INFLUENCE OF SOIL WATER DEFICIT ON THE GROWTH AND ROOT GROWTH POTENTIAL OF *DALBERGIA SISSOO* SEEDLINGS IN AN ARID ENVIRONMENT

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Introduction

Water and nutrient availability are the main limitations to plant growth and biomass production in arid areas. These resources may be limiting concurrently or consecutively over the growing period and/or the complete life of the plants. The nutrients used by plant species for growth and biomass production generally come from the internal cycling of the reserve materials, which require water for their solubilization and translocation (Sanchez *et al.*, 1991). Reduced water supply may influence partitioning of carbohydrates to root and reduced partitioning to shoot growth. Therefore, irrigation is a basic need for sustaining high productivity in arid and semi-arid regions to meet the rising demands of food, fodder, fuel and fiber for the steadily growing human and livestock population.

Irrigated plantations are raised in the Indira Gandhi Canal command area of Thar desert with the primary aim being to prevent siltation of the canal from the wind blown soil particles and increase the socio-economic status of the inhabitant. *Dalbergia sissoo* Roxb. ex. DC. Prodr. is one of the important multipurpose tree species planted in this area under irrigation for its valuable timber and fuelwood. However, the tendency to over water, faulty method of irrigation and seepage from the canal has resulted in rise of ground water table (Mathur, 1990) causing problem of water logging and salinity at several places. Further, frequent and excess watering leads to surface spreading of the root systems resulting in mortality of plantations when irrigation is ceased after 5 to 8 years (Gupta *et al.*, 1995). Therefore, to attain maximum productivity without deterioration of the natural resources, the irrigated plantation need to be raised using scientific principles and adopting an optimum level of irrigation.

Present study was carried out to determine the effect of varying level of irrigation on root, shoot and leaf growth of *Dalbergia sissoo* with the aim to find out (i) the level of soil water availability at which the growth and root development of *D. sissoo* would be best, and (ii) critical level of soil water availability for growth and survival of the seedlings.

Material and Methods

Study site : The experiment was carried out at the experimental farm of Arid Forest Research Institute (AFRI), Jodhpur (26° 45' N lat., 72° 03' E long.). Mean monthly minimum and maximum temperatures were 10.0°C in winter and 41.3°C in summer, respectively. Rainfall was 237 mm and total potential evapotranspiration was 2109 mm (August 1998 to May 1999) showing high water deficit. Soil filled in the iron containers was loamy sand having pH 8.32, EC 0.52 dSm^{-1} and with water holding capacity of 10.67% (w/w) at -0.03 MPa. Soil water storage in 0 - 50 cm layer varies from 82 mm at -0.03 MPa to 24 mm at -1.5 MPa. The soil was deficient in available nitrogen (12.56 mg kg^{-1}), phosphorus (10.01 mg kg^{-1} P_2O_5) and potash (106 mg kg^{-1} K).

Plant material and plantation : Four-month-old single clone (candidate plus tree no. 103) seedlings of *D. sissoo* from the experimental nursery of AFRI were used. Seedlings were planted in August 1998 in galvanised iron containers of 45 cm diameter and 55 cm depth. 120 kg of loamy sand soil was filled up to 50 cm of container (i.e., 0.08 m^3) leaving 5 cm depth for irrigation. A drainage hole of 25 mm diameter was present in the container. Treatment in the form of irrigation was initiated in the first week of October 1998. At the time of treatment initiation, seedling height and collar diameter were 52 1.8 cm and 0.4 0.08 cm (mean SEm).

