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Research article

Forage productivity and carbon storage from *Hardwickia binata* based silvopasture systems in semi-arid rainfed conditions

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Abstract

A study was conducted from 2018 to 2022 on ten year old *Hardwickia binata* based silvopasture system at Indian Grassland and Fodder Research Institute, Jhansi. The treatment consisted of establishment of three types of grasses *viz. Cenchrus ciliaris, Chrysopogon fulvus* and *Panicum maximum* in association with *H. binata* and three pruning intensities of *H. binata viz.* 30%, 45% and 60%. Establishment of *C. fulvus* in association with *H. binata* recorded significantly higher dry pasture yield (7.91- 8.93 t/ha) as compared to *P. maximum* (6.19-7.08 t/ha) and it was found at par with *C. ciliaris* (7.62-8.70 t/ha) during 1st to 4th years. In pruning, 60% canopy pruning of *H. binata* recorded significantly higher pasture yield (7.99, 8.40 and 8.99 t/ha) as compared to 30% canopy pruning (7.19, 7.27 and 7.38 t/ha) and 45% canopy pruning (7.67, 7.95 and 8.33 t/ha) during 2nd, 3rd and 4th years respectively. Organic carbon content (0.646%) was significantly increased with *C. fulvus* as compared to *P. maximum* (0.591%) and it was found at par with *C. ciliaris* (0.627%) in 4th year of study. Available nitrogen (260.60 kg/ha), phosphorus (9.36 kg/ha), potash (238.70 kg/ha) and organic carbon (0.663%) were also significantly increased with 30% canopy pruning of *H. binata* as compared to 60% canopy pruning in 4th year. *H. binata* recorded 79.90% higher carbon stock in 4th year of study (19.61 t/ha) as compared to initial year. Total carbon stock of the system was maximum with *C. fulvus* in association with *H. binata* (39.29 and 50.73 t/ha) closely followed by *C. ciliaris* (38.51 and 50.30 t/ha) and *P. maximum* (36.20 and 46.68 t/ha) during 1st and 4th years respectively. Among pruning, 30% canopy pruning of *H. binata* recorded significantly higher total carbon stock of the system (50.82 t/ha) as compared to 60% canopy pruning (47.42 t/ha) during 4th year of study.

Keywords: Carbon storage, Forage productivity, Grasses, Pruning intensities, Silvopasture systems

Introduction

In hot arid and semiarid regions where erratic rainfall and recurrent drought is the common phenomenon, development of suitable silvopasture systems can play an important role in increasing system productivity, enhancing fodder availability and checking soil erosion (Soni *et al*. 2013; Sharma, 2014). Establishment of silvopasture systems on degraded lands can serve the important role of bridging the gap in fodder supply during lean period of the year. In silvopasture systems grasses provide green forage during the monsoon season and trees provide top feeds during winter and summer seasons (Kumar *et al*., 2017; Ram *et al*., 2019). In silvopasture systems, canopy management of tree components is essential to obtain a sustained yield of understorey pasture, top feeds and wood. Without proper pruning management trees develop larger taper and side branches which provide more shade and decrease understorey pasture productivity, besides these larger branches produce larger knots on the stems and reduce the wood quality (Rosso and Ninin 1998). Canopy management in silvopasture systems alleviates shades and facilitate penetration of light to understorey pasture which improves the growth of pasture components than un-pruned trees (Thakur and Sehgal, 2000; Dar and Newaj, 2007).

Silvopasture systems play an important role in sustainable production through nutrient cycling, soil and water conservation, microclimate modification and sequestrating carbon which considered as potent instrument against climate change mitigation (Thomas *et al*., 2021; Tudu *et al*., 2021). Evidences are now emerging that silvopasture system are promising land use system to increase aboveground and soil carbon stock to mitigate greenhouse gas emissions. In India, average sequestration potential in agroforestry has been estimated to be 25 t C/ha over 96 million ha (Sathaye and Ravindranath, 1998), but there is considerable variation in different regions depending upon biomass production. The role of land use systems in stabilizing the carbon dioxide levels and increasing the carbon sink potential has attracted considerable scientific attention in the recent past, especially after the Kyoto Protocol (IPCC, 2007). However, in addition to production aspects, there is also a need to quantify the ecosystem services in terms of carbon storage potential, for reducing carbon emissions for climate change mitigation. In view of this the present study was carried out to record the effect of grasses and pruning intensities on forage productivity and carbon storage from *Hardwickia binata* based silvopasture systems in semiarid rainfed conditions.

