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Agroforestry: Viable alternatives for ensuring green fodder production around the year

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ABSTRACT

Agroforestry is an integration of tree species with agricultural crops or livestock that can be directly used to enhance agro biodiversity, rural livelihood and to meet the demand of green fodder throughout the year. Considering this fact, a study was done at Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana to assess the productivity of fodder crops under poplar based agroforestry system. In February 2016, poplar was planted in six different spacing of 3× 3 m, 4×3 m, 5×3 m, 6×3 m, 7×3 m and 8×3 m. In this study, fodder crops (sorghum during *Kharif* season and oat and berseem during *Rabi* season) were intercropped in different spacing's of poplar and compared with control in three replications. The results revealed that the maximum DBH (13.92 cm), basal diameter (16.90 cm) and crown spread (6.79 m) attained in 8×3 m spacing while maximum height (9.61 m) is attained in 3×3 m spacing. The highest pH (7.94) and EC (0.27 dS/m) were recorded in 8×3 m spacing while highest SOC (0.47 %), N (158.5 kg/ha), P (16.8 kg/ha) and K (343.8 kg/ha) were recorded in 3×3 m spacing. Green fodder biomass of sorghum (38.45 t/ha), berseem (64.56 t/ha) and oat (52.62 t/ha) was recorded higher in wider spacing (8×3 m) as compared to sole crops. The maximum light intensity (672.4 Lux) was recorded in 8×3 m at 1.00 pm in the month of July, 2018. Higher value of BCR was observed for poplar with oat (2.44) followed by poplar with sorghum (2.31) and poplar with berseem (2.28) under 3×3 m spacing indicating that closer spacing of 3×3 m of poplar is more economic than the other spacings due to more number of trees per unit area and more production of wood.

Introduction

Animal husbandry is an important sector of India, as it contributes 4.1 per cent to national GDP and 25.6 per cent to agricultural GDP (Gupta *et al.*, 2020). Despite of this, the dairy industry is relatively not so much beneficial and competitive as compared to global productivity and profitability scenario (Patel, 2016). The low productivity of animals is affected by factors such as lesser cultivation of fodder crops, insufficient and unbalanced diet, different kind of diseases and disorders due to the lack of proper feed and traditional way of animal husbandry (Malhi *et al.*, 2020). An animal keeper generally invests around 60-70 per cent of his expenditure in arranging feed

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to animals (Gupta *et al.,* 2020). Hence, in order to make animal husbandry a profitable and productive enterprise, it is important to provide them balanced and sufficient diet. The major components of nutritious diet are dry fodder, green fodder, chuni-chokar, grains, oilcakes and mineral mixtures. Green fodder is an important component of animal nutrition which is required to be accessible throughout the year. During the year the availability of green fodder can be assured through adaptation of fodder crops production with conservation approach.

Agroforestry has potential for taking a leading and catalytic role in providing green fodder throughout the year. Due to its inherent integrative, multidisciplinary nature and the optimization rather than component-maximization aims, great interest shown in it today (Lundgren, 1987). It is a land use system characterized by the combination of forestry and agriculture and an alternative to foster the much needed balance between food production and biodiversity conservation (Salinas, 2016). It is recognized as an efficient ecological basis for increasing crop productivity, more dependable economic returns, and greater diversity (Amatya *et al.,* 2018). Agroforestry has a long tradition in the Indian subcontinent. The socio-religious fabric of the people of the subcontinent is interwoven to a very great extent with raising, caring and respecting trees. Trees are integrated extensively in the crop and livestock production systems of the region according to the agro climatic and other local conditions. The aim of agroforestry is to optimize the positive interactions between components in order to achieve a more productive, sustainable and diversified (in relation to need of land users). Agroforestry plays a significant role in increasing agricultural productivity by nutrient recycling, reducing soil erosion, and increasing soil fertility and farm income compared with conventional system of crop production (Kang & Akinnifesi, 2000). Furthermore, agroforestry offers a range of ecological, economic, social and religious functions (Idol *et al.,* 2011). The immense potential of agroforestry has helped to improve the livelihoods of the rural farmers.

