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Root Penetration and Survival of *Prosopis chilensis* and *Dalbergia sissoo* in Dry Regions

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The present investigation was carried out on the seedlings of *Prosopis chilensis* (Molina) Stuntz and *Dalbergia sissoo* Roxb. under field capacity and drier (10% soil moisture) water treatments to assess their ability of root penetration and survival in dry regions. Roots of *P. chilensis* penetrated the moist as well as dry soils to an equal depth in the subsoil layer. However, *D. sissoo* did not extend its roots out of 10 cm thick upper soil layer. *P. chilensis* began wilting when water content of the upper soil was reduced to 8% whereas wilting of *D. sissoo* occurred at 15.2% soil moisture. The ability of *P. chilensis* to thrive in dry regions is further conferred by the xeromorphic characteristics of its leaves.

Key Words: ***Prosopis chilensis*, *Dalbergia sissoo*, seedlings, Water treatments, Dry regions, Root penetration, Growth and survival, Adaptation**

Introduction

Prosopis chilensis (Molina) Stuntz is a noxious, woody, invasive exotic (Poyton 1990, Pandey & Rokad 1992) and threatens to infest much of the best land in semi-arid and arid regions of Western India. In dry climate, moisture is the primary limiting factor for growth and survival, especially of woody species. It is suggested that either the roots of plants from dry habitats are better able to exploit dry soil (Shantz 1927, Etherington 1987) or the aerial parts of the plants have water conservative adaptation (Kramer 1983). The present investigation was undertaken to assess the adaptive features of *P. chilensis* which make it possible for the species to invade and successfully thrive on the habitats in dry regions of Western India. *Dalbergia sissoo* Roxb., subclimax woody species and native to subhumid and semiarid regions, is extensively planted on good soils in marginal semi-arid (closer to arid) regions of Western India. Study was also conducted simultaneously on this species to have comparative information on two successionally different woody species.

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Materials and Methods

Seedlings of each species were grown from seeds collected at Rajkot, Western India, experiencing marginal semi-arid climate (Pandeya et al. 1977). Fifty seedlings of each species were selected on 13 August 1991. Single seedlings were then planted on the top of soil contained in open-bottomed cylinders (10 cm diameter × 10 cm depth, cut from PVC pipe). The bottom of each cylinder was affixed with a wire-net so that roots can easily pass through. The cylinders contained black cotton soil, rich in clay content (Pandeya et al. 1977). The soil was watered to field capacity (sufficient water just to cause drainage).

Cylinders with seedlings were kept inside a wire cage for three weeks for the establishment of seedlings. The top of the wire cage was covered with thinly spread hay of dry grasses. The mean maximum temperature of the cage was about 5°C lower than ambient mean maximum temperature (30.6 ± 0.2°C). Since August is the peak period of rainfall and rain water dripped down the dry hay cover, soil was watered on alternate days. During this period, seedlings of both the species developed 3 to 4 leaves. Soil was finally watered on 2 September 1991 and thereafter the seedlings were not irrigated. The cylinders with seedlings were transferred to a glasshouse.

Thirty seedlings of each species, thus established, were further selected for water treatment. Each cylinder was then placed on top of an identical cylinder containing soil at either field capacity (30% water : dry weight) or at 10% water content. The junction was sealed with waterproof adhesive tape. The soil surface in the upper cylinder was covered with an aluminium foil to check evaporation loss and both the cylinders together were wrapped with polyethylene sheet. Fifteen replicates for each of the two water treatments, factorialized with two species, were prepared; this gave a total of sixty cylinders, which were arranged in 15 randomized blocks.

Seedlings of *D. sissoo* with both type of water treatments began wilting after 11 days while the soil moisture in the upper cylinder was near field capacity. This unexpected result was probably due to high temperature (mean maximum : 35.1 ± 0.4°C) inside the glasshouse. The seedlings of both the species were then transferred to the laboratory. White fluorescent light was provided to the seedlings for 12 hr during day time. Seedlings of *D. sissoo* recovered and resumed growth under that condition. The experiment on *D. sissoo* was terminated after 23 days following the cessation of watering. At this time, about 50% of seedlings under drier treatment began to wilt. Seedlings of *P. chilensis* continued to grow or survive until 47 days. Thereafter, the seedlings under drier treatment began to wilt and the experiment was then terminated. Additional seedlings of each species, grown under field capacity treatment, were used to determine certain physiological attributes. Two days before the termination of experiment on *D. sissoo*, water loss during 24 hr through transpiration for both the species was measured by weighing. Leaf area and dry weight of the leaves were determined. Relative water content (RWC) of leaf was determined following Weatherley (1950). Collidian solution was applied on the upper and lower leaf surfaces at mid-day, dry films were taken off, and stomatal number was counted and the size of stomatal aperture was measured under the microscope.

