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Temperature and Saline Stress on Seedlings of *Swietenia macrophylla*: A Comparative Study

[1]M. Siddiqur Rahman, [2]S. Akter and [1]M. Al-Amin
[1]Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh
[2]Department of Environment, Chittagong Division, Ministry of Environment and Forest, People's Republic of Bangladesh

Abstract: Physical responses of plants to change in climatic factors like temperature, precipitation and abiotic factors like salinity intrusion may lead positive or negative effects. Some factor may promulgate growth while other may stunts their vigour. Present study seeks growth of a plantation species at its early stage of life towards elevated temperature and saline water stresses. Growth records of *Swietenia macrophylla* seedlings were enumerated by measuring height, collar diameter and leaf number development of the replicates growing at an environment-controlled plant growth chamber. One experimented with merely elevated temperature while other tries to find results of combined effect of elevated temperature (30, 32 and 34°C) and saline (0.5, 1.5 and 2.5 g L^{-1} NaCl) to said species seedlings. Seedling replicates showed diverse response to elevated temperature and saline irrigation at height, collar diameter and leaf number development. Results depict that elevated temperature alone might be positive for *S. macrophylla* seedlings, rather most favourable for its growth in height, however, collar diameter and leaf number may remain unaffected. Saline treatment along with higher temperature stresses may lead seedlings toward stunted or very low growth. As saline intensity increases, species growth tends to decrease proportionally. Elevated temperature aided with higher salinity may direct further under development of *S. macrophylla* seedlings which is distressing to plantation establishment of this species in sites which are vulnerable to salinity intrusion due to climate change. However, *S. macrophylla* may be a promising plantation species in drier part of the globe in near future.

Key words: *Swietenia macrophylla*, plant growth, elevated temperature, saline treatment, plant growth chamber

INTRODUCTION

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), there would be four climate change responses on the earth viz. temperature change, precipitation change, sea level rise and extreme events. MEF (2009) identified that all these three responses are happening and will happen in Bangladesh due to climate change phenomenon as Bangladesh is the worst affected due to climate change impacts (MEF, 2008). When climate of any region or as a whole being changed, it affects everywhere (Rahman *et al*., 2012). Like any other natural resources, forest flora may experience the extreme threat of elevated temperature and saline water submergence at different stages of their lives i.e. from germination to maturity due to climate change effects (Rahman *et al*., 2012). Bangladesh would face 3.4°C temperature increase within the year 2100 as the country is a poor one with limited resources but contribute less to global emission (IPCC, 2007). Where national estimations prove that the country would face an additional 2.4°C temperature increase and an 88 cm sea level rise by 2100 (MEF, 2009).

Response of elevated temperature to forest flora depends on the climatic conditions such as temperature, precipitation, humidity and light intensity. Several studies pointed out that temperature increase may lead the forest ecosystem to change considerably in forest growth over the next century (Kellomaki *et al*., 1997). Response to elevated temperature and precipitation change, forest flora might experience greater survivability challenge in a climate change prone country like Bangladesh. Mahtab (1992) identified that if there would temperature rise there will be salinity intrusion in southern part of Bangladesh. Due to climate change effects, forest growth may be stunted due to salinity intrusion in coastal and offshore areas of Bangladesh (Rahman, 2012b). Moreover, the combined effect of elevated temperature and salinity intrusion might affect forest trees at their early stages of life (Rahman *et al*., 2012).

Swietenia macrophylla King (big-leaf mahogany) is one of the most economically important tree species (Morris *et al*., 1999). The species is found in elevations that range from 50 to 1400 m with precipitation from 1500 to 4000 mm and temperatures of 23 to 28°C (Lamb, 1966).

Corresponding Author: M. Siddiqur Rahman, Flat No. C1, House No. D14, Road No. 8, Chandgoan RIA, Chittagong 4212, Bangladesh

Annual temperature averages of greater than or equal to 24° C and 1000-2000 mm annual precipitation (Holdridge, 1967).