Experimental details

Experiment I : Treatment was initiated by saturating the soil of all the containers through addition of 82 mm of water. Drainage of excess water was allowed till the soil water ceased to drain down. Soil water content was continuously monitored gravimetrically after oven drying of soil samples at 110°C to a constant mass. Irrigations were based on the per cent soil water content (w/w) at the pressures of –0.03 MPa (10.7 %), –0.05 MPa (9.9 %), –0.10 MPa (7.4 %), –0.50 MPa (5.6 %), –1.00 MPa (4.3 %), and –1.50 MPa (3.2 %). The seedlings were re-irrigated by addition of differences in soil water content between –0.05 to –0.10 MPa (20 mm, 3.2 litres), –0.10 to –0.50 MPa (14 mm, 2.2 litres), –0.50 to –1.00 MPa (10 mm, 1.6 litres), and –1.00 to –1.50 MPa (8 mm, 1.3 litres) when the soil water content reached 7.4, 5.6, 4.3, and 3.2 % in the W_1, W_2, W_3 and W_4 treatments, respectively (Singh and Singh, 2004). Total quantity of water added was 112.0 litres in W_1 in 35 irrigation events, 63.8 litres in W_2 in 29 irrigation events, 27.2 litres in W_3 in 17 irrigation events and 16.9 litres in W_4 in 13 irrigation events in 210 days. No irrigation was done in control (W_5). Each treatment was taken in eight replications (i.e., one seedling in each container) and the experiment was laid in Randomised Complete Block Design. The experiment was terminated in the first week of May 1999 (9 months after planting) when the seedlings of W_5 treatments suffered permanent wilting (soil water content of 4.2 mm or 0.56 % of the soil mass).

Experiment II : A root growth potential (RGP) test was performed to assess the growth of roots under different irrigation level. It is useful indicator for testing quality of seedling to be planted on stressful sites (Tinus, 1996). Thirty seedlings of *D. sissoo* were grouped into five treatments with six seedlings (replicates) in each treatment in September 1998. The seedling roots were washed gently to make them free of growing medium. Immediately after washing, roots were cut leaving the rootstock of 5 cm length and transferred them to the soil in 2 kg polythene bags. Soil was saturated with water and subsequently the five treatments were maintained as described in experiment I. After 21 days all the seedlings were uprooted and root length and root dry weight of freshly growing roots recorded.

Observations

Height, collar diameter, number of leaves, leaf size, total leaf area, and number of branches were recorded monthly. Collar diameter of seedlings was measured 2 cm above the soil surface. Leaf size was measured for 20 leaves of each treatment and replication using a Portable Leaf area meter, CI-203 CA, CID Inc. USA. Daily leaf expansion rate was determined using the formula :

LAE (leaf area expansion) = $(A_2 - A_1/ t)$.

where :

A_1 and A_2 are the initial and subsequent measured leaf area, and

t is the time interval (day) between the treatment initiation (October 1998) and termination (May 1999).

Root dry weight/shoot dry weight ratio, total leaf area, leaf weight, shoot weight, root weight, root length, root surface area and root volume were recorded after termination of the experiment and uprooting of the seedlings. Total root volume was measured by water displacement method. Leaf, shoot (stem + twigs) and root were dried at 80 ^{0}C in oven to a constant weight. Relative growth rate (unit dry weight of plant per unit time) was calculated using following formula (West, 1920) :

RGR = $2.303 (\mathrm{Log}_{10} W_2 - \mathrm{Log}_{10} W_1)/t_2 - t_1$

where :

W_1 and W_2 are the initial and subsequent measured dry weight of the seedlings, and

t_1 and t_2 are the interval of time between October 1998 and May 1999.

Statistical analysis : To test the effect of different irrigation levels on different growth parameters, one-way ANOVA was carried out. Pearson correlation was carried out to assess the relation between seedling growth and soil water availability. Regression coefficients for seedlings height, collar diameter, leaf area, number of leaves and root volume were determined.

Results

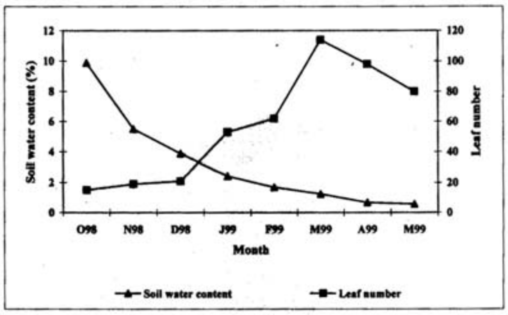
Experiment I

Depletion in soil water content : Soil water content (SWC) in W_5 treatment reached 1.73% (-1.5 MPa) in February 1999 from 9.88% in October 1998. SWC was 1.23% (-1.96 MPa) in March and 0.56% (-2.02 MPa) in May 1999 (Fig. 1) resulting in drying of leaf and seedling mortality, respectively.

Root growth : Mean primary and secondary root length, root volume and root biomass were highest ($P<0.001$) in W_1 (Table 1). Primary root was 6% shorter whereas the secondary root length, root volume and root biomass were 18%, 40%, and 26% lesser in W_2 than in W_1 treatment, respectively. Reductions in these variables were 41%, 90%, 85% and 82% in the seedling of W_5 (at the water stress level of -2.02 MPa).

