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Original Article

Mortality of tropical forest tree seedlings under water and salt stress conditions

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ABSTRACT

Mortality of selected tropical forest tree species seedlings, *viz.*, *Tectona grandis, Pongamia pinnata*, *Dalbergia latifolia,* and *Gmelina arborea* were tested under water and salt stress conditions for 4 months under nursery stage. Water stress included moderate and severe waterlogging and moderate and severe drought conditions. The salt stress in the soil was maintained to 4, 8, and 12 ds/m. Pot culture experiments with 20 treatment combinations following randomized block design factorial design were conducted in Tropical Forest Research Institute, Jabalpur Nursery. The water equivalent to the field capacity of the soil was provided to the seedlings to maintain waterlogging. The drought condition in polybags was maintained according to the permanent wilting point (PWP), which was calculated on the basis of cumulative pan evaporation (CPE) values measured through Open Pan Evaporimeter. Mortality of seedlings of the species under study increased with the increase in salt concentration from 4 to 12 ds/m. *G. arborea* shows 100% mortality in 4, 8, and 12 ds/m concentration of salt. Cumulative effect of salt and waterlogging and salt and drought was found to be more prominent in *G. arborea* as compared to other three species. *T. grandis* was found to be more tolerable to waterlogged followed by drought conditions. Waterlogging conditions observed to be excellent for *P. pinnata* seedlings plantation shows 0% mortality. As a whole, the mortality of seedlings due to water and salt stress was found in the order *D. latifolia* (90.95%) > *G. arborea* (82.50%) > *T. grandis* (74%) > *P. pinnata* (35.56%).

KEY WORDS: *Dalbergia latifolia,* drought, *Gmelina arborea*, mortality, *Pongamia pinnata*, salt stress, waterlogging, *Tectona grandis*

INTRODUCTION

The problem of degraded and wastelands is increasing largely in India due to improper utilization of land resources by anthropogenic activities and changing the climate (Gabriels and Cornelis, 2007). About 20.17% of the total geographic area which is 328.2 M ha (Trivedi *et al.*, 2010) is covered under wasteland in India, of which, some of the abiotic stressed lands such as waterlogged and marshy land covers 0.52% and salinity lands cover 0.65% (National Remote Sensing Agency, 2000). Plants encountered by various abiotic stresses in wastelands (Bhattacharyya, 2012) are getting adversely affected, consequential into increasing mortality (Harfouche *et al.*, 2014). The increasing deforestation situation due to abiotic stresses and climate change is expanding the area of degraded lands which is increasing the challenging situation for growing population demand (FAO, 2016). Therefore, to maintain the proper balance between nature and livelihood, there is need to convert wastelands into productive land for agricultural and non-agricultural uses (National Remote Sensing Agency, 2000). For this purpose, there is a requirement to raise the plantation of environment-friendly and economically important plants, not only to make the land productive but also valuable.

In the present study, four tropical forest tree species seedlings, *viz.*, *Dalbergia latifolia, Gmelina arborea, Tectona grandis,* and *Pongamia pinnata* have been selected on the basis of good plantation and economic value. The effect of abiotic stresses (drought, waterlogging, and salinity) on the mortality rate of selected seedlings in different doses was studied. This study will help in knowing the ability and inability of the selected tree species seedlings to withstand in water and salt stress conditions in different doses, providing an idea of the suitable tolerating environment to raise the plantation in abiotic stress prone areas and degraded lands.

MATERIALS AND METHODS

Pot culture experiments were conducted in the nursery of Tropical Forest Research Institute (TFRI), Jabalpur, for 1 year having 23°5'57.2" N latitude, 79°59'2" E longitude, and 394 m altitude. The seeds of *D. latifolia, G. arborea, T. grandis,* and *P. pinnata* were collected from TFRI campus and sown in nursery beds in the month of June. The seedlings having 2-3 leaves were transferred to polythene bags of 15 cm × 23 cm size, filled with soil, sand, and farm yard manure in 2:1:1 ratio. The polythene bags were kept in shade for 1 month to protect the seedlings from direct sunlight and afterward transferred to open area.

