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# Effect of Irrigation on Growth of Three Tree Species in Indian Arid Zone

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**Abstract:** A trial was initiated in July 1995 to study the performance of *Acacia nilotica*, *Eucalyptus camaldulensis* and *Dalbergia sissoo* under two irrigation levels ($W_1$ = 30 mm and $W_2$ = 45 mm) and three frequencies ($I_1$ = 0.2, $I_2$ = 0.3 and $I_3$ = 0.4) on a loamy sand soil. Irrigation schedule was maintained on the basis of IW/CPE ratio (irrigation water/cumulative pan evaporation). Average height of all three species was best ($P<0.01$) in $I_3W_2$ treatment. In spite of receiving more irrigation water, the average height of plants in $I_3W_1$ was less in comparison to plants in $I_3W_2$ treatment. Same trend was observed in case of collar girth and incremental growth. Variation in soil pH and electrical conductivity was also significant among the treatments. Results show that the quantity of water added per irrigation is more important than the total water applied. $I_3W_2$ treatment provided more soil volume with favorable moisture condition for roots which resulted in better growth.

**Key words**: Irrigation, IW/CPE ratio, *Acacia*, *Eucalyptus*, *Dalbergia*.

Irrigation has for long been recognized as a basic necessity for sustaining high productivity in arid regions, prone to water deficit. Several-fold increase in biomass production in irrigated treatments over control (rainfed) has been reported from different places (Singh *et al.*, 1989, 1993; Gupta, 1994). The amount of irrigation required for optimum growth of different tree species has also been worked out by hit and trial method at different places. Annual water requirement for *Dalbergia sissoo* was reported to be 910 to 1220 mm (Sheikh, 1974). Khan (1966) recommended 1240 mm of water per anum for *Eucalyptus microtheca* in Sudan. It was observed that the local species of arid zone, which are known to be extremely slow growing, responded well to irrigation in IGNP Stage II area of Indian desert (Gupta *et al.*, 1994).

The irrigation method influences the root growth behavior. Excessive watering in early establishment phase results in shallow root system. This results in mortality if watering rates are reduced or discontinued. Localized irrigation may restrict the spread of roots if the wetted rooting zone is too small (Vermeiren and Jobling, 1980). For the same reason, trees under localized irrigation would suffer more stress if the water supply is reduced than trees growing under flood irrigation. Under furrow irrigation the root system is long and narrow and root competition occurs along ridges (Bosshard and Wander, 1966).

To attain maximum production without deterioration of the soil resources, the irrigated plantation need to be raised on scientific principles. Tendency to over-irrigate and faulty irrigation method may slowly raise the groundwater level

and create salinity and water logging. Annual rise in water table in Stage 1 of IGNP area, mainly due to indiscriminate use of water, was reported to be approximately 0.5 m (Gupta *et al.*, 1994). It suggests that specific irrigation practices need to be developed. Therefore, performance of three important species (*Acacia nilotica*, *Eucalyptus camaldulensis* and *Dalbergia sissoo*), under different irrigation regimes was studied. These species have been taken up for large scale plantation in arid zone.

## Materials and Methods

The experiment was conducted at the experimental farm of Arid Forest Research Institute, Jodhpur (situated at 26°45′ N latitude and 72°03′ E longitude), having loamy sand soil underlain by a thick layer of $CaCO_3$ at 75 cm depth. Moisture storage in the upper 75 cm layer varied from 120 mm at 0.1 bar to 35 mm at 15 bar. Organic matter content of the soil was 0.35% and pH was 8.2. Average annual rainfall of the region is 360 mm, with 10 to 15 rainy days. Cumulative pan evaporation recorded at the experimental site was 2666 mm (December 1995 to March 1997). Maximum temperature in the area may reach upto 49°C in summer and minimum may drop to 0°C in winter.

