were recorded in April, 2023 (Table 1). The kadam tree showed considerable increase in basal diameter (18.24 cm) and DBH (12.46 cm). Similar trends in the growth of kadam under

TABLE 1
Growth performance of kadam (April, 2023)

Tree spacing (m)	Basal diameter (cm)	DBH (cm)
7x3	18.24	12.46

different spacings in irrigated ecosystem with slightly variable values have been reported by several researchers such as (Bijalwan *et al.,* 2014 and Ghosh, 1977). The soil properties of the experimental field are presented in Table 2. The soil was non- saline, low in organic carbon and available nitrogen, medium in available P and K. Significantly higher availability of N, P as well as K content was observed under poplar windbreak agroforestry system than the sole crop (Sirohi *et al.,* 2022b).

TABLE 2
Soil chemical properties of the experimental field (October, 2022)

pH	EC (dS/m) 1:2	OC (%)	Available nutrients (kg/ha)		
			N	P	K
7.74	0.42	0.41	129.2	11.3	282.1

Crop growth studies of sorghum and barley

Significant variation was observed in the physiological parameters (chlorophyll, photosynthesis, transpiration and stomatal conductance) of sorghum with kadam plantation and in sole sorghum (devoid of trees). Physiological parameters were recorded at 40 DAS in sorghum during the study period. Different physiological parameters of sorghum were higher under control (sole crop) as compared to kadam based AFS except chlorophyll content. The chlorophyll content was recorded higher in kadam based AFS as compared to control (Table 3).

The reason for the higher chlorophyll content in fodder sorghum grown under agroforestry systems could be because the plant develops bigger light-harvesting complexes under low light availability. Larger light-harvesting complexes reaction to reduced light hence caused an increase in chlorophyll pigment and, consequently, in total chlorophyll concentration. The present findings are consistent with the current results of Ahmed *et al.* (2019) who investigated the effects of three acacia species (*Acacia nilotica, Acacia seyal,* and *Acacia tortilis*) on the growth and physiological processes of sorghum.

The plant height, leaf area, fresh leaf and stem weight, and green fodder yield (Table 4) in sorghum also showed significant variation in kadam based AFS as well as sole sorghum (devoid of trees). Similar findings were also reported by Birhane *et al.* (2018) who showed that aboveground biomass of sorghum increased by 22% in *F. albida* canopy plots compared to control plots. This could be attributed to the nitrogen that *F. albida* provides, which increases plant height, stem diameter, and number of effective tillers (Maranville and Clark, 1979).

Results showed that the fodder yield varied from 32.24 (with kadam) to 40.90 (control) t/ha. The per cent yield reduction in kadam plantation was 21.16 %, respectively over control. In barley, physiological parameters were recorded at 7 days after anthesis which also showed significant variation for the above traits under kadam based AFS as well as sole barley (devoid of trees). The plant height of barley at harvest showed significant variation under kadam based AFS as well as sole barley. Results revealed that there was

TABLE 3
Physiological parameters of sorghum and barley under kadam-based agroforestry system and control (devoid of tree)

Treatment	Physiological parameters of sorghum at 40 DAS			
	Chlorophyll (CCI)	Photosynthesis rate (μ mol CO_2 m^{-2}/s^{-1})	Transpiration rate (m mol H_2O m^{-2}/s^{-1})	Stomatal conductance (mol m^{-2}/s^{-1})
With Kadam #	13.1	8.78	4.02	0.13
Control (Devoid of tree)	11.6	10.26	4.53	0.14
t-value	6.9**	7.92**	5.96**	3.68**
Physiological parameters of barley (after 7 days of anthesis)				
With Kadam #	26.25	6.44	2.83	0.11
Control (Devoid of tree)	22.39	7.87	3.74	0.14
t-value	4.36**	5.39**	5.62**	2.89**

**Significant at 0.01 per cent level of P, *Significant at 0.05 per cent level of P, # Kadam planted at a spacing of 7×3 m.