Seedling height and collar diameter : Height and collar diameter decreased in the seedlings from W_1 to W_5 treatments (Table 2). The decline in height and collar diameter was not significant ($P>0.05$) in W_2 whereas these growth variables were 21% and 22% less in the seedlings of W_3 as

Fig. 1



Soil water depletion and its relationship with leaf dynamics in *D. sissoo* seedlings under W_5 treatment (from 82.0 mm to 4.2 mm per 50 cm soil depth).

compared to the seedlings in W_1. Further increasing water stress caused reduction in height and collar diameter. The seedling in W_5 treatment indicated 38%, 50% and 67% reduction in height, collar diameter and number of branches respectively as compared to the seedlings in W_1. Height and collar diameter growth was recorded up to the soil water content of 1.23% (i.e., –1.96 MPa) in the seedling of W_5 (Fig. 1). The periodical growth in height and collar diameter showed two-inflection point one between W_2 and W_3 and the other between W_4 and W_5 treatment (Fig. 2).

Leaf growth and phenology : Rate of leaf area expansion (LAE) was highest (15 x 10^{-4} m^2 day^{-1}) in the seedlings of W_1 (Table 2) and indicated a decrease in LAE by 60% for the seedlings of W_3 treatment. Rate of LAE was 93% lower in W_5 that resulted in a decrease in leaf size by 27%. Emergence of new leaves initiated in January 1999 and was greater in seedlings of W_1 and W_2 as compared to those in the other treatments. Addition of new leaves and increase in leaf area continued till the end of the experiment (i.e., May 1999) in the seedlings of all the treatments except in W_5. In the seedling of W_5, drying and abscission in the leaf started after March resulting in decrease in leaf number and total leaf area (Fig. 2c, 2d). Increase in leaf area up to March 1999 was <50% in W_1 and W_2, >75% in W_3 and W_4 and about

