Effect of Different Watering Regimes on Growth Performance of Five Tropical Trees in the Nursery

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Abstract— This study assessed the growth performance of five species namely Acacia tortilis subspecies raddiana, and subspecies spirocarpa, Acacia ehrenbergiana, Azadirachta indica and Eucalyptus microtheca, and evaluated the extent of tolerance to drought. Two experiments were conducted, to assess the level of drought tolerance of the different species used. Seeds were sown directly into polythene bags and portrayed in the conventional and modern nursery respectively. Four irrigation frequencies 3, 6, 9 and 12 days were used. Clay soil was used as planting media in the traditional nursery and the beat moss and clay in the modern nursery. Different growth parameters were studied and evaluated for the five species in the traditional and modern nurseries at Soba, South of Khartoum. Height (cm), collar diameter (mm), canopy diameter (cm), shoot and root length (cm), shoot and root fresh and dry weight (g) were assessed during the nursery stage for the five species. Nine day irrigation frequency was found most suitable in traditional nursery. Whereas in the modern nursery irrigation frequency of 6 days under shade 20% were found to be the most suitable. The exotic, Eucalyptus microtheca, has larger canopy and height, lower root/shoot ratio. Generally little variation was found among the four Acacias. Eucalyptus microtheca produced the highest shoot fresh weight and dry weight with frequent irrigation (3 and 6 days). The performance of Azadirachta indica was generally very poor.

I. INTRODUCTION

Species such as: Acacia tortilis subspecies retina, and subspecies spirocarpa, Acacia ehrenbergiana, Azadirachta indica and Eucalyptus microtheca, have multiple uses for both humans and animals. They fix nitrogen into the soil, reduce desertification, enhance soil moisture conservation and decrease soil erosion. Any meaningful afforestation and reforestation programme of Sudan and Sahel (semiarid) Zones should notably consider these plants in view of their several benefits. People use their wood as a source of fuel wood and building materials. In the recent years, the fuel wood scarcity started to emerge as a result of population growth. The species under study if well managed can contribute to a large extent in solving these critical problems. Both domestic and wild animals feed on leaves, branches and pods, in areas where forage is meager. The drought resistant local species under study are: Acacia tortilis subspecies raddiana, and subspecies spirocarpa, Acacia ehrenbergiana, these species could be regenerated naturally and artificially. Nonetheless, due to their palatability and preference by livestock, presently the natural regeneration of these species is facing difficulties. Because of grazing pressure and human impact these species are considered endangered. There is great need to promote the natural regeneration through protection. Another technique to conserve these species is artificial regeneration by seedlings raised in the nurseries using treated seeds to accelerate germination. Despite the social, economical and ecological importance of these species, very little research has been carried out to pick the best methods for raising them in the nursery. The objective of the study is to assess the growth performance of the five species grown in the traditional and modern nurseries, and their degree of tolerance to drought conditions using different irrigation regimes.

II. MATERIALS AND METHODS

Seeds of the three species, A. tortilis sub sp raddiana, A. tortilis sub sp spirocarpa, A. Ehrenbergiana were collected from Wad Sayedna, 45 Km north of Khartoum, Latitude 14 -18° N and longitude 31-32° E. Viable seeds were processed in the field and brought to the National Seed Center Laboratory, Soba. Seeds of E. microtheca and A. indica were supplied by the National Seed Center, Soba.

Experiment I. The Traditional Nursery:

Acacia seeds were treated with concentrated sulfuric acid (95%) for five minutes, washed thoroughly with distilled water and dried. Dried seeds were then sown (3 seeds per bag) in plastic bags (10 x 20 cm dimension). They were reserved in 10 X 1.2 m seed beds in direct sunlight in Soba Traditional Nursery. Seed beds were constructed with bricks and cement to avoid water loss. Irrigation was carried every two days for one month during the seedlings establishment phase. One month after sowing, the irrigation treatment was applied. Irrigation frequencies used were 3, 6, 9 and 12 day intervals. Flood irrigation of seed bed was used. Seedlings

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were irrigated to field capacity. Planting media used was clay soil. Hand weeding was carried twice during the experiment.