Materials and Methods

Experimental site and design: The study was conducted during 2018 to 2022 on ten years old *Hardwickia binata* based silvopasture system at Central Research Farm (25^0 27' N latitude, 78^0 34' E longitude and 275 m above mean sea level), Indian Grassland and Fodder Research Institute, Jhansi. The soil of experimental site was sandy loam, low in available nitrogen and phosphorus and medium in organic carbon and available potash. The region receives an annual rainfall of 906.5 mm and annual potential evapotranspiration of 1512 mm (Singh *et al*., 2007). The total rainfall received 1054.6, 714.2, 786.5 and 816.8 mm in 43, 54, 45 and 33 rainy days during 2018, 2019, 2020 and 2021, respectively. There were 9 treatment combinations replicated thrice in randomized block design. The treatment consisted of establishment of three grasses viz. *Cenchrus ciliaris, Chrysopogon fulvus* and *Panicum maximum* in association with *H. binata* and three pruning intensities of *H. binata viz.* 30%, 45% and 60%. *H. binata* was established at 6 x 6 m spacing and grasses were established in association with *H. binata* at 50 x 50 cm spacing. Green crown lengths of trees were pruned once every year as per treatments during winter season.

Sampling and methods of analysis: Pruned yields of *H. binata* were recorded every year as per treatments during winter season. Grasses were harvested by tractor operated side reaper at 15 cm above the ground surface in second fortnight of September in each year. Fodder yield of grasses were recorded at the time of harvesting. Dry fodder yield was recorded in each plot on the basis of per square meter area and values were converted into tonne/ hectare. Dry matter yield was computed by drying 500 g plant sample of each treatment and replication in hot-air oven at 70^0C. The experimental data collected were subjected to statistical analysis using Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984). The level of significance used in 'F' and 't' tests was P=0.05. Critical difference values were calculated, wherever F tests was found significant.

Light transmission measurement: The light transmission by the canopy of the *Hardwickia binata* under different pruning regimes and grass combinations was measured by using canopy analyzer. The light intensity above canopy (I_0) and at the ground level (I) was recorded between 12:30 and 1:00 pm. Light transmission ratio was calculated by the following formula. Measurements were conducted consequently in the month of August-2018, 2019, 2020 and 2021, respectively. The light interception was measured above a canopy and beneath a canopy of different range grasses near solar noon when the light is unobstructed by cloud cover (Board *et al*., 1992). LTR (%) = $(I/I_0) \times 100$; where, I = Light intensity received at the ground level and I_0 = Light intensity received at the top of grass canopy.

Carbon stock estimation: Tree, grass, litter, soil and total carbon stock was estimated under various pruning regimes. Carbon stock in *Hardwickia biñata* trees was calculated based upon dry matter content of the tree which was calculated for various parts of *H. binata* tree using allometric equations given by Newaj *et al.,* (2014; Table 1). Total dry matter of *H. binata* tree was calculated by adding dry matter of tree bole, branches, leaves and roots. The total carbon stock in tree was determined by multiplying respective dry matter of various parts with their carbon content as given by Newaj *et al*. (2014) and then adding up the carbon content of all the parts. The carbon stock was then calculated per hectare basis based on the tree density (278 trees/ha). In grasses, above and below ground carbon stock was calculated by multiplying above and below ground dry biomass per hectare basis with conversion factor of 0.50 (IPCC, 2006). Litter carbon stock was estimated by multiplying litter dry biomass per hectare basis with conversion factor of 0.50 (IPCC, 2006). Total system carbon stock in *H. binata* based silvopasture was determined by adding total carbon stock of trees, grasses and soil per hectare basis. Soil organic carbon percentage was calculated using Walkley and Black method (1934) and soil bulk density was determined using a specific gravity method given by Singh (1980). Soil organic carbon stock was determined up to 30 cm depth using equation given by Nelson and Sommers (1996); Soil organic carbon stock = [Soil bulk density (g cm^{-3}) x Soil depth (cm) x Carbon (%)] x100