Material and Methods

The study was conducted at CCSHAU, Hisar, Haryana, situated in the north-western India. Figure 1 presents the monthly mean data of meteorological parameters during the interval of study (July, 2018-April, 2019) at the experimental site. The experiment was carried out on sandy-loam soil and medium in available nitrogen, phosphorus and potassium and organic carbon. The poplar plants were planted during February, 2016 at six different spacings (3 × 3 m, 4 × 3 m, 5 × 3 m, 6 × 3 m, 7 × 3 m and 8 × 3 m). The present study was carried out during *Kharif*, 2018 and *Rabi* 2018-19. Intercropping of fodder crops, viz. sorghum (*Sorghum bicolour*), berseem (*Trifolium alexandrinum*) and oat (*Avena sativa*) were taken under six geometries of poplar and compared with monocropping (devoid of trees). During *kharif* season, sorghum var. (HC-171) was sown during first week of July,2018 and oat (var. HJ-8) and berseem (var. HB-1) were sown in all spacing's of poplar under study during first fortnight of November, 2018 and also in control (sole crop) in three replications employing the standard package of practices developed by CCSHAU, Hisar to cultivate fodder crops.

Tree height and diameter at breast height (DBH) were measured randomly using Ravi altimeter (m) and measuring tape (cm) respectively. The crown spread (m) was measured in north-south and east-west directions with the help of a measuring tape. In case of fodder crops, plant population, plant height and leaf area were measured at different time intervals using quadrant in three replications under different spacing's of poplar as well as in control (sole crop). The leaf area index was calculated using the formula;

$$Leaf\ area\ index\ \Rightarrow \frac{Leaf\ area}{Ground\ area}\ X\ 100$$

Quadrate-basis fodder biomass yield (fresh and dry) was taken and converted to tones per hectare, and price of fodder crops was considered on the basis of market rates during the respective years. The soil samples were taken randomly in three replicates from 0-15 cm and 15-30 cm soil depth before sowing and after harvesting of both season crops from all six geometries of poplar and control field (devoid of trees). The soil pH, EC, available nitrogen, available phosphorus, available potassium and organic carbon were analyzed using standard methodologies.

Light intensity: Light intensity was recorded with lux meter in different spacings of poplar and in control (open area) at two hour interval from 7.00 am to till 5.00 pm.

Economic evaluations: Economic analysis was quantified by comparing poplar based agroforestry system with sole fodder crops including trees by estimating the land rent, cost of cultivation and price of fodder crops and trees (according to girth of trees). The cost-benefit parameters used for comparison of systems were net returns, net present value (NPV) @ 12% discounting rate, internal rate of return (IRR) and benefit/cost ratio (BCR). Cost and income from intercropping as well as trees were calculated. The replicated data of all the characters recorded (yield and biomass of fodder crops, soil parameters and growth traits of the trees) were analyzed statistically using model suggested by Panse and Sukhatme (1989).

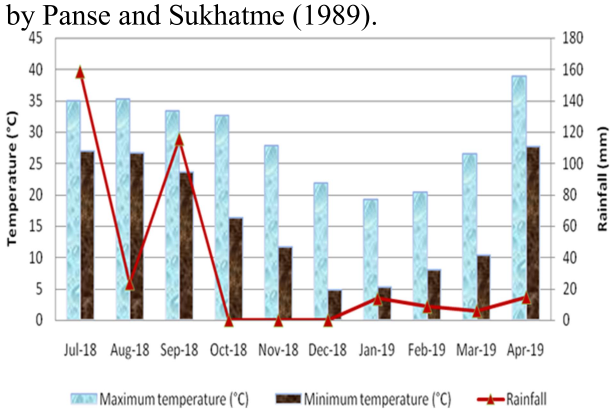

Figure 1: The monthly mean meteorological data of the experimental site from July, 2018 to April, 2019.