**Experiment II. The Modern Nursery:**

Collected Acacia seeds were treated with concentrated sulfuric acid (95%) for five minutes, washed thoroughly with distilled water and dried. They were then sown in pot-tray (10 X 5 cm). The planting media used was peat moss mixed with clay soil at a ratio of 2:1. Watering frequencies used were 3, 6, 9 and 12 days. Overtop irrigation was applied.

The following parameters were measured for all the seedlings in both nurseries: the shoot height (cm), the canopy diameter (cm) by taking two diameters at the right angle and the collar diameter (mm). Destructive sampling was carried for assessment. A sub-sample of 5 seedlings in each experimental unit was used to measure root length (cm), shoot fresh weight (g), root fresh weight (g), shoot dry weight (g), and root dry weight (g). The root shoot/ratio was calculated using root and shoot dry weight.

**Experimental Design and Statistical Analysis:**

Collected data were analyzed (2160 seedlings in each nursery) as 4 X 6 factorial in a randomized complete block design with three replications (Snedecor and Cochran 1989). Each nursery was considered as a separate experiment. Treatments (four irrigation frequencies and five species) were arbitrarily assigned to 720 seedlings within each block, with 30 seedlings from each species.

Analysis of variance was carried out on each experimental unit (means of 30 seedlings). To cater for the initial variation, the initial height was employed as a Co variable in the traditional nursery. Whereas the initial diameter was used as a covariable for the modern nursery. The following model (Steel and Torrie 1980) was utilized:

\[ Y_{ijk} = \mu + \rho_i + \tau_j + \kappa_k + \tau_i \kappa_k + \beta(X_{ijk} - \bar{X}) + \epsilon_{ijk} \]

Where:
- \( Y_{ijk} \) = dependent variable.
- \( \mu \) = overall mean.
- \( \rho_i \) = effect of the jth block.
- \( \tau_j \) = effect of the ith treatment.
- \( \kappa_k \) = effect of the kth treatment.
- \( \beta \) = regression coefficient.
- \( X \) = independent or covariable.
- \( \epsilon_{ijk} \) = random error.

Significant differences between the means were separated using Fisher’s Protected LSD procedure (Snedecor and Cochran, 1989). Differences were tested for significance at (P ≤ 0.05).

### III. RESULTS AND DISCUSSION

**EXPERIMENT I. TRADITIONAL NURSERY**

**Above Ground Growth Parameters:**

**Irrigation comparison:**

No differences (P = 0.22, R² = 0.60) in tree collar diameter (mm) were observed among all irrigation frequencies.

With reference to seedlings height, it was observed that heights significantly increase (P = 0.049, R² = 0.80) when irrigated every 9 days as compared to other frequencies (Table 1). The increase was 25, 34 and 23% compared with 3, 6 and 12 days respectively. This could be attributed to the longer intervals (moderate stress) will facilitate height development compared to frequent irrigation (3 and 6 days). While longer period (12 days) may perhaps have resulted in negative impact on the seedling development by affecting the water potential. With moderate stress (9 days), the carbohydrates are transported to the root system. The root system will benefit from this supply. By being under less stress compared to the shoot, it will grow better (Hsiao 1973). Moderate stress also has minute effect in carbon uptake (Waring 1985). Nitrogen and mineral uptake by the actively growing root system may concentrate in the shoot. Simon et al, (2011) stated that for tree nurseries, regular watering is necessary to produce good quality seedlings at economic rate. This is because any stagnation in seedling growth or subsequent mortality translates into economic loss to a nursery operator. With the effects of climate change, water will become increasingly scarce in most geographical zones of the world (Morrison et al., 2009).

