Indian Journal of Agricultural Sciences 76 (12) : 716–20, December 2006

Root distribution pattern of sewan (*Lasiurus sindicus*) and buffel grass (*Cenchrus ciliaris*) of arid ecosystem of western Rajasthan in relation to their soil binding capacity

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Received : 24 October 2005

ABSTRACT

An experiment was carried out during 2003–2004 and 2004–2005 on a coarse textured sandy soil to study the root distribution pattern and soil-binding capacity of the 2 grasses, viz sewan grass (*Lasiurus sindicus* Henr.) and buffel grass (*Cenchrus ciliaris* L.). The distribution of roots 4 and 16 months after sowing in both the grasses indicated that majority of roots was confined to the top 20-cm soil layer. The total length of roots (33.51, 105.38 m after 4 and 16 months respectively) of *C. ciliaris* was more than *L. sindicus*. A strong relationship was found between actual root length and estimated root length from biomass root length ratio from every 10-cm layer ($R^2 \geq 0.90$). Although the roots of *L. sindicus* penetrated to deeper layer than *C. ciliaris* but its root biomass (6.4 g) and root biomass density (255.8 g/m^3) were less than *C. ciliaris* (13.33 and 533.08 g/m^3 respectively). In *C. ciliaris* the root volume (30.53 mL) was higher and average root radius (0.31 cm) was lower than that of *L. sindicus* which results in higher soil binding capacity of *C. ciliaris* compared with *L. sindicus*.

Key words: Root distribution, *Lasiurus sindicus*, *Cenchrus ciliaris*, Arid ecosystem, Soil-binding capacity

In the arid ecosystem of northwestern Rajasthan, low and erratic rainfall, high temperature and dust storm in summer impose severe restrictions for arable cropping. Under such extreme conditions, soil conservation practices involving grasses could play an important role in reducing soil erosion and providing fodder for animals. The perennial grasses with better rooting ability especially in the top 15 cm soil profile are able to bind the soil particles, check soil erosion, add soil fertility through decayed roots and foliage parts and thus help in soil conservation (Reeves 1987). Therefore, the information on the development of root systems in grass species assumes considerable importance. Several investigations have been conducted regarding the root distribution of trees and grasses (Belsky 1994, Sala *et al.* 1989, Walter 1971, Hipondoka *et al.* 2003) in different parts of the world. However, relatively little work has been done on root distribution of arid zone grasses and their capabilities to control soil erosion. Therefore, the present investigation was planned with the objective to study the root distribution pattern and soil-binding capacity of the 2 prominent grasses, viz *Lasiurus sindicus* Henr. and *Cenchrus ciliaris* L. of low rainfall areas of western Rajasthan.

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MATERIALS AND METHODS

The experiment was conducted at the research farm of Regional Research Station, Central Arid Zone Research Institute (CAZRI), Bikaner during 2003–2004 and 2004–2005. The climatic condition of the area is hyper aridic with low rainfall, high temperature and high evaporation. The rainfall data during 2003–2004 and 2004–2005 was 221 and 128 mm which was 17.1 and 53.5 % less over the normal rainfall of 275 mm. The soil was alkaline, non-saline, loamy sand in texture with organic carbon 0. 10 %, *p*H 8.5, EC_2 0.22 dS/m. Water retention at field capacity was 8.1 (%, w/v). Two grasses, viz *L. sindicus* and *C. ciliaris* were sown in replicated plots after receiving 40 mm monsoon rain during first week of July 2003. Root growth and proliferation was monitored at 4 and 16 months after sowing through monoliths method. Three monoliths (each 50 cm × 50 cm × 50 cm) for each grass were exposed. Each monolith was further subdivided into 5 sections (0–10, 10–20, 20–30, 30–40 and 40–50 cm). Roots were recovered carefully from each section by removing the soils through dry sieving through a 2 mm sieve. Root fresh weight was recorded immediately after the collection. Vertical roots distribution of both the grasses in each layer was then counted and recorded. Root diameter of 5 randomly selected roots from each monolith section was measured with screw gauge at 3 spots along the root length. The root diameter was recorded as the average of 15 values.

