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Soil Moisture Dynamics in Silvopastoral Systems in the Thar Desert of India

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Abstract: Variation in soil moisture level was studied under different silvopastoral systems that were established in the arid alluvial soil at the Central Research Farm of the Central Arid Zone Research Institute, Jodhpur. Season and soil depth had significant control on soil moisture differences in all the systems. Minimum soil moisture (1.92%) was observed in the upper soil profile of grass strips in the silvopastoral system in summer. High soil moisture was recorded near tree bole or fallow soil strips between top feed tree rows in the afforested area. Rapid moisture depletion was observed during winter and summer in 0 to 60 cm soil profile. Soil moisture status was higher in *Prosopis cineraria - Cenchrus ciliaris* than *Hardwickia binata - C. ciliaris* system under the similar soil and environmental conditions. Soil moisture status within 100 cm soil profile of the plots having different densities of *P. cineraria* remained unaffected across the seasons.

Key words: Phytomass, understorey, soil profile, phraeatophyte.

The aboveground phytomass production in arid climate is predominantly governed by availability of soil moisture. Productivity on a specific location could, therefore, be enhanced by manipulating soil moisture either through adoption of proper soil conservation measures or selection of suitable plant cover that can conserve adequate moisture at different soil depths. In arid sandy loam soils, crops established early get advantage of a longer period of moisture availability as compared to the late-sown crops (Dayal *et al.*, 1973). Woody species like *Grewia tenex* have very efficient root system, which penetrates into the hard rocky, gravelly substratum and extracts moisture for growth. Studies on soil moisture in the afforested areas have shown variable moisture levels under the canopy of different tree species. Aggarwal *et al.* (1976) observed higher soil moisture in the surface soil under the canopy of *Prosopis cineraria* and *Tecomella undulata* at a soil depth 75 to 90 cm. In the arid and semi-arid conditions, planting tree or shrub species in lines 5 m apart or more in the silvopastoral systems, do not adversely affect the production of understorey forage in the establishment phase of the system (Ahuja *et al.*, 1978; Sharma *et al.*, 1980; Sharma and Vashishtha, 1985). Several such studies have shown yearly variations in forage production from sown pasture in the silvopastoral systems, mainly due to fluctuations in the annual precipitation and availability of moisture in the soil. In order to understand the role of soil moisture and its availability at different soil depths, its dynamics was studied under different silvopastoral systems and results of the study are discussed here.

Materials and Methods

The study was conducted at the Central Research Farm of the Central Arid Zone

Research Institute, Jodhpur (73°3′E, 26°15′ N). The experiment site represents alluvial plains of the Thar Desert. The climate of the region is characterized by low and erratic rainfall, high temperature, low relative humidity and higher loss of water from the soil and vegetation in summer. The average annual rainfall is 366 mm, and varies from year to year. The soil is coarse loamy sand (Typic Camborthid) with kankar pan at a depth of 50 to 150 cm.

Soil moisture studies were conducted under *Prosopis cineraria* (L) Druce-*Cenchrus ciliaris* (L) and *Hardwickia binata* Roxb-*C. ciliaris* silvopastoral systems. Trees in both the systems were 12-year-old. The spacing between and within tree rows was 5 m. The pasture of buffel grass (*C. ciliaris*) was sown between tree rows in lines 50 cm apart in July 1990. Soil moisture studies in another experimental site with different tree densities of naturally grown *P. cineraria* in *C. ciliaris* pasture plots (20 x 15 m) having one, two, three and four trees, corresponding to 33, 66, 100 and 133 trees ha^{-1}, respectively, were initiated in July 1993. Soil moisture in first two systems sites was estimated by gravimetric method at 20 cm interval up to 80 cm depth. Soil moisture samples were collected at monthly interval from center of grass strips and at 30 cm distance from the tree boles. In third experiment soil moisture was estimated with neutron moisture meter. Total sampling depth was 100 cm and other conditions were similar to gravimetric method. Soil moisture for different depths was estimated in cm. Total annual precipitation during 1992, 1993 and 1994 was 435.4, 312.8 and 595.9 mm, respectively. Soil moisture data collected from different silvopastoral systems were analyzed statistically using one-way analysis of variance.