The experiment was initiated in July 1995 with 6 treatment combinations i.e., $I_1W_1$, $I_1W_2$, $I_2W_1$, $I_2W_2$, $I_3W_1$ and $I_3W_2$, where I stands for irrigation frequency ($I_1$ = 0.2, $I_2$ = 0.3 and $I_3$ = 0.4 IW/CPE ratio) and W stands for quantity of water per irrigation (W1 = 30 mm and W2 = 45 mm). Treatments were replicated thrice in factorial RBD. The treatment combinations and species were randomly distributed in the blocks. One-year-old seedlings of *A. nilotica*, *E. camaldulensis* and *D. sissoo* having average height of 64, 70 and 50 cm, respectively, were planted in July 1995. Average height of plants at the time of treatment initiation was 70 cm in *A. nilotica*, 75 cm in *E. camaldulensis* and 53 cm in *D. sissoo*. Saucer shaped catchments of 1.5 m diameter were prepared around each plant to accommodate irrigation water. There were 9 plants per plot at a spacing of 3 x 4 m.

Irrigation, based on cumulative pan evaporation data, was initiated in December 1995. Total water applied was 978, 1008, 1158, 1143, 1338 and 1323 mm in $I_1W_1$, $I_1W_2$, $I_2W_1$, $I_2W_2$, $I_3W_1$ and $I_3W_2$ treatments respectively, including 648 mm received through rainfall. Irrigation interval varied from 10 days in $I_3W_1$ to 25 days in $I_1W_2$ during summer and 20 days to 55 days in winter, respectively. The cumulative pan evaporation, after which irrigation was applied in different treatments, is as follows:

| | $W_1$ | $W_2$ |
|---|---|---|
| $I_1$ (0.2) | 150 | 225 |
| $I_2$ (0.3) | 100 | 150 |
| $I_3$ (0.4) | 75 | 113 |

Plant survival and growth parameters viz., plant height and collar girth (5 cm above the soil surface) were recorded quarterly. Soil samples, 50 cm away from the plants, at three depths (0-25, 25-50 and 50-75 cm), were collected in February 1997. The samples were then air-dried, ground and passed through 2 mm sieve and analyzed for pH, electrical conductivity and per cent soil organic matter by standard methods (Jackson, 1973).

Data on plant height and collar girth, as well as on incremental plant height and collar girth, were statistically analyzed using a two-way ANONA. Levels of irrigation and species (three) were the main factors. Since the interaction of these two main factors were highly significant, the performance of different treatments within a particular species was compared with the help of Duncan Multiple Range Test (DMRT) at 5% level. Three-way ANOVA were performed for soil pH, electrical conductivity and soil organic matter, keeping treatment, species and soil depths (three) as fixed factors.

**Results**

High plant survival was recorded in all the three species though it was more in *A. nilotica* (94%), followed by *D. sissoo* (86%) and *E. camaldulensis* (85%).

*Growth parameters*

The effects of treatments and species and their interactions on growth were highly significant (Table 1). Effect of treatments differed significantly with the species tested. Plants attained greater height and collar girth in $I_3W_2$ treatment for all the species except for *A. nilotica* (Table 2). Incremental height and girth were also high in $I_3W_2$ treatment except in case of *A. nilotica*, where incremental girth was greater in $I_3W_1$ treatment. However, this is not attributed to treatment effect ($P>0.05$). *E. camaldulensis* attained greater average height (371 cm) in $I_3W_2$ treatment, which was at par with $I_3W_1$ (339 cm) treatment. The treatments were arranged into three groups that differed significantly from each other. $I_1W_1$ (172 cm) and $I_1W_2$ (187 cm) treatments were found to be the least performers with no significant difference between them. In case of *A. nilotica* average height of plants in $I_1W_1$ and $I_1W_2$ were at par and the remaining four treatments were placed in one homogenous group ($P>0.05$). Plants in $I_3W_2$ treatment, however, attained greater average height (259 cm) than $I_3W_1$ (237 cm), $I_2W_1$ (233 cm) and $I_2W_2$ (230 cm). In *D. sissoo,* the treatments were arranged into three different groups, highest being in $I_3W_2$, where plants attained average height of 231 cm. The least performer was $I_1W_1$ with an average height of 136 cm.