Morphological characteristics of each seedling were record. Shoot and root length was measured and leaf area was marked out on the graph sheets. Dry weight of leaves, stems, upper and lower cylinders' roots was determined together with residual water content of the soil. Plant tissues and soils were oven-dried at 90°C. The data were analysed by t-test of 15 and 12 randomized blocks of *P. chilensis* and *D. sissoo*, respectively. Three of the *D. sissoo* seedlings had died during the course of the experiment.

Results

The drier soil treatment significantly reduced the shoot height ($p < 0.05$), leaf area ($p < 0.01$), leaf weight ($p < 0.05$) and shoot growth ($p < 0.05$) of *P. chilensis* (table 1).

Table 1 *Effect of field capacity and drier* (10% *soil moisture*) *water treatments on shoot and root growth of the seedlings of **Prosopis chilensis** and **Dalbergia sissoo** previously established in soil maintained at field capacity*

Species	Treatment	Shoot height cm $(plant^{-1})$	Root length cm $(plant^{-1})$	Leaf area cm^2 $(plant^{-1})$	Leaf weight mg $(plant^{-1})$	Stem weight mg $(plant^{-1})$	Shoot weight (Leaf + stem) mg $(plant^{-1})$	Root weight in upper soil layer mg $(plant^{-1})$	Root weight in lower soil layer mg $(plant^{-1})$	Total root weight mg $(plant^{-1})$	Shoot/root ratio
Prosopis chilensis	Field capacity	12.7^b ±1.3	18.8 ±1.5	22.8^a ±3.2	48.0^b ±6.2	29.3 ±4.0	77.3^b ±10.1	14.0 ±1.7	13.2 ±3.8	27.2 ±5.1	3.4 ±0.4
Prosopis chilensis	10% soil moisture	8.8^b ±0.8	19.4 ±1.5	11.6^a ±1.8	28.0^b ±4.0	20.1 ±2.9	48.1^b ±6.9	10.9 ±1.6	8.7 ±1.9	19.6 ±3.2	2.9 ±0.3
Dalbergia sissoo	Field capacity	15.5 ±0.7	7.9 ±0.4	9.8 ±0.8	34.4 ±1.9	23.5 ±1.1	57.9 ±2.8	9.3 ±0.9	—	9.3 ±0.9	6.6 ±0.5
Dalbergia sissoo	10% soil moisture	14.2 ±0.7	7.4 ±0.5	7.6 ±0.8	29.8 ±1.0	20.0 ±1.1	49.8 ±2.0	7.7 ±0.7	—	7.7 ±0.7	6.9 ±0.5

Mean values with superscript letter *a* differ at $p<0.01$ and with *b* at $p<0.05$ as compared by t-test.

± = 1 SE

Leaves made major contribution to the shoot weight. Roots penetrated the moist as well as dry soils to an equal depth in the lower cylinders. However, root weight in the upper cylinder was affected by the wetness of the soil sublayer. The total root weight in the drier treatment was reduced by 27% of that in the field capacity treatment. Growth of the shoot components of *D. sissoo* was also reduced by the drier treatment. Seedlings of this species survived for a shorter period and hence shoot growth did not show significant reduction. Shoot/root ratio of *P. chilensis* was considerably lower than that of *D. sissoo*. Seedlings of *P. chilensis* and *D. sissoo* began to wilt when the soil in the upper cylinder above the dry sublayer dried to 8% and 15.2%, respectively (table 2) suggesting that *P. chilensis* extracts water from highly dry soil.

Pot-grown plants of two species in a similar volume of the same soil showed significant differences in specific leaf area ($p < 0.01$) and water loss per unit leaf area ($p < 0.01$) (table 3). Water loss by *P. chilensis* was about one half of that by *D. sissoo*. The number of stomata mm^{-2} leaf area significantly differed ($p < 0.01$) at the upper leaf

Table 2 *Effect on water content of upper and lower layers of soil of transferring the seedlings of* ***Prosopis chilensis*** *and* ***Dalbergia sissoo****, previously established in soil at field capacity. The lower layer of soil was initially at either field capacity or at 10% water content*

Species	Treatment	Soil water content (% of dry weight)	
		Upper layer	Lower layer
Prosopis chilensis	Field capacity	$12.0^a \pm 0.8$	16.8 ± 0.9
Prosopis chilensis	10% soil moisture	$8.0^a \pm 0.1$	11.4 ± 0.3
Dalbergia sissoo	Field capacity	$22.7^a \pm 0.2$	27.6 ± 0.3
Dalbergia sissoo	10% soil moisture	$15.2^a \pm 0.2$	14.2 ± 0.1

Mean values with superscript letter *a* differ at $p < 0.01$ as compared by t-test.
$\pm$ = 1 SE

