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Effect of Lopping and Root Barrier on Pasture Production in *Colophospermum mopane* Based Silvipastoral System in Western Rajasthan

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Abstract

Economy of the people of dry region mainly depends on animal husbandry, where silvopastoral system plays an important role by providing not only grass fodder but also feed from the tree component together with benefits of carbon sequestration and soil improvement. Tree component influences pasture production by competing for light, soil water and nutrients, which needs to be managed for increased production. A silvopastoral experiment was conducted at AFRI, Jodhpur involving *Cenchrus ciliaris* grass intercropped with 17 years old *Colophospermum mopane* trees at spacing of 5×10 m^2. Four treatments were: Intact tree, Tree pruning up to 70% tree height, root barrier treatment, and both tree pruning and root barrier treatment. Pooled data of last four years revealed non-significant variations in clump number, tillers number and clump diameter of *C. ciliaris* grass among treatments and sole grass plots. Dry mass production of *C. ciliaris* was significantly high in sole grass plot than in treatments. However, grass production was highest in pruned and root barrier tree and lowest in intact tree than in other treatments. Photosnthetically Active Radiation (PAR) was highest (p<0.05) in sole grass plots. PAR varied from 325 to 1285 µmol m^{-2} s^{-1}. PAR was highest in lopped and root barrier tree and increased with distances from tree trunk. Soil water content (SWC) increased (p<0.05) with increasing soil depth and distances from tree. SWC was highest in pruned and root barrier tree than intact tree. Results indicate that tree pruned along with root barrier is beneficial in enhancing productivity of silvipostoral system in dry areas.

Keywords: Dry region, PAR, soil water, tree-grass interaction

1. Introduction

Rainfall variability and drought are significant contributors to low economy, poverty and food insecurity in dry areas (Brown, 2012). Trees in grassland increases total land productivity, reduce land degradation and improve nutrient recycling, while producing fuel wood, fodder, fruits and timber from tree and fodder from grasses. In addition to potential benefits of higher productivity and improved sustainability of silvipastoral systems, livestock is an important component of such mixed tree-crop-livestock systems in dry areas (Herrero et al., 2009).

Rainfed agro-ecosystem has a distinct place in agriculture, occupying 67% of the cultivated area in India, contributing to 44% of the food grains and supporting 40% of the human and 65% of the livestock populations (Venkateswarlu, 2005). In Rajasthan, 70% economy of the rural people earns from rearing of livestock. Livestock act as insurance in times of extreme climatic conditions in arid and semi arid region of Rajasthan. In arid region of Rajasthan, low and irregular rainfall and poor soil fertility makes fodder availability to livestock only for 3 to 4 months in a year from agriculture field. Thus availability of feed in quantity as well as quality is one of the most limiting factors to improve the livestock productivity in such region (Birthal and Jha, 2005). Tree leaves and pods form a natural part of the valuable diet of livestock and have been used traditionally as sources of feed for domesticated animals and serves as protein banks during dry season.

Integrating trees with grasses seems a suitable agroforestry practice for managing land degradation processes as well as biomass production for livelihood security in the region (Chauhan et al., 2014; Yadav et al., 2014). Tree component influences pasture production by competing for light, soil water and nutrients. Thus productivity of understorey grassland depends on the interaction mainly for soil water availability and light (Perri et al., 2016). In this, tree roots extend to considerably greater distances and depths than crop/grass roots, where root competition affects the balance between competing species more than shoot competition (Toky and Bisht, 1992; Singh, 2010).

Obtaining optimum production from tree and grass in an agroforestry system requires management interventions in the form of pruning and thinning to reduce competition effects and enhance production (Nicodemo et al., 2016). Tree lopping increases light availability to the under canopy crops/ vegetation and improves their performance. Tree root pruning is a potential tool for managing belowground competition when trees and crops are grown together. Management like root barrier around trees and pruning of trees canopy may minimize competition between grass and trees and help increase production of the companion grass with overall improvement in system production. The objectives of this study were to assess the effects of tree pruning on root dynamics and crop production, and the effect of root pruning on tree growth, grass yield and soil for resource availability in *Colophospermum mopane* based silvipastoral system.

