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Different Silvi-pastoral systems for improving livestock production in rainfed areas of North Western Zone of Tamil Nadu

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Abstract
A field study was conducted with different silvi-pastoral systems established at Livestock Farm Complex, Veterinary College and Research Institute, Namakkal during the year 2022 and 2023. There were combination of seven treatments replicated thrice in randomized block design. The treatment consist of productive performance of different silvipasture systems T_1 - *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio), T_2 - *Hardwickia binata* with understorey *of Cenchrus ciliaris*, T_3 - *Hardwickia binata* with understorey of *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio), T_4 - *Hardwickia binata* with understorey of natural pastures, T_5 - *Azardiracta indica* with understorey *of Cenchrus ciliaris*, T_6 - *Azardiracta indica* with understorey *of Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) and T_7 - *Azardiracta indica* with understorey of natural pasture. In the existing 10 years old *Hardwickia binata* and *Azardiracta indica* with a tree to tree spacing of 6 m x 6 m was taken up for the study. In the existing trees of *Hardwickia binata* and *Azardiracta indica* with fodder crops viz., *Cenchrus ciliaris* and *Stylosanthus scabra* and trees along with natural pastures were compared. The parameters of density, dry matter, biomass yield (*Cenchrus* equivalent yield) and proximate composition (Dry matter basis) of fodder crops, trees and natural pastures were recorded. The observations were recorded in three times during a year *viz*, Last week of July, First week of October and First week of January. The pooled data in two year experiment revealed that, T_3 - *Hardwickia binata* with understorey *of Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) recorded higher density, dry matter and biomass yield followed by T_6 - *Azardiracta indica* with understorey of *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) recorded higher biomass yield when compared to other treatments. The nutrient content particularly crude protein content was recorded higher in T_3 - *Hardwickia binata* with understorey of *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) and T_6 - *Azardiracta indica* with understorey of *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio).

Keywords: Silvi-pastoral systems, trees, grasses, legumes and biomass production

1. Introduction
Silvipasture in rainfed areas increases livelihood security through production of fodder and firewood requirement and similarly in total productivity per unit area of land. Management of fodder value trees in conjunction with dry land fodder crops in rainfed areas minimizes the risk associated with livestock farming. The districts of Dharmapuri, Krishnagiri, Salem and Namakkal were categorized under North western zone of Tamil Nadu. Acute fodder shortage due to severe in this zone, has forced the farmers to sell their animals for a less amount. The silvipasture systems involving multi-purpose trees and grass species provide multiple outputs such as, forage, fuelwood, fodder, fibre and industrial raw material, besides over their positive environmental effects. The fodder trees along with grasses are perceived as a climate change-resilient cropping system for farmers to mitigate climate change with adaptation (Mbow *et al*., 2014) [8]. Increasing the biodiversity of grassland ecosystems by introduction of silvi-pastoral system is having many benefits to the farming system, i.e. stabilizing soil, providing shelter and shade to animals (Gregory, 1995) [5], diversification of income through tree products, enhancing soil fertility (Gregorich *et al*., 1994) [4] and increases the water and carbon retention in the soil. *Hardwickia binata* (Anjan tree) has been reported as suitable agroforestry tree

species is in arid and semi-arid regions of India especially for small ruminants. *Azadirachta indica* (Neem tree) is also a multipurpose tree and its leaves are served as a very good fodder for goat and sheep. With this background, *Hardwickia binata* and *Azadirachta indica* based agroforestry models with understorey of *Cenchrus ciliaris* and *Stylosanthus scabra* were studied for fodder availability during drought period of north western zone of Tamil Nadu.