Mean maximum and mean minimum tolerable temperature for optimum growth of *Swietenia macrophylla* is 32 and 16°C, respectively (Troup, 1921, 1986; Das and Alam, 2001; Luna, 1996), however, literature for salinity acceptance was not found. Considering silvicultural requirements and changing climate scenarios for future in Bangladesh the potential suitable lands for indigenous species like *Swietenia mahagony* may decrease significantly by 22.07% than present by the year 2100 (Al-Amin and Rahman, 2011; Rahman, 2012a). For this, temperature-humidity-light controlled plant growth chamber was used to enunciate stated seedling growth. Using environment controlled plant growth chamber is helpful in analysing responses to environmental factors to plants like temperature, humidity and also to salinity. Olszyk *et al.* (1998) reported that responses to elevated atmospheric temperature over several years in controlled-environment chamber facility shows plant morphological disturbances.

The aim of present study was to enunciate this species ability to withstand higher temperature (30-34°C) than its normal range (20-30°C) along with saline water treatment (0.5, 1.5 and 2.5 g L^{-1} NaCl concentrations). This experiment might be helpful in asking the answer whether *Swietenia macrophylla* would be tenable to elevated temperature and saline stress in future or not.

MATERIALS AND METHODS

Materials: Initial growth performance of *S. macrophylla* at three different parameters viz. height, collar diameter and number of leaves were measured by meter scale, slide callipers and manual reading, respectively. For temperature, light and humidity control the seedlings were reared in the Weiss Gallenkamp fitotron Plant Growth Chamber (Tree propagation laboratory, IFES, University of Chittagong). Temperature records were taken by atmospheric thermometer placed at outdoor condition to measure existing temperature.

Study site and period: The experiment was conducted in the nursery and Tree Propagation laboratory of Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh. Study conducted during the month of January, February and March 2009. The mean monthly temperature varies from 19.44°C in January to 28.88°C in May (UNEP (Islam *et al.*, 1979).

Samples: Healthy seedlings of same age and origin were used for treatments. For elevated temperature treatment, forty seedlings were taken, where replication was ten for each. While for combined experiment, thirty samples taken where replicates were three for each. A two-factor split-plot design with ten and three randomly assigned complete replications was used (Morris *et al.*, 1999).

Methods: Two types of experiments were conducted with different treatment to seedlings.

Experiment 1: Temperature elevation at 30, 32 and 34°C compared with existing temperature (26.31°C).

Experiment 2: Temperature elevation at 30, 32 and 34°C along with NaCl concentrations of 0.5, 1.5 and 2.5 g L^{-1} in each of the three elevated temperature compared with existing temperature (26.31°C) and fresh water irrigation.

Seedlings were reared in the Weiss Gallenkamp Plant Growth Chamber where the temperature, light intensity and relative humidity were controlled strictly. The growth chamber was programmed with a pick temperature of 30, 32 and 34°C and with relative humidity 80% at pick point. Ramping increase of temperature was 0.02 and for humidity it was 0.01. Day light was considered at maximum twelve hours a day because Mejia *et al.* (2008) showed that seedlings growth of this species depends largely on light availability. The study was conducted with heating the seedlings at day and night time both. Therefore, programming was done according to this context. Un-purified salt from salt bed of coastal areas of Chittagong district was collected and packed in vacuum packet to protect them from moisture intrusion. Solution of NaCl with water according to predetermined amount was irrigated to each seedling as treatment at every day. Data collected about the height, collar diameter and number of leaves of the seedlings recorded at every fourth day. After three months observation the data were analyzed. Growth data of height, collar diameter and leaf number were measured by subtracting final measurement with initial measurement during the observation.

Statistical analysis: Statistical software used to analyze the growth measurements was Minitab 2002 version 13.2. Analysis of variance (ANOVA) was used to analyze both responses (Morris *et al.*, 1999). Growing seedlings in a controlled Plant Growth Chamber and observing their performances is supported by Rahman *et al.* (2012); Al-Amin and Afrin (2011); Ullah and Al-Amin (2008) and Kotoky *et al.* (2000).