2. Materials and Methods

Experiment was started with an exiting 17 years old *Colophospermum mopane* (Mopane) tree based agroforestry system, planted in July 1994 at 5x5 m^2 spacing at Arid Forest Research Institute (AFRI), Jodhpur (26° 45′ N, 72° 03′ E). Average annual rainfall for last four years (2012 to 2015) was 435.87 mm. Soil of the site is loamy sand in texture which contains 81% sand and calcium carbonate deposits below 80 cm soil depth. Trees were removed in July 2012 to maintain 5x 10 m^2 spacing in the experiment.

Cenchrus ciliaris grass variety CAZRI 358 was sown in August 2012 and yields were assessed for four subsequent years. There were five levels of silvicultural treatment like Intact tree (T_1), tree pruning up to 70% of tree total height (T_2), root barrier (T_3), both tree pruning and root barrier (T_4), and sole *C. ciliaris* grass (T_5). Trench of 0.70 m depth and 2 m diameter was excavated around the tree and UV stabilized Polythine sheet of 200 µm size was utilized to put as root barrier.

Tree height, diameter at breast height (DBH), canopy diameter and canopy height were recorded in July, just before in monsoon season in each year. Height and diameter at breast height (dbh) increments were calculated for each year over the previous year. Photosynthetically active radiation (PAR) were recorded during growth and maturity phase of the grass in each year at 0.5 m, 2.5 m and 5.0 m distance from the tree trunk. Soil water content (SWC) was determined gravimetrically in the upper 0–75 cm layer divided into 0–25, 25–50, 50–75 cm soil layers and at 0.5 m, 2.5 m and 5.0 m distance from the tree trunk during growth and maturity phase of the grass in September and October each year. *C. ciliaris* grass growth and fodder yields were recorded at 0.5 m, 2.5 m and 5 m distance from tree trunk in the month of October-November It was air dried and fodder production was presented in the form of tons per hectare.

All data collected on tree growth, grass growth and biomass, PAR and soil water content were subjected to statistical analysis using SPSS statistical package. The least significant difference test was used to compare treatments at $p<0.05$ level.

3. Results and Discussion

3.1. Dynamics of soil water

Soil water content varied ($p>0.05$) considerable between the treatments as well as sole grass plot in *C. mopane* based system (Table 3). The decreases in SWC under intact trees, lopped trees, root barrier trees, and lopped trees with root barrier treatment plots were 23.04%, 14.79%, 14.10%, 10.81%, respectively as compared to SWC in sole grass plot. This highest amount of soil water was use by intact trees, whereas the lowest amount of soil water was used by pruned trees with root barrier plot. Thus effect of root barrier was more favourable in conserving SWC as compared to the pruned treatments.

SWC increased with increasing distances from tree trunk to open area. Total soil water content was lowest (3.55%) near the tree trunk (0.5 m) and it increased by 17.48% at 2.5 m distance and by 25.37% at 5 m distance as compared the value near the tree trunk (Table 1). SWC also differed ($p<0.05$) due to soil layers, where it was lowest in the upper soil layer in all plots and showed an increasing trend downward. Treatment×distance, treatment×depth and distance×depth

Table 1: Soil water content (%) in *C. ciliaris* grass integrated with *C. mopane* trees in an agroforestry system. Values are mean±1SD of 3 replication plots

Treat-ment	Soil depth (cm)	Distance from tree trunk			
		0.5 m	2.5 m	5.0 m	Mean
T_1	0-25	2.87±0.37	2.81±0.40	3.69±0.24	3.37
	25-50	3.61±0.23	4.11±0.13	3.72±0.13	3.56
	50-75	3.62±0.16	3.77±0.18	4.50±0.25	3.97
T_2	0-25	2.74±0.47	3.57±0.28	3.84±0.34	3.56
	25-50	3.64±0.9	4.46±0.26	4.73±0.39	4.18
	50-75	4.29±0.31	4.52±0.16	4.92±0.83	4.50
T_3	0-25	2.98±0.73	3.54±0.23	4.22±0.19	3.60
	25-50	3.70±0.34	4.39±0.28	4.62±0.47	4.14
	50-75	4.14±0.33	4.50±0.29	4.68±0.36	4.51
T_4	0-25	3.29±0.23	3.87±0.07	4.28±0.22	3.66
	25-50	3.81±0.52	4.97±0.24	4.83±0.39	4.14
	50-75	3.86±0.43	4.82±0.30	4.60±0.47	4.51
Mean	0-25	2.97	3.45	4.12	3.55
	25-50	3.69	4.48	4.69	4.27
	50-75	3.98	4.40	4.76	4.38
Con-trol	0-25		4.55±0.62		
	25-50		5.56±0.61		
	50-75		5.10±0.26		

Control: Sole grass plot

were not-significant (p>0.05) for soil water content. Relatively low soil water in deeper soil layer near root zone of the trees that increased towards the 5 m distance from the trees indicated greater utilization of soil water near the root zone. Reduced soil water use with increasing distance and consequently enhanced soil water availability facilitate growth and yield of companion crops (Mertia et al., 2006). However, reduction in SWC in top soil layer (0–25 cm) was due to its utilization by both tree and the companion grass along with surface evaporation.