Results and Discussion

Growth of poplar

Tree growth parameters revealed that with the advancement of age, a gradual increase in DBH and height was observed. While with the increasing space in between tree rows, tree height decreases with maximum height (9.61 m) is attained in 3×3 m spacing (Figure 2 a) this may be due to increasing competition in between trees for light, while DBH (Diameter at breast height), basal diameter and crown spread increases with increases in tree spacing, maximum DBH (13.92 cm), basal diameter (16.90 cm) and crown spread (6.79 m) attained in 8×3 m spacing (Figure 2 b, c, d) as they have more space to grow wider. The height and DBH of poplar plantation was affected significantly in different spacing geometries under agroforestry, this may be due to more intra-line competition of poplar plants for different growth resources. Similar findings have been highlighted by (Ajit *et al.,* 2011; Chauhan *et al.,* 2011). The rate of increase in crown spread is more than DBH and basal diameter due to more availability of space in wider spacings for crown spread as compared to narrow spacing of poplar plantation.

Influence of poplar spacing's geometry on soil properties

Table 1 shows data on soil chemical properties (0-15 cm depth) under different spacing's geometries of poplar plantation before sowing of fodder crops (July, 2018) and after harvesting of both season fodder crops (April, 2019). The soil pH and available potassium content were found non-significant among different spacing geometries of poplar and control (devoid of trees). Among different spacing geometries, the highest pH (7.94) and EC (0.27 dS/m) were recorded in the 8×3 m spacing after harvesting of fodder crops. The soil organic carbon (SOC) was significantly influenced by tree spacing and increased (0.47%) from its initial status (0.43%) under 3×3 m spacing of poplar based agroforestry system which is higher as compared to sole cropping (0.30%). Available nutrients (nitrogen, phosphorus and potassium) were also significantly influenced by tree spacing and the magnitude of increase in available nutrients was highest under 3×3 m spacing and lowest in control (sole crops). The average available nitrogen content in 3×3 m, 4×3 m, 5×3 m, 6× 3 m, 7×3 m and 8×3 m spacing geometries was higher by 22.29%, 19.67%, 17.51%, 13.58%, 11.72% and 9.95% respectively, over sole crop (129.6 kg/ha). The higher build-up of soil organic carbon and nutrients on the surface layer (0-15 cm) of soils may be attributed to the regular accumulation of litter fall of poplar on the soil surface, fine root biomass and availability of sufficient moisture level. Similar trends of improvement in the nutrient status of soil due to intercropping in an agroforestry as reported by Chavan and dhillon (2019), Dhillon *et al.* (2020) and Kumar *et al.* (2019).

Yield performance of fodder crops in intercropping with various spacing's of poplar

It is evident from Table 2 that green fodder biomass of sorghum, berseem and oat was found to be higher in wider spacing (8 × 3 m) followed by 7 × 3 m, 6 × 3 m, 5 × 3 m, 4 × 3 m and 3 × 3 m spacing,