Results and Discussion

Buffel grass-based silvopastoral system

Soil moisture in buffel grass-based silvopastoral system of *Prosopis cineraria* and *Hardwickia binata* was studied during monsoon, winter and summer seasons 1992-93. Results are presented in Table 1. Interactions of season, soil depth and sampling site were non-significant in both the systems, but individual factors of season and soil depth had significant difference in soil moisture content under *P. cineraria* - *C. ciliaris* system. Maximum soil moisture was recorded during monsoon months (S_1). Remaining two seasons, i.e., autumn (S_2) and winter (S_3), with decreasing soil moisture status had non-significant moisture variation. Least soil moisture (2.63%) was recorded in 0 to 20 cm (d_1) soil depth and it increased correspondingly in 21 to 40 (d_2), 41 to 60 (d_3) and 61 to 80 (d_4) cm depths. Though the lower soil depths (d_2, d_3 and d_4) were rich in soil moisture, variation in moisture content amongst these depths was non-significant. Less soil moisture was recorded in grass strips of silvopastoral (L_1) and pasture strip (L_5) sites. Maximum moisture (3.88%) was found in ploughed fallow soil strip between tree rows (L_4) and near the tree boles (L_2 and L_3). However, soil moisture difference among these sites was not significant.

In case of *H. binata* - *C. ciliaris* system more or less similar trend was observed in soil moisture status during different seasons, soil depths and sampling sites,

Table 1. Soil moisture (%) status in buffel grass-based silvopastoral systems

Factors	Silvopastoral systems	
	Prosopis cineraria-Cenchrus ciliaris	*Hardwickia binata-Cenchrus ciliaris*
Season		
Monsoon (S_1)	6.13	5.12
Winter (S_2)	2.88	2.16
Summer (S_3)	1.92	1.92
CD (5%)	1.22	1.25
Soil depth (cm)		
0 to 20 (d_1)	2.63	2.24
21 to 40 (d_2)	3.53	2.64
41 to 60 (d_3)	4.13	3.25
61 to 80 (d_4)	4.30	4.13
CD (5%)	1.41	1.44
Soil profile location		
Silvopastoral		
In grass strip (L_1)	3.54	2.83
30 cm from tree bole (L_2)	3.78	3.14
Tree plantation		
30 cm from tree bole (L_3)	3.74	2.92
Between tree rows (Fallow) (L_4)	3.88	3.09
Pasture plot		
In grass strip (L_5)	3.34	3.34
CD (5%)	NS	NS

but overall soil moisture status was better in *P. cineraria - C. ciliaris* system. This might be due to high transpiration losses through broad-leaved *H. binata* tree in the system. Further, though leaf transpiration rate was comparable between both species, more foliage of *H. binata* resulted in higher transpiration losses compared to *P. cineraria* (Burman and Dutta, 1997). Consequently, residual soil moisture below *H. binata* was less than that below *P. cineraria*. Sharma (1987) observed large variations in soil moisture status near tree boles (30 cm from tree bole) in *Acacia tortilis*-based silvopastoral system.

Soil moisture and top feed tree population

The study conducted during 1993-94 revealed that due to low rainfall, maximum soil moisture in monsoon season was 1.72 cm and soil moisture status in later two seasons (S_2 and S_3) remained unchanged with non-significant variation in all the seasons. Soil moisture significantly

Table 2. Soil moisture changes in different tree density plots of silvopastoral system

Factors	Soil moisture (cm) in *P. cineraria* - *C. ciliaris* system
Seasons	
Monsoon (S_1)	1.72
Autumn (S_2)	1.59
Winter (S_2)	1.59
CD (5%)	NS
Soil depth (cm)	
0 to 20 (d_1)	1.02
21 to 40 (d_2)	1.53
41 to 60 (d_3)	1.77
61 to 80 (d_4)	1.86
81 to 100 (d_5)	2.02
CD (5%)	0.18
Tree population	
One tree (P_1)	1.75
Two trees (P_2)	1.77
Three trees (P_3)	1.73
Four trees (P_4)	1.78
Only pasture (P_0)	1.17
CD (5%)	0.18

increased from 1.02 to 2.02 cm with increasing depth. Though soil moisture variation was significant between pasture (no tree) plot and silvopastoral plots of different tree population. Interactions among seasons soil depth and soil profile location did not reveal significant variation in soil moisture (Table 2). Increasing tree density did not influence soil moisture content and availability within one meter soil profile, which may be beneficial to the understorey forage or grain crop in the agroforestry system. Rich soil moisture status in this zone may be due to phreatophyte nature of *P. cineraria*, which extracts moisture from deeper layers (Lahiri and Kumar, 1967; Muthana *et at.*, 1984). On the other hand, increasing the population of *P. cineraria* trees had resulted in poor tree growth and top feed production (Sharma and Dutta, 1999).

Conclusions

Soil moisture studies in different silvopastoral systems revealed vividly more active soil moisture dynamics in 0 to 40 cm soil profile zone predominantly in autumn, winter and summer seasons. Further near tree bole in silvopastoral system and clean fallow strips between top feed tree rows were the sites of high moisture availability in the system.

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