Materials and methods

The Livestock Farm Complex, Veterinary College and Research Institute, Namakkal is located at 11 and $12^0$55' North latitude and $77^0$28' and $78^0$50' East longitude, Temperature ranges from maximum of 39^0C and minimum of 18^0C. Average annual rainfall in this region was 732 mm. The soil is red loamy in texture and the climate is basically semi-arid tropical. There were seven treatment combinations replicated thrice in randomized block design. The treatments are, T_1 - *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio), T_2 - *Hardwickia binata* with understorey *of Cenchrus ciliaris*, T_3 - *Hardwickia binata* with understorey *of Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio), T_4 - *Hardwickia binata* with understorey of natural pastures, T_5 - *Azardiracta indica* with understorey of *Cenchrus ciliaris*, T_6 - *Azardiracta indica* with understorey of *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) and T_7 - *Azardiracta indica* with understorey of natural pastures. In the existing 10 years old *Hardwickia binata* and *Azardiracta indica* with a tree to tree spacing of 6 m x 6 m was taken up for the study. There were 50 number of trees existed randomly in each treatment. The size of the experimental plot was 0.20 ha with interspace of the trees were grown with fodder crops *viz*., grasses and legumes. The pasture was maintained under rainfed conditions and this was compared with existing ten years old *Hardwickia binata* and *Azardiracta indica* with understorey of natural pastures. Biomass yield of trees, fodders and natural pastures were recorded.

Natural grazing lands comprising a mixture of forages like, *Cenchrus ciliaris, Cenchrus setigerus, Chloris barbata, Cynodon dactylon, Panicum repens, Aerva javanica, Abutilon indicum, Aerva lanata, Boerhaavia diffusa, Corchorus olitorius, Leucas aspera, Amaranthus viridis, Tridax procumbens* and *Achyranthus aspera.*

Table 1: Forage species in natural grazing lands

Botanical Name	Common Name	Habit	Family
A. Grasses			
Cenchrus ciliaris	African foxtail grass	Perennial	Poaceae
Cenchrus setigerus	Bird wood grass	Perennial	Poaceae
Chloris barbata SW.	Finger grass	Perennial	Poaceae
Cynodon dactylon (L.) Pers.	Bermuda grass	Perennial	Poaceae
Panicum repens (L.)	Ginger grass	Perennial	Poaceae
C. Broadleaved weeds			
Aerva javanica	Desert cotton	Perennial	Amaranthaceae
Aerva lanata	Mountain knotgrass	Perennial	Amaranthaceae
Abutilon indicum (L.) Sweet sp.	Country mallow	Annual	Malvaceae
Boerhavia diffusa (L)	Hog weed	Perennial	Nyctaginaceae
Corchorus olitorius (L.)	Jew's mellow/ wild jute	Annual	Tiliaceae
Leucas aspera	Thumba	Annual	Lamiaceae
Amaranthus viridis (L.)	Pig weed	Annual	Amaranthaceae
Tridax procumbens	Coat buttons	Annual	Asteraceae
Achyranthes aspera	Prickly chaff flower	Perennial	Amaranthaceae

Forage density

The forage count was recorded by using 0.5 m x 0.5 m (0.25 m^2) quadrate from four randomly fixed places in each plot and the forage falling within the frames of the quadrat were counted, recorded and its mean values were expressed in number m^{-2} as suggested by Burnside and Wicks (1965) [2]. The total density was recorded by adding three observations *viz*, last week of July, first week of October and first week of January and expressed in numbers m^{-2}.

Forage dry weight

The forage falling within the frames of quadrats were collected, dried under shade and later dried in hot-air oven at 80ºC for 72 hours. The dry weight of forage were recorded at three times like last week of July, first week of October and first week of January and expressed in gram m^{-2}.

Annual forage yield

Annual forage yield was calculated by adding forage yield in three cuttings per year (last week of July, first week of October and first week of January). At the beginning of each cutting forage samples were collected and weighed immediately. Forage biomass for grasses and legumes were determined by harvesting the forage using quadrate in four places at random. For trees, 60% canopy pruning was followed for four trees in each treatment randomly.

Cenchrus equivalent yield (CEY)

The productivity of each component was converted in to Cenchrus equivalent yield for better comparison and expressed in tonnes.

$$CEY = \frac{Productivity\ of\ crop\ component\ (t)\ X\ Cost\ of\ crop\ component\ (Rs.per\ tonne)}{Cost\ of Cenchrus\ (Rs.per\ tonne)}$$

The data were statistically analysed by the procedure given by Gomez and Gomez (2010) [3] for randomised block design. The data pertaining to weeds and germination were transformed to square root scale of $\sqrt{(X+2)}$ and analysed. Whenever significant difference existed, critical difference was constructed at 5 per cent probability level.