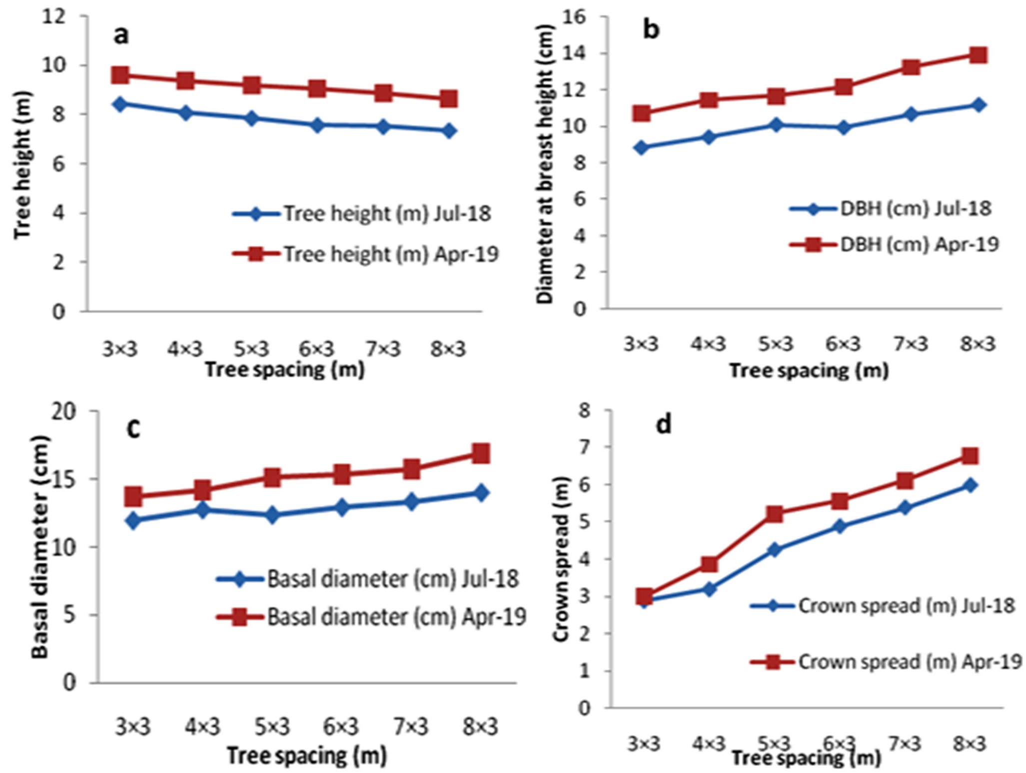

Figure 2: (a) Plant height (m), (b) diameter at breast height (cm), (c) basal diameter (cm) (d) crown spread (m) of poplar in different planting geometries.

Table 1: Soil properties under different spacing's of poplar-based agroforestry systems

Tree spacing's (m)		pH	EC (dsm-1)	Organic carbon (%)	Available nutrients (Kg/ha) N	P	K
3×3	**BS**	7.82	0.22	0.43	151.5	13.6	325.8
	AH	7.75	0.19	0.47	158.5	16.8	343.8
4×3	**BS**	7.85	0.23	0.40	148.0	13.4	315.8
	AH	7.77	0.20	0.44	155.1	16.5	342.0
5×3	**BS**	7.87	0.25	0.38	144.0	13.1	332.6
	AH	7.80	0.22	0.42	152.3	16.2	339.3
6×3	**BS**	7.91	0.26	0.37	141.0	13.0	318.6
	AH	7.85	0.24	0.41	147.2	16.0	338.1
7×3	**BS**	8.01	0.28	0.34	138.6	12.8	317.9
	AH	7.88	0.26	0.39	144.8	15.9	335.5
8×3	**BS**	8.18	0.29	0.30	137.2	12.5	316.4
	AH	7.94	0.27	0.33	142.5	15.5	332.9
Control	**BS**	8.26	0.34	0.28	126.6	11.3	310.8
	AH	8.08	0.33	0.30	129.6	12.3	330.3
CD at 5%		NS	0.017	0.026	6.84	0.75	NS

Table 2: Green fodder yield of fodder crops under different geometries of poplar-based agroforestry systems.

Tree spacing's (m)	Fresh green fodder yield		
	Sorghum	Berseem	Oat
3×3	24.27	47.70	40.68
4×3	27.78	51.30	41.99
5×3	34.38	54.75	45.32
6×3	35.85	57.62	47.55
7×3	37.98	62.68	50.65
8×3	38.45	64.56	52.62
Control	43.37	68.52	60.11
CD at 5%	1.78	3.28	2.28

