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Research article

PHYSIOLOGICAL RESPONSE OF *EUCALYPTUS CAMALDULENSIS* SEEDLINGS UNDER WATER DEFICIT CONDITIONS

Mudawi Mukhtar Elobeid

Department of Silviculture, Faculty of Forestry, University of Khartoum, Khartoum north, Postal Code 13314, P.O Box 32 Shambat – Sudan.
To whom correspondence should be addressed: E-mail: emudawi@hotmail.com

ABSTRACT: Drought is one of the most serious environmental problems that critically affects plant growth and development. In the present study young *Eucalyptus camaldulensis* seedlings were grown under varying levels of irrigation. The main aim of this study was to investigate the response of *Eucalyptus camaldulensis*, an important forest tree species to water deficit conditions. To address this goal, *Eucalyptus camaldulensis* seedlings were maintained in long soil columns containing a mixture of silt: sand in a 2:1 ratio (by volume), respectively under nursery conditions. Growth performance was monitored by taking regular measurements of plant shoot height and stem diameter and the growth rates were determined. Total plant dry mass as well as root-to-shoot ratio were determined to evaluate the impact of water deficit on dry mass production and partitioning. The obtained results indicated that both plant shoot height and stem diameter were significantly reduced and the effect was most substantiated in the seedlings which were irrigated at the longest irrigation interval. Root and shoot growth were adversely affected and in consequence the total plant dry mass as well as root-to-shoot ratio assumed the same patterns like those observed in plant shoot height and stem diameter. These findings might strongly suggest that *Eucalyptus camaldulensis* is rather sensitive to water deficit conditions. Further experiments are required to provide answers underlying the physiological events responsible for the weak performance of *Eucalyptus camaldulensis* under water deficit conditions.
Keywords: *Eucalyptus camaldulensis*, growth, dry mass, water deficit**.**

INTRODUCTION

Trees – like other plants are naturally subjected to a spectrum of biotic as well as abiotic stresses throughout their lifetime. Drought is considered of the most influential abiotic factors that critically limits the growth and productivity of forests particularly in dry regions [1, 2]. Even tree mortality, in most cases though it was primarily attributed to infection by forest insects, however several evidences showed that drought stress had a mediatory role in predisposing trees to infection [3, 4, 5, 6]. Drought conditions trigger a multitude of plant responses ranging from cellular metabolism to changes in growth rates and crop yields [7]. Such responses to water deficit are dependent on the amount of water lost, the rate of loss and the duration of the stressed conditions [8]. These responses are complex and usually expressed in deleterious and/or adaptive changes, and under field conditions these responses can be synergistically or antagonistically modified by the superimposition of other stresses [9]. However, it has been indicated that such plant responses to water stress conditions are species-specific [10].

The primary response of the plant when exposed to water stress conditions is a substantial reduction in its total biomass [11, 12, 13]. It has been postulated that plant growth reduction as a result of water deficit is likely a consequence of both reduced rates of photosynthesis and leaf area development [14, 15, 16]. Physiologically, mild drought induces in plants regulation of water loss and uptake allowing maintenance of their leaf relative water content within the limits where the photosynthetic capacity shows no or little changes. However, severe drought induces in plants unfavourable changes leading to inhibition of photosynthesis and growth [17, 18, 19]. Studies on the physiological and morphological responses of *Populus davidiana* seedlings to progressive drought stress showed that drought caused a decrease in transpiration rate as well as net photosynthesis with an overall reduction in total biomass [20]. Some studies showed that inhibition in plant growth and photosynthetic rates under drought was more pronounced in sensitive plants relative to the less sensitive [21].

An important question is how plants handle such drought stress conditions. Generally, in dry environments plants possess special strategies for adaptation in response to water stress including drought avoidance and drought tolerance mechanisms [22, 23, 24]. For instance, olive trees respond quickly to drought stress conditions by reducing leaf stomatal resistance, a physiological behaviour that can be considered as an adaptational mechanism to water stress [25].