The experiments were conducted in factorial random complete block design having 20 salt and water stress treatment combinations. Each treatment consisted of 3 seedlings in *P. pinnata*, 7 seedlings in *D. latifolia,* 5 seedlings in *T. grandis*, and 4 seedlings in *G. arborea,* and the experiment was replicated thrice. The number of seedlings per treatment decided according to availability of seeds.

S_1W_1	S_2W_1	S_3W_1	S_4W_1
S_1W_2	S_2W_2	S_3W_2	S_4W_2
S_1W_3	S_2W_3	S_3W_3	S_4W_3
S_1W_4	S_2W_4	S_3W_4	S_4W_4
S_1W_5	S_2W_5	S_3W_5	S_4W_5

Where,

S_1 –No salt	W_1-3 days interval (control) in all species
S_2 – 4 ds/m salt	W_2-14 days interval (moderate drought) – Winter (*P. pinnata*)
	- 6 days interval (moderate drought) – Summer
	- 23 days interval (moderate drought) – Winter (*T. grandis*)
	- 12 days interval (moderate drought) – Summer
	- 6 days interval (moderate drought) – Winter (*G. arborea*)
	- 3 days interval (moderate drought) – Summer
	- 8 days interval (moderate drought) – Winter (*D. latifolia*)
	- 4 days interval (moderate drought) – Summer
S_3 – 8 ds/m salt	W_3- 28 days interval (severe drought) – Winter (*P. pinnata*)
	- 12 days interval (severe drought) – Summer
	- 48 days interval (severe drought) – Winter (*T. grandis*)
	- 24 days interval (severe drought) – Summer
	- 12 days interval (severe drought) – Winter (*G. arborea*)
	- 5 days interval (severe drought) – Summer
	- 18 days interval (severe drought) – Winter (*D. latifolia*)
	- 7 days interval (severe drought) – Summer
S_4 – 12 ds/m salt	W_4-3 cm from soil surface (severe waterlogged) in all species
	W_5-6 cm from soil surface (moderate waterlogged) in all species

T. grandis: *Tectona grandis, P. pinnata*: *Pongamia pinnata, D. latifolia*: *Dalbergia latifolia, G. arborea*: *Gmelina arborea*

The application of treatments was started in the 1st week of October. The amount of water equal to the field capacity of the soil was given to each treatment. Field capacity of the soil was calculated to be 24.86% for *P. pinnata,* 36.76% for *T. grandis,* 39.75% for *G. arborea, and* 43.23% for *D. latifolia*. Keeping the weight of soil fixed in each polythene bag (2 kg), the amount of water given to each polythene bag was 497.20 ml. for *P. pinnata,* 735.20 ml for *T. grandis,* 795.00 ml for *G. arborea,* and 864.60 ml for *D. latifolia,* respectively.

The drought conditions were maintained according to PWP, which was calculated on the basis of CPE values measured through Open Pan Evaporimeter. At wilting point, CPE values were calculated for all species separately. For *P. pinnata,* it came out to be 80 mm, which attained in 31 days in winter and 15 days in summer. Accordingly, seedlings kept under drought conditions were irrigated, i.e. after 14 days (W2) and 28 days (W3) in winter; 6 days (W2) and 12 days (W3) in summer. At wilting point, the soil moisture content was found to be 3.41%.

In *T. grandis,* CPE values calculated to be 120 mm, which attained in 50 days in winter and 25 days in summer. Accordingly, seedlings kept under drought conditions were irrigated, i.e., after 23 days (W2) and 48 days (W3) in winter; 12 days (W2) and 24 days (W3) in summer. At wilting point, the soil moisture content was found to be 6.42%.

In *G. arborea,* CPE values calculated to be 40 mm, which attained in 14 days in winter and 5 days in summer. Accordingly, seedlings kept under drought conditions were irrigated, i.e., after 6 days (W2) and 12 days (W3) in winter; 3 days (W2) and 5 days (W3) in summer. At wilting point, the soil moisture content was found to be 8.61%.