but lower than sole cropping (devoid of trees). The performance of both *Kharif* and *Rabi* season fodder crops was strongly influenced under poplar based agroforestry system with reduction of spacing geometries of the trees because of increased competition for solar radiation, moisture and nutrients between the trees and fodder crops. The overall yield of *Rabi* season (Berseem and Oat) fodder crops (Table 2) was higher than *Kharif* season (Sorghum) fodder crop (Table 2) under different spacing geometries of poplar. Dry fodder yield was obtained maximum in sorghum followed by berseem and oat. Under control (sole cropping) maximum dry fodder yield was recorded as compared to different spacing of poplar (Figure 3). Green fodder biomass was reduced from 11.34% to 44.03% in sorghum (Figure 4) under various plant geometries of poplar over control (sole crop). There was significantly more reduction in yield of sorghum under 3×3 m spacing i.e. 44.03% and 35.94 % under 4×3 m spacing as compared to wider spacings of poplar. The production of winter crops (berseem and oat) in the open (devoid of trees) was higher than intercropping under different spacing of poplar plantation. Yield reduction varied from 5.77% to 30.38% in berseem and 12.46% to 32.32% in oat under different spacing's of poplar over control. In poplar based agroforestry system, fodder yield of crops increased with the increased distance between tree rows. In winter season, crop yield started decreasing considerably in narrow spacing; however, reduction in yield was less under wider spacing's (Figure 4).

It is widely acknowledged that the yield of agricultural crops grown in an agroforestry system is lower than that of crops grown in a monoculture system. The fact that the yield of rainy-season crops is significantly lower than that of winter-season crops has been pointed out by numerous researchers (Chauhan *et al.,* 2012; Chaturvedi and Pandey, 2001 and Nandal and Hooda, 2005). This is due to the heavy shade cast by poplar trees during the rainy season, which prevents light from reaching the crop and reduces its yield. In contrast, the

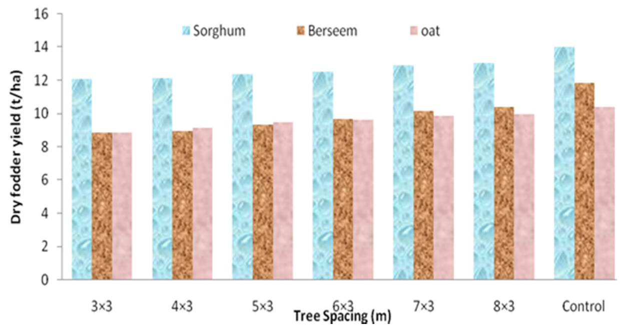

Figure 3: Dry fodder yield of fodder crops under different geometries of poplar-based agroforestry systems

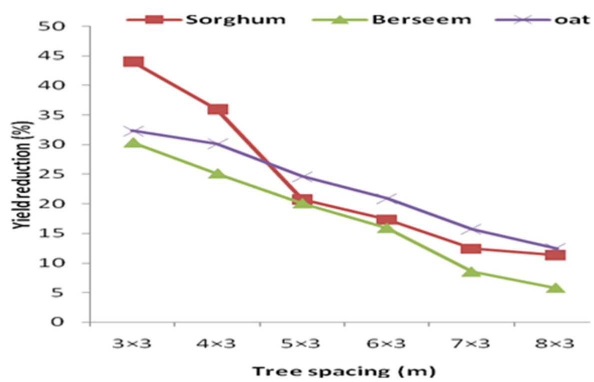

Figure 4: Green fodder yield reduction (%) of fodder crops under different spacing of poplar-based agroforestry system

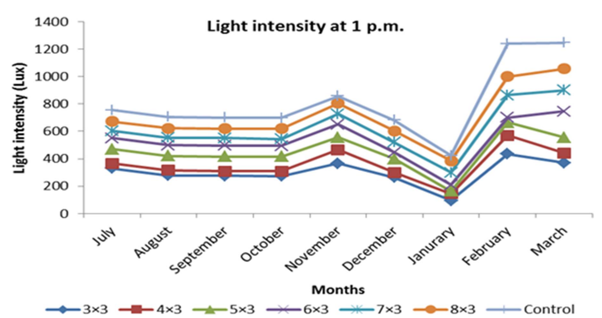

Figure 5: Light intensity (Lux) underneath different spacing's of poplar and control