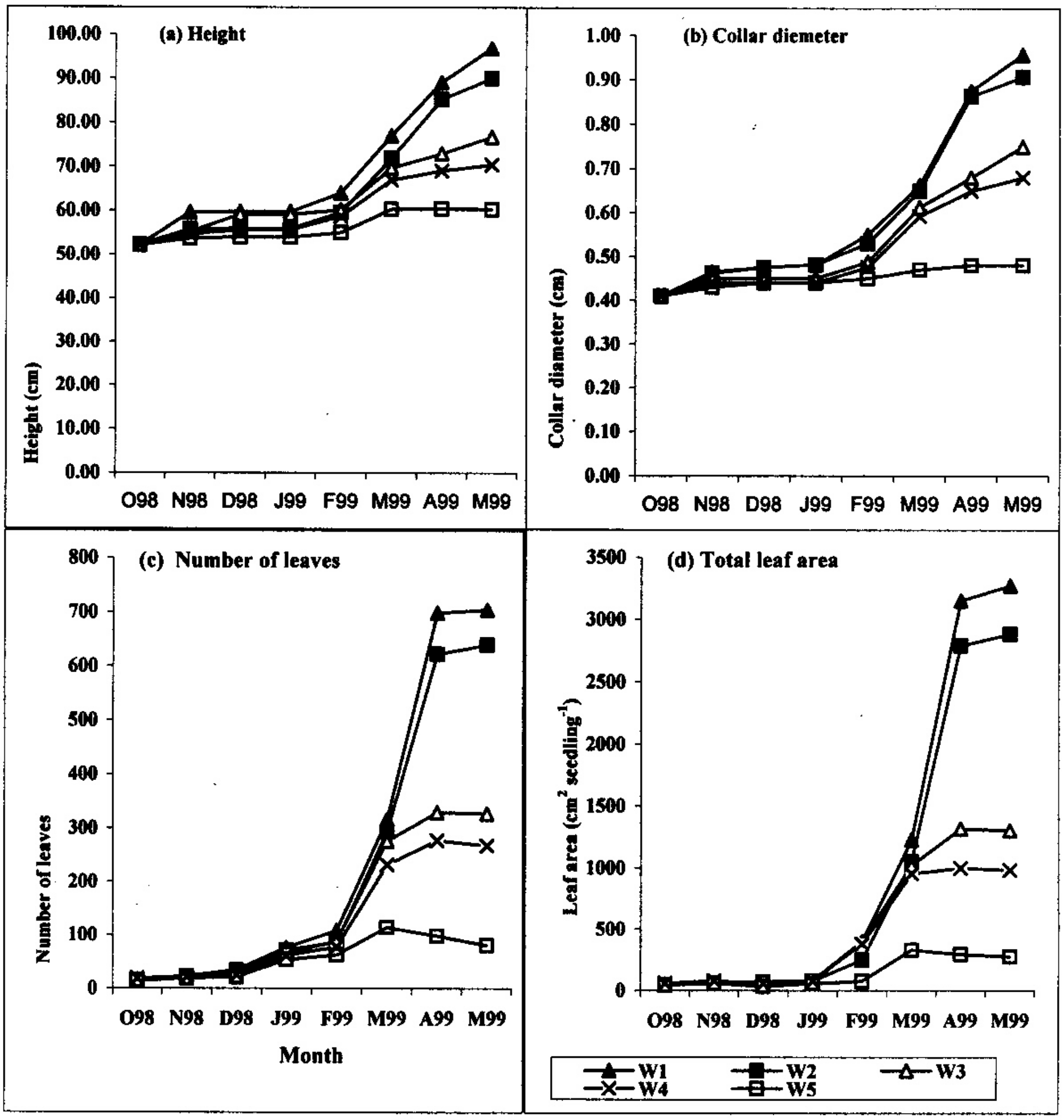
Table 1

Influence of soil water stress on root growth and biomass of nine months old Dalbergia sissoo seedlings.

Parameter	W_1	W_2	W_3	W_4	W_5	P value
Primary root length (cm)	96.0 (6.2)	90.7 (5.7)	67.7 (6.6)	66.0 (5.9)	57.4 (5.8)	0.001
Secondary root length (cm)	38.3 (3.0)	30.5 (2.2)	22.1 (1.1)	19.4 (1.5)	13.0 (0.4)	0.001
Root volume (cm^3)	67.4 (4.3)	40.1 (2.3)	20.3 (1.6)	18.6 (1.5)	10.2 (0.6)	0.000
Root biomass (g)	26.9 (1.3)	19.9 (0.5)	11.3 (0.5)	10.6 (0.8)	4.7 (0.3)	0.001

The values are means of eight replicates with standard error in the parentheses.
W_1, W_2, W_3, and W_4 are 20, 14, 10 and 8 mm irrigation levels and W_5 is control (from 82.0 to 4.2 mm).

Fig. 2



Response of water stress on periodical growth parameters of *D. sissoo* seedling (a) height, (b) collar diameter, (c) number of leaves and (d) total leaf area. W_1, W_2, W_3, and W_4 are 20, 14, 10 and 8 mm irrigation levels and W_5 is control (from 82.0 to 4.2 mm).

100% in W_5 as compared to the total leaf area in May 1999 in the respective treatments. Among the treatments, soil water deficit caused a decrease in leaf number and total leaf area by 54% and 58% for W_3 and 89% and 91% for W_5, respectively than in the seedling of W_1 treatment.

Table 2

Growth and growth component of nine months old seedlings of D. sissoo affected by different levels of soil water availability.

Growth variables	W_1	W_2	W_3	W_4	W_5	P value
Height (cm)	97 (1.9)	90 (2.1)	77 (1.5)	71 (2.1)	60 (1.9)	0.001
Collar diameter (cm)	0.96 (0.01)	0.91 (0.01)	0.74 (0.01)	0.70 (0.03)	0.48 (0.02)	0.001
Number of branches	15 (1.2)	11 (0.7)	11 (0.9)	10 (0.7)	5 (1.0)	0.001
Leaf area expansion (x 10^{-4} m^2 day^{-1})	15.0 (0.14)	13.0 (0.19)	6.0 (0.18)	4.3 (0.30)	1.1 (0.11)	0.001
Leaf size (cm^2)	4.1 (0.16)	4.1 (0.23)	3.6 (0.20)	3.4 (0.16)	3.0 (0.45)	0.001
Number of leaves	704 (12.4)	640 (16.7)	327 (15.1)	268 (13.8)	80 (5.1)	0.001
Total leaf area (cm^2)	3140 (34.5)	2857 (41.3)	1322 (41.3)	775 (70.3)	272 (21.5)	0.001
Relative growth rate (g g^{-1} day^{-1} x 10^{-3})	18 (0.2)	17 (0.3)	13 (0.2)	11 (0.6)	8 (0.4)	0 .001
R mass /shoot mass ratio	0.68 (0.03)	0.58 (0.02)	0.80 (0.02)	1.02 (0.07)	1.18 (0.08)	0.001
Leaf area/Root dry weight ratio	118.8 (6.6)	144.0 (2.9)	117.9 (2.6)	92.8 (3.8)	57.3 (3.0)	0.001