<table>
<thead>
<tr>
<th>Species</th>
<th>A. microtheca</th>
<th>A. ehrenbergiana</th>
<th>A. raddiana</th>
<th>A. spirocarpus</th>
<th>A. indica</th>
<th>C. deciduala</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>5.59</td>
<td>5.10</td>
<td>5.00 ab</td>
<td>4.88</td>
<td>3.91</td>
<td>-</td>
</tr>
<tr>
<td>Std. Error</td>
<td>0.39</td>
<td>0.14</td>
<td>0.24</td>
<td>0.26</td>
<td>0.11</td>
<td>-</td>
</tr>
<tr>
<td>Height</td>
<td>61.5</td>
<td>44.26</td>
<td>45.19 b</td>
<td>41.1</td>
<td>18.0</td>
<td>9 c</td>
</tr>
<tr>
<td>Std. Error</td>
<td>3.68</td>
<td>2.03</td>
<td>4.31</td>
<td>4.26</td>
<td>0.55</td>
<td>-</td>
</tr>
<tr>
<td>Canopy</td>
<td>41.1</td>
<td>28.03</td>
<td>27.92 b</td>
<td>24.8</td>
<td>23.2</td>
<td>2 b</td>
</tr>
<tr>
<td>Std. Error</td>
<td>3.37</td>
<td>1.87</td>
<td>3.41</td>
<td>2.68</td>
<td>0.87</td>
<td>-</td>
</tr>
</tbody>
</table>

Means in the same row followed by the same letter do not significantly differ from each other. (P ≤ 0.05, Fisher's Protected LSD).

Similar to tree height, it is also observed that the canopy diameter increases (P = 0.042, R² = 0.67) in the same trend as the height. Remarkably, 9 days frequency produced the best canopy compared to other frequencies. As an example, a 39% improvement in canopy diameter compared to 3 and 6 days was observed. This indicates that frequent irrigation is not always suitable for plant growth and development. Since it will negatively affect the root development, which will influence the water and nutrient uptake.

No significant differences (P = 0.74, R² = 0.59) were observed in shoot fresh weight. Likewise, shoot dry weight did not differ (P = 0.78, R² = 0.60) amongst the different irrigation frequency.

**Species comparison:**

Significant differences (P = 0.041, R² = 0.60) were found among species in collar diameter. The diameter of E. microtheca was similar to A. ehrenbergiana and A. raddiana. The collar diameter of all the acacias was similar. A. indica had the smallest diameter (Table 1).

Similar to diameter, significant differences (P = 0.0001, R² = 0.80) in height were observed between species (Table 1). E.
Microtheca produced the tallest shoot. As anticipated, the height of the three acacias, A. ehrenbergiana, A. raddiana and A. spirocarpa, was similar. While A. indica was the shortest. This signifies that E. microtheca as an irrigated species; tend to develop a better above ground biomass compared to the acacias. The acacias being drought tolerant species are liable to develop little above ground biomass to minimize water loss through stomata (Jackson 1966).

The canopy diameter followed the same tendency of height. The canopy of E. microtheca was the largest (P = 0.042, R² = 0.67) compared to all other species. The canopy diameter of the three acacias was similar. The average canopy diameter of the acacias was 35% lower than E. microtheca.

As shown in Table (2), E. microtheca, being a fast growing species, produced significantly higher (P = 0.038, R² = 0.59) shoot fresh and dry weight (P = 0.028, R² = 0.60) than the other species. The shoot fresh weight of E. microtheca, was 1.4 greater than the acacias. The high fresh and dry weight produced by E. microtheca reveal that the priority of carbon allocation is for the new foliage. This is in line with the normal allocation of the carbohydrates suggested by Waring (1985). Furthermore the time when the measurements were taken (February), is within the climax period (August-April) for E. microtheca leafing time suggested by Khan (1963).

Table 2: Shoot fresh and dry weight (g) of the different species.

<table>
<thead>
<tr>
<th>Species</th>
<th>E. micro</th>
<th>A. ehren</th>
<th>A. raddiana</th>
<th>A. spiro</th>
<th>A. indica</th>
<th>C. decidua</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh weight</td>
<td>38.8</td>
<td>16.76</td>
<td>16.04b</td>
<td>14.9</td>
<td>6.39b</td>
<td>-</td>
</tr>
<tr>
<td>Dry weight</td>
<td>18.6</td>
<td>9.68b</td>
<td>8.79b</td>
<td>7.91</td>
<td>2.99c</td>
<td>-</td>
</tr>
</tbody>
</table>

Means in the same row followed by the same letter do not differ (P ≤ 0.05, Fisher’s Protected LSD).