Table 3: Leaf area indexof fodder crops under different spacing's of poplar

Tree spacing's (m)	Leaf area index (at harvest)		
	Sorghum	Berseem	Oat
3×3	5.2	3.6	4.2
4×3	5.3	3.7	4.4
5×3	5.4	3.9	4.5
6×3	5.6	4.0	4.7
7×3	5.9	4.1	4.8
8×3	6.0	4.2	4.9
Control	6.4	4.6	5.3
CD at 5%	0.54	0.38	0.45

absence of leaves on poplar trees during the winter season allows for ample light to reach the crops, which results in a higher yield as compared to the rainy season. Agroforestry systems also compensate for year-to-year yield reductions of various crops by producing woody biomass, which has been shown to be effective in a number of economic evaluations (Jain and Singh, 2000 and Singh and Mavi, 2016).

Leaf area index

Under poplar based agroforestry system, the higher leaf area index of sorghum (6.00), berseem (4.20) and oat (4.90) was recorded under 8×3 m and minimum under 3×3 m spacing at harvest. However, the highest leaf area index was recorded under control (sole cropping) in all fodder crops (Table 3). The decrease in the leaf area index with the decrease in the spacing may be due to the light, nutrients and moisture between tree and crop components. Thus, competition for utilization of growth resources adversely affected the leaf area index of intercropped fodder crops under different spacing's of poplar. Kumar *et al*. (2014) revealed the similar results that leaf area index increased significantly with wider spacing and also with stage of growth.

Light intensity on fodder crops under different spacing's of poplar

Trees reduce the amount of sunlight reaching to soil and crops through shading. Light capture is influenced by both environmental and plant factors such as tree leaf area, leafing phenology, crown structure and management. Unless trees are leafless during the cropping season or heavily pruned, competition can be substantial (Luedeling *et al.,* 2016). The light intensity available to fodder crops of both seasons (rainy and winter season) was noticed on monthly interval at two hours interval of the day (7A.M. to 5 P.M.) under different spacing's as well as in open condition (devoid of trees). Results highlighted that the light intensity to fodder crops is significantly affected by poplar trees at different stages of growth. The highest light intensity (672.4 Lux) was recorded in 8×3 m followed by 7×3 m (604.4 Lux), 6×3 m (550.1 Lux), 5×3 m (469.8 Lux), 4×3 m (365.4 Lux) and minimum under 3×3 m (331.4 Lux) at 1.00 pm in the month of July (2018) as shown in figure 5. The light intensity trends under different spacing's of poplar was observed in decreasing order from July to October, 2018 and then it follows increasing trend from November, 2018 to February,2019. From the month of March, 2019 it starts to reduced due to the appearance of new foliage in poplar. The light intensity available to the sole crop found greater than various spacing's of poplar tree. From December to February, the difference in the light intercepted by sole crop and poplar-intercropped was less but after mid of March it starts to increase as the dense foliage in the poplar. Among different spacing's of poplar, the maximum light intensity was observed in 8×3 m however, in closer spacing (3×3 m) it was significantly less. These findings are also supported by the findings of Bhandari *et al.* (2015).

Economic analysis of poplar-based agroforestry systems

In the present study, detailed observations in terms of accurate record of rental value of land, input costs, expenditure on labour and inter-cultural operations, tree and crop growth and their yield, and market price help portray the economic overview of agroforestry systems. *Populus deltoides* based silvi-pastoral systems fetched higher net returns as compared to sole fodder crops (Table 4 and 5). It can be clearly observed from the data that the cost of cultivation, gross return and net return increased with the increase in number of trees per hectare in different spacing's of poplar. The figures presented in Table 4 that the maximum gross return was obtained from poplar + sorghum system, *i.e*. Rs. 241943/ha under 3×3 m spacing due to more number of trees in this spacing. The gross return decreased with the increase in the spacing of poplar, however the minimum gross return was obtained under sole cropping of sorghum *i.e*., Rs. 61392/ha. The maximum net