Performance of these three species varied widely as far as girth is concerned. In case of *A. nilotica* no significant difference was observed at 5% level. Plants in $I_2W_1$ had greater average girth (15.7 cm), the least being in $I_1W_2$ where 12.6 cm of average girth was recorded. In *E. camaldulensis* performance-wise treatments were arranged into three homogenous groups, which were significantly different from each other (Table 2). Highest average girth was recorded in $I_3W_2$ treatment that was significantly different from other treatments. Plants in $I_1W_1$ treatment attained 9.1 cm average girth, which was the lowest. In case of *D. sissoo* the treatments were arranged into two groups. However, highest girth was recorded in $I_3W_2$ and lowest was in $I_1W_1$ treatment.

*Incremental growth*

Incremental height for *A. nilotica* was high (266%) in $I_3W_2$ treatment. This was followed by $I_3W_1$ (253%), $I_2W_1$ (243%) and $I_2W_2$ (220%). Plants in $I_1W_1$ and $I_1W_2$ treatments registered low incremental height, lowest being in $I_1W_1$, and were

*Table 1. Effect of irrigation frequency and levels on growth of tree saplings*

| | MSE | F | P |
|---|---|---|---|
| **Height** | | | |
| Treatment | 22099.050 | 31.792 | 0.000 |
| Species | 35305.020 | 50.790 | 0.000 |
| Treatment x species | 2238.596 | 3.220 | 0.005 |
| **Girth** | | | |
| Treatment | 48.143 | 12.237 | 0.000 |
| Species | 29.765 | 7.566 | 0.002 |
| Treatment x species | 10.439 | 2.653 | 0.016 |
| **Incremental height** | | | |
| Treatment | 68589.352 | 16.344 | 0.000 |
| Species | 10886.463 | 2.594 | 0.089 |
| Treatment x species | 5764.107 | 1.374 | 0.234 |
| **Incremental girth** | | | |
| Treatment | 35209.707 | 3.093 | 0.021 |
| Species | 210487.463 | 18.492 | 0.000 |
| Treatment x species | 5957.196 | 0.523 | 0.862 |

significantly different from other group. *E. camaldulensis* recorded 429% incremental height in $I_3W_2$ treatment. It was followed by $I_3W_1$ (Table 3). Lowest incremental height was recorded in $I_1W_1$ treatment. *D. sissoo* also registered highest incremental height in $I_3W_2$ treatment, which was significantly different from other treatments. Similarly lowest incremental height of 140% was recorded in $I_1W_1$. Comparatively high incremental girth was recorded in $I_3W_2$ treatment for *E. camaldulensis* (476%) and *D. sissoo* (590%). In *A. nilotica* high incremental girth was recorded in $I_3W_1$ and the low in $I_1W_2$ treatment.

*Table 2. Growth of 20-month-old plants as affected by different treatments*

| Treatment | Height (cm) | | | Girth (cm) | | |
|---|---|---|---|---|---|---|
| | *A. nilotica* | *E. camaldulensis* | *D. sissoo* | *A. nilotica* | *E. camaldulensis* | *D. sissoo* |
| $I_1W_1$ | 170a | 172a | 136a | 13.3a | 10.3a | 9.3a |
| $I_1W_2$ | 177a | 187a | 145ab | 12.6a | 9.1a | 10.5a |
| $I_2W_1$ | 233b | 252b | 287abc | 15.7a | 14.3b | 11.9ab |
| $I_2W_2$ | 230b | 279b | 180abc | 14.8a | 16.6b | 12.0ab |
| $I_3W_1$ | 237b | 339c | 197bc | 15.1a | 16.6b | 12.7ab |
| $I_3W_2$ | 259b | 371c | 231c | 14.3a | 19.5c | 16.2b |

Wihtin rows, means followed by the same letter are not significantly different (P >0.05).

