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INFLUENCE OF PLANTING GEOMETRY OF *PROSOPIS CINERARIA* ON GROWTH AND YIELD OF FODDER SORGHUM IN SEMI-ARID ECOSYSTEM

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SUMMARY

Performance of fodder crop *Sorghum bicolor* was investigated with different spacing's of *Prosopis cineraria* to evaluate productivity and economics of the silvopastoral agroforestry system at Forestry research farm , CCS HAU, Hisar Haryana during 2021-22.The experiment was laid out by planting fodder sorghum (var, HJ 541) in between 5.9 years old *Prosopis cineraria* at different spacing's *i.e*. 8m x 3 m, 9m x 3m, 10m x 3 m, and a control treatment in randomized block design (RBD) with five replications during the summer seasons (*kharif*). Growth parameters including plant height, stem diameter, fresh fodder yield, and total soluble solids (T.S.S.) content were assessed, along with an economic analysis based on the benefit-cost (B:C) ratio. Study revealed that the Growth performance of the crop *viz*. Plant height (cm), stem diameter (mm) and fresh fodder yield t/ha was recorded at the time of harvest. Plant height varied from 256.15cm (10m x 3m) to 261.36cm (8m x 3m) but was found statistically non-significant among different spacing's of *Prosopis cineraria* and in open (control) Fresh fodder yield was highest under the 8m x 3m spacing (46.27 t/ha), followed by the 9m x 3 m (45.96 t/ha) and 10m x 3m (45.79 t/ha) spacing's. The 8m x 3m spacing consistently produced the highest plant height, stem diameter, and fresh fodder yield, although differences were not statistically significant. The B:C ratio was highest under the 8m x 3m spacing, suggesting slight economic benefits. Overall, *Prosopis cineraria* agroforestry systems demonstrate minimal negative impacts on sorghum performance, with the 8m x 3m spacing's providing the best balance of growth, yield, and economic returns.

Key words: Agroforestry, *Khejri*, spacing's, sorghum, fodder production, semi-arid ecosystem

Agroforestry systems of land use are not new to our rich heritage. It is an integrated approach to land use that is characterized by deliberate maintenance of trees and other woody perennials in fields and pastures. This system offers a good scope for more efficient use of land, water, other natural and human resources which has both productive and protective potential so can play an important role in enhancing the productivity of our land to meet the demands of the human and livestock (Pandey *et al.*, 2018). Although, India is home to 535.78 million livestock (Anonymous, 2019), but the country is deficit in fodder availability. The green and dry fodder is deficit to the tune of 11.24 and 23.40 percent respectively (Roy *et al*., 2021). 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 and providing a beneficial shade effect in arid and semi-arid regions. Shading effect of trees under agroforestry reduces under story temperature and helps mitigate evapotranspiration (Bunderson *et al*., 1990).

Prosopis cineraria (L.) Druce, locally known as Khejri, is a hardy, drought-resistant leguminous tree that has proven to be a keystone species in agroforestry systems across these regions. With its deep root system, ability to fix atmospheric nitrogen, and tolerance to extreme climatic conditions (Kaushal *et al*., 2021) in semi-arid regions. Often referred to as the "Golden Tree" or "King of the Desert," it offers multiple benefits. It also helps stabilize farmers'

incomes during droughts and enhances the overall landscape quality (Singh *et al*., 2008; Khatri *et al*., 2010; Jodha *et al*., 2012) Agroforestry systems, especially those incorporating nitrogen-fixing trees like Khejri, have emerged as viable approaches for sustainable agriculture in dry land areas. The tree's canopy structure and root architecture minimize resource competition with crops, making it suitable for integration with fodder crop such as sorghum. Integrating P. cineraria into farming systems not only boosts crop yields but also offers multiple socio-economic benefits through the provision of food, fodder, fuel wood, and timber.

Global reports exist for several strains of sorghum, including grain, sweet, and forage sorghum and the purpose of cultivation extends from human consumption to the production of animal feed (Hariprasanna and Rakshit, 2016). 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 stress, and become dormant in unfavourable environmental conditions (Labuschagne, 2018).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 critical necessity to expand the area under fodder cultivation, as the primary constraints to current livestock productivity are the pressures from a continuously growing animal population and a significant disparity between the demand and availability of nutrient-rich fodder. Keeping in view, the present study was conducted to evaluate the influence of different spacing's of *P. cineraria* on growth and fodder biomass production of sorghum in Semi-Arid ecosystem.