Table 2 Effect of sub-sectioning of monolith on coefficient of variation (CV, %) in root thickness at two growth stages in *Cenchrus ciliaris* and *Lasiurus sindicus*

Species	Growth stages (Months)	Sub-sectioning of monolith (cm) 0-10	10-20	20-30	30-40	40-50	Entire monolith (cm) 0-50
Cenchrus	4	16.53	21.99	20.02	26.16	26.22	43.47
ciliaris	16	14.31	13.04	18.16	7.08	18.65	48.65
Lasiurus	4	16.53	20.42	18.17	28.82	27.05	47.88
sindicus	16	16.47	23.66	28.89	27.97	22.71	53.05

The volume of roots was recorded by immersing fresh roots in a measuring cylinder by water displacement method. While recording the volume of fresh roots, the loss of water if any was accounted for at each successive immersion.

Root length under each monolith section was measured using a modified line intercept method (Tennant 1975). Since these grass species were having profuse and large number of roots, therefore a sub sampling technique was adopted to estimate the root length and further verified with the actual root length. For this purpose, the biomass of a sub sample of 200-cm length of root was recorded for each monolith section. On the basis of sub sample weight, the root length under each monolith section was estimated and plotted against the actual root length recorded by Tennant (1975) method. Soil binding capacity of the root was calculated by the formula $F= V/r^2$. Where F is the binding factor, V is the volume of roots (mL) and r is the average radius of roots (mm). Roots were dried in oven at 80 °C for 48 hr and root weight and root biomass density (g/m^3) were determined.

RESULTS AND DISCUSSION

Root distribution and depth of penetration

Both the grasses expand majority of their roots in upper 20 cm soil layer (Fig 1). More than 70% of the grass roots were found within this layer. Only 5–10 % of the total roots in *C. ciliaris* and 15–20 % in *L. sindicus* was present below 40-cm depth. Studies conducted at 4 different sites in Savannas also showed that more than two third of grass roots was found between surface and 30 cm soil depth (Hipondoka *et al.* 2003, Knoop and Walker 1984Nu).

Depth of root penetration has often been emphasized in relation to drought resistance (Ludlow and Muchow 1990). Several authors have suggested that the depth of penetration increases the drought resistance in particular species (Hays *et al.* 1991, Ludlow and Muchow 1990, Marcum *et al.* 1995). In the present study, depth of root penetration in *L. sindicus* is higher (75.3 and 107 cm after 4 and 16 months respectively) as compared to *C. ciliaris* (62.7 and 86.0 cm after 4 and 16 months respectively) which helps in the greater adaptability of this species under arid environment. The depth of root penetration in *L. sindicus* was 20.4 and 24.4 % higher than *C. ciliaris* at 4 and 16 months after sowing respectively but