Table 4: Economics of sorghum with poplar and control (sole fodder crops)

Tree spacing (m)	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
3×3	104679	241943	137264	2.31
4×3	101409	194781	93373	1.92
5×3	99447	173675	74228	1.75
6×3	98139	154916	56777	1.58
7×3	97827	143244	45417	1.46
8×3	96504	132687	36183	1.37
Control	35892	61392	25500	1.71

Table 5: Economics of berseem and oat with poplar and control (sole fodder crops)

Tree spacings (m)	Cost of cultivation (Rs./ha)		Gross return (Rs./ha)		Net return (Rs./ha)		B:C ratio	
	P + B	P + O	P + B	P + O	P + B	P + O	P + B	P + O
3×3	111867	105291	255001	257058	143134	151767	2.28	2.44
4×3	108597	102021	204743	206315	96146	104294	1.89	2.02
5×3	106635	100059	175492	178405	68857	78346	1.65	1.78
6×3	105327	98751	157748	158856	52421	60105	1.50	1.61
7×3	105015	98440	148317	146681	43302	48241	1.41	1.49
8×3	103692	97116	138044	137500	34352	40383	1.33	1.42
Control	45081	38505	66164	64499	21083	25994	1.47	1.68

***P + B, Poplar and Berseem P + O, Poplar and Oat**

return (Rs. 137264/ha) was obtained under poplar + sorghum at 3×3 m, while the minimum net return was obtained under sole cropping of sorghum *i.e.*, Rs. 25500/ha. The figures indicate (Table 5) that the cost of cultivation of winter season fodder crops increased with the decrease in poplar spacing's. Poplar + oat cropping system gained maximum gross returns (Rs. 257058/ha) and net return (Rs. 151767/ha) closely followed by poplar + berseem system Rs. 255001/ha (gross return) and Rs. 143134/ha (net return) respectively under 3×3 m spacing of poplar due to more number of trees. On the other hand, the gross and net return decreased with the increase in the spacing of poplar and minimum was obtained under sole cropping of berseem and oat.

Benefit cost ratio

BCR is the most important and accepted parameter in agricultural production systems. Higher value of BCR was observed for poplar with oat (2.44) followed by poplar with sorghum (2.31) and poplar with berseem (2.28) under 3×3 m spacing. It indicates that closer spacing of 3×3 m of poplar is more economic than the other spacing's due to more number of trees per unit area and more production of wood (Table 4 and 5). The lowest value of BCR (1.33) was reported in poplar + berseem followed by poplar + sorghum (1.37) under 8×3 m spacing. Thus poplar + oat is found to be more profitable than other fodder crops in poplar based silvi-pastoral systems. Some researchers have reported the higher BCR (more than 2.0) for poplar based agroforestry system in the Indo-Gangetic plains. Banerjee *et al*. (2010), Chisanga *et al.* (2013) also reported that benefit cost ratio (BCR) was maximum (6.63) from silvi-pasture and least from sole agriculture (without trees).

Conclusion

Economic evaluation for adoption of various agroforestry systems is essential due to increasing land pressure and diversification of traditional cropping system. Agroforestry based on poplar is more beneficial than the other traditional cropping system. The study pointed out that poplar based agroforestry system at spacing of 8×3 m is superior over other spacing geometries in terms of tree growth and fodder yield. The benefit cost ratio (BCR) of poplar with oat (2.44) was highest followed by poplar with sorghum (2.31) and poplar with berseem (2.28) at 3×3 m spacing due to more number of trees per unit area. Poplar also plays an important role in adaptation and mitigating climate change because it sequesters more atmospheric carbon in plant parts and soil and reduces the concentration of green house gases in environment.

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Conflict of interest

The authors declare that they have no conflict of interest.

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