Table 1. Allometric equations for estimation of biomass of *H. binata*

Tree components	Allometric equations
Bole	$0.232\ (DBH)^{2.046}$
Branch	$0.002\ (DBH)^{3.142}$
Leaves	$0.0002\ (DBH)^{3.514}$
Root	$0.036\ (DBH)^{2.337}$

DBH: Diameter at breast height

Results and Discussion

Growth parameters of H. binata: Establishment of different grasses in association with *H. binata* did not significantly affect the growth parameters of *H. binata* during different years (Table 2). However, 60% canopy pruning of *H. binata* attained maximum height (9.16, 9.83 and 10.37 m) followed by 45% canopy pruning (8.93, 9.55 and 10.02 m) during 2nd, 3rd and 4th years of study, respectively. While collar diameter and diameter at breast height of *H. binata* were higher with 30% canopy pruning (23.92 cm and 19.05 cm) as compared to 45% (23.62 cm and 18.80 cm) and 60% canopy pruning (23.40 cm and 18.63 cm) during 4th year of study. However, canopy spread was significantly higher with 30% canopy pruning (4.57 and 4.93 m) as compared to 45% (4.31 and 4.63 m) and 60% canopy pruning (4.15 and 4.41 m) during 3rd and 4th years of study, respectively. Similar result was also reported earlier (Víquez and Pérez, 2005).

Pasture and sustainable yield index: Establishment of *C. fulvus* in association with *H. binata* recorded significantly higher dry pasture yield (7.91, 8.33, 8.66 and 8.93 t/ha) as compared to *P. maximum* (6.19, 6.37, 6.54 and 7.08 t/ha) and it was found at par with *C. ciliaris* (7.62, 8.15, 8.44 and 8.70 t/ha) during 1st, 2nd, 3rd and 4th years, respectively (Table 3). The higher pasture yields of *C. fulvus* and *C. ciliaris* were due to their adequate plant stands and dense vegetative growth over the years as compared to *P. maximum* under semiarid rainfed condition. In pruning, 60% canopy pruning of *H. binata* recorded significantly higher pasture yield (7.99, 8.40 and 8.99 t/ha) as compared to 30% canopy pruning (7.19, 7.27 and 7.38 t/ha) and 45% canopy pruning (7.67, 7.95 and 8.33 t/ha) during 2nd, 3rd and 4th years, respectively.

Table 2. Effect of pruning intensities and grasses on growth parameters of *Hardwickia binata*

Treatment	Height (m)				Collar diameter (cm)				Diameter at breast height (cm)				Canopy spread (m)			
	2018-19	2019-20	2020-21	2021-22	2018-19	2019-20	2020-21	2021-22	2018-19	2019-20	2020-21	2021-22	2018-19	2019-20	2020-21	2021-22
Grasses																
C. ciliaris	7.97	8.80	9.49	9.96	18.01	20.29	22.15	23.63	14.52	16.18	17.59	18.81	3.71	3.94	4.33	4.64
C. fulvus	8.13	9.00	9.66	10.10	18.21	20.46	22.26	23.81	14.66	16.30	17.74	18.95	3.83	4.00	4.41	4.74
P. maximum	7.94	8.87	9.39	9.88	17.99	20.18	21.85	23.50	14.51	16.11	17.50	18.72	3.70	3.91	4.28	4.59
SEM	0.07	0.09	0.08	0.09	0.09	0.11	0.13	0.16	0.06	0.09	0.11	0.11	0.05	0.06	0.07	0.07
CD(P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pruning (%)																
30	8.08	8.59	9.16	9.55	18.13	20.47	22.21	23.92	14.61	16.30	17.75	19.05	3.76	4.10	4.57	4.93
45	7.90	8.93	9.55	10.02	17.93	20.29	22.16	23.62	14.45	16.18	17.60	18.80	3.69	3.92	4.31	4.63
60	8.05	9.16	9.83	10.37	18.16	20.18	21.89	23.40	14.62	16.10	17.49	18.63	3.80	3.82	4.15	4.41
SEM	0.07	0.09	0.08	0.09	0.09	0.11	0.13	0.16	0.06	0.09	0.11	0.11	0.05	0.06	0.07	0.07
CD(P<0.05)	NS	0.26	0.25	0.26	NS	NS	NS	0.47	NS	NS	NS	0.33	NS	NS	0.20	0.21