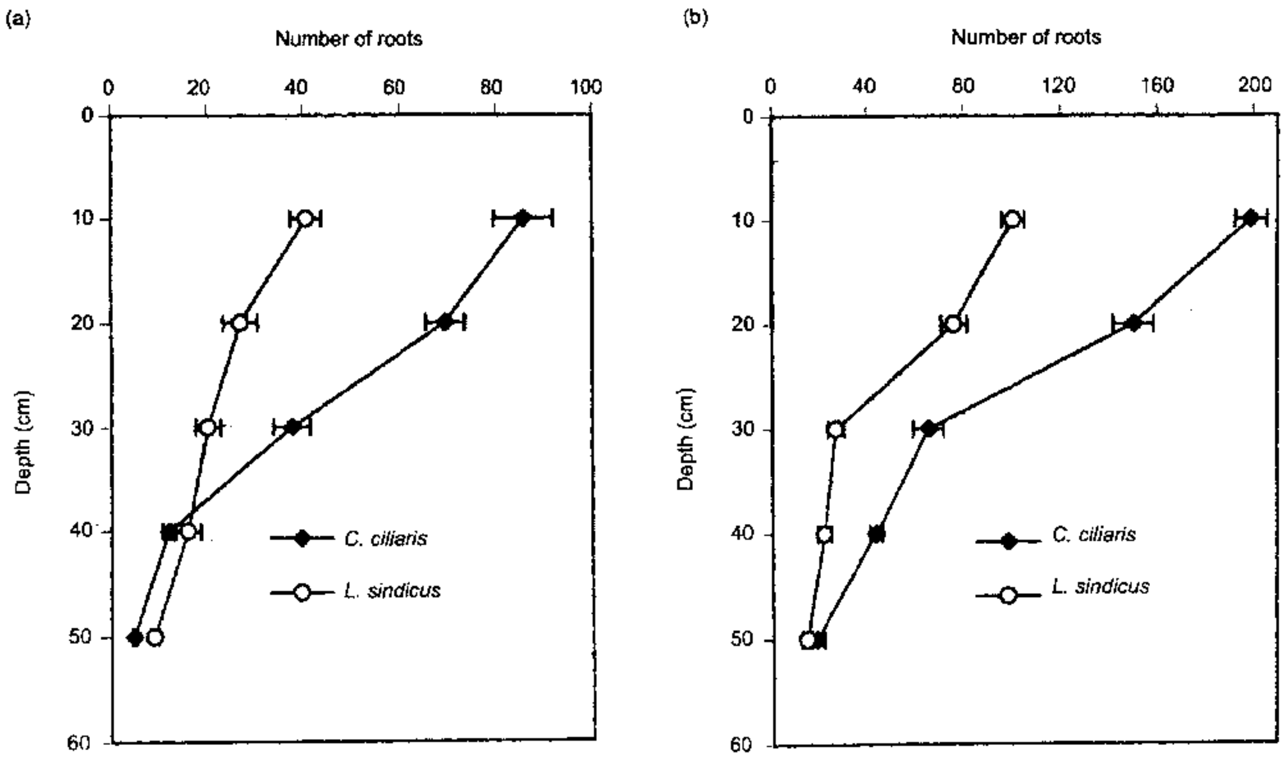

Fig 1 Number of roots in *C. ciliaris* and *L. sindicus* at different soil depths at (a) 4 months (b) 16 months after sowing.

Table 1 Variations in root length, root biomass, root biomass density (RBD), root radius, root volume and soil binding capacity (SBC) with increasing soil depth at two growth stages in *Cenchrus ciliaris* and *Lasiurus sindicus*. Values are means ± 1 SE

Soil depth (cm)	Root length (m)		Dry root biomass (g)		RBD (g/ m³)		Mean root radius (mm)		Root volume (mL)		SBC (mL/ mm²)	
	After 4 months	After 16 months	After 4 months	After 16 months	After 4 months	After 16 months	After 4 months	After 16 months	After 4 months	After 16 months	After 4 months	After 16 months
					Cenchrus ciliaris							
0–10	14.30±1.7	44.66±0.8	0.96±0.14	6.84±0.28	38.24±5.8	273.73±11.0	0.38±0.03	0.50±0.03	2.43±0.3	15.33±1.9	16.70±0.8	61.50±8.41
10–20	11.22±1.6	32.81±1.2	0.61±0.09	4.89±0.42	24.42±3.6	195.58±16.8	0.32±0.03	0.46±0.02	1.97±0.2	11.33±1.5	19.41±3.1	54.58±5.83
20–30	4.89±0.7	10.43±0.9	0.20±0.02	0.85±0.15	7.95±0.6	33.88±5.8	0.25±0.02	0.31±0.01	0.90±0.1	2.17±0.6	13.91±2.1	22.16±4.69
30–40	2.58±0.5	9.69±0.5	0.07±0.00	0.39±0.03	2.87±0.1	15.65±1.2	0.15±0.02	0.19±0.01	0.27±0.1	1.17±0.2	12.12±2.0	34.09±4.49
40–50	0.53±0.1	7.79±0.3	0.02±0.00	0.36±0.03	0.79±0.1	14.25±1.1	0.08±0.02	0.13±0.01	0.04±0.1	0.53±0.1	6.55±1.6	31.63±5.77
					Lasiurus sindicus							
0–10	6.03±0.4	15.02±1.6	0.74±0.06	4.09±0.16	29.49±2.5	163.64±6.5	0.41±0.01	0.60±0.02	2.03±0.1	16.15±1.1	12.04±0.7	44.16±4.64
10–20	4.06±0.6	11.98±1.7	0.41±0.03	1.45±0.12	16.30±1.2	57.82±4.7	0.34±0.02	0.44±0.04	1.33±0.4	5.83±0.93	11.58±2.0	29.63±2.21
20–30	2.85±0.6	3.87±0.4	0.20±0.01	0.52±0.05	8.09±0.5	20.71±2.1	0.27±0.01	0.35±0.03	0.83±0.1	3.03±0.6	11.15±3.2	24.21±2.41
30–40	2.70±0.7	3.32±0.3	0.30±0.02	0.24±0.06	12.00±1.0	9.44±2.3	0.14±0.01	0.23±0.01	0.23±0.0	0.93±0.1	11.63±2.0	18.06±2.82
40–50	1.45±0.1	1.67±0.8	0.06±0.00	0.11±0.01	2.47±0.2	4.23±0.4	0.12±0.01	0.17±0.02	0.13±0.0	0.33±0.2	8.58±2.1	12.05±3.52