RESULTS

Plant seedlings grown at elevated temperature shows a positive response. or increment within stipulated study

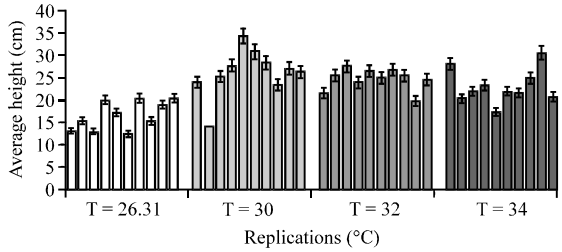

Fig. 1: Mean height growth comparison of *Swietenia macrophylla* under different temperature scenarios (T) compared with existing study site temperature

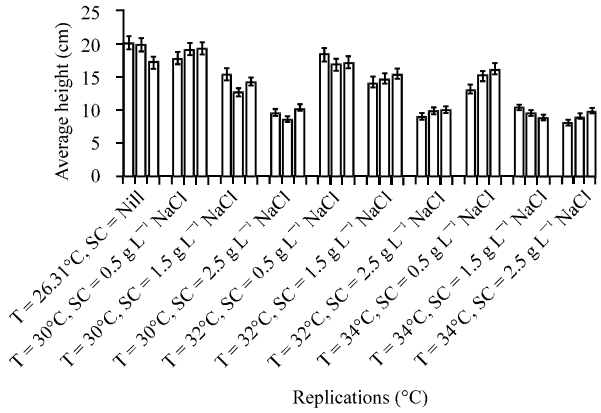

Fig. 2: Mean height growth of *S. macrophylla* under different Temperatures (T) and Saline Concentrations (SC) comparing to existing temperature- no saline treatment

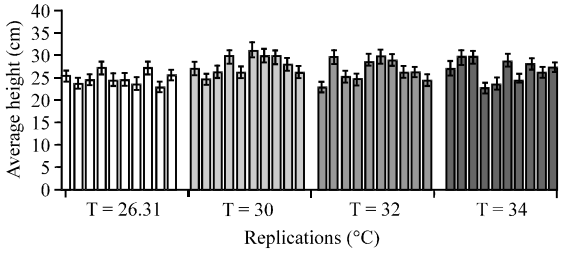

Fig. 3: Collar diameter growth of *Swietenia macrophylla* under different Temperatures (T) compared with existing study site temperature

period. The study seeks to find effects of higher temperature in one experiment and another with elevated temperature along with saline treatment. Figure 1-5 show mean height collar diameter and leaf number development growth after treatments given to same origin and same age seedlings was increased due to elevated temperature in a controlled plant growth chamber. This denotes that after

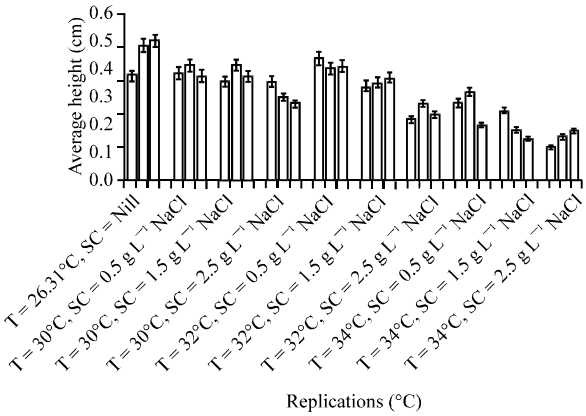

Fig. 4: Collar diameter growth of *Swietenia macrophylla* under different Temperatures (T) and Saline Concentrations (SC) comparing to existing temperature- no saline treatment