Below Ground Growth Parameters:

Irrigation comparison:

No differences (P = 0.92, R² = R 0.37) were found in root fresh weight, root dry weight (P = 0.80, R² = 0.44) among all irrigation frequencies tested.

No significant effect was detected among the four irrigation frequencies in root/shoot ratio (P = 0.58, R² = 0.87. Likewise, no effect was observed among the different frequencies with respect to root length (P = 0.07, R² = 0.71). Since no difference was noticed between the different frequencies, it is more appropriate to pursue the 12 days system in the traditional nursery when growing those species. This is more feasible and cost effective.

Species comparison:

The data for root parameters of the different species are given in Table (3). Eucalyptus produces root fresh weight similar to the three acacias (P = 0.91, R² = 0.37). Comparable to the root fresh weight the root dry weight of E. microtheca was found to be similar to the acacias (P = 0.44, R² = 0.18). The large aboveground (height and canopy) of E. microtheca, greater transpirational area, will put the plant under higher water stress. This will make this species more suitable in irrigated areas. However, the acacias are more suitable to harsh condition since they tend to develop longer root system that seeks water in deeper soil horizons.

Table 3: Root fresh and dry weight (g) of the different species.

<table>
<thead>
<tr>
<th>Species</th>
<th>E. micro</th>
<th>A. ehren</th>
<th>A. raddiana</th>
<th>A. spiro</th>
<th>A. indica</th>
<th>C. decidua</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh weight</td>
<td>12.8</td>
<td>9.48a</td>
<td>10.73a</td>
<td>10.0</td>
<td>10.0</td>
<td>7a</td>
</tr>
<tr>
<td>Dry weight</td>
<td>5.75a</td>
<td>5.38a</td>
<td>6.04a</td>
<td>5.56a</td>
<td>3.64a</td>
<td>-</td>
</tr>
</tbody>
</table>

Means in the same row followed by the same letters do not differ (P ≤ 0.05, Fisher’s Protected LSD).

Significant differences (P = 0.0001, R² = 0.71) were found among species with regard to root length (Table 4). A. ehrenbergiana, A. raddiana and A. spirocarpa produced significantly longer roots than E. microtheca and A. indica. A. indica yielded the lowest root length.

Significant differences (P = 0.0001, R² = 0.87) were also found among species in root/shoot ratio. A. indica gave the highest root/shoot ratio. The root/shoot of the acacias, A. ehrenbergiana, A. spirocarpa and A. raddiana was similar. In contrast to its above ground superiority, E. microtheca produced the lowest root / shoot ratio.

The species respond differently to the experimental conditions or allocation of photosynthetic. In addition to differences in the distribution of resources, growth may also differ in the way available carbohydrates may be used within each organ system (Ledig, 1983). Plants vary considerably in their capacity to sustain root growth as soil water diminishes (Kramer 1983). Moreover plants that are capable of sustaining root growth in drying soil have roots that are adapted to soil water deficits; accordingly root growth is ceased as soil dries (Davis et al 1989).

Table 4: Root length (cm) and root/shoot ratio the different species.

<table>
<thead>
<tr>
<th>Species</th>
<th>E. micro</th>
<th>A. ehren</th>
<th>A. raddiana</th>
<th>A. spiro</th>
<th>A. indica</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root length</td>
<td>33.1</td>
<td>40.34</td>
<td>39.62a</td>
<td>38.1</td>
<td>26.4</td>
</tr>
<tr>
<td>Std. Error</td>
<td>1.94</td>
<td>2.43</td>
<td>2.50</td>
<td>2.23</td>
<td>1.46</td>
</tr>
</tbody>
</table>

Means in the same row followed by the same letter do not differ (P ≤ 0.05, Fisher’s Protected LSD).

EXPERIMENT II. MODERN NURSERY

Above Ground Growth Parameters:

Irrigation comparison:

Generally different irrigation frequencies did not affect above ground trees growth in the modern nursery.
There was no significant difference in collar diameter between different irrigation frequencies (P = 0.62, R² = 0.76). Similar to the collar diameter, the height was not significantly affected by different irrigation frequencies (P = 0.54, R² = 0.69).

The effect of irrigation frequencies on canopy size was not significant (P = 0.33, R² = 0.73).