*Table 3. Per cent incremental growth of 20-month-old plants as affected by different treatments*

| Treatment | Height | | | Girth | | |
|---|---|---|---|---|---|---|
| | *A. nilotica* | *E. camaldulensis* | *D. sissoo* | *A. nilotica* | *E. camaldulensis* | *D. sissoo* |
| $I_1W_1$ | 143a | 113a | 140a | 269ab | 261a | 397a |
| $I_1W_2$ | 153a | 174a | 175a | 245a | 208a | 421ab |
| $I_2W_1$ | 243b | 245ab | 235a | 265ab | 294a | 470ab |
| $I_2W_2$ | 220b | 242ab | 228a | 284ab | 356a | 493ab |
| $I_3W_1$ | 253b | 364bc | 264a | 326b | 403a | 546ab |
| $I_3W_2$ | 266b | 429c | 430b | 277ab | 476a | 590b |

Within rows, means followed by the same letter are not significantly different ($P > 0.05$).

*Soil properties*

The change in soil pH was significant ($P<0.05$) for treatment and species. Treatment wise pH was high in the soil of $I_1W_2$ at all the three depths in *E. camaldulensis* and *D. sissoo* (Table 4). In *A. nilotica*, however, it varied with depth, being high in $I_1W_2$ and $I_3W_2$ treatments. Low pH was observed in the soil of $I_3W_2$ at 0 to 25 cm depth for *E. camaldulensis* (Table 4). Among trees low pH was observed in soil under *E. camaldulensis* (8.4), followed by *D. sissoo* (8.5) and *A. nilotica* (8.6). The soil pH did not change with soil depth. EC varied significantly among treatments ($P<0.05$) and was high in the soil under $I_2W_1$. Though there was no significant variation in EC as per different soil depths, it was more in deeper soil layers in case of *A. nilotica* and *D. sissoo*. *E. camaldulensis*, however, showed a reverse trend, where EC was low in deeper soil layers. Soil organic matter (mean of species and soil depths) was more (0.37%) in $I_3W_2$ treatment, though the variation was not significant. However, *D. sissoo* had comparatively high (37%) soil organic matter among species.

## Discussion

Among three species *E. camaldulensis* showed largest variation in growth performance, followed by *D. sissoo* and *A. nilotica*. Plants of *E. camaldulensis* in $I_3W_2$ were on an average taller by 116% and thicker by 89% than in $I_1W_1$. In case of *D. sissoo* the plants in $I_3W_2$ treatment were on an average taller by 70% and thicker by 74% than in $I_1W_1$. The plants of *A. nilotica* in $I_3W_2$ treatment were 52% taller and 7.5% thicker than the trees in $I_1W_1$ treatment. The results showed that the height of *E. camaldulensis* plants was affected the most due to irrigation schedule. However, in *D. sissoo* it was collar girth that was affected the most. It appears that because of strong and deep root system (Dwivedi, 1993) *A. nilotica* was not affected much by spot irrigation.

Best performance was recorded in $I_3W_2$ where more water was added per irrigation with 675 mm of total irrigation. Burman *et al.* (1991) reported that watering upto field capacity at 1 and 2 week interval brought about maximum increase in height and stem diameter of *Azadirachta indica* seedlings. However, in the present study

*Table 4. Soil pH, electrical conductivity and organic matter under different treatments of irrigation in April 1997*

