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Citation: Yousaf, M.S., Farooq, T.H., Ahmad, I., Gilani, M.M., Rashid, M.H., Gautam, N.P., Islam, W., Asif, M., Wu, P., 2018. Effect of Drought Stress on the Growth and Morphological Traits of *Eucalyptus camaldulensis* and *Eucalyptus citriodora*. PSM Biol. Res., 3(3): 85-91.

Received: April 3, 2018

Accepted: April 30, 2018

Online first: June 24, 2018

Published: June 24, 2018

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Effect of Drought Stress on the Growth and Morphological Traits of *Eucalyptus camaldulensis* and *Eucalyptus citriodora*

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Abstract

Drought stress is the basic ecological stress in growth and development of the trees. A pot experiment was designed to analyze the growth and germination potential of *Eucalyptus camaldulensis* and *Eucalyptus citriodora* against the drought stress via completely randomized designed experiment with four replications along with four stress intervals. Seedlings were raised in pots by irrigating at four different levels i.e. 1 day (W0), 5 day's (W1), 10 day's (W2) and 15 day's (W3). Several morphological parameters were studied. The plant height of both the species was maximum when the plants were irrigated after 1 day time interval and it gradually decreased as the irrigation interval increased. Root length varied drastically against the influence of the drought. Maximum root length 6.5 cm was observed in *E. camaldulensis* when the water was applied after 1 day interval followed by the *E. citriodora* yielding 6.1 cm of the root length against the same treatment. As the irrigation interval increased, the shoot fresh weight decreased leading to the minimum value for the shoot fresh weight at the treatment W3. Root dry weight was more as compared to *E. citriodora* for all treatments. Maximum root-shoot ratio (5.2) was observed in *E. camaldulensis* when the water was applied after 5 day interval (W1). Hence, we suggest that *Eucalyptus* plantation should not be done at fertile agricultural lands as its plantation can be very favorable in waterlogged and saline conditions.

Keywords: Drought stress, Morphology, *Eucalyptus camaldulensis*, *Eucalyptus citriodora*.

INTRODUCTION

In Pakistan, nearly 7.8 million hectares of land is influenced by drought stress which can be mitigated by growing the drought-tolerant species (Irshad *et al.*, 2011). Pakistan is one of the most populated country of the world with a density of 189 persons per square kilometer having an estimated population over 148.72 million (GOP, 2013). According to an estimation, population of the country is expected to reach 250 million by the end of this decade. Assuming that the domestic energy requirement of additional population will met entirely from firewood, thus the total wood demand by the year 2020 would be about 140 million cubic meters for this large population (GOP, 2012).

Climate change is a continuous threat to crop production at global level. Rise in temperature and precipitation patterns as well as increasing drought conditions are the major features of it (Dastagir, 2015), which are resulting extensive loss in agricultural production. Drought resistance in plants is the term that includes a range of mechanism whereby plants withstand a specific period of dry weather (Farooq *et al.*, 2014). Water stress is one of the major problems in plant's ability to tolerate stress (Bartels and Sunkar, 2005). Drought is a period of below normal water availability that reduces plant productivity (Nezhadahmadi *et al.*, 2013) and growth of naturally occurring or cultivated plants (Moumeni *et al.*, 2011).

The plants have evolved some mechanisms to survive with drought like drought escape, drought avoidance and drought tolerance. Generally, plants respond to this stress by accumulation of solutes in cells, osmotic adjustments, thus improving their environmental stress tolerance (Bauer *et al.*, 2013). The quality and quantity of plant growth depends on cell division, enlargement and differentiation which are affected by water stress (Conesa *et al.*, 2016). Water stress in climatic terms is a preserving break of certified moisture interval with an overall all precipitation (Chaves *et al.*, 2003). Drought stress conditions result in poor growth with smaller plant height, root length, and less number of stomata. The growth of a plant under water stress is dependent on its developmental potential and survival rate during the drought period (Bauer *et al.*, 2013). Drought and water stress are some of the major threats that influence production, plant yield and quality (Nezhadahmadi *et al.*, 2013) and the strategies to reduce the effects of drought and water stress are under research investigations (Mwadzingeni *et al.*, 2016). Exploring the water stress tolerance species is necessary for wood based industries for the sustained and balanced growth of agriculture products (Qureshi, 2003). Therefore, several morphological characteristics and growth comparison studies of *E. camaldulensis* and *E. citriodora* as affected by drought stress are included in this experiment. The goal of

the study was to complete the assessment of the effects of drought conditions on the germination and growth of these species.