In *D. latifolia* CPE values calculated to be 60 mm, which attained in 20 days in winter and 8 days in summer. Accordingly, seedlings kept under drought conditions were irrigated, i.e. after 8 days (W2) and 18 days (W3) in winter; 4 days (W2) and 7 days (W3) in summer. At wilting point, the soil moisture content was found to be 10.89%.

To maintain the waterlogging, the polybags were perforated below 3 and 6 cm from soil surface for severe and moderate conditions, respectively, and regularly watered. Salinity was artificially created in the polybags through salt (NaCl) dissolved water, which was maintained to be 4, 8, and 12 ds/m.

The weekly observation of seedlings from October after applying treatments shows starting of mortality from January. Therefore, the mortality of seedlings was recorded for 14 weeks from 31st January to 1st May 2016.

The data were statistically analyzed with the help of SX software. Analysis of variance and standard error mean were calculated. For pairwise comparison, the critical difference at 1% and 5% rejection levels were determined.

RESULTS

The effect of salt and water (waterlogging and drought) stress on the mortality rate of selected tree species seedlings is shown in Table 1.

The 14-week (Figure 1) mortality data on selected *D. latifolia, G. arborea, T. grandis,* and *P. pinnata* species show increasing mortality trend in salt and drought stress conditions as compared to waterlogging. The cumulative effect of salt and drought and salt and waterlogging was found to be more deadly than any individual stress.

The mortality shown by control (S_1W_1) seedlings was 76.19% in *D. latifolia*, 25% in *G. arborea,* 13.33% in *T. grandis,* and 0% in *P. pinnata*. Comparatively, with the increase in salt concentration, i.e. 4 (S_2W_1), 8 (S_3W_1), and 12 ds/m (S_4W_1), it was observed that *G. arborea* shows highest and *P. pinnata* shows lowest mortality percentage in all three salt concentrations (Figure 2).

The joint effect of medium (S_1W_2) and severe (S_1W_3) drought stress (S_1W_{23}) as compared to control was found to be increase in mortality by 92.86% in *D. latifolia,* followed by 72.23% in *P. pinnata,* 70.83% in *G. arborea,* and 66.67% in *T. grandis,* respectively. *D. latifolia* shows highest and *T. grandis* shows lowest sensitivity to the drought stress conditions (Figure 3).

The severe (S_1W_4) and medium (S_1W_5) waterlogging (S_1W_{45}) combinely gives 66.67% mortality in *D. latifolia* followed by 16.67% in *T. grandis,* 4.17% in *G. arborea,* and 0% in *P. pinnata,* respectively, than control seedlings. *D. latifolia* shows highest mortality and *P. pinnata* shows good adaptability in waterlogging conditions. The waterlogging conditions proved to be more favorable stress condition as compared to salt and drought stress for all seedlings (Figure 4).

The cumulative effect of salt and drought stress was found to be more lethal as compared to individual salt and drought stress commonly in all species with some variations. The effect of 4 ds/m salt concentration with

Table 1: Percent mortality of tree seedlings

Treatments	*D. latifolia* (%)	*G. arborea* (%)	*T. grandis* (%)	*P. pinnata* (%)
S_1W_1	76.19	25.00	13.33	0.00
S_1W_2	95.24	58.33	80.00	55.56
S_1W_3	90.48	83.33	53.33	88.89
S_1W_4	61.90	8.33	26.67	0.00
S_1W_5	71.43	0.00	6.67	0.00
S_2W_1	85.71	100.00	86.67	11.11
S_2W_2	95.24	91.67	73.33	11.11
S_2W_3	90.48	83.33	66.67	66.67
S_2W_4	90.48	100.00	86.67	11.11
S_2W_5	80.95	100.00	66.67	11.11
S_3W_1	95.24	100.00	86.67	22.22
S_3W_2	95.24	100.00	86.67	22.22
S_3W_3	100.00	100.00	100.00	88.89
S_3W_4	100.00	100.00	93.33	55.56
S_3W_5	95.24	100.00	86.67	33.33
S_4W_1	95.24	100.00	93.33	44.44
S_4W_2	100.00	100.00	80.00	55.56
S_4W_3	100.00	100.00	100.00	44.44
S_4W_4	100.00	100.00	93.33	33.33
S_4W_5	100.00	100.00	100.00	55.56
Total mortality (%)	90.95	82.50	74.00	35.56
$CD_{0.05}$	1.0979	0.7212	1.7127	0.9779
$CD_{0.01}$	1.4706	0.9659	2.2941	1.3098
SE±	0.5424	0.3562	0.846	0.4831