3.2. Photosynthetically active radiation (PAR)

PAR varied significantly (p<0.05) due to treatments and it was highest under pruned trees with root barrier (T_4) treatment (630 µmol m^{-2} s^{-1}) and lowest (511 µmol m^{-2} s^{-1}) under the intact trees (T_1) (Table 2). Reductions in PAR were 54% and 52% under pruned trees treatment of T_2 and T_4 and 61% and 59% under intact canopy treatments, i.e. T_1 and T_3 than control plot. PAR increased significantly (p<0.05) with increase in distance from the trees to open area. Interaction of treatment×distance was significant (p<0.05) indicating that PAR value under tree canopy of *C. mopane* depended upon canopy size and foliage density.

Table 2: PAR (µmol m^{-2} s^{-1}) of *C. ciliaris* grass integrated with *C. mopane* trees in the agroforestry system. Values are mean±1SD of 3 replication plots

Treatment	Distance from tree trunk			Mean of 0.5 m and 2.5 m distances from tree trunk
	0.5 m	2.5 m	5.0 m	
T_1	327±101	695±113	1255±127	511^d
T_2	429±125	762±137	1239±149	596^c
T_3	348±98	738±117	1275±115	546^{cd}
T_4	442±94	818±141	1285±139	630^b
Mean	387^e	753^f	1275^g	
Control		$1319±137^a$		

Mean values with different alphabets (superscript) in a column indicate significant (p<0.05) difference. Control: Sole grass plot

Canopy management (T_2 and T_4 treatments) favoured (p<0.01) PAR percolation than unpruned trees (i.e., T_1 and T_3 treatments). Increased light penetration beneath the tree has been observed enhancing plant growth and light use efficiency (Binkley et al., 2013). Reduction in PAR by 52 to 61% under the trees with canopy resulted in growth and grass yield as observed for agricultural crops (Bargali and Bargali, 2009). Significantly (p<0.01) high PAR at 5 m distance followed by 2.5 m distance from tree trunk was the effects of canopy diameter and foliage density at the edge as observed under the canopy zone of scattered trees of *P. cineraria*, *P. juliflora*, *A. indica* and *A. nilotica*, where 83 to 88% reduction in photosynthetically active radiation (PAR) was observed (Singh et al., 2008).

3.3. Tree growth

Initial height, dbh and crown diameter of *C. mopane* did not differ between treatments (Table 3). Dbh of *C. mopane* was positively correlated with tree height (r=0.386, p<0.01, n=129) in 2015. The increase in height and dbh of *C. mopane* during 2012 to 2015 was by 20.49% and 21.48%, respectively. Incremental growth in height and dbh were highest (p<0.01) under intact tree as compared to the trees of other treatments. Root barrier treatments (average of T_3+T_4) affected incremental growth of dbh negatively than the pruned treatments (average of T_2+T_4). It is reflected clearly in height and dbh increment reduction by 17.7% and 7.58%, respectively due to pruning and by 20.8% and 19.5%, respectively due to root barrier treatments. There was a positive correlation of percent increment in collar diameter with crown diameter (r=0.341, p<0.01) of *C. mopane*. Height and dbh reduced

Table 3: Effect of tree pruning and root barrier on different tree growth, grass yield, PAR and soil water control. Values are mean±1SD of 3 replication plots