MATERIALS AND METHODS

Germination and growth of *E. camaldulensis* and *E. citriodora* is effected by different levels of drought stress. To examine this, the experiment was carried out under natural conditions in the experimental area of department of Forestry and Range management, University of Agriculture, Faisalabad during the year 2015-16. Soil and seeds of both the species were collected from the healthy trees of the Forestry departmental nursery. Soil pH was determined with the pH meter (McLean, 1982), organic matter content was determined according to the method of (Nelson and Sommers, 1996), cation exchange capacity with the method of (Rhoades, 1982) and particle size analyses by the pipette method (Kilmer and Alexander, 1949). Soil used in the experiment had exact pH 6.9 and electrical conductivity (EC) (3.61 dsm^{-1}).

Air dried soil was sieved and mixed thoroughly before putting it into the pots. No treatment was given to *E. camaldulensis* and *E. citriodora* seeds. The experiment was conducted in green net house and plastic sheet on its roof but keeping the sides open. There was no air restriction but pots were strictly protected from rainfall water. These conditions were maintained throughout the experimental duration. Completely randomized design (CRD) was used as it was a pot trial of 6 months. Five plants per specie per treatment were used to record and analyze the data by uprooting the plants manually. Cutter was used to separate different plant parts, measuring tape was used to record different parts length, weighing balance was used to record weight and oven was used to dry these plant parts. Recorded data was then analyzed by using statistical software (minitab).

Following irrigation levels were maintained throughout the experiment;

Wo= 1 day interval, W1= 5 days interval, W2= 10 days interval, W3 =15 days interval. Following morphological parameters were studied during the course of experiment;

- 1) Germination rate (%)
- 2) Plant height (cm)
- 3) Root length (cm)
- 4) Shoot fresh weight (gm)
- 5) Root fresh weight (gm)
- 6) Dry weight of shoots (gm)
- 7) Dry weight of roots (gm)
- 8) Root-shoot ratio

RESULTS AND DISCUSSION

Seed germination percentage

As per data recorded, there was no seedling emergence of both *Eucalyptus* species from the 1st day up to 4th day of sowing. It was the 10th day when seedling emergence was started under different irrigation intervals i.e. after 1 day (Wo), after 5 days (W1), after 10 days (W2) and after 15 days (W3). Both of the species of *Eucalyptus* showed significant changes in performance against all the treatments. However, the interaction between the treatments and the species was highly significant. As recorded seed germination percentage (SGP) of *E. camaldulensis* according to observation was 70% while *E. citriodora* showed 62% germination at 1 day interval (Wo), the germination rate of *E. camaldulensis* was 65% higher as compared to *E. citriodora* i.e. 40%. The seed germination percentage (SGP) of *E. camaldulensis* showed 50% while *E. citriodora* showed 35% at (W2). Proper seed germination was the basic requirement for normal growth, increased development and yield of ideal crop. Figure (1) showed that highest SGP was recorded in the seeds of *E. camaldulensis* (70%) and *E. citriodora* (58%) when irrigation interval was only one day. Aranjuelo also mentioned that germination percentage was affected by the water availability variations (Aranjuelo *et al.*, 2010).