The accumulated knowledge regarding the responses of tree species – particularly *Eucalyptus species* to water stress conditions is quite massive. However, our information on the actual mechanisms giving rise to such responses is far in-complete. The present work was carried out under nursery conditions on young *Eucalyptus camaldulensis* seedlings and the main purpose was to evaluate the physiological behaviour of this species under water deficit conditions. To realise this goal, growth was analysed and related to the patterns of dry matter production, accumulation and partitioning.

MATERIALS AND METHODS

Production of plant materials and experimental conditions

The present work was carried out to investigate the response of young *Eucalyptus camaldulensis* seedlings to water deficit conditions. Germination and early establishment of the seedlings were performed in a nursery under partial shade. *Eucalyptus camaldulensis* seeds, which were collected fresh were directly sown in black non-transparent polythene bags (10 cm diameter X 20 cm height), three to five seeds per bag. The polythene bags were filled with a soil mixture containing silt: sand in a 2: 1 ratio (by volume) respectively, leaving the top 5 cm of the polythene bag as a margin for watering. The bags were perforated (6 holes/ bag) to ensure good aeration and also to facilitate easy drainage of excess water. Irrigation was applied daily by flood irrigation to field capacity for one month. During this phase of seedlings establishment singling was timely carried out. Following this establishment period which lasted for one month, seedlings were transplanted in larger polythene bags (20 cm diameter X 40 cm height) and the plants were allowed to grow further in these containers for one month. Out of the growing stock of the seedlings, 18 seedlings were assigned to conduct the water stress experiment on the basis of uniformity in plant shoot height (mean shoot height 41.17 ± 0.98 cm). Watering was maintained close to field capacity every second day.

Experimental design and water stress treatments

The seedlings chosen for the experiment were divided into three groups of six seedlings each. Each group was assigned for each of the following irrigation intervals: 2 (control), 4 and 6 days representing three different water stress treatments. Irrigation intervals were perfectly maintained till the final harvest of the seedlings. The water stress treatments (i,e., different irrigation regimes) lasted for four weeks.

Growth performance

To monitor growth, plant shoot height and stem diameter at the stem-root interface were regularly determined once a week throughout the experimental period before and after the commencement of water stress treatments. During water stress treatments, the growth rates of these growth variables were calculated for the last two weeks of the water stress treatments.

Dry mass production and partitioning

After four weeks exposure to water stress treatments, the experiment was terminated by destructive harvesting of all the seedlings. Each seedling was separated into shoot and root. The shoot was further divided into leaves and stem. Similarly, the root system was carefully rinsed with distilled water immediately after harvest then divided into coarse and fine roots. The fresh mass of each plant fraction was determined and for dry mass determination all plant materials were oven-dried to a constant weight at 60°C for seven days.

Statistical analysis

Data was statistically treated using the statistical programme JMP 5.1 Start Statistics, 3rd edition (SAS Institute, Inc., Cary, North Carolina, USA). Data were expressed as means of six replicates for each water stress treatment. Analysis of variance was performed as One-Way-ANOVA and the separation of the means was performed by Tukey-test. A probability level of $P \leq 0.05$ was considered to show the statistically significant variations among the means. Means followed by same letters are not significantly different from each other.

RESULTS AND DISCUSSION

The current investigation evaluated the physiological performance of young *Eucalyptus camaldulensis* seedlings under different watering regimes. The water deficit treatments were applied by exposing the seedlings to three different irrigation intervals in an attempt to mimic the variable drought intensities in the field under natural conditions. Both dry mass production and growth performance were evaluated to characterise the response of the seedlings under a four weeks exposure period to varying levels of water stress.