Results and Discussion

Forage density and dry weight

Density of pasture land forage was significantly higher in *Hardwickia binata* with understorey *of Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) (T_3) during both the years of study. This was on par with *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) (T_1), *Azardiracta indica* with understorey *of Cenchrus ciliaris* (T_5) and *Azardiracta indica* with understorey *of Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) (T_6) and during the year 2023, T_2 - *Hardwickia binata* with understorey *of Cenchrus ciliaris* also found comparable with the above said treatments. Dry weight of forages was significantly higher in *Hardwickia binata* with understorey of *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) (T_3) with 127.09 g/m^2 and 139.42 g/m^2 during the year 2022 and 2023, respectively. This was significantly on par with *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) (T_1), *Azardiracta indica* with understorey *of Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) (T_6) during the year 2022. During the year 2023, *Hardwickia binata* with understorey of *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) (T_3) was on par with *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) (T_1), *Azardiracta indica* with understorey *of Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) (T_6) and A*zardiracta indica* with understorey *of Cenchrus ciliaris* (T_5) regarding dry weight. This could be due to significant increase in growth and yield parameters of both pasture species resulted higher biomass production (Meena *et al*., 2018) [9]. The forage production of mixed pasture of *Cenchrus ciliaris* + *Stylosanthus hamata* has improved by fertilizer application which was reported by Ram and Kumar (2010) [12]. Mavji Patidar *et al.* (2015) [7] also supported that dry forage yield of grasses in silvipasture was higher compared to natural pasture but less than pure pasture of *Cenchrus ciliaris* and *Cenchrus setigerus*.

Annual *Cenchrus* Equivalent Yield (Annual CEY)

Annual *Cenchrus* equivalent yield was recorded in different silvipastoral systems by cumulatively adding the yield of three cuttings (Last week of July, First week of October and First week of January). During the period of study, *Hardwickia binata* with understorey of *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) (T_3) recorded higher Annual *Cenchrus* equivalent yield of 15.92 and 17.63 t ha^{-1} in the year 2022 and 2023, respectively. Under semiarid conditions *Hardwickia binata*, *Zizyphus mauritiana* (shrub), *Cenchrus ciliaris* and *Stylosanthes seabrana* based three tier silvipasture system has developed and ensured quality fodder supply to the livestock (ICAR-IGFRI, annual report, 2018-19) [1]. Three tier system of forage production produces more biomass than pasture alone. Pasture with *Leucaena* produced 29 per cent more biomass and 64 per cent more protein than monoculture systems. Meanwhile, association of leguminous trees with grasses in pastures has positive effects on yield of grasses, which are nourished with part of the nitrogen biologically fixed by the leguminous trees (Nahed-Toral *et al*., 2013) [11]. However, this was followed by T_6 - *Azardiracta indica* with understorey *of Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) recorded higher Annual *Cenchrus* equivalent yield when compared to all other treatments during the period of study. Annual *Cenchrus* equivalent yield was higher in *Cenchrus setigerus* + *Stylosanthes hamata* along with fodder trees when compared to that of grasses alone which could be due to the combined production of grasses and legumes along with trees and similar findings were found by Jayanthi *et al.* (2013) [6].