Values are means of eight replicates with standard error in the parentheses.
W_1, W_2, W_3, and W_4 are 20, 14, 10 and 8 mm irrigation levels and W_5 is control (from 82.0 to 4.2 mm).

Growth component : Relative growth rate (RGR) was 0.018 g g^{-1} day^{-1} in W_1. RGR decreased to 0.013 g g^{-1} day^{-1} (28% reduction) in W_3 and 0.008 g g^{-1} day^{-1} (56% reduction) in W_5 seedlings. Root biomass/ shoot biomass (R/S) ratio was lowest for the seedlings of W_2 and increased from W_3 to W_5 treatments (Table 2). Seedlings of W_1 treatment had higher R/S ratio than in the W_2 treatment. Ratio of leaf area to root dry weight (LA/RDW) was highest in W_2 seedlings and decreased with water stress (60% reduction in W_5 than in W_2 seedlings).

Experiment II

Root growth potential (RGP) was highest ($P<0.001$) than the stressed seedlings of for the seedlings of W_1 treatment and decreased with decreasing the irrigation levels (Table 3). RGP of seedlings in W_2 dropped by 27% in term of root length and 43% in term of root dry weight as compared with the seedling of W_1 treatment. Further increase in soil water stress to W_3 resulted in 60% decline in root length and 63% decline in root dry weight. The decline in RGP continued in the seedlings of W_4 and W_5 treatments.

Discussion

Dalbergia sissoo seedlings indicated significant changes in root and shoot growth and leaf area accretion under varying levels of soil water regime. Larger ($P<0.001$) root and seedling dry matter in W_1 as compared to those in the other treatments was due to rapid growth of roots for utilization of available soil water (Table 1). RGP test also suggested larger root and greater root dry weight in the seedlings of W_1 (Table 3). A respective reduction in root length and root dry weight by 60% and 63% in W_3 and 87% and 95% in W_5 seedlings in RGP test might be due to loss in turgidity and vigour in the seedlings. Similar observations have been recorded in the studies of Tinus (1996) and Landis and Skakel (1988) in which non-stressed seedlings showed maximum RGP and indicated a reduction in RGP with soil water stress. Relatively greater reduction in the secondary root length (by 42% and 66% in W_3 and W_4) as compared to the primary root length (30% and 41% in the respective treatments) suggested that the adverse effect of soil water stress was greater on development of secondary roots than on the primary roots. This affected water and mineral absorption and regulated leaf initiation, expansion, and other development processes as observed by Fort *et al.* (1998). It therefore suggests that the rate with which new roots absorb water and minerals varies with root length and total root biomass. Our results are consistent with the result of Smit and Driessche (1992) where similar water stress response was reported for the seedlings of *Pseudotsuga menziesii*.

Greater height and collar diameter in the seedlings of W_1 and W_2 was due to maintenance of cell turgor maintaining greater total growth and biomass under sufficient soil water availability. Similar ($P>0.05$) height in the seedlings of W_1 and W_2 treatments suggested that mild soil water stress did not affected height growth of *D. sissoo* seedlings. Tinus (1996) reported that drought stress at the assumed turgor loss point reduced RGP by half but did not reduce survival or height growth. High rate of LAE in the W_1 seedlings is indicative of the greater leaf size and leaf area (Table 2). Higher soil water availability resulted in increase in leaf area and numbers of leaf and ultimately height and

Table 3
Influence of soil water stress on root growth potential of D. sissoo seedlings.