Growth analysis

To monitor the response patterns of *Eucalyptus camaldulensis* seedlings subjected to different levels of irrigation regimes, the growth was assessed by taking regular measurements of two growth variables; plant shoot height and stem diameter. Growth analysis revealed that plant shoot height was not affected when the irrigation interval was extended to four days. However, significant reductions were noticed in growth rates of plant shoot height of the seedlings under the irrigation interval of six days compared to their respective controls (Fig. 1).

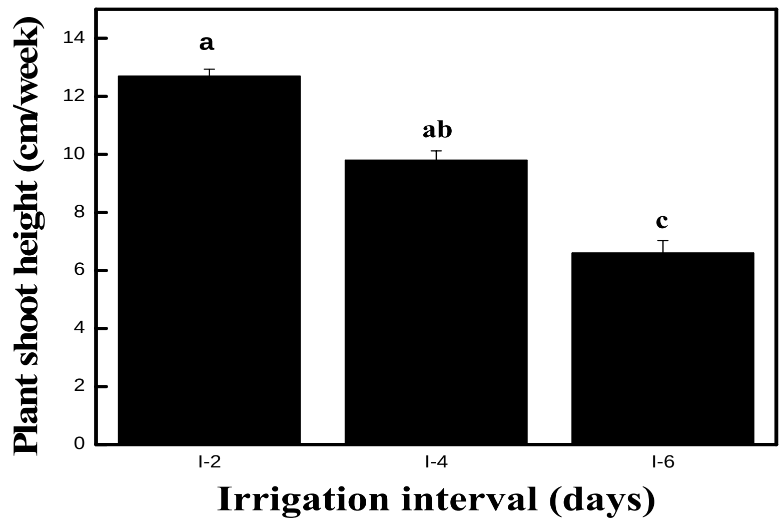

Figure 1: Effect of different irrigation intervals [2 (control), 4 and 6 days] on the growth rate of plant shoot height of *Eucalyptus camaldulensis* seedlings. The water treatments lasted for four weeks. Growth measurements were carried out every week before and after the start of water stress. Values presented are the mean growth rate of six plants per treatment (n = 6, ± SE). Means separation was performed by Tukey-test at $P \leq 0.05$. Means connected by similar letters are not significantly different from each other.

Similar trend was observed in the diameter growth where it was found that the growth rates of the stem diameter were significantly affected only at the longest watering regime, six days interval (Fig. 2).

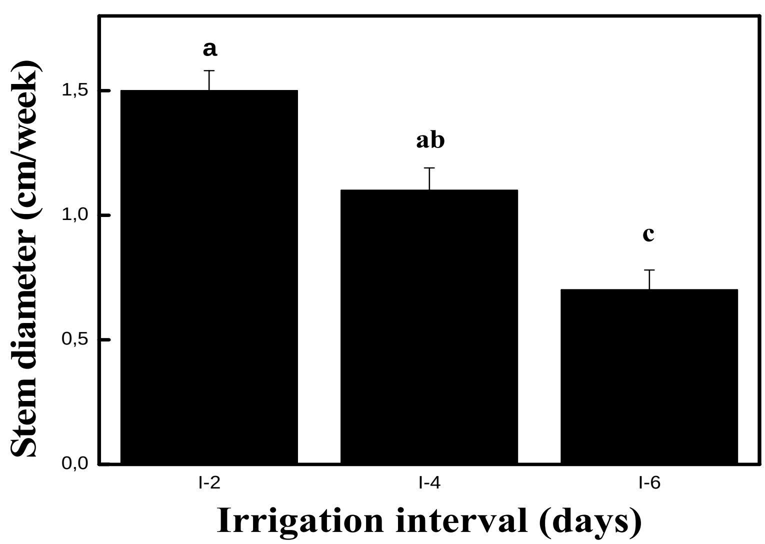

Figure 2: Effect of different irrigation intervals [2 (control), 4 and 6 days] on the growth rate of the stem diameter of *Eucalyptus camaldulensis* seedlings. The water treatments lasted for four weeks. Growth measurements were carried out every week before and after the start of water stress. Values presented are the mean growth rate of six plants per treatment (n = 6, ± SE). Means separation was performed by Tukey-test at $P \leq 0.05$. Means connected by similar letters are not significantly different from each other.