TABLE 4
Growth, yield parameters, yield and economics of sorghum under kadam based agroforestry system and control (devoid of tree) at harvest

Treatment	Plant height (cm)	Stem diameter (mm)	Leaf area (cm^2)/ plant	Fresh leaf weight/ plant (gm)	Fresh stem weight/plant (gm)	TSS	Fodder yield (t/ha)	B:C ratio
With Kadam #	198.59	13.40	1982.67	124.15	256.80	6.65	32.24	0.85
Control (Devoid of tree)	245.69	14.79	2368.22	156.18	321.48	7.14	40.90	1.08
t-value	10.86**	4.91**	7.81**	12.26**	10.68**	3.60**	11.58**	-

** Significant at 0.01 per cent level of P, # Kadam planted at a spacing of 7×3 m.

significant variation in spike length, number of grains per spike, grain and straw yield among kadam and control (Table 5). The grain yield varied from 2.21 (kadam) to 3.91 (control) t/ha. The per cent yield reduction in kadam plantation was 43.43%, respectively over control. The B:C ratio in the above experiment was 0.73 (under kadam) and 1.28 (control).

It is widely acknowledged that light competition significantly impacts the yield of agricultural crops within agroforestry systems compared to sole cropping. This decrease in yield could be caused by a number of factors, including root interference, above- and below-ground competition, shade, etc. These outcomes are in line with the findings of Sirohi *et al.* (2022a), who found that the production of green fodder crops increased significantly under poplar based agroforestry system as the distance between the rows increased from 3 to 8 meters. In this study, all forage crops were assessed, and it was shown that a wider spacing of 8×3m produced the highest green fodder yield. They studied that when tree density increased, the percentage reduction in the sorghum-berseem copping system was 10 to 22 per cent. The B: C ratio was also negative in both the systems and it varying from 0.85 (with kadam) to 1.08 (control). Similar results were obtained by Chavan *et al.* (2022) in their experiment in which sorghum and wheat yields showed a notable decline in fodder biomass up to nine meters away from the poplar tree line. The declines ranged from 10 to 60% during the *Kharif* season and from 7.2 to 29.5% for *Rabi* crops from second year to eight years of rotation. In this study, based on the the economic analysis, an East-West poplar boundary plantation showed the highest net returns, at INR 549,367 ha^{-1}, net present value, at INR 222,951 ha^{-1}, BC ratio, at 1:1.65, IRR, at 85%, and LEV, at INR 1,220,337 ha^{-1}. They concluded that intercropping of sorghum-wheat crop rotation in East-West poplar boundary plantation led to higher farm income than traditional agriculture methods.

The impact of poplar rows in an alley-cropping system on the productivity of soybeans and sorghum over a two-year rotation were also studied by Mantino *et al.* (2023). In this study, the effects of variations in light availability on the growth rate of two-year poplar rows on soybean-sorghum and sorghum-soybean rotations were observed. In the tree-crop interface, there was a significant reduction in above-ground biomass, grain yield, and crop residue of up to 74%.

Tree intercropping systems had a highly substantial impact on sorghum grain yield, with yields being greatly lowered by the presence of acacia trees (Deng *et al.,* 2017). They found that, the yield differences between the two cropping systems were more noticeable in the first year, when sorghum planted

TABLE 5
Growth, yield attributes, yield and economics of barley under kadam based agroforestry system and control (devoid of tree)

Treatment	Plant height at harvest (cm)	Number of effective tillers (m^{-2})	Length of spike (cm)	Number of grains/spike (No.)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	B:C ratio
With Kadam#	55.24	134.90	3.91	26.30	23.44	2.21	2.93	5.14	0.73
Control (Devoid of tree)	101.15	294.40	7.14	44.20	38.51	3.91	5.01	8.92	1.28
t-value	26.64**	34.14**	26.04**	25.91**	20.06**	23.48**	17.92**	21.39**	-

**Significant at 0.01 per cent level of P, *Significant at 0.05 per cent level of P, # Kadam planted at a spacing of 7m×3 m.

alone were almost 400% of the yields in the dense acacia+sorghum cropping system, and nearly 300% better in the second year. This decline in sorghum yields is the result of crop and tree roots competing with one another for water. Shading was therefore most likely a contributing factor in the decrease in intercropped sorghum yields as *A. seyal* has a dense canopy cover and sorghum does not grow well in shade (Gnangle *et al.,* 2013).

CONCLUSION

Production of fodder yield of sorghum and barley was significantly reduced in association with kadam based agroforestry system in comparison to control. In semi-arid regions, sorghum-barley intercropped with kadam based agroforestry system can enable to land use system diversification towards more sustainable systems, thereby reduce the gap between demand and supply of fodder. Although Farmers are facing challenges of yield reduction in adopting tree-based systems due to shading effect but at the same time this system not only improving farm income in long run through crop diversification and agroforestry but also its helps in addressing the problem of climate change as well as hardship of rural communities, which is a today's national priority.

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