its total root length, total root numbers and root biomass was less. Number of roots in the upper 10 cm soil layers in *C. ciliaris* was almost double (87.7 and 199.0 after 4 and 16 months respectively) as compared to *Lasiurus sindicus* (40.7 and 100.3). This suggests that the *C. ciliaris* was densely rooted at the surface and mid zone of the soil profile and decreased at lower soil depths.

The method suggested by Tennant (1975) to measure the total root length is laborious and time consuming hence we tried to determine the root length indirectly from root biomass: root length ratio. But unfortunately no relationship was found between root biomass and root length, when single sample of root length for entire monolith of 0–50 cm was taken. This seems to be due to the higher coefficient of variation (43–50%) in the root thickness with varying depth (Table 2). To overcome this, we applied a sub sampling technique to measure the root length by dividing the entire monolith into sub sections of 10-cm each and then measured the root thickness and root length. This has resulted in a significant reduction in coefficient of variation (7–29 %) in the root thickness at each depth (Table 2) and strengthening the relationship between the actually measured and calculated root length from root biomass: root length ratio ($R^2 \geq 0.90$, Fig 2).

Root biomass density

The root biomass of both grasses at each growth stages suggests that most of the roots were confined in the upper layer 20 cm soil layer. A sharp decrease in root biomass and root biomass density was observed after 20-cm soil depth in both the grasses (Table 1). Between the 2 grasses, root biomass density (RBD) of *C. ciliaris* was significantly higher as compared to *L. sindicus*. This was due to its fine root system and higher root length (Table 1) as compared to *L. sindicus*. The data on root length after 16 months showed that the root grows at faster rate in *C. ciliaris* (105.3 m) as compared to *L. sindicus* (35.9 m). The increase in root length was two and half times in *L. sindicus* and three times in *C. ciliaris* at 16-months growth stage as compared to that at 4-months growth stage. The age has a significant effect on root biomass of grasses. In the present study, the total root biomass and thus the root biomass density after the 16 months was significantly more as compared to 4 months growth period. This confirms the earlier findings that the root development during first two years is faster and then increases at a slower rate with increase in root radius (Ranade *et al.* 2002). The increase in RBD at 16 months as compared to that at 4 months growth stage were 6.1 and 7.0 times more in *C. ciliaris* and 4.5 and 2.5 times more in *L. sindicus* in upper 0–10 and 10–20 cm soil layer respectively. The increase in root biomass density with age was also observed in other grasses like *Vetivera zizanioides, Dichanthium annulatum, Panicum maximum* and *Cymbopogon martinii* (Ranade and Mishra 2000).