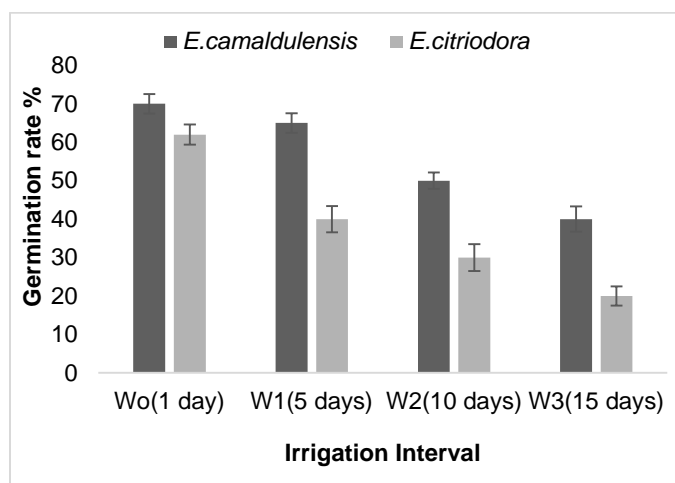


Fig. 1. Mean values of Plant germination as affected by various irrigation time intervals.

Plant height

Plant height varied significantly against all treatments as depicted from the analysis of variance in the figure (2). The comparison of the means by LSD test also categorized the both species and the treatments with respect to their performance which depicted that, both of the *Eucalyptus* species showed significant changes. However, the

interaction between the treatment and the varieties was not significant. Plant height at the termination of the experiment was calculated and showed marked variations at all-time intervals. The plant height of both the species was maximum when the plants were irrigated after 1 day time interval (Wo). The plant height gradually decreased as the irrigation interval increased. Maximum plant height (44.3 cm) was recorded in *E. camaldulensis* for the treatment (W1). Overall, the performance of the *E. camaldulensis* for the plant height was better as compared to *E. citriodora* for all treatments. As the irrigation interval increased, the plant height dramatically decreased leading to the minimum value for the plant height (Cheng & Cheng, 2015) at the treatment W3 as depicted from the figure. Among all the treatments, the treatment (Wo) yielded maximum cumulative value of plant height for both species as compared to all other treatments. Our results showed contrast to (Haworth *et al.*, 2017) who stated that significant differences were not observed in mean height but our results authenticate the findings of (Allen *et al.*, 2010).

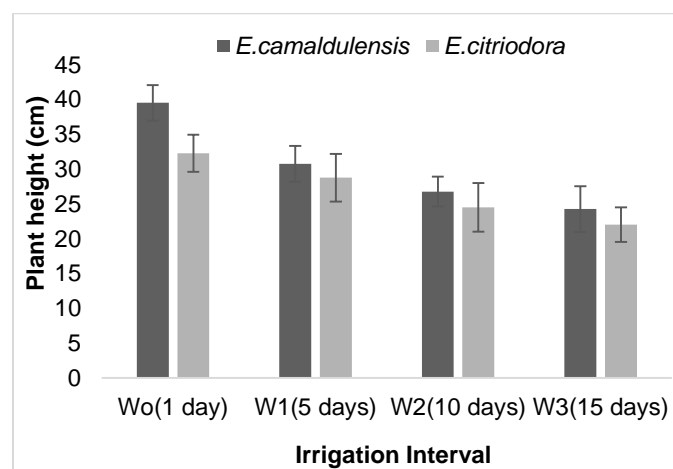


Fig. 2. Mean values of the plant height as affected by various irrigation time intervals (P value 0.0000 < F value 19.20).

Root length

When the performance of the both species for root length against all treatments was compared by LSD test it was clear that root length was influenced significantly against all treatments as predicted from the figure (3). The effect of species on the root length and the interaction between the treatment and the species were significant. Maximum root length 6.5 cm was observed in *E. camaldulensis* when the water was applied after 1 day interval followed by the species *E. citriodora* yielding 6.1 cm of the root length against the same treatment. Similarly, the treatment W1 and W2 performed drastically and yielding 5.6 cm and 5.2 cm for *E. camaldulensis* and 4.8 cm for

E.citriodora respectively. It was obvious from the comparison of means that both of the species behaved differently for the root length. Maximum length of root was recorded against (Wo) in which irrigation was applied after 1 day interval. The treatment (W1) also showed better result as it yielded 5.11 cm of the root length in *E.camaldulensis*. Poor performance with respect to root length was exhibited by the treatment (W3). Irrigation interval is one of the main causes which effect the root growth morphology (Scheres *et al.*, 2016), in their study Ma *et al.*, (2007) and Wu *et al.*, (2000) also found that root lengths are affected by different irrigation intervals.