SE: Standard error, *T. grandis*: *Tectona grandis, P. pinnata*: *Pongamia pinnata, D. latifolia*: *Dalbergia latifolia, G. arborea*: *Gmelina arborea*

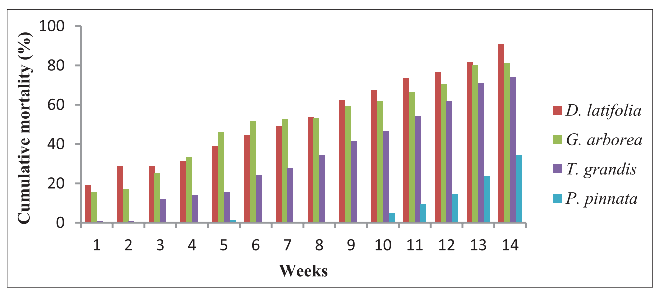

Figure 1: Weekly measurement of mortality in tree seedlings under salt and water stress conditions

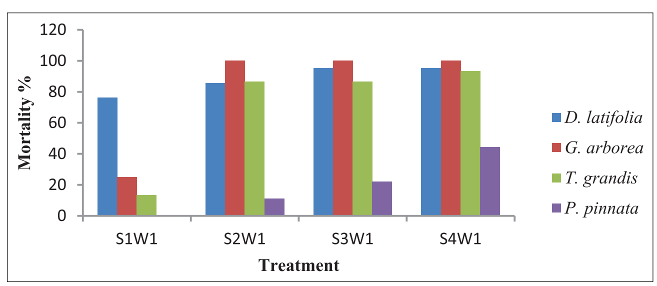

Figure 2: Effect of salt on mortality of tree seedlings

drought stress (S_2W_{23}) shows highest mortality (92.86%) by *D. latifolia* and lowest mortality (38.89%) by *P. pinnata*. The 8 ds/m salt and drought stress (S_3W_{23}) showed the highest mortality (100%) by *G. arborea* and the lowest mortality (55.56%) by *P. pinnata*. The 12 ds/m salt and drought stress (S_4W_{23}) showed the highest mortality (100%) by *D. latifolia* and *G. arborea* and the lowest mortality

(50%) by *P. pinnata*. With the increase in salt concentration along with drought stress, *D. latifolia* and *G. arborea* show increasing mortality except *T. grandis* and *P. pinnata* which observed to be slightly decreased in mortality in high salt (12 ds/m) concentration. *P. pinnata* exceptionally shows decrease in mortality percentage under mutual salt and drought stress conditions as compared to individual drought stress (Figure 3).

The salt and waterlogging mutual effect was found to be more lethal as compared to individual salt and waterlogging stress, equivalent to the mutual effect of salt and drought stress. The increasing salt concentration, i.e., 4 (S_2W_{45}), 8 (S_3W_{45}), and 12 ds/m (S_3W_{45}) with waterlogging shows the highest mortality by *G. arborea* along with *D. latifolia* in 12 ds/m and lowest by *P. pinnata* (Figure 4).

The total percentage of mortality in *D. latifolia* is 90.95%, in *G. arborea* is 82.50%, in *T. grandis* is 74%, and in *P. pinnata* is 35.56%, respectively (Figure 5).