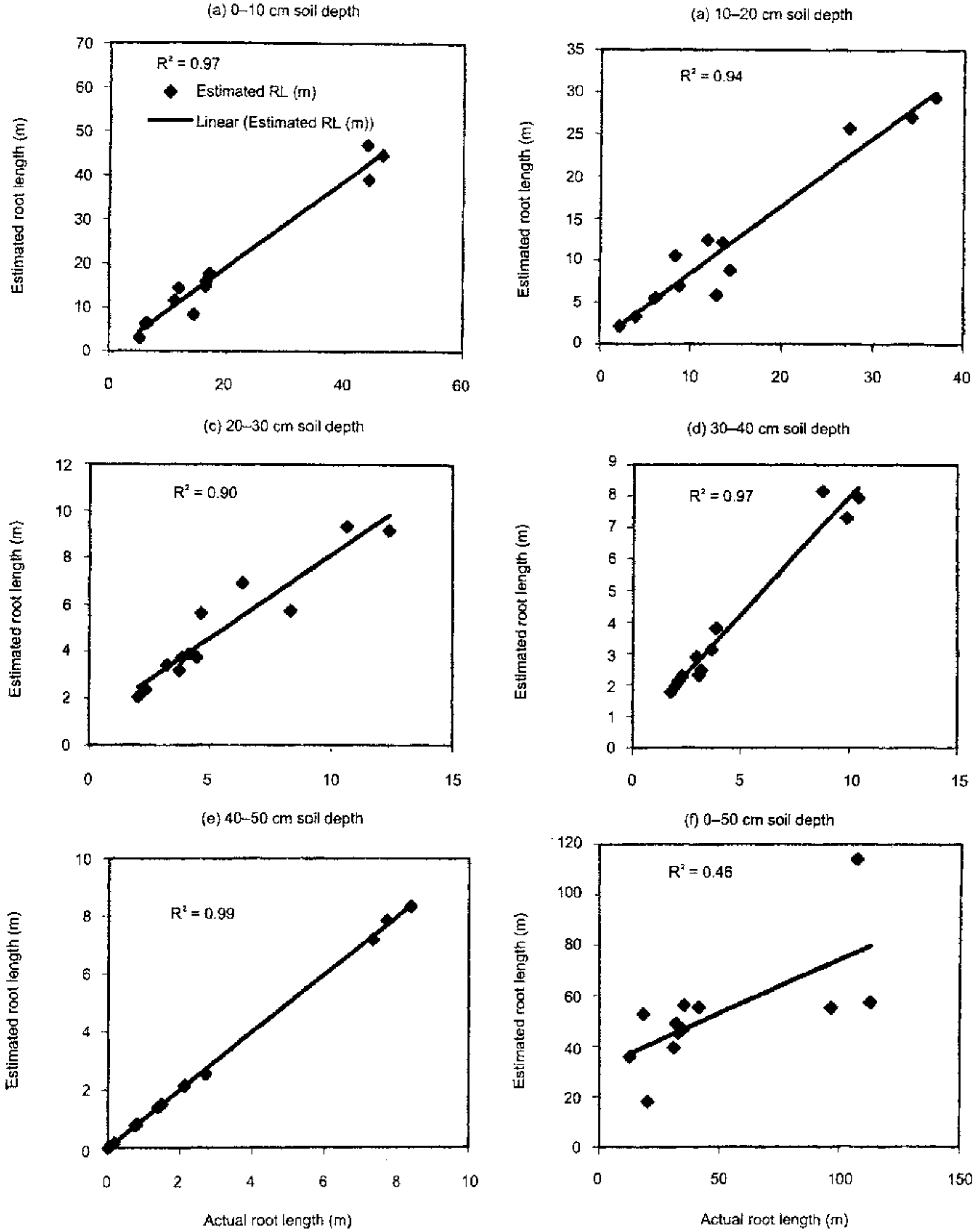

Fig 2 Relationship between actual and estimated root length measured by (a to e) sub sectioning the monolith into 10-cm section each and (f) without sub section

Soil binding capacity

Soil binding capacity of a plant species depends on total volume of roots and root thickness. In general, the grasses with higher root volume with greater length and lesser root thickness will have greater growth around the soil particles and bind them strongly. In present study *C. ciliaris* has higher root volume with lesser root radius, therefore, its soil binding capacity is more as compared to *L. sindicus*. Soil binding capacity of *Cenchrus ciliaris* in the top 0-10 and 10–20 cm soil layer was 28 and 40% higher after 4 months and 28 and 46% higher after 16 months as compared to *L. sindicus*, respectively (Table 1).

It may be concluded that higher depth of penetration of *Lasiurus sindicus* makes it more hardy and adaptable to extreme conditions of arid zone. But, due to higher root volume, total number of roots and lesser root diameter, the soil binding capacity of *C. ciliaris* is more which makes it more efficient in soil conservation programme.

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