| Treatment | pH | | | EC (dS $m^{-1}$) | | | Soil organic matter (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0-25 | 25-50 | 50-75 | 0-25 | 25-50 | 50-75 | 0-25 | 25-50 | 50-75* |
| ***Acacia nilotica*** | | | | | | | | | |
| $I_1W_1$ | 8.7 | 8.7 | 8.5 | 0.18 | 0.20 | 0.20 | 0.31 | 0.35 | 0.43 |
| $I_1W_2$ | 8.8 | 8.5 | 8.5 | 0.24 | 0.20 | 0.25 | 0.31 | 0.33 | 0.35 |
| $I_2W_1$ | 8.4 | 8.0 | 8.0 | 0.54 | 0.56 | 0.56 | 0.36 | 0.26 | 0.32 |
| $I_2W_2$ | 8.6 | 8.5 | 8.6 | 0.15 | 0.16 | 0.19 | 0.39 | 0.34 | 0.31 |
| $I_3W_1$ | 8.5 | 8.5 | 8.5 | 0.28 | 0.28 | 0.26 | 0.36 | 0.34 | 0.35 |
| $I_3W_2$ | 8.8 | 8.5 | 8.5 | 0.13 | 0.21 | 0.14 | 0.32 | 0.31 | 0.37 |
| ***Eucalyptus camaldulensis*** | | | | | | | | | |
| $I_1W_1$ | 8.6 | 8.6 | 8.5 | 0.27 | 0.13 | 0.18 | 0.39 | 0.36 | 0.32 |
| $I_1W_2$ | 8.7 | 8.6 | 8.5 | 0.12 | 0.17 | 0.17 | 0.32 | 0.39 | 0.40 |
| $I_2W_1$ | 8.5 | 8.4 | 8.3 | 0.18 | 0.32 | 0.35 | 0.32 | 0.34 | 0.42 |
| $I_2W_2$ | 7.9 | 8.5 | 8.3 | 0.49 | 0.29 | 0.28 | 0.39 | 0.34 | 0.37 |
| $I_3W_1$ | 8.2 | 8.5 | 8.5 | 0.30 | 0.38 | 0.46 | 0.38 | 0.33 | 0.34 |
| $I_3W_2$ | 7.6 | 7.8 | 8.3 | 0.32 | 0.14 | 0.17 | 0.48 | 0.46 | 0.40 |
| ***Dalbergia sissoo*** | | | | | | | | | |
| $I_1W_1$ | 8.6 | 8.5 | 8.5 | 0.20 | 0.23 | 0.13 | 0.36 | 0.33 | 0.35 |
| $I_1W_2$ | 8.8 | 8.7 | 8.9 | 0.18 | 0.24 | 0.23 | 0.36 | 0.32 | 0.33 |
| $I_2W_1$ | 8.7 | 8.3 | 8.6 | 0.24 | 0.15 | 0.22 | 0.27 | 0.38 | 0.36 |
| $I_2W_2$ | 8.5 | 8.5 | 8.4 | 0.19 | 0.14 | 0.18 | 0.35 | 0.38 | 0.42 |
| $I_3W_1$ | 8.8 | 8.2 | 8.3 | 0.16 | 0.32 | 0.31 | 0.38 | 0.38 | 0.38 |
| $I_3W_2$ | 8.3 | 8.3 | 8.3 | 0.17 | 0.17 | 0.23 | 0.35 | 0.45 | 0.40 |

* Depth in cm.

growth of plants in $I_3W_1$ was less compared to $I_3W_2$ in spite of receiving more amount (690 mm) of total irrigation. Similar observation was made by Gupta *et al.* (1994) where increasing the irrigation frequency after certain level was not found to be beneficial. The study shows that the quantum of water added per irrigation is more important than the total irrigation applied. $I_3W_2$ treatment provided more soil volume with favorable moisture condition for roots where wetted rooting zone was more and thus resulted in better growth. This is in conformity with the finding of Vermeiren and Jobling (1980) who found that if wetted rooting zone is too small, the spread of roots will be restricted and this would affect growth of the trees. Among the species, *E. camaldulensis* was found to be the most irrigation-sensitive.

Comparatively high pH in the soil of $I_1W_2$ was probably due to low quantity of water added to the plants as well as the arid climate. The increase in EC in the lower soil layers might have been due to leaching of salts to the lower soil horizons.

Singh *et al.* (1990) reported a decrease in EC in upper soil layer, which was suggested to be due to leaching of salts from upper soil layer to the lower layers. The reverse trend in case of *E. camaldulensis* regarding EC may be attributed to strong evapotranspirational pull of *E. camaldulensis* as compared to other two species and high uptake of Na from the lower soil layers (Bhati, 2001). Among the species, the soil under *D. sissoo* had comparatively higher soil organic matter and was probably due to high litter addition in comparison to the other two species.

In conclusion, the study suggests that quantity of water per irrigation is more important than the total quantity of irrigation, as evident by the performance of plants in $I_3W_2$ compared to $I_3W_1$.

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