Rai (2006) also found that pruning of *Acacia nilotica* and *Dalbergia sissoo* up to 50% height gave higher dry forage yield of *C. fulvus* as compared to unpruned trees in silvopasture systems. Higher biomass production under pruned treatments might be due the fact that pruning of trees facilitated more light to understorey pasture which resulted into higher growth and yield. Light availability was the most important limiting factor for the performance of under storey pasture, particularly where upper storey perennial formed a dense cover storey canopy (Miah *et al*., 1995).

Sustainable yield index of *C. fulvus* was maximum (0.665) closely followed by *C. ciliaris* (0.638) which indicated that *C. fulvus* and *C. ciliaris* were produced more stable yields over the years than *Panicum maximum* (0.638) under semiarid rainfed conditions. Similarly, 60% canopy pruning of *H. binata* also recorded higher sustainability yield index (0.676) than 45% canopy pruning (0.627) and 30% canopy pruning (0.546) which showed that total productivity of the system obtained from 60% canopy pruning of *H. binata* was more stable over the years than 45% and 30% canopy pruning.

Top feed and fire wood yields of H. binata: Top feed (TF) and fire wood (FW) yields of *H. binata* also did not affected significantly by establishment of different grasses in association with *H. binata* (Table 3). However, 60% canopy pruning of *H. binata* recorded significantly higher top feed (TF: 1.48, 1.77, 2.23 and 2.68 t/ha) and fire wood (FW: 2.74, 3.17, 3.49 and 3.79 t/ha) yields as compared to 30% canopy pruning (TF: 0.93, 1.01, 1.19 and 1.55 t/ha and FW: 1.76, 1.90, 1.98 and 2.26 t/ha) and 45% canopy pruning (TF: 1.21, 1.41, 1.75 and 2.15 t/ha and FW: 2.33, 2.59, 2.82 and 3.08 t/ha) during 1st, 2nd, 3rd and 4th years of study, respectively. Biomass production was directly correlated with pruning intensity. Hence, severely pruned trees tended to produce more biomass as compared to lightly pruned trees. The reason was that more foliage was removed in 60% pruning which increased the pruned biomass. Similar results were also observed by Zeng (2001), Uotila and Mustonen (1994) and Palsaniya *et al.* (2012). Pruning resulted in usage of stored reserve for its growth and production of leaves. Indeed, this happened because of the exposure of pruned portion to sunlight and dormant buds became active and sprouted into shoots with the available reserves present in the trees (Muhamad and Paudyal, 1992).

Light transmission: Different grasses did not significantly affect the light transmission in *H. binata* based silvopasture system (Table 4). However, 60%

Table 3. Effect of pruning intensities and grasses on dry pasture yield, top feed, fire wood and sustainable yield index (SYI)