MATERIALS AND METHODS

The present investigation was carried out at the Forestry Research Farm during the *kharif season* of 2020-21 at CCS Haryana Agricultural University, Hisar, Haryana (India) at 29° 10‘ N latitude and 75° 43‘ E longitude at an elevation of 215 m above mean sea level. The site is situated in the semi-arid environment of North-Western India. The climate is subtropical - monsoonic with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with maximum temperature ranging from 40 to 45°C in May and June whereas, December and January are the coldest months. Soil analysis revealed non-saline, medium organic carbon content, and low available nitrogen. The present investigation was conducted in an already established 5.9 years old *Prosopis cineraria* (*Khejri*) planted in different spacing of 8 m × 3 m, 9 m × 3 m and 10 m × 3 m following randomized block design with five replications by digging out pits of 30 cm filled with 3:1 potting mixture of (soil: FYM) during July, 2016. The experiment was regularly monitored for replacement planting, irrigation and protective measures. Tree height and diameter at breast height (DBH) were measured randomly using measuring tape (cm). During the summer seasons *kharif* crop sorghum (var. HJ 541) was sown in already established *Prosopis cineraria* based all spacing's and control with standard package of practices developed by CCS Haryana Agricultural University, Hisar was followed to cultivate fodder sorghum crops to evaluate the influence of different spacing's of *P. cineraria* on growth and fodder biomass production of sorghum in semi-arid ecosystem.

RESULTS AND DISCUSSION

Growth Performance of *Prosopis cineraria*

The growth parameters *viz*, Basal diameter and girth at breast height (GBH) of *Prosopis cineraria* were recorded. The observations of khejri tree showed considerable increase in growth parameters. Plant height and girth at breast height (GBH) were recorded before sowing of *Kharif* crops. At the age of 5.9 years old trees recorded maximum height (4.93 m) and girth at breast height (GBH) (38.2 cm) were recorded in 10 m × 3 m spacing. This spacing also recorded the highest current annual increment (CAI) in both height (0.63 m/ year) and GBH (5.4 cm/year) was also recorded in 10 m × 3 m spacing, aligning with previous findings that wider spacing reduces intra-specific competition (Kumar *et al*., 2012; Singh and Rathore, 2016). (Table 1). In contrast, the narrowest spacing (8 m × 3 m) exhibited lower growth increments (CAI in height: 0.54 m; CAI in GBH: 2.92 cm). These findings are consistent with previous studies by Singh *et al*. (2012) and Kaushik *et al*. (2015), which reported that wider spacing's in agroforestry systems provide better light penetration and reduced root competition, thereby enhancing the growth performance of tree species like *P. cineraria*. The higher resource availability per tree at wider spacing's likely contributed to these improved growth

metrics. Tree height and CAI increased progressively with wider spacing (Fig. 1.). The highest growth increment was observed under 10 m × 3 m spacing, suggesting that wider spacing favours vertical growth in *Prosopis cineraria*. These results indicate reduced competition for resources (light, nutrients, and water) at wider spacing, promoting better growth performance. Progressive Increase in GBH: All three series showed positive growth in girth from April 2021 to April 2022. Best Performance: Series3 (10 m x 3 m spacing) consistently recorded the highest GBH values and CAI, indicating superior girth growth compared to the other treatments. The results suggest that the spacing or treatment represented by Series3 (10 m x 3 m spacing) is most favourable for *Prosopis cineraria* girth development (Fig. 2.). Likely, this treatment provides optimal resource availability (less competition), resulting in better radial growth. Growth Trend: There is a consistent and incremental gain in GBH across all treatments, affirming healthy stand development during the study period.