No significant differences were found among the four irrigation frequencies (P = 0.27, R² = 0.65) with respect to shoot fresh weight. Also no significant differences (P = 0.54, R² = 0.63) were found amongst the different irrigation frequencies in shoot dry weight.

**Species comparison:**

A. raddiana gave significantly greater collar diameter (P = 0.002, R² = 0.76) compared to E. microtheca, A. indica, but it showed no significant difference in collar diameter compared to A. ehrenbergiana and A. spirocarpa. No differences in diameters were observed between E. microtheca and A. indica. Also there was no difference in collar diameter among the different Acacia species. Generally Acacias had larger diameter compared to the other species.

Trees height followed the same trend as the collar diameter. A. raddiana was remarkably taller (P = 0.002, R² = 0.69) compared to E. microtheca, A. indica. No difference in height was observed among E. microtheca, A. indica. The height of the acacias was larger than other species particularly A. raddiana.

Concerning the canopy size, A. raddiana attained the largest canopy size compared to A. indica.

The large diameter and height attained by the Acacias are at the expense of a long root system.

Significant differences (P = 0.04, R² = 0.64) were found among species with respect to shoot fresh weight. The shoot fresh weight of all the acacias was similar. Similar performance was reported for E. microtheca and the other acacias. The shoot fresh weight of A. indica was the lowest.

Similar to shoot fresh weight, significant differences were found in shoot dry weight (P = 0.04, R² = 0.65) among the species used. A. raddiana produced the highest shoot dry weight. All the acacias produced similar dry weight.

**Below Ground Growth Parameters:**

**Irrigation comparison:**

No significant difference (P = 0.77, R² = 0.63) in root fresh weight with respect to irrigation frequency. Similarly, irrigation frequency did not affect the root dry weight (P = 0.97, R² = 0.63).

No significant (P = 0.06, R² = 0.72) difference in root length among irrigation frequencies. The root/shoot ratio differed significantly (P = 0.04, R² = 0.68) among irrigation treatments whereby irrigation frequency of 12 days produced higher value than 9 and 6 days.

**Species comparison:**

In contrast to the conventional nursery no significant differences (P = 0.17, R² = 0.63) were found among the different species with regard to root fresh weight. Also no differences were found (P = 0.17, R² = 0.56) in root dry weight. The slight lower performance of the acacias in the below ground parameters is probably due to the small size of pot-trays used. This indicates that smaller size containers will be of negative effect on root growth and development. This is supported by Zimmer and Grose (1958) who studied the physiology of woody plants and stated that, in dry areas, species tend to develop a long tap root with few lateral roots on good sites. Mathers et al, 2007 stated that Growing plants in containers, however, alters root growth and function and can change root morphology. Numerous factors influence root growth in containers. Roots of container-grown plants are subjected to temperature and moisture extremes not normally found in field production.

There was no significant (P = 0.72, R² = 0.52) difference in root length among the six species. This was also applicable to the root/shoot ratio (P = 0.16, R² = 0.68).

**IV. CONCLUSIONS AND RECOMMENDATIONS**

Various benefits are claimed for tree legumes. Apart from their value for livestock, they are documented for their contributions to farming systems, the welfare of rural populations, and protection of the environment. It is important to reconcile need, environment, and sustainability with choice of species (Shelton, 2000).

- In the traditional nursery, 8-day irrigation frequency was found to be the most appropriate. This frequency if adopted will save time, labor and money, so it is highly recommended to be applied as an irrigation regime in Forests National Corporation’s nurseries when growing the same species under similar conditions.
- In the modern nursery (Finnish nursery) irrigation frequency of 5 days fewer than 20% shade was found to be the most appropriate irrigation frequency. So it is recommended to be adopted in modern nurseries when growing the same species.
- Great variation was found between the indigenous and the introduced species with respect to above and below ground growth. This was attributed to the small leaf area and the higher root/shoot ratio of the indigenous species. On the contrary, the exotics have larger canopy and lower root/shoot ratio.
- It is highly recommended that indigenous tree species should not be overlooked when selecting species for afforestation programme.
- More research is needed for the same species to follow their field performance and adaptation under different dry land conditions.

**V. REFERENCES**


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