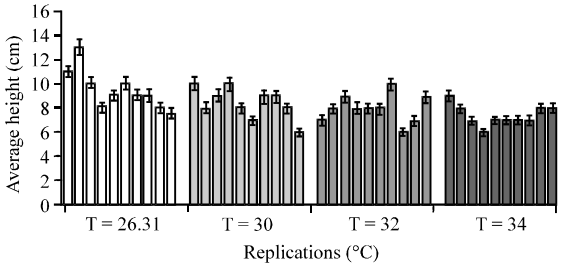

Fig. 5: Comparison of leaf number of *Swietenia macrophylla* under different temperature scenarios (T)

elevated temperature treatment, seedlings might find suitable condition rather than stunted growth. However, different situations occur when elevated temperature associated with saline water treatment affects seedlings drastically (Fig. 2-6). Plants height growth was decreased due to mostly salinity treatment. Only elevated temperature can have less effect on seedling mortality or stunted growth. Seedling s grow at collar diameter and leaf number development at decreasing rate.

Table 1 illustrates that number of days and higher temperature had significantly affected the height and collar diameter growth but number of leaf development was only affected by varying temperature. However, accept collar diameter growth, higher temperature and saline treatment affect plant growth significantly. Collar diameter can be in responsive to higher temperature effect.

DISCUSSION

Climate change can pose both positive and negative effects on forests and its components (Rahman, 2012a).

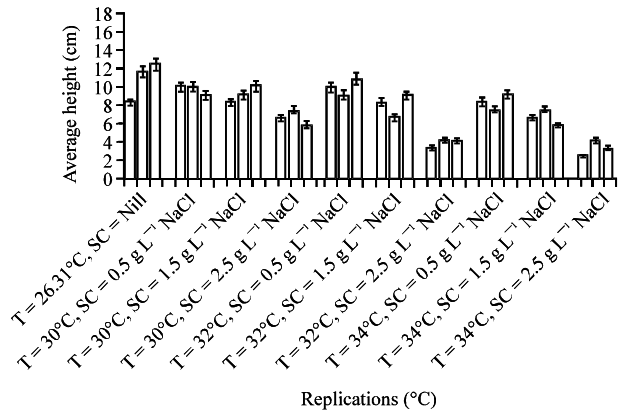

Fig. 6: Leaf number of *Swietenia macrophylla* under different Temperatures (T) and Saline Concentrations (SC)

Table 1: Statistical analysis of the effect of growing period and treatments on growth performance of *Swietenia macrophylla*

Treatments	Sources of variations	F-value	p-value
Higher temperature without saline	Height	68.29	0.000
	Collar diameter	1.22	0.303
	No. of leaf development	55.72	0.000
Higher temperature with saline	Height	76.18	0.000
	Collar diameter	39.21	0.000
	No. of leaf development	1.96	0.045

F means mean value obtained at fishers test, P means probability distribution ($p<0.05$)

Thus, these responses are noted as following several example as the present study indicates that several areas are there at which tree seedlings may alter their normal growth rate, whether this may be positive or negative.

Positive response: Increased CO_2 concentrations in the atmosphere and favourable elevated temperature may grow floral species positively. Reported that seedling survival and growth increased both under the future climate regime in USA for black spruce (*Picea mariana*) (Wang *et al*., 1994). With increased temperature and CO_2, forest ecosystems may grow faster, mature earlier and die younger (Ryan, 1991). Several studies pointed out that temperature increase may lead the forest ecosystem to change considerably in forest growth over the next century (Kellomaki *et al*., 1997). Some examples are here. *Lagerstroemia speciosa* showed tolerance with high temperature when grown at elevated temperature in controlled growth chamber conditions and initial growth was better in existing temperature comparison to mid and high temperatures for *Albizia procera* (Ullah, 2008). Ahmed (2007) found positive response at elevated temperature between 31.58^0 and 39.6^0C for germination and initial growth performance of *Shorea robusta*. Also for *Gmelina arborea* grown in growth chambers there showed a positive response to elevated temperature (Rahman, 2009). Leaf number may promulgate or decrease due to salinity impacts with sharp changes. For *Anthocephalus chinensis*, mean number of leaves per seedlings at 28°C (4.1) and 32°C (3.2) was found significantly higher than that at 24°C (Kotoky *et al*., 2000).