Parameter	W_1	W_2	W_3	W_4	W_5	P value
Root length (cm)	15 (0.09)	11 (0.93)	6 (0.05)	4 (0.04)	2 (0.09)	0.05
Root dry weight (g)	0.65 (0.07)	0.37 (0.02)	0.23 (0.02)	0.11 (0.01)	0.03 (0.003)	0.05

Values are mean of six replicated with standard error in the parentheses.
W_1, W_2, W_3, and W_4 are 20, 14, 10 and 8 mm irrigation levels and W_5 is control (from 82.0 to 4.2 mm).

collar diameter. Higher leaf area might have converted more solar energy to produce more photosynthates and thus greater growth and biomass production in poplar (Souch and Stephens, 1998)

Significantly ($P<0.001$) low number of leaves (a reduction by 54%) and leaf area (by 58%) in the seedlings of W_3 as compared to those in the W_1 treatment was due to increased severity in soil water deficit that affected leaf biomass. Therefore, reduced rate of leaf production and expansion in the seedlings of W_3, W_4 and W_5 caused a decline in the leaf biomass and seedling growth. Roden *et al.* (1990) recorded similar observations on number of leaves, leaf size, total leaf area and leaf biomass under water deficit indicating sensitivity of LAE to water stress. A decrease in total leaf area with continuous depletion of soil water in the seedlings of W_5 treatment was due to low rate of LAE. It was consistent to the observations on leaf production and enlargement in *Eucalyptus globulus* (Metcalfe *et al.*, 1990) and poplar seedlings (Souch and Stephens, 1998). Leaf area expansion up to >75% in W_3 and W_4 and 100% in W_5 (Figure 2c) by March 1999 as compared to the leaf area in May 1999 is indicative of adaptation to the xeric environment. It was probably to increase carbon stock during the spring season (Goulden, 1996) or before the growing conditions become more adverse. Though the total leaf area reduced significantly with water stress and the reduction was highest for the severely stressed seedlings of W_5 treatment (91% reduction) indicating that the effect of soil water stress was greater on leaf growth than the growth of other parts of the seedling. Reduction in growth rate at sever water stress has also been reported by Paulilo *et al*. (1998) for *Quercus grandiflora* and Alvarenga *et al*. (1994) for *Eucalyptus grandis*.

Low root to shoot dry mass (R/S) ratio in W_2 as compared to W_1 seedlings was due to less accumulation of photosynthates in the root of the seedling of W_2 and was a useful utilization and balancing of carbon allocation in *D. sissoo* seedlings. Increase in R/S ratio with water stress was believed to be due to reduced shoot growth, particularly leaf, which was probably more sensitive to water stress than the root. This is supported by a reduction in above ground biomass by 66% to 90% in the seedlings of W_3 to W_5 treatment as compared to only 26% to 82% reduction root biomass indicating greater partitioning of photosynthates towards root as compared to shoot at soil water stress.

Conclusion and Recommendations

Low level of irrigation reduced root and shoot growth in *D. sissoo* seedlings and leaf was the most affected part. Seedlings exhibited early leaf area development under soil water deficit to increase carbon assimilation. Reduction in growth variables was greater between W_2 and W_3 level and again for the seedlings of W_5 treatment. Soil water content of 1.73% (-1.96 MPa) and 0.56% (i.e., -2.02 MPa) resulted in drying of leaf and death of the seedlings, respectively and were critical points of seedling survival. Growth of W_2 seedlings was equally good as in W_1 for which carbon allocation in shoot was high. Below W_2 (i.e., W_3 to W_5) growth reduction was significantly greater indicating that W_2 level of irrigation is the critical limit for growth. Conclusively, *D. sissoo* showed moderate tolerance to water stress and required >50% of soil field capacity for better growth. The tolerance limit of soil water potential for survival was –1.96 MPa below which, *D. sissoo* could not survive. Thus, irrigation above 50% of soil filed capacity will be the optimum for best growth and biomass productivity. Irrigation below 50% of soil filed capacity will only conserve the seedlings for survival.

