

Hardwickia binata based silvipasture systems: Ideal for sustainable forage production on degraded lands

Shivnath Ram*, Kamini, Arun Kumar Shukla, Madan Mohan Das and Avijit Ghosh

ICAR-Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh 284 003

The productivity of degraded grazing lands in arid and semi-arid regions under rainfed conditions is often poor because of the dominance of low yielding annual grasses and lack of suitable fodder tree species. In this context, introduction of suitable drought resistant grasses along with trees can play a vital role in improving the productivity of degraded grazing lands. Hardwickia binata Roxb. is considered to be an important multipurpose tree species suitable for forage and wood production in semi-arid regions of India. It provides good quality nutritious fodder rich in crude protein and also provide extremely hard, heavy and durable timber in addition to high quality fuel-wood. In semi-arid regions where erratic rainfall and recurrent drought is the common phenomenon, development of Hardwickia binata based silvipasture systems are recommended to increase system productivity, enhancing fodder availability and improving soil fertility. In this system, grasses provide green forage during monsoon season and H. binata provide top feed during winter and summer seasons. Further, soil quality was improved via leaf litter decomposition and nitrogen fixation by leguminous tree Hardwickia binata.

Keywords: *Cenchrus ciliaris*, *Chrysopogon fulvus*, Fodder security, *Hardwickia binata*, *Panicum maximum*, Semi-arid region, Silviculture

DESIGNING an agro-ecosystem that caters to the diversified needs of human being for food, fodder, and nutrition which is environmentally sustainable as well as provide livelihood security is the biggest challenge. This challenge is more severe in arid and semi-arid regions across the globe, which is inhabited by 20% of the world population. In India, arid and semi-arid regions almost cover 166.2 million ha area across the country and are characterized by high human population pressure and human to livestock ratio. Moreover, 80% people follow agriculture as an occupation and of which livestock is an integral part. As these regions are characterized by prevalence of very hostile environmental conditions i.e. erratic rainfall, high wind velocity, intense solar radiation, high potential evapotranspiration, drought, soil with low water and nutrient holding capacity, land degradation, etc. livestock remains

sole source of sustainable income even when agricultural crops fails due to climate variability. Moreover, livestock also ensures manure inputs to farms, nutrition supply to human beings and employment generation to the rural people. But the average milk productivity of milch animal in India is very low (2.5 kg/day/indigenous animal and 7.2 kg/day/cross breed animal) in comparison to 22 kg/day/animal in USA and 28kg/day/animal in UK. This low livestock productivity is attributed mainly due to the shortage of quality fodder supply. Thus, to sustain local economy and to meet out nutritional demand of people in semi-arid India, livestock productivity needs to be enhanced via ensuring round the year quality fodder supply. Since there is prevalence of small and marginal farmers in the region, utilizing agricultural land for cultivation and production of fodder crop is not possible, thus innovative interventions utilizing marginal and

alternate lands to make them ready to support economically viable and environmentally sustainable agro-ecosystems systems that can sustain food, fodder, environmental and livelihood security in the region are needed.

Hardwickia binata based silvipasture systems are one of such ecologically and economically viable options that can be established on marginal and alternate lands for fodder, environmental and livelihood security in the region. Livestock generally needs more than 7% crude protein in forage for optimum growth, and the leaves of *H. binata* can easily meet out this need as they have 10–12% crude protein and are also rich in macro- and micro-nutrients content essential for enhancing livestock productivity. Moreover, *H. binata* based silvipasture system can enhance average carrying capacity of land by 50% and sustain round the year fodder availability which is

very much required for sustainable livestock production. Thus, *H. binata*, an important indigenous fodder tree species; and fodder grasses- *Chrysopogon fulvus*, *Cenchrus ciliaris* and *Panicum maximum* can be selected for establishment of silvipasture under semi-arid zone on degraded lands for sustaining quality fodder supply.