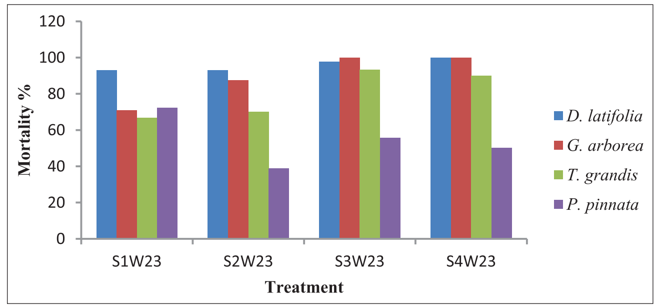

Figure 3: Combine effect of salt and drought on mortality of tree seedlings

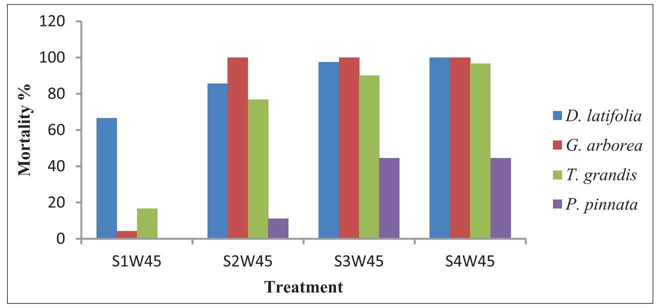

Figure 4: Combine effect of salt and waterlogging on mortality of tree seedlings

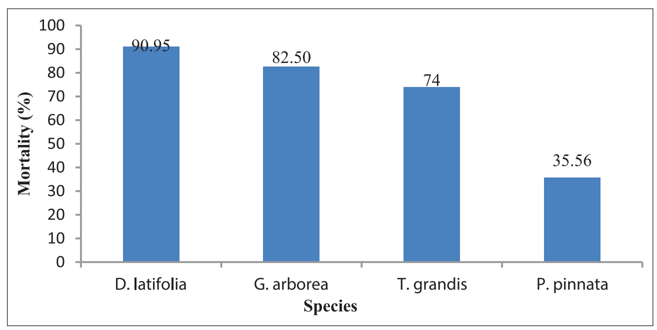

Figure 5: Percent mortality in tree seedlings under salt and water stress conditions

DISCUSSION

The results of the study show that *D. latifolia* seedlings are very week to plant in salt and water stress prone areas but show slight tolerance to waterlogging stress. Basak (2006) found *Dalbergia sissoo*, the weak species to exist in salt and water stress prone areas. *G. arborea* seedlings show similar behavior in case of salt and drought stress but show better adaptablity for waterlogging stress. Likewise, Osundina and Osonubi (1988) found the flood tolerance behavior of *G. arborea*. *T. grandis* seedlings were also unable to tolerate salt stress conditions but show slight and good tolerance behavior to drought and waterlogging conditions respectively. Rao *et al.* (2008) have shown the medium drought tolerance quality of *T. grandis*. *P. pinnata* seedlings show excellent tolerant behavior against salt and water stress conditions. They were exceptionally observed to be decrease in mortality percentage under mutual salt and drought stress conditions as compared to individual drought stress which is a kind of adaptation under the influence of two strong stresses according to Oliveira *et al*. (2013). Hence, *P. pinnata* seedlings were found to be best suited for cultivation in degraded land and waterlogged canal command areas. Arpiwi *et al*. (2013) also found this tree species as salt and water tolerant. Rest three species seedlings were found to be suited for plantation in waterlogged prone areas.

CONCLUSION

The situation of land degradation is increasing day by day gradually as a result of human disturbances to the environment. Due to continuously increase of deforestation, not only enlarging the wasteland area but also strengthening the effect of abiotic stresses and turning to change in climate or *vice versa*. To combat with the problem, it is required to control and manage the human activities inside the natural vegetation. Furthermore, aforestation is necessary with the environment-friendly and economically important plants. This will reduce the mortality of plants in such unfavorable (wastelands and abiotic stress prone areas) areas and will going to upgrade the value of land. From present study, we conclude that analysis of mortality percentage for *T. grandis, P. pinnata*, *D. latifolia,* and *G. arborea* under salt and water stresses in different doses. *P. pinnata* is a hard species having good survivability in such areas.

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