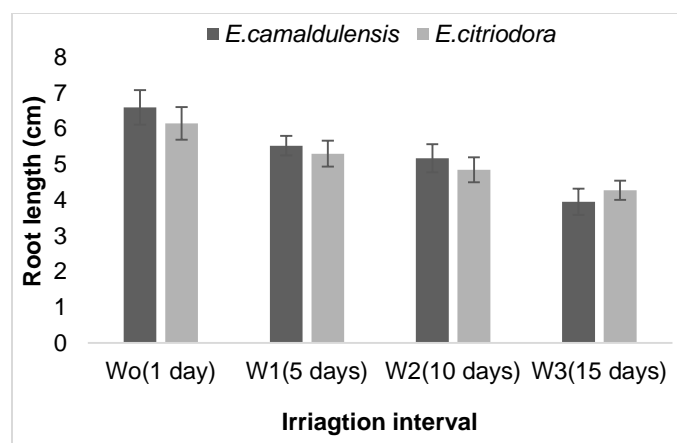


Fig. 3. Mean values of the root length as affected by various irrigation time intervals (P value 0.0000 < F value 12.41).

Shoot fresh weight

Shoot fresh weight varied significantly in all treatments as depicted from the analysis of variance in the figure (4). The comparison of the means by LSD test also categorized for both the species and the treatments with respect to their shoot fresh weight. Both of the *Eucalyptus* species showed significant changes in performance for shoot fresh weight in all treatments. However, the interaction between the treatment and the species was not significant. Shoot fresh weight at the termination of the experiment was calculated and it showed variation in all irrigation intervals. The shoot fresh weight of both the species was maximum when the plants were irrigated after one day time interval. The shoot fresh weight gradually decreased as the irrigation interval increased. Maximum shoot fresh weight (15.5 g) was yielded by the *E. citriodora* also by the same cultivar for the treatment W1. Overall, the performance of the species *E. citriodora* for the plant height was better as compared to species *E. camaldulensis* for all treatments. As the irrigation interval increased, the shoot fresh weight dramatically decreased leading to the minimum value for the shoot fresh weight at the treatment (W3) as depicted

from the figure (4). Our results showed that irrigation had an direct impact on plant root growth and shoot fresh weight varied among different irrigation levels. When drought stress occurs it affects the yield and production by affecting the weight and number of branches (Nawaz *et al.*, 2013b). According to one study, plant height, shoot weight, leaves area and plant biomass showed a decline in response of less-water conditions (Sirousmehr *et al.*, 2014). They noted negative correlation of head diameter values with fresh root and shoot weights under water stress conditions while positive correlations were mentioned between dry shoot weight and yield of achene per plant.

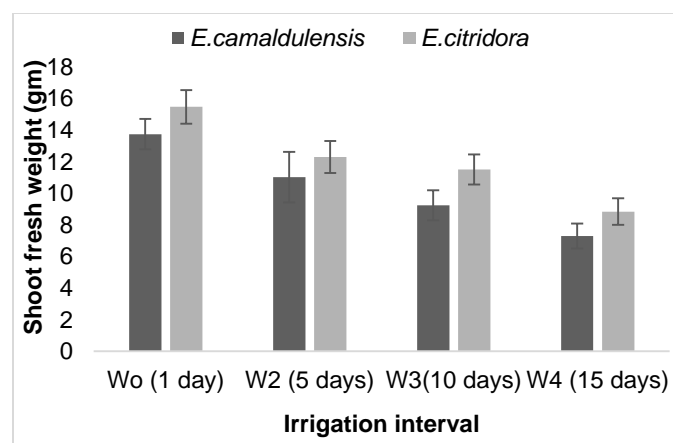


Fig. 4. Mean values of the Shoot fresh weight as affected by the irrigation time intervals (P value 0.0000 < F value 19.35)