Negative response: The combined effect of high salinity and higher elevated temperature results in seedling mortality to *Artocarpus chaplasha*. This happens with chronological increase of temperature and saline intensity. At extreme stage i.e. with higher most temperature and maximum saline water treatment, *Artocarpus chaplasha* tend to die rather than increase in height, collar diameter and leaves number (Rahman *et al*., 2012).

Height growth of *Taxadium distichum* and *Sapium sebiferum* seedlings were affected by salinity with 0 and 2 ppt (parts per ton) water, but heights of plants watered with 10 ppt water were significantly lower. Diameter growth was much more variable (Corner, 1994).

Leaf and height growth were significantly reduced after 3 and 5 days following exposure to salinity, respectively for all four experimented poplar clones (Fung *et al*., 1998).

Average number of leaf developed during the observation period showed that as temperature rises and salinity increases, seedlings of *Artocarpus chaplasha* shed their leaves. This condition led to total leaflessness of the seedlings with respect to succeeding thermal and salinity condition (Rahman *et al*., 2012).

Leaf, stem and root of sunflower and maize showed an almost similar growth reduction due to salinity. The higher the salinity, the lower the leaf area and dry matter production of trees (Katerji *et al*., 1994). During early growth under field-like soil moisture and fertility conditions, elevated temperatures associated with global warming effects (salinity) may reduce shoot height, but not necessarily stem diameter (Olszyk *et al*., 1998).

CONCLUSION

Out of several climate change affects, raise in temperature and salinity intrusion in forest arenas may hamper their actual undisturbed growth. Elevated temperature has reported to be suitable for several species while some species tend to response negatively. *Swietenia macrophylla* is a common plantation species that grows all over the country. It has proved to be potential at future elevated atmospheric temperature condition. Nonetheless, this species might face a drastic situation at saline water intrusion in its plantation at their early stage of life. Therefore, plantations might be raised or planned in sites where there would be a salinity intrusion in near future. On the other hand, plantations might be raised in drier places facing or will face atmospheric temperature raise within 2050 or 2100.

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REFERENCES

Ahmed, S., 2007. Germination and initial growth of arjun and sal under different temperatures. B.Sc. (Honours) Thesis, Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh.

Al-Amin, M. and M.S. Rahman, 2011. Sketching future forest of Bangladesh considering climate change scenarios, silviculture and productivity of species using GIS. Proceedings of the IUFRO International Conference on Research Priorities in Tropical Silviculture: Towards New Paradigms? November 15-18, 2011, Montpellier, France, pp: 70.

Al-Amin, M. and S. Afrin, 2011. Adaptive responses of *Artocarpus chaplasha* to stresses induced by changing climate. Proceedings of the 1st Bangladesh Forestry Congress, April 19-21, 2011, Forest Department, Bangladesh, pp: 11-15.

Corner, W.H., 1994. The effects of salinity and water logging on growth and survival of baldcypress and Chinese tallow seedlings. J. Coastal Res., 10: 1045-1049.

Das, D.K. and M.K. Alam, 2001. Trees of Bangladesh. Bangladesh Forest Research Institute, Chittagong, Bangladesh, pp: 324.

Fung, L.F., S.S. Wang, A. Altman and A. Hutterman, 1998. Effect of NaCl on growth, photosynthesis, ion and water relations of four poplar genotypes. Forest Ecol. Manage., 107: 135-146.

Holdridge, L., 1967. Life Zone Ecology. 1st Edn., Tropical Science Center, San Jose, Costa Rica.

IPCC, 2007. Climate change 2007: The physical science basis summary for policy makers. Contribution of Working Group ² to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland, pp: 21.

Islam, A.T.M.T., M.S. Chowdhury, A.K.M.M. Hoque and S.A. Malek, 1979. Detailed soil survey. Chittagong University Campus, Hathazari, Chittagong, Bangladesh, pp: 4-10.

Katerji, N., J.W. Von Hoorn, A. Hamdy, F. Karam and M. Mastrorilli, 1994. Effect of salinity on emergence and on water stress and early seedling growth of sunflower and maize. Agric. Water Manage., 26: 81-91.