The observed effect of increasing irrigation interval on the growth of both plant shoot height and stem diameter in our current investigation might be in accordance with the findings in outdoor pot-grown eggplants (*Solanum melongena*) where it was found that severe water stress caused reductions in plant shoot height and stem diameter [26].

Dry mass production and partitioning

To evaluate the impact of different levels of irrigation regimes on the growth of *Eucalyptus camaldulensis* seedlings total plant dry mass as well as root-to-shoot ratio were determined. Total plant dry mass was not affected when the seedlings were irrigated every four days, however significant reductions in total plant dry mass were observed in seedlings irrigated at six days interval relative to their corresponding well-watered control seedlings (Fig. 3). Root-to-shoot ratios showed typical patterns where statistically significant reductions were found only in seedlings irrigated every six days (Fig. 4).

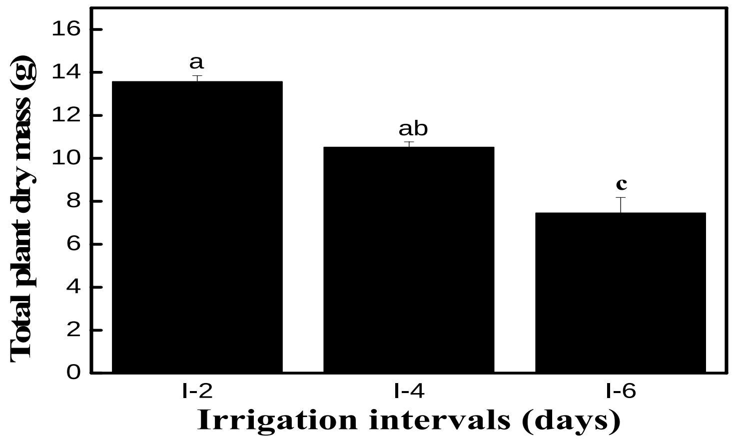

Figure 3: Effect of different irrigation intervals [2 (control), 4 and 6 days] on the total plant dry mass of *Eucalyptus camaldulensis* seedlings. The water treatments lasted for four weeks. Values presented are the mean of six plants per treatment (n = 6, ± SE). Means separation was performed by Tukey-test at $P \leq 0.05$. Means connected by similar letters are not significantly different from each other.

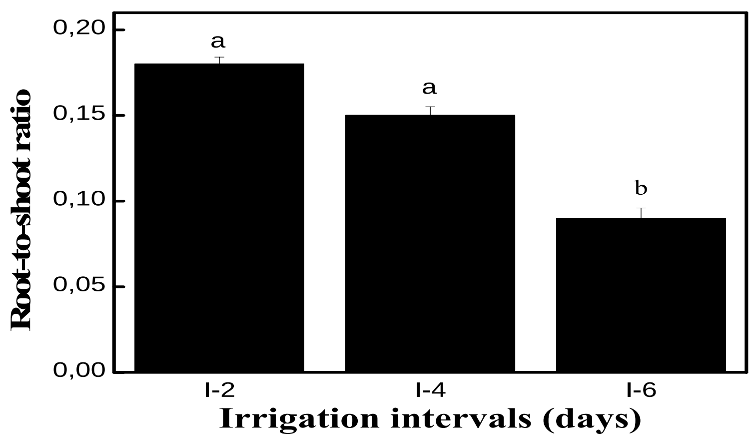

Figure 4: Effect of different irrigation intervals [2 (control), 4 and 6 days] on the root-to-shoot ratio of *Eucalyptus camaldulensis* seedlings. The water treatments lasted for four weeks. Values presented are the mean of six plants per treatment (n = 6, ± SE). Means separation was performed by Tukey-test at $P \leq 0.05$. Means connected by similar letters are not significantly different from each other.