Table 3 *Specific leaf area, number of stomata at upper and lower surfaces of leaves, length and width of stomatal aperture, water loss per unit leaf area and relative water content of leaves of the seedlings of* ***Prosopis chilensis*** *and* ***Dalbergia sissoo*** *of the same age and grown in soil at field capacity in the same environmental conditions as those of shoot and root growth experiment*

Species	Treatment	Specific leaf area ± SE mm^2 (mg^{-1})	Number of stomata at upper surface of leaf ± SE number (mm^{-2})	Number of stomata at lower surface of leaf ± SE number (mm^{-2})	Length of stomatal aperture ± SE (μm)	Width of stomatal aperture ± SE (μm)	Water loss per unit leaf ara ± SE $(mg\ mm^{-2} h^{-1})$	Relative water content ± SE (%)
Prosopis chilensis	Field capacity	49.0 ± 5.1	495 ± 32	121 ± 12	5.6 ± 0	0.75 ± 0	6.5 ± 0.8	78.8 ± 2.3
Dalbergia sissoo	Field capacity	27.4 ± 3.2	893 ± 53	181 ± 21	5.6 ± 0	1.9 ± 0	12.6 ± 0.6	61.0 ± 1.6

surface of the two species. Length of the stomatal aperture was similar for both the species, but the width of the stomatal aperture in *P. chilensis* was less than half of that *D. sissoo*. Relative water content of leaf was significantly higher ($p<0.01$) in *P. chilensis* than in *D. sissoo*.

The relationship between root dry weight and final water content in the upper layer soil showed dissimilarity for the two water treatments. A significant inverse correlation between final water content and upper layer root weights or total shoot weight was obtained for *P. chilensis* ($r = -0.571$) and *D. sissoo* ($r = -0.579$) in the field capacity treatment, but in drier treatment there was no marked correlation. However, in subsoil layer, root weight of *P. chilensis* and final water content gave high correlation coefficient for field capacity ($r = -0.876$) and drier water treatment ($r = -0.893$).

Discussion

Plants subjected to water stress show a general reduction in size and dry matter production (Kramer 1983). The reduced growth of shoot components of *P. chilensis* and *D. sissoo* under drier treatment can be attributed to the water stress. In addition to moisture, which is the major limiting factor, plants are also affected by high temperatures in the dry climate of Western India (Pandeya et al. 1977). Interestingly, seedlings of *P. chilensis* showed greater ability to endure high temperatures of the glasshouse. The long survival (47 days) after cessation of watering and heat endurance by the seedlings of *P. chilensis* suggest that this species can successfully invade the open lands in dry climate.

The technique of measuring root elongation in soil drier than that in which the plants were initially established has not been perfected. Portas and Taylor (1976) used a water repellent barrier that prevented water from migrating downward into the lower soil container. Etherington (1987) used the soil of low hydraulic conductivity. In the present study reliance was placed on the higher permanent wilting point of clay-rich black cotton soil. The seedlings of *P. chilensis* penetrated roots into soil near the permanent wilting percentage and it was not restricted by the wetness of soil in the lower cylinder. Etherington (1987) reported that root penetration ability of *Dactylis glomerata* L. clone from a cliff-ledge dry soil was more than its clone from moist alluvial soil. Park (1990) reported that *Digitaria adscendens* (H.B.K.) showed no reduction in root penetration under unwatered conditions. According to Sydes and Grime (1984), rapid root extension insures the existence of plants in droughty habitats.

Root growth was related with the growth of the shoot and consequently there was a close resemblance of shoot: root proportion in the two water treatments. However, root weight in the upper and lower cylinders considerably differed for two water treatments indicating that in drier treatment proliferation of roots in the subsoil depended on moisture content in the upper cylinder. As a result, in natural condition, the available rainfall can wet the surface soil and *P. chilensis* can use the moisture for the proliferation of roots in the subsoils over the monsoon season. Seedlings of *D. sissoo* showed poor growth of roots and had mean root depth of only 7.6 cm.

The greater water loss by *D. sissoo* than by *P. chilensis* suggests that latter growing in dry habitats has experienced selection favouring water-conservative or drought-surviving adaptations. Difference in water loss is further related with xeromorphic characteristic of stomata in *P. chilensis* as its specific leaf area was significantly greater than that of *D. sisso*. The higher relative water content of leaf in *P. chilensis* also assumes importance for its drought-resistance. Davidson and Reid (1989) studied the response of three

Eucalyptus species to severe drought in summer of 1982/83 at Snug Plains, south-eastern Tasmania, Australia, and found that *E. pulchella* maintained higher relative water content and is relatively drought-resistant species. The relationship between root weight and water extraction was, perhaps, influenced by the downward movement of water from the upper cylinder to sublayer dry soil. In order to explain this result, refinement of technique is necessary.

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