Ideal multipurpose tree for sustainable fodder production under semi-arid India

Hardwickia binata Roxb., a medium to large sized (9–30 m in height; 0.9–3 m in girth) deciduous tree belonging to the family Leguminosae, is well suited for fodder production under semi-arid conditions as it can tolerate up to 48°C temperature. Moreover, it can grow well on sandstone, gravels and deep rocky degraded soils. It is a drought hardy tree which can tolerate prolonged drought and high temperature. Its tap root goes extremely deep allowing it to fetch water from deep horizon of the soil ensuring its survival under drought conditions and under shallow soil and rocky areas. Its multiple uses (timber, fodder, fuel wood, charcoal, medicinal, rope making) and canopy structure make it suitable for silvipasture systems in semi-arid regions especially degraded lands where it can reclaim the wastelands and provide economic benefits. Studies carried out at ICAR-Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh (a semi-arid region) revealed that *H. binata* based silvipasture system reclaimed as well as restored the degraded lands and can provide sufficient amount of fodder for livestock.

Source of nutritious fodder

Leaves of *H. binata* are highly nutritive, palatable and rich in crude protein and essential minerals. Its leaves can meet out maintenance requirements of the goats as sole fodder. It remains leafless for very short period of time i.e. in the end of the winter (March month end only) and they reappear during April month, thus, it can supply fodder for longer duration. During

the time when green grasses are not available, its leaves can be used as high-value fodder. Its leaves can also be mixed with grasses to increase the nutrient value of fodder ration. Its amenability for pruning practices and good coppicing and pollarding capacity makes it a suitable tree species under agroforestry as boundary plantations, block plantations and on wastelands forestry. Under silvipasture system in semi-arid conditions, 15 years old *H. binata* trees (277 trees/ha) following 60% canopy pruning have been observed to provide 7 t/ha green and 3 t/ha dry top feed and 4.5 t/ha dry firewood.

Table 1. Leaf fodder quality traits of *H. binata*

Traits	On dry matter basis
Crude protein	9.86–11.2%
Dry matter	42.21%
Organic matter	93.2%
Crude fibre	28.16%
Extract	6.17%
Total ash content	8.92%
Neutral detergent fibre	50.64–57%
Acid detergent lignin	15.85%
Hemi-cellulose	16.43%
Cellulose	18.36–25.7 %
Digestibility coefficients	
Dry matter	52.41%
Organic matter	56.46%
Crude protein	44.53%
Ether extract	48.96%
Crude fibre	50.21%
Nitrogen free extract	62.66%

Establishment and management of *H. binata* based silvipasture systems

Before planting of *H. binata*, all the bushes should be uprooted and one operation with disc plough followed by two operations with disc harrow should be done and all the vegetation should be removed. Five months old polybags raised seedlings of *H. binata* should be planted at a distance of 6 x 6 m in field during monsoon season. Basins of one meter diameter should be made at the base of tree seedlings and water should be applied to the seedlings during the summer season in initial years of establishment.

The seedlings of grasses, viz. *Cenchrus ciliaris*, *Chrysopogon fulvus* and *Panicum maximum* should be transplanted in July at 50 x 50 cm spacing in association with *H. binata*. For fertilizer application, 40:30:30 kg NPK/ha should be applied each year after onset of monsoon. *H. binata* trees can be pruned once every year during November-December from 3rd year onwards to ensure proper canopy and shape of trees and to provide dry leafy forage yields during lean periods. After 10 years owing to the shade being imposed by grown up canopy of trees, 60% canopy pruning based on the percentage of total green crown length should be followed to optimize pasture productivity as it enhances light interception by 30–40% which increases pasture quality and biomass production.

To sustain grasses biomass production potential and quality for long run, time to time removal of unwanted bushes, weeds and other vegetation should be carried out in the pasture. Grasses should be cut during August to October months. In case of utilizing the pasture using grazing, two to three Adult Cattle Units (ACU) of small ruminants can be sustained on pasture. Rotational grazing should be carried out to utilize pasture more efficiently and for longer duration.

Productivity, soil fertility, carbon storage, grazing capacity and economics of *H. binata* based silvipasture systems

Under semi-arid region, *C. ciliaris*, *C. fulvus* and *P. maximum* have been found suitable for forage production under *H. binata* based silvipasture system recorded 22.11–24.79 t/ha green and 7.24–8.48 t/ha dry under pasture yields during different years. Similarly, 5.91 t/ha green, 2.65 t/ha top feed and 3.71 t/ha fire wood yields obtained from *H. binata* during 15th year of establishment. Top feed of around 2–3 t/ha dry and 4–6 t/ha green along with dry firewood yields of 3–4 t/ha can also be obtained following 60% tree canopy pruning. Under semi-arid conditions to ensure moisture conservation for enhanced pasture production, bunding and staggered