Treatment	**Pasture yield (t/ha)**				**Top feed (t/ha)**				**Fire wood (t/ha)**				**SYI**
	2018-19	2019-20	2020-21	2021-22	2018-19	2019-20	2020-21	2021-22	2018-19	2019-20	2020-21	2021-22	
Grasses													
C. ciliaris	7.62	8.15	8.44	8.70	1.19	1.39	1.72	2.13	2.25	2.53	2.74	3.03	0.638
C. fulvus	7.91	8.33	8.66	8.93	1.25	1.45	1.81	2.20	2.37	2.67	2.92	3.16	0.665
P. maximum	6.19	6.37	6.54	7.08	1.17	1.34	1.64	2.06	2.21	2.46	2.64	2.95	0.547
SEM	0.11	0.11	0.13	0.14	0.05	0.05	0.06	0.08	0.10	0.10	0.14	0.15	0.010
CD(P<0.05)	0.33	0.32	0.39	0.42	NS	NS	NS	NS	NS	NS	NS	NS	0.030
Pruning (%)													
30	7.12	7.19	7.27	7.38	0.93	1.01	1.19	1.55	1.76	1.90	1.98	2.26	0.546
45	7.37	7.67	7.95	8.33	1.21	1.41	1.75	2.15	2.33	2.59	2.82	3.08	0.627
60	7.23	7.99	8.40	8.99	1.48	1.77	2.23	2.68	2.74	3.17	3.49	3.79	0.676
SEM	0.11	0.11	0.13	0.14	0.05	0.05	0.06	0.08	0.10	0.10	0.14	0.15	0.010
CD(P<0.05)	NS	0.32	0.39	0.42	0.16	0.16	0.19	0.24	0.30	0.29	0.42	0.46	0.030

Table 4. Effect of pruning intensities and grasses on transmitted radiation and light transmission ratio in *H. binata* based silvopasture system

Treatment	2018-19			2019-20			2020-21			2021-22		
	Transmitted radiation (Lux)		LTR (%)	Transmitted radiation (Lux)		LTR (%)	Transmitted radiation (Lux)		LTR (%)	Transmitted radiation (Lux)		LTR (%)
Grasses												
C. ciliaris	1306.40	421.75	32.27	1423.98	467.79	32.95	1365.19	424.27	31.01	1396.22	442.90	31.58
C. fulvus	1337.91	444.05	33.17	1458.32	495.93	34.05	1398.12	450.99	32.29	1429.38	469.54	32.97
P. maximum	1241.12	417.68	3.59	1352.82	466.72	34.29	1296.97	423.25	32.59	1327.50	441.89	33.54
SEM	24.94	13.84	2.28	27.18	9.41	1.51	26.06	8.94	1.31	28.36	8.92	1.15
CD(P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Pruning (%)												
30	1282.04	320.90	25.15	1397.42	356.77	25.59	1339.73	318.83	23.81	1370.57	337.79	24.78
45	1297.72	409.31	31.49	1414.51	477.32	33.79	1356.12	433.32	31.90	1387.08	451.93	32.77
60	1305.67	416.25	31.86	1423.18	596.34	41.98	1364.43	546.36	40.01	1395.45	564.62	40.53
SEM	24.94	13.84	2.28	27.18	9.41	1.51	26.06	8.94	1.31	28.36	8.92	1.15
CD(P<0.05)	NS	NS	NS	NS	27.75	4.49	NS	26.64	3.89	NS	26.97	3.46

canopy pruning of *H. binata* recorded significantly higher light interception (41.98, 40.01 and 40.53%) as compared to 30% canopy pruning (25.59, 23.81 and 32.77%) and 45% canopy pruning (33.79, 31.90 and 24.78%) during 2nd, 3rd and 4th years, respectively. The higher light interception in 60% canopy pruning might be due to lower canopy spreading of the trees leading to more penetration of light to the understorey pastures.

Carbon stock status of silvopastures: Carbon stock of *H. binata* was not significantly affected by different grasses and pruning intensities in 1st year of study (Table 5). However, in 4th year of study, 30% canopy pruning intensities of *H. binata* recorded significantly higher carbon stock (20.16 t/ha) as compared to 60% canopy pruning intensities (19.13 t/ha). The decrease in carbon stock of *H. binata* with 60% canopy pruning intensities in 4th year was probably due to decrease in diameter at breast height with continuous pruning at high intensities which resulted in lower biomass production and ultimately carbon stock. *H. binata* recorded 79.90% higher carbon stock in 4th year of study (19.61 t/ha) as compared to initial year. Carbon storage by trees was basically a function of their dry biomass production and tissue carbon concentration (Nair *et al.,* 2009).