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SUMMARY

Leaf, shoot, root growth and root growth potential of *Dalbergia sissoo* Roxb. ex. DC. Prodr seedlings were studied at irrigation levels of 20 (W_1), 14 (W_2), 10 (W_3), and 8 (W_4) mm with a view to determine the optimum level of irrigation for better growth and development. Treatments were maintained by re-irrigation when water content of the soil reached 7.4 % in W_1, 5.6 % in W_2, 4.3 % in W_3, and 3.2 % in W_4. Seedlings in a control (W_5) were left without irrigation after maintaining the soil field capacity (10.7 %). Height, collar diameter, number of branches, leaves and root growth potential decreased ($P<0.01$) with soil water stress. The differences in height and collar diameter between W_1 and W_2 treatments were not significant but the seedlings of W_3 had less height, collar diameter, number of branches, leaves, root growth potential and root dry weight. The stressed seedlings tended to maximize leaf area before the environmental condition become more adverse. Leaf area/root dry weight ratio was high whereas root/ shoot dry mass ratio was low for the seedlings under W_2 treatment. With increasing stress from W_2 to W_3, growth reduction was high and may be the critical point. Seedlings of W_5 treatment survived till Ψs of –1.96 MPa. Thus W_2 treatment was the best where seedlings showed high above ground/root dry weight ratio and was maintained by addition of half quantity of water than that in W_1. The results indicate that *D. sissoo* seedlings is moderately tolerant to water stress and had high growth when soil water status was >50% of soil field capacity.

शुष्क पर्यावरण में *डलबर्गिया सिस्सु* पौधों की बढ़वार और जड़वृद्धि क्षमता पर मृदा जल की कमी से पड़ता प्रभाव

विलास सिंह व जी० सिंह

सारांश

डलबर्गिया सिस्सु राक्स० निषेध डीकै० प्रोडर० पौधों की पत्तियों, प्ररोहों जड़ों की बढ़वार और जडें बढ़ने की संभावनाओं का अध्ययन 20 (W_1), 14 (W_2), 10 (W_3) और 8 (W_4) मिमी सिंचाई स्तरों पर उनकी श्रेष्ठतर बढ़वार और विकास के लिए सिंचाई का इष्टतम स्तर विनिश्चित करने की दृष्टि से किया गया। जब मृदा का जल स्तर W_1 में 7.4% पर, W_2 में 5.6% स्तर पर, W_3 में 4.3% स्तर पर और W_4 में 3.2% स्तर पर पहुंच गया तो पुनः सिचांई करके उपचारों को वांछित स्तरों पर रखा गया। नियामक (W_5) के पौधों को मृदा की क्षेत्र धारिता (10.7:) बनाए रखने के बाद बिना सिंचाई किए छोड़ दिया गया। जब मृदा में जल की कमी हो गई ($P<0.01$) तो पौधों की ऊंचाई, मूलसंधि पर व्यास, शाखाओं, पत्तियों की संख्या और जड़ें बढ़ने की संभावनाए घट गई। W_1 और W_2 उपचारों में पोधों की ऊंचाई और मूलसंधि पर व्यास में कोई खास अन्तर नहीं था परन्तु W_3 उपचार वाले पौधों की ऊंचाई, मूलसंधि पर व्यास, शाखाओं, पत्तियों की संख्या, जड़ों की बढ़ने की संभावनाएं और जड़ों का शुष्क भार कम हो गए थे। कमी से प्रभावित हुए पौधों ने पर्यावरण दशाएं और ज्यादा प्रतिकूल बन जाने से पूर्व अपना पर्णक्षेत्र अधिकतम बनाने की प्रवृति दिखाई थी। पर्णक्षेत्र/जड़ों के शुष्क भार का अनुपात

अधिक या उच्च था किन्तु जड़ों/प्ररोहों के शुष्कपुंज का अनुपात W_2 उपचार वाले पौधों में कम या निम्न था। कमी का दबाव W_2 से बढ़कर W_3 का हो जाने पर, बढ़वार में कमी ज्यादा हो गई और हो सकता है क्रान्तिक बिन्दु की हो गई हो। W_5 उपचार के पौधे –1.96 MPaΨs तक जीवित बचे रहे। अतः W_2 उपचार सबसे अच्छा रहता पाया गया जिसके पौधे भूमि से ऊपर/जड़ों के शुष्क भार अनुपात में ऊंचे रहे और जिन्हें W_1 उपचार की तुलना में जल की आधी मात्रा अतिरिक्त देने पर ही ठीक–ठाक बनाए रखा जा सका। ये परिणाम संकेत देते हैं कि *ड० सिस्सु* के पौधे जल की कमी से पड़ते दबाव के प्रति मध्यम सहिष्णु होते हैं और उनकी अच्छी बढ़वार तभी होती है जब जल की स्थिति मृदा की क्षेत्र क्षमता से >50% होती है।

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