Soil fertility of the field

The site is situated in the semi-arid region of North-Western India characterized by subtropical - monsoonic with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with maximum temperature ranging from 40 to 45°C in May and June whereas, December and January are the coldest months. Soil analysis (Table 2) indicated non-saline conditions with neutral to slightly alkaline pH (7.96 to 8.01) and moderate EC across all spacing treatments. Organic carbon was medium (0.46–0.48%), while available nitrogen was low (130.2–133.4 kg/ha), and phosphorus and potassium were medium. These findings are consistent with previous findings from Yadav *et al*. (2014) that sandy soils under arid agroforestry systems often exhibit low fertility status. The slight variations in OC and nutrient content across spacing were marginal and are expected in perennial

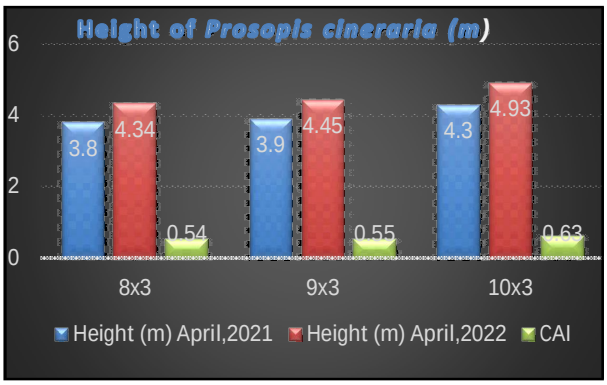
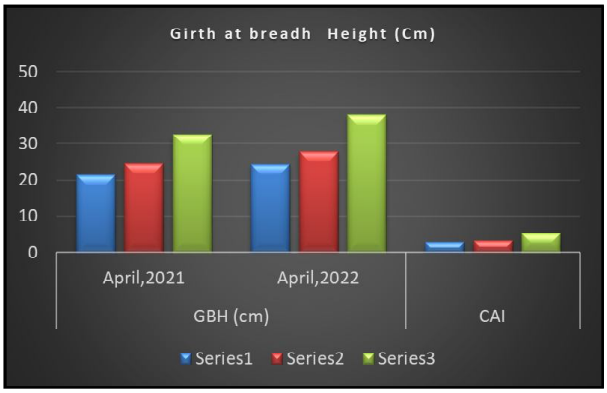


Fig. 1. *Prosopis cineraria* height under different spacing's in the Agri-silviculture system.

tree-based systems, where litter fall and root biomass turnover play a role in soil enrichment. Positive effect of khejri like increased organic matter content from leaf litter decomposition might have resulted in improvement in soil fertility, porosity, texture, essential nutrient and yield improvement of *kharif* crop. *Prosopis cineraria* based agroforestry plays a crucial role in the dry land economy through its contributions to soil stabilization, especially in sand dune regions, improvement of soil fertility, provision of animal fodder, fuel wood, and timber resources (Jaimini and Tikka, 1998). The higher nutrient status near the tree and close spacing's might be due to the addition of large



Series 1 (8x3), Series 2 (9x3) and Series 3 (10x3)

Fig. 2. *Prosopis cineraria* GBH under different spacing's in the Agri-silviculture system.

TABLE 1

Growth performance of *Prosopis cineraria* under different spacing's in the Agri-silviculture system

Spacing (m)	Height (m)		CAI	GBH (cm)		CAI
	April, 2021	April, 2022		April, 2021	April, 2022	
8m x 3m	3.8	4.34	0.54	21.6	24.52	2.92
9m x 3m	3.9	4.45	0.55	24.6	27.93	3.33
10m x 3m	4.3	4.93	0.63	32.8	38.20	5.40

quantity of leaf litter. The higher decomposition of leaf litter favours the higher nutrient status of the soil. Similar findings were also observed by (Singh and Sharma, 2007). Increase in soil carbon through plantations may also act as an important carbon sink. The higher available nutrient content in agroforestry system over the agriculture system may be attributed to litter fall addition from trees as well as addition of root residues of crops and trees.