In soybean (*Glycine max*) plants, [27] demonstrated that drought stress negatively affected the photosynthetic gas exchange variables with a consequent decline in photosynthetic rate resulting in significant reductions in the total plant dry mass. In another investigation on *Dalbergia sissso* seedlings, [28] also found reductions in net photosynthetic rates under water stress conditions. Following these reductions the biomass of this species was also reduced at severe soil water stress. .

These fingings might be in well agreement with the reductions in the total plant dry mass observed in our current investigation. With regard to root-to-shoot ratio and in contrast to our findings, [26] found that in pot-grown eggplants (*Solanum melongena*) under severe water stress the root-to-shoot ratio was 2.1 times greater in water-stressed plants indicating that in eggplants the water stress modifies the dry matter pattern and distribution in favour of the root growth. Considering the current findings, it is obvious that the growth of *Eucalyptus camaldulensis* seedlings is quite sensitive to water shortage which might prescribe application of shorter irrigation intervals in the nursery. In conclusion, the present findings demonstrated that water deficit conditions induced adverse alterations in growth performance and dry mass production of *Eucalyptus camaldulensis* seedlings. Further work is needed to elucidate the physiological mechanisms responsible for poor performance of *Eucalyptus camaldulensis* seedlings under water deficit conditions. Better understanding of these physiological mechanisms under such conditions would no doubt help in proper management to optimise the growth conditions via implementing appropriate silvicultural techniques for successful raising of *Eucalyptus camaldulensis* seedlings intended for multipurpose utilization.

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REFERENCES

[1] Teskey RO, Hinckley TM 1986. Moisture Effects of water stress on trees. Forestry Sciences 21: 9 – 33.

[2] Rahbarian R, Khavari-Nejad R, Ganjeali A, Bagheri A, Najafi F 2011. Drought stress effects on photosynthesis, chlorophyll fluorescence and water relations in tolerant and susceptible chickpea (*Cicer arietinum* L.) genotypes. Acta Biologica Cracoviensia Series Botanica 53 1: 47 – 56.

[3] Guarin A, Taylor AH 2005. Drought triggered tree mortality in mixed conifer forests in Yosemite National Park, California, USA. Forest Ecology and Management 218: 229 – 244.

[4] Breshears DD, Myers OB, Meyer CW, Barnes FJ, Zou CB, Allen CD, McDowell NG, Pockman WT 2009. Tree die-off in response to global change-type drought: mortality insights from a decade of plant water-potential measurements. Frontiers in Ecology and the Environment **7**:185 –189. http://dx.doi.org/10.1890/080016.

[5] Ganey JL, Vojta SC 2011. Tree mortality in drought-stressed mixed-conifer and ponderosa pine forests, Arizona, USA. Forest Ecology and Management 261: 162 – 168.

[6] Vacchiano G, Garbarino M, Mondino EB, Motta R 2011. Evidences of drought stress as a predisposing factor to Scots pine decline in Valle d' Aosta (Italy). European Journal of Forest Research, © Springer-Verlag 10.1007/s10342-011-0570-9.

[7] Anjum SA, Xie X, Wang L, Saleem MF, Man C, Lei W 2011. Morphological, physiological and biochemical responses of plants to drought stress. African Journal of Agricultural Research 6 (9): 2026 – 2032.

[8] Bray EA 1997. Plant responses to water deficit. Trends in Plant Science 2 (2): 48 – 54.

[9] Chaves MM, Pereira JS, Maroco J, Rodriues ML, Ricardo CPP, Osorio ML, Carvalho I, Faria T, Pinheiro C 2002. How plants cope with water stress in the field: Photosynthesis and growth. Annals of Botany 89: 907 – 916.