Root fresh weight

When the performance of the both species for root fresh weight against all treatments was compared by LSD Test, it was found that root, fresh weight was influenced significantly against all treatments as predicted from the figure (5). Similarly, the effect of species on the root length was also significant. However, the interaction between the treatment and the species was not significant. Maximum root fresh weight (6.9 g) was produced by the cultivar *E. camaldulensis* when the water was applied after 1 day interval followed by the species *E. citriodora* yielding 5 g of the root fresh weight against the same treatments. Similarly, the treatment W1 and W2 performed drastically and yielding 5.8 g and 4.3 g for *E.camaldulensis* and 4.2 and 3.0 g for *E.citriodora* respectively. It was obvious from the comparison of means that both of the species behaved differently for the root fresh weight. Maximum root fresh weight (5.96 g) was yielded against (Wo) in which irrigation was applied after 1 day interval. The treatment (W1) also showed much better results as it yielded 5.097 g of the root fresh weight. Poor performance with respect to root fresh weight (2.607 g) was exhibited by the treatment (W3).

Water shortage is responsible to decline the biomass in fibrous roots of *Avocado* varieties. Substantial losses in fresh weight, leaf area and root length and effects of soil drought on growth resulting in the increase of root and decrease in number and area of leaves (Allen *et al.*, 2010).

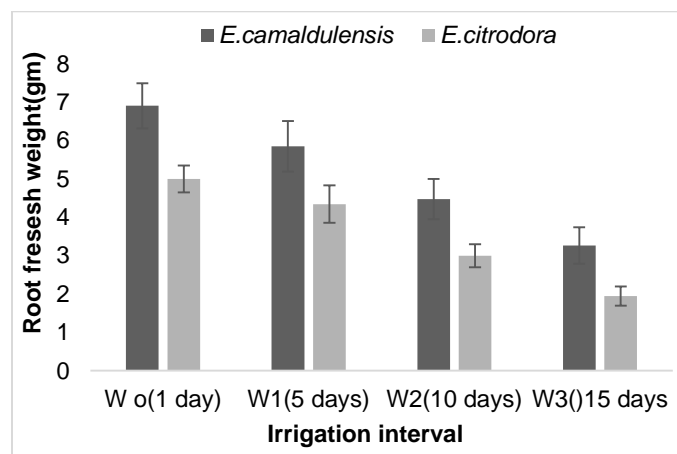


Fig. 5. Mean values of the root fresh weight as affected by the irrigation time intervals (P value 0.0000 < F value 16.5).

Shoot dry weight

Analysis of variance revealed that, the dry weight of the shoot was significantly affected by all treatments. Similarly, the effect of the species was also significant as indicated by the figure (6). It was clear from the analysis that the interaction between the treatments and the species was also not significant. In general, the dry weight of the shoot in response to all treatments showed variation in their values. The comparison of the both cultivars with respect to the dry weight of the shoot depicted that among both the *E.camaldulensis* produced the maximum dry weight of shoot (5.98 g) followed by *E.citriodora* (5.3 g) for the treatment Wo. It was obvious from the results that, the dry weight of shoot gradually decreased as the irrigation interval increased. The minimum (2.3 g) values for the dry weight of shoot were recorded in the species *E.citriodora* at the irrigation interval of 15 days. Soil moisture shortage positively decreased shoot dry matter weight (Nawaz *et al.*, 2013a) and area of leaf in alfalfa crop plants but there was very less impact of soil moisture treatments. Water deficit decreased leaf area and plant dry weight while stem length showed less effect as compare to other root traits (Aranjuelo *et al.*, 2010).