Fodder crop sorghum (Var., HJ 541) was sown under *Prosopis cineraria* plantation planted at different 8m×3m, 9m×3m and 10m×3m spacing's and in open (devoid of tree) during *Kharif* season. Growth performance of the crop *viz*. Plant height (cm), stem diameter (mm) and fresh fodder yield t/ha was recorded at the time of harvest. Plant height varied from 256.15 cm (10m x 3m) to 261.36 cm (8m x 3m) but was found statistically non-significant among different spacing's of *Prosopis cineraria* and in open (control). Although there was no statistical difference but numerically higher green fodder yield was recorded under the 8m x 3m spacing (46.27 t/ha), followed by the 9m x 3m (45.96 t/ha) and 10m x 3m (45.79 t/ha) spacing. The control treatment produced 44.12 t/ha, and the overall mean fresh fodder yield was 45.53 t/ha. Although there was a slight decrease in fresh fodder yield for the control treatment, the results across all treatments remained similar, indicating that *Prosopis cineraria* spacing's had little impact on fodder yield. The lack of significant variation suggests that *P. cineraria* trees, even at closer spacing, do not exert substantial competition on sorghum during early growth stages, possibly due to their deep rooting pattern and sparse canopy, as observed by Sharma and Dagar (2008). These traits enable light and water availability for understory crops, maintaining crop productivity even under tree canopies. Total soluble solids (TSS) content in the fresh fodder was highest under the control treatment (7.14%), followed by the 10m x 3m spacing's (7.12%). The 9m x 3m (7.10%) and 8m x 3 m (6.90%) spacing's had the lowest TSS values, with an overall mean of (7.06%). These findings suggest that *Prosopis cineraria* had a minimal impact on TSS content in sorghum, with the control treatment exhibiting slightly higher values. The TSS content (%) of sorghum did not differ significantly across treatments, with values ranging from 6.90% to 7.14%. This indicates that tree spacing's had no adverse effect on the fodder quality of sorghum. Similar findings were reported by Kumar *et al*. (2011) in Acacia-based agroforestry systems, where tree-crop interactions did not impact the fodder's nutritional quality. Furthermore, the benefit-cost (B:C) ratio was highest under the 8m × 3m spacing (1.19), followed by 9m×3 m and 10m × 3m (1.18 each), and lowest in the control (1.13). This highlights the economic advantage of integrating *P. cineraria* in agroforestry systems without compromising the short-term

TABLE 2
Soil chemical properties of the experimental field (0-15 cm) *Prosopis cineraria* based Agri-silviculture system

Spacing (m)	pH	$EC_{1:2}$ (dS/m)	OC (%)	Available nutrients (kg/ha)		
				N	P	K
8m x 3m	7.96	0.56	0.48	133.4	13.5	267.2
9m x 3m	8.01	0.57	0.46	131.8	13.2	264.9
10m x 3m	8.01	0.60	0.46	130.2	13.0	265.1

TABLE 3
Growth and fodder biomass production of sorghum under different spacing's of *Prosopis cineraria* based Agri-silviculture system

Tree spacing (m)	Plant height (cm)	Stem diameter (mm)	Green fodder yield (t/ha)	TSS content (%)	B:C ratio
8m x 3m	261.36	15.63	46.27	6.90	1:19
9m x 3m	259.82	15.57	45.96	7.10	1:18
10m x 3m	256.15	15.48	45.79	7.12	1:18
Control	251.67	15.15	44.12	7.14	1:13
Mean	257.25	15.45	45.53	7.06	-
C.D. at 5%	NS	NS	NS	NS	-

productivity of seasonal crops. The B:C ratio was highest under the 8 m x 3 m spacing (1:19), followed by 9mx3 m and 10m x 3m spacing's (1:18). The control treatment had the lowest B:C ratio (1:13), indicating that the 8mx3 m spacing provided the best economic returns, while the control treatment was less profitable. These findings are in line with Meena *et al*. (2017), who reported that *Khejri* does not significantly suppress *kharif* crops when pruned timely.

CONCLUSION

The integration of *Prosopis cineraria* with agricultural crops like sorghum is feasible and beneficial. While tree growth favours wider spacing, crop performance remained statistically unaffected by spacing treatments. The 8m x 3m spacing consistently provided the encouraging results in terms of plant height, stem diameter, fresh fodder yield, and economic returns, although the differences were not statistically significant. By cultivating diverse crops within these systems, farmers effectively minimize risks, stabilize production over time, and ensure sustainable livelihoods, even under resource-scarce conditions. Soil health remained stable, and the highest economic returns were achieved under 8m × 3m spacing. Hence, this agroforestry system is suitable for sustainable land use in semi-arid regions.

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