Carbon stock in *C. ciliaris* was significantly higher (5.57 and 6.35 t/ha) as compared to *Chrysopogon fulvus* (5.03 and 5.67 t/ha) and *P. maximum* (3.68 and 4.21 t/ha) in both initial and 4th years of study. The higher carbon stock in *C. ciliaris* was due to higher root-shoot ratio of *C. ciliaris* as compared to *Chrysopogon fulvus* and *P. maximum*. Among pruning intensities, 60% canopy pruning intensities significantly increased carbon stock of grasses (5.91 t/ha) as compared to 30% canopy pruning intensities (4.85 t/ha) and 45% canopy pruning intensities (5.48 t/ha) in 4th year of study. The higher carbon stock with 60% canopy pruning intensities was due to higher biomass yield of grasses with 60% canopy pruning intensities as compared to 30% and 45% canopy pruning intensities.

Litter carbon stock was also not significantly affected by different grasses in 1st year of study (Table 5). However, in 4th year of study *C. fulvus* recorded significantly higher litter carbon stock (1.65 t/ha) as compared to *P. maximum* (1.46 t/ha) and it was found at par with *C. ciliaris* in association with *H. binata* (1.59 t/ha) during 4th year. This was might be due to higher litter biomass of *C. fulvus* as compared to *P. maximum* which also resulted in higher litter carbon stock. 30% canopy pruning of *H. binata* also significantly increased litter carbon stock (0.88 and 1.84 t/ha) as compared to 45% canopy pruning (0.77 and 1.52 t/ha) and 60% canopy pruning (0.66 and 1.34 t/ha) during 1st and 4th years, respectively. This might be also due to higher litter biomass recorded with 30% canopy pruning of *H. binata* as compared to 45% canopy pruning and 60% canopy pruning.

Chrysopogon fulvus resulted in significantly higher soil carbon stock (22.99 and 25.15 t/ha) as compared to *P. maximum* (21.92 and 23.11 t/ha) and it was found at par with *C. ciliaris* (22.11 and 24.38 t/ha) during 1st and 4th year, respectively. This was might be due to higher litter biomass of *C. fulvus* as compared to *P. maximum* which also resulted in higher soil carbon stock. Soil carbon stock was also significantly increased (25.82 t/ha) with 30% canopy pruning of *H. binata* as compared to 45% canopy pruning (24.45 t/ha) and 60% canopy pruning (22.38 t/ha) in 4th year of study. This was probably due to higher litter biomass addition in soil with 30% canopy pruning of *H. binata* as compared to 45% and 60% canopy prunings.

Total carbon stock of the systems was also maximum with *C. fulvus* in association with *H. binata* (39.29 and 50.73 t/ha), closely followed by *C. ciliaris* (38.51 and 50.30 t/ha) and *P. maximum* (36.20 and 46.68 t/ha) during 1st and 4th year, respectively. This was due to higher biomass production and higher litter addition in soil with *C. fulvus* as compared to *P. maximum* which resulted in higher total carbon stock of the systems. Pruning intensities of *H. binata* did not significantly affect the carbon stock of *H. binata* based silvopasture system in 1st year of experiment (Table 5). However, during 4th year, 30% canopy pruning of *H. binata* recorded significantly higher total carbon stock of the system (50.82 t/ha) as compared to 60% canopy pruning (47.42 t/ha). This was also due to higher litter biomass addition in soil with 30% canopy pruning of *H. binata* as compared to 45% and 60% canopy prunings.

***Soil fertility status*:** Available nutrients in *H. binata* based silvopasture system were not significantly affected by establishment of different grasses (Table 6). However, organic carbon content (0.646%) was significantly increased with *C. fulvus* as compared to *P. maximum* (0.591%) and it was found at par with *C. ciliaris* (0.627%) in 4th year of study. This was probably due to addition of higher litter biomass of *C. fulvus* as compared to *P. maximum.* Canopy pruning of *H. binata* did not affect significantly available nutrients and organic carbon in *H. binata* based silvopasture system in 1st year. However, in 4th year

Table 5. Carbon stock (t/ha) as influenced by pruning intensities and grasses in *Hardwickia binata* based silvopasture systems