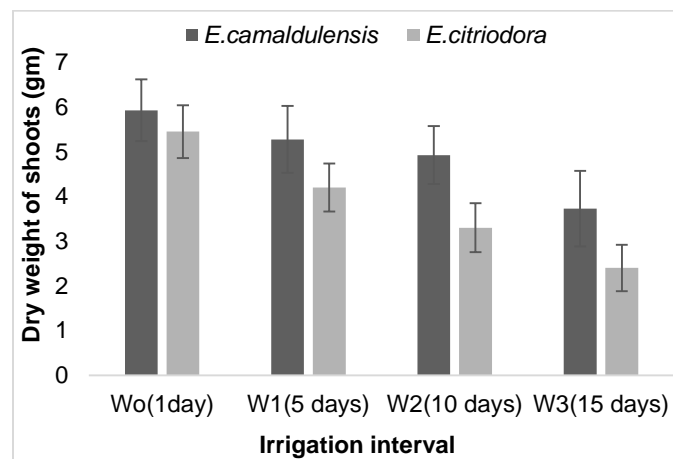


Fig. 6. Mean values of the shoot dry weight as affected by the irrigation time intervals (treatment P value 0.0041 < F value 5.77).

Root dry weight

Analysis of variance revealed that, the dry weight of the shoot was significantly affected by all treatments as. Similarly, the effect of the species was also significant as indicated by the figure (7). It was clear from the analysis that, the interaction between the treatments and the species was also not significant. The value of the dry weight for root at the termination of the experiment was calculated and did vary at all irrigation time intervals. The dry weight of the root of both the species was maximum when the plants were irrigated after one day time interval. The root dry weight gradually decreased as the irrigation interval increased. Maximum root dry weight (5.88g) was yielded by the species *E.camaldulensis* in (Wo) followed by the same species for the treatment W1. Over all the performance of the variety *E.camaldulensis* for the root dry weight was better as compared to variety *E.citriodora* for all treatments. Our results are more or less similar to (Allen *et al.*, 2010) who reported that, in wheat cultivar drought stress inhibited the growth of root elongation, fresh weight, dry weight (Nawaz *et al.*, 2013a) and a leaf area in wheat variety.

CONCLUSION

The plant height gradually decreased as the irrigation interval increased. Root length varied drastically against the influence of the drought. Maximum root length was produced by the *E.camaldulensis* when the water was applied after 1 day interval followed. As the irrigation interval increased, the shoot fresh weight decreased leading to the minimum value for the shoot fresh weight at the treatment W3. Root dry weight was better in *E.camaldulensis* against all treatment as compared to *E.*

citriodora. Maximum root-shoot ratio was observed in *E. camaldulensis* when the water was applied after 5 day interval (W1). It was observed that by increasing the irrigation interval the growth of *E. camaldulensis* was more as compared to *E. citriodora*. As in Pakistan, water shortage in future is a continues threat, so our research can be a small gateway for future large scale researches on this important topic to find the optimum levels of irrigation intervals from where more benefit can be drawn.

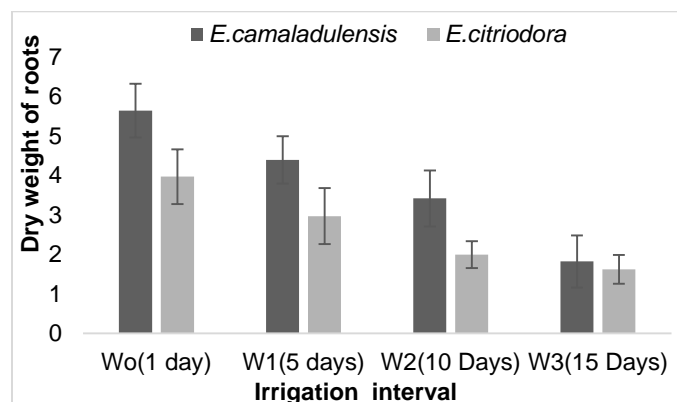


Fig. 7. Mean values of the root dry weight as affected by the irrigation time intervals (P value 0.0003 < F value 9.32).

ACKNOWLEDGEMENTS

We are highly thankful to Dr. Muhammad Farrakh Nawaz for his guidance in project makeup. We would also like to thank Mr. Muhammad Furqan Shaheen for his support in conducting field experiment and data analysis.

CONFLICT OF INTEREST

All the authors have declared that no conflict of interest exists.

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