[10] Saraswathi SG, Paliwal K 2010. Drought induced changes in growth, leaf gas exchange and biomass production in *Albizia lebbeck* and *Cassia siamea* seedlings. Journal of Environmental Biology 32: 173 – 178.

[11] Anyia AO, Herzog H 2004. Water-use efficiency, leaf area and leaf gas exchange of cowpea under mild-season drought. European Journal of Agronomy 20: 327 – 339.

[12] Klamkowski K, Treder W 2006. Morphological and physiological responses of strawberry plants to water stress. Agriculturae Conspectus Scientificus 71 (4): 159 – 165.

[13] Alvarez S, Navarro A, Nicolas E, Sanchez-Blanco MJ 2011. Transpiration, photosynthetic responses, tissue water relations and dry mass partitioning in *Callistemon* plants during drought conditions. Scientia Horticulturae 129: 306 – 312.

[14] Kramer PJ, Boyer JS 1995. Water relations of plants and soil. Academic Press, San Diego.

[15] Delfine S, Loreto F 2001. Drought-stress effects on physiology, growth and biomass production of rainfed and irrigated bell pepper plants in the Mediterranean region. Journal of the American Society for Horticultural Science 126 (3): 297 – 304.

[16] Yin CY, Berninger F, Li CY 2006. Photosynthetic responses of *Populus przewalski* subjected to drought stress. Photosynthetica 44 (1): 62 – 68.
[17] Dougherty PM, Hinckley TM 1981. The influence of a severe drought on net photosynthesis of white oak (*Quercus alba*). Canadian Journal of Botany 59: 335 – 341.
[18] Yordanov I, Velikova V, Tsonev T 2003. Plant responses to drought and stress tolerance. Bulgarian Journal of Plant Physiology, Special issue: 187 – 206.
[19] Manes F, Vitale M, Donato E, Giannini M, Puppi G 2006. Different ability of three Mediterranean oak species to tolerate progressive water stress. Photosynthertica 44 (3): 387 – 393.
[20] Zhang X, Zhang R, Li C 2004. Population differences in physiological and morphological adaptations of *Populus davidiana* seedlings in response to progressive drought stress. Plant Science 166: 791 – 797.
[21] Loggini B, Scartazza A, Brugnoli E, Navari-Izzo F 1999. Antioxidative defense system, pigment composition and photosynthetic efficiency in two wheat cultivars subjected to drought. Plant Physiology 119: 1091 – 1099.
[22] Abrams MD 1990. Adaptations and responses to drought in *Quercus species* of North America. Tree Physiology 7: 227 – 238.
[23] Nardini A, Gullo MAL, Salleo S 1999. Competitive strategies for water availability in two Mediterranean *Quercus species*. Plant, Cell and Environment 22: 109 – 116.
[24] Fini A, Bellasio C, Pollastri S, Tattini M, Ferrini F 2013. Water relations, growth, and gas exchange as affected by water stress in Jatropha curas. Journal of Arid Environments 89: 21 – 29.
[25] Saei A, Zamani Z, Talaie A-R, Fatahi R 2006. Influence of drought stress periods on olive (*Olea europaea* L. cv. Zard) leaves stomata. International Journal of Agriculture and Biology 8 (4): 430 – 433.
[26] Kirnak H, Kaya C, Tas I, Higgs D 2001. The influence of water deficit on vegetative growth, physiology, fruit yield and quality in eggplants. Bulgarian Journal of Plant Physiology 27 (3-4): 34 – 46.
[27] Ohashi Y, Nakayama N, Saneoka H, Fujita K 2006. Effects of drought stress on photosynthetic gas exchange, chlorophyll fluorescence and stem diameter of soybean plants. Biologia Plantarum 50 (1): 138 – 141.
[28] Singh B, Singh G 2003. Biomass partitioning and gas exchange in *Dalbergia sisso* seedlings under water stress. Photosynthetica 41 (3): 407 – 414.