Parameters	Treatments					p value
	T_1	T_2	T_3	T_4	Control	
Initial tree height (m)	3.9±0.4	4.6±0.1.2	3.7±0.7	3.9±0.7	-	NS
Initial tree dbh (cm)	9.35±2.7	11.29±4.1	8.67±2.6	8.90±2.4	-	NS
Initial tree crown diameter (m)	4.5±0.6	4.4±0.7	4.3±0.9	3.8±0.6	-	NS
Initial canopy volume of tree (m^3)	26.1±12.4	24.9±10.8	24.4±17.5	18.4±5.2	-	<0.05
Incremental height growth (%)	7.16±3.55	5.89±2.11	5.67±2.15	4.41±1.33	-	NS
Incremental dbh growth (%)	8.04±4.65	7.43±3.86	6.47±4.17	5.44±3.99	-	NS
Incremental crown diameter growth (%)	7.09±4.19	10.1±5.88	8.8±7.29	8.9±5.71	-	NS
Grass height (cm)	76.39±15.48	78.76±15.81	79.30±13.45	81.43±15.11	83.22±16.78	NS
Clump diameter (cm)	9.43±3.93	9.75±3.47	9.11±3.32	10.18±3.62	11.92±4.54	<0.01

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Parameters	Treatments					p value
	T_1	T_2	T_3	T_4	Control	
Clump no. (m^{-2})	10.37±4.73	11.58±7.33	10.61±3.89	9.42±4.02	8.92±2.94	NS
Tiller no. $clump^{-1}$	12.60±8.45	12.18±4.08	11.41±4.17	13.75±6.36	15.19±4.89	NS
Grass production (Q ha^{-1})	13.53±6.05	14.67±5.58	15.76±4.28	16.72±6.38	20.61±6.79	<0.01
PAR (μm m^{-2} s^{-1})	758.82±267	810.01±258	786.86±280	848.17±248	1318.71±167	<0.01
Soil water content (%)	4.22±1.09	4.67±1.18	4.69±1.03	4..87±1.12	5.79±1.28	<0.01

*Control: Sole grass plot; NS: Non-significant (p>0.05)

significantly under pruned tree with root barrier treatments than the intact trees treatment indicating the negative effect of canopy removal and trenching (root barrier) application. Singh and Shukla (2011) also observed reduced resource use under root barrier and reduction in canopy and thus reduced total amount of photosynthetic materials affecting growth.

3.4. Growth and fodder yield of cenchrus ciliaris grass

Clump diameter and grass yield differed significantly (p>0.05) between treatments across the years (Table 1). Clump diameter was highest in sole grass plot followed by pruned tree with root barrier plot. All growth variables of grass increased with increasing distance from the tree base to the open area across the years and treatments. Grass yield was highest in sole grass plot (Table 4). Among the treatments, grass yield was highest (p<0.05) under pruned tree with root barrier and lowest in Intact trees plot.

Table 4: Dry biomass (t ha^{-1}) of *C. ciliaris* grass integrated with *C. mopane* trees in an agroforestry system. Values are mean±1SD of 3 replication plots

Treat-ment	Distance from tree trunk			Mean
	0.5 m	2.5 m	5.0 m	
T_1	8.93±3.7	13.71±1.6	18.21±2.3	13.61d
T_2	10.75±1.1	15.41±2.7	17.86±3.4	14.67c
T_3	14.78±3.7	15.47±2.8	17.03±1.5	15.76bc
T_4	13.07±2.3	17.87±5.3	19.23±2.89	16.72b
Mean	11.88^e	15.61^f	18.59^g	
Control		$20.61±2.59^a$		

Mean values with different alphabets (superscript) in a column indicate significant (p<0.05) difference; Control: Sole grass plot

Grass yield increased (p<0.05) with increasing distance from the tree trunk and highest yield was in open area (Table 4). The average reduction in grass yield at 0.5 m, 2.5 m, and 5.0 m distances was by 42.36%, 24.26% and 9.80%, respectively as compared to sole grass plot. Low grass yield in tree integrated plot as compared to sole grass plots indicates a competitive effect of *C. mopane* with the grass particularly near the root zone. Roots of *C. mopane* tree are mostly spreading in top 80 cm soil layer due to shallow root system which competes with companion crops for soil resources (Singh and Singh, 2015; Singh and Rathod, 2007). In such a situation root barrier appears more beneficial as indicated by 16.86 % increase in grass yield under T_3 treatment as compared to T_1.

4. Conclusion

Through tree pruning along with root barrier observed detrimental for the growth of *C. mopane*, but it was beneficial in enhancing productivity of the silvipostoral system. *C. mopane* was observed competitive with *C. ciliaris* grass with an average reduction of 34.35%, 28.82%, 23.53%, 18.87% grass yield in intact trees, pruned trees, root barrier trees and pruned and root barrier trees plot as compared to sole grass plot. However, it can be minimized through silvicultural practices like pruning and trenching around tree in benefits of improved production and people livelihood.

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