Proximate composition

Proximate composition on dry matter basis was analysed for moisture content, crude protein, ether extract, crude fibre and total ash during the first year of study. Regarding crude protein content, *Hardwickia binata* with understorey of *Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) and *Azardiracta indica* with understorey *of Cenchrus ciliaris* + *Stylosanthus scabra* (3:1 ratio) recorded 7.96 and 7.90 percent on DMB. The cumulative of *Cenchrus ciliaris* + *Stylosanthus scabra* had recorded a crude protein, ether extract, crude fibre and total ash content of 7.87, 26.12, 2.42 and 7.97 per cent DMB, respectively. *Cenchrus ciliaris* had a crude protein, ether extract, crude fibre, total ash and nitrogen free extract of 13.29, 3.66, 20.76, 8.53 and 53.76 per cent DMB, respectively. *Stylosanthes scabra* had a crude protein, ether extract, crude fibre, total ash and nitrogen free extract of 13.29, 3.66, 20.76, 8.53 and 53.76 per cent DMB, respectively (Mynavathi, 2011) [10]. Rekhate, *et al.*, (2002) [13] reported that, proximate chemical composition includes DM, CP, EE, CF, NFE, ash, Ca and P of Anjan tree leaves were 36.68, 12.76, 2.80, 29.45, 6.75, 2.20 and 0.10%, respectively.

The agroforestry for livelihood security reflects the positive way in utilization of resources in rainfed areas. *Hardwickia binata* based agroforestry model with fodder crops comprising of *Cenchrus ciliaris* and *Stylosanthus scabra* found to be suitable than natural pasture for small ruminants in North western agroclimatic zones of Tamil Nadu. The shrubs present in natural pasture will deplete all the nutrients from the soil which retards the growth of tree.

Table 2: Forage density (No./m^2), forage dry weight (g/m^2), Annual CEY (t/ha) and proximate composition (% DM basis) of different silvi-pastoral systems

Treatments	Forage density (No./m^2)*		Forage dry weight (g/m^2)*		Annual CEY (t/ha)**		Proximate composition - 2022 (% DM basis)				
	2022	2023	2022	2023	2022	2023	Moisture	CP	CF	EE	TA
T_1 - *C. ciliaris* + *S. scabra*	16.94 (285.00)	17.38 (300.00)	10.47 (107.55)	11.22 (125.94)	10.20	13.47	9.04	7.87	26.12	2.72	8.34
T_2 - *H. binata* with *C. ciliaris*	15.81 (248.33)	16.73 (264.33)	9.78 (93.58)	10.71 (114.73)	9.57	12.85	7.86	7.43	22.90	2.92	9.69
T_3 - *H. binata* with *C. ciliaris* + *S. scabra*	17.52 (305.67)	17.92 (332.33)	11.41 (127.09)	11.72 (139.42)	15.92	17.63	8.88	7.96	23.07	3.28	9.09
T_4 - *H. binata* with natural pastures	13.34 (176.33)	14.25 (201.67)	8.27 (66.42)	9.00 (81.00)	6.53	6.27	8.32	6.98	24.56	3.05	8.97
T_5 - *A. indica* with *C. ciliaris*	16.85 (282.67)	16.73 (278.00)	10.19 (101.92)	10.38 (107.73)	10.07	9.45	8.02	7.54	22.67	2.80	9.45
T_6 - *A indica* with *C. ciliaris* + *S. scabra*	16.34 (265.00)	16.85 (282.00)	10.41 (106.42)	10.55 (111.22)	14.33	15.11	8.97	7.90	22.85	2.95	8.78

T_7 - *A. indica* with natural pastures	11.70 (135.33)	12.33 (150.33)	7.41 (52.94)	7.81 (61.00)	7.07	7.95	8.50	7.04	25.65	2.87	9.12
SEd	0.64	0.82	0.59	0.62	0.75	0.83	0.60	0.51	1.68	0.30	0.92
CD (P=0.05)	1.32	1.40	1.15	1.23	1.45	1.62	NS	NS	NS	NS	NS

*Figures in parenthesis are original values
**Annual CEY- Annual *Cenchrus* Equivalent Yield

Conclusion

From the study, it is concluded that higher biomass yield of agroforestry system was recorded with *Hardwickia binata* and *Azardiracta indica* with fodder crops comprising of *Cenchrus ciliaris* and *Stylosanthus scabra*. Hence, *Hardwickia binata* based agroforestry model with fodder crops comprising of *Cenchrus ciliaris* and *Stylosanthus scabra* found to be suitable than natural pasture in terms of biomass production and nutrient composition for North western agroclimatic zone of Tamil Nadu.

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