Treatment	2018-19					2021-22				
	HBCS	GCS	LCS	SCS	TCS	HBCS	GCS	LCS	SCS	TCS
Grasses										
C. ciliaris	10.83	5.57	0.78	22.11	38.51	19.57	6.35	1.59	24.38	50.30
C. fulvus	11.06	5.03	0.80	22.99	39.29	19.91	5.67	1.65	25.15	50.73
P. maximum	10.81	3.68	0.74	21.92	36.20	19.36	4.21	1.46	23.11	46.68
SEM	0.11	0.07	0.03	0.38	0.48	0.27	0.09	0.03	0.44	0.51
CD(P<0.05)	NS	0.22	NS	1.14	1.44	NS	0.27	0.10	1.34	1.54
Pruning (%)										
30	10.98	4.68	0.88	21.85	37.51	20.16	4.85	1.84	25.82	50.82
45	10.72	4.84	0.77	22.93	38.49	19.55	5.48	1.52	24.45	49.47
60	11.01	4.75	0.66	22.24	38.00	19.13	5.91	1.34	22.38	47.42
SEM	0.11	0.07	0.03	0.38	0.48	0.27	0.09	0.03	0.44	0.51
CD(P<0.05)	NS	NS	0.08	NS	NS	0.81	0.27	0.10	1.34	1.54

HBCS: *H. binata* carbon stock; GCS: Grass carbon stock; LCS: Litter carbon stock; SCS: Soil carbon stock; TCS: Total carbon stock

Table 6. Effect of pruning intensities and grasses on soil fertility status of *H. binata* based silvopasture system

Treatment	**2018-19**	**2021-22**						
	Available nutrients (kg/ha)			**OC (%)**	**Available nutrients (kg/ha)**			**OC (%)**
	N	**P**	**K**		**N**	**P**	**K**	
Grasses								
C. ciliaris	226.77	8.26	212.57	0.581	248.25	9.04	228.01	0.627
C. fulvus	238.55	8.54	221.78	0.601	256.70	9.20	234.49	0.646
P. maximum	222.84	8.16	209.85	0.571	244.18	8.97	224.23	0.591
SEM	4.31	0.14	4.08	0.008	4.39	0.15	4.07	0.012
CD(P<0.05)	NS	NS	NS	NS	NS	NS	NS	0.035
Pruning (%)								
30	225.19	8.21	211.03	0.571	260.60	9.36	238.70	0.663
45	235.81	8.46	219.39	0.601	251.12	9.11	230.16	0.627
60	227.17	8.29	213.78	0.581	237.41	8.73	217.88	0.574
SEM	4.31	0.14	4.08	0.008	4.39	0.15	4.07	0.012
CD(P<0.05)	NS	NS	NS	NS	13.27	0.44	12.29	0.035

available nitrogen (260.60 kg/ha), phosphorus (9.36 kg/ha), potash (238.70 kg/ha) and organic carbon (0.663%) were significantly increased with 30% canopy pruning of *H. binata* as compared to 60% canopy pruning (N: 237.41 kg/ha, P: 8.73 kg/ha, K: 217.88 kg/ha and OC: 0.574%). This might be due to higher litter biomass addition in soil with 30% canopy pruning of *H. binata* as compared to 45% and 60% canopy prunings. Establishment of *H. binata* based silvopasture systems on poor shallow soil and degraded land recorded 6-9% improvement in available nutrients in 4th year than initial.

Conclusion

It was concluded that 60% canopy pruning of *H. binata* recorded higher production from understory pasture and top feed components as compared to 30% and 45% canopy pruning in silvopasture systems. However, carbon stock and nutrients build up in soil were higher with 30% canopy pruning in *H. binata* based silvopasture systems. Among grasses, *C. fulvus* recorded maximum forage production, carbon stock and available nutrients in soil followed by *C. ciliaris* and *P. maximum* under semi-arid rainfed conditions. *H. binata* being straight growing, hardy and deep rooted, was proved to be a potential tree suitable for silvopasture system on degraded lands in rainfed areas of semiarid region. Thus, *H. binata* based silvopasture system is an ideal alternate land-use option in degraded lands for forage production, carbon stock and nutrients build up in soil under semi-arid rainfed situations.

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