H. binata based silvopasture system



Pruning management of *H. binata* trees



Grazing by goat and sheep in *H. binata* based silvopasture systems

trenches can be used which will result in gain of 1–1.5 t/ha in dry and 2–4 t/ha in green pasture yields. Crude protein yield of 0.45–0.70 t/ha can be obtained from these pastures. Establishment of this system on degraded land recorded 9.11–15.50% improvement in available nutrients and organic carbon (N-258.58 kg/ha, P-9.61 kg/ha and K-234.29 kg/ha and OC 0.639%) in 15th year as compared to 11th year (N-229.39 kg/ha, P-8.32 kg/ha and K 214.73 kg/ha and OC 0.584%).

Besides sustaining fodder supply and improving soil fertility, *H. binata* based silvopasture systems have potential to mitigate climate change by storing huge amount of atmospheric carbon dioxide in biomass and soil carbon pools. *H. binata* trees at the age of 15 years are capable of storing 22–24 t C/ha in its above and below ground biomass pool. Similarly, grasses can store 5–6 t C/ha/year in its above and below ground biomass pool in 15 years of establishment. Soil carbon pool under these silvopasture systems can range from 23–27 t C/ha up to 30 cm depth. In totality, these *H. binata* based silvopasture systems can store 51–56 t C/ha in its biomass, litter and soil carbon pools. Thus, it has a huge potential to mitigate climate change as they can sequester 190–210 t CO₂-equivalent/ha at the age of 15 years.

Forage produced from *H. binata* based silvopasture system was also utilized in grazing mode by mixed herd of Bundelkhandi goats and Jalauni sheep at the rate of 2 ACU. Uniform grazing in all the experimental plots was carried out from August to January. The average daily gain in sheep and goat observed during August-January

Table 2. Forage and fire wood productivity from *H. binata* based silvopasture system

Years of establishment	<i>C. ciliaris</i> , <i>C. fulvus</i> and <i>P. maximum</i> (mean of 3 grasses)		<i>H. binata</i> (t/ha)		
	Pasture yield (t/ha)		Top feed		Dry fire wood
	Green	Dry	Green	Dry	
11 th	22.11	7.24	3.10	1.21	2.28
12 th	22.52	7.62	3.22	1.40	2.55
13 th	21.82	7.87	3.71	1.72	2.76
14 th	23.52	8.23	4.67	2.13	3.04
15 th	24.79	8.49	5.91	2.65	3.71

Table 3. Soil fertility build up, carbon storage and economics from *H. binata* based silvopasture systems

Parameters	11 th year of establishment	15 th year of establishment
Soil fertility status		
Available N (kg/ha)	229.39	258.58
Available P (kg/ha)	8.32	9.61
Available K (kg/ha)	214.73	234.29
Organic carbon (%)	0.58	0.64
Carbon storage in <i>H. binata</i> and grasses (t/ha)	15.66	28.61
Economics		
Net return (₹/ha)	29633	50909
Benefit: cost ratio	1.97	1.92

was 48 and 45 g/day, respectively. This system supported mixed herd grazing of Bundelkhandi goats and Jalauni sheep @2 ACU/ha for six months. In term of monetary return, *H. binata* based silvopasture system gave gross returns of ₹106031/ha, net returns ₹ 50909/ha and benefit-cost ratio of 1.92 in 15th year of establishment. Cost incurred on management of *H. binata* based silvopasture system was ₹ 55122/ha in 15th year of establishment.

SUMMARY

H. binata based silvopastures are best land use system that can ensure round the year fodder supply for livestock in the region besides sequestering huge amount of carbon dioxide in biomass and soil carbon pools. Further during the

lean period, ensuring green fodder supply is must to sustain livestock production. The degraded lands in semi-arid zones can be utilized for the establishment of the *H. binata* based silvopasture models like boundary plantation, block plantation, etc. for sustaining fodder supply. Further, soil quality can be improved via leaf litter decomposition and nitrogen fixation by leguminous tree *H. binata*. Besides sustaining fodder supply and improving soil fertility, *H. binata* based silvopasture systems have the potential to mitigate climate change by storing huge amount of atmospheric carbon dioxide in biomass and soil carbon pools.

*Corresponding author email: ramshivnath@yahoo.com