Kellomaki, S., T. Karjalainen and H. Vaisanen, 1997. More timber from boreal forests under changing climate? For. Ecol. Manage., 94: 195-208.

Kotoky, A., J. Devi and P.C. Deka, 2000. Effect of different temperatures and substrates on the germination of kadam (*Anthocephalus chinensis* walp.) seeds. Indian J. For., 23: 139-141.

Lamb, F.B., 1966. Mahogany of Tropical America: Its Ecology and Management. 1st Edn., University of Michigan Press, Ann. Arbor, Michigan Pages: 220.

Luna, R.K., 1996. Plantation Trees. International Book Distributors, Dehradun, India.

MEF, 2008. Bangladesh climate change strategy and action plan 2008. Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, pp: 1-86. http://www.sdnbd.org/moef.pdf

MEF, 2009. National adaptation programme for Action (NAPA). Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

Mahtab, F.U., 1992. Climate Change and Sea Level Rise due to Green House Effect: Its Consequences on Bangladesh. In: Training Manual on Environmental Management in Bangladesh, Rezauddin, M. and L. Khan (Eds.). Department of Environment, Dhaka, Bangladesh, pp: 148-172.

Mejia, E., X. Buitron, M. Pena-Claros and J. Grogan, 2008. Big-leaf mahogany (*Swietenia macrophylla*) in peru, Bolivia and Brazil. NDF Workshop Case Studies, WG 1-Trees, Case Study 4, pp: 1-36.

Morris, M.H., P. Negreros-Castillo and C. Mize, 1999. Sowing date, shade and irrigation affect big-leaf mahogany (*Swietenia macrophylla* King). For. Ecol. Manage., 132: 173-181.

Olszyk, D., C. Wise, E. VanEss and D. Tingey, 1998. Elevated temperature but not elevated CO_2 affects long-term patterns of stem diameter and height of Douglas-fir seedlings. Can. J. For. Res., 28: 1046-1054.

Rahman, M.S., 2009. Elevated temperature and saline stress on selected indigenous and introduced exotic tree species of Bangladesh. B.Sc. (Honours) Thesis, Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh.

Rahman, M.S., 2012a. Climate Change and Forest in Bangladesh: Growth, Survivability, Stress Adoption and Spatial Shift to Forest Species Due to Climate Change. LAP Lambert Academic Publishers, Saarsbrucken, Germany, ISBN-13: 9783659247347, Pages: 60.

Rahman, M.S., 2012b. Future Forest of Bangladesh: How Climate Change Alter Spatial and Temporal Distribution of Species. LAP Lambert Academic Publishers, Saarsbrucken, Germany, ISBN-13: 9783659135750, Pages: 52.

Rahman, M.S., M. Al-Amin and S. Akter, 2012. *Artocarpus chaplasha*: Establishment and initial growth performance at elevated temperature and saline stresses. J. For. Sci., 28: 12-18.

Ryan, M.G., 1991. Effects of climate change on plant respiration. Ecol. Appl., 1: 157-167.

Troup, R.S., 1921. The Silviculture of Indian Trees. Clarendon Press, Oxford, UK., Pages: 1195.

Troup, R.S., 1986. The Silviculture of Indian Trees. Clarendon Press, Oxford, UK., Pages: 833.

Ullah, M.R. and M. Al-Amin, 2008. Seedling growth performance of *Cassia fistula* (Linn.) using climate change scenarios for Bangladesh. Forestry Nepal Publications, Nepal.

Ullah, M.R., 2008. Tree composition, regeneration and initial organic carbon stock of selected trees using climate change scenarios. B.Sc. (Honours) Thesis, Institute of Forestry and Environmental Sciences, University of Chittagong, Bangladesh.

Wang, Z.M., M.J. Lechowicz and C. Potvin, 1994. Early selection of black spruce seedlings and global change: Which genotypes should we favour? Ecol. Appl., 4: 604-616.