Research Article

Growth Potential of Two Agroforestry Tree Species under Salt Stress Condition

Syed Hammad ul Hassan*, Irfan Manj, Junaid Naseer
Department of Forestry Range and Wildlife Management, Faculty of Agriculture and Environment The Islamia University, Bahawalpur, Pakistan-63100
Email: hamdgilani@gmail.com

Cultivable soils are declining worldwide, including in Pakistan, due to increasing soil salinity, which poses a serious threat to agricultural productivity and food security. An effective strategy to mitigate this challenge is the identification of salt-tolerant agroforestry tree species suitable for salt-affected soils. Therefore, the present study was conducted to evaluate the growth potential of two agroforestry tree species, *Eucalyptus camaldulensis* and *Syzygium cumini*, under salt stress conditions during a seventy-day experimental period in saline soils of Bahawalpur, Pakistan.

Three salinity treatments were imposed using sodium chloride at control, moderate, and high levels, following a Randomized Complete Block Design (RCBD) with factorial arrangement and three replications. Growth parameters including plant height, stem diameter, number of leaves, and total biomass were recorded, and soil properties were analysed before and after planting.

Salinity significantly influenced growth responses in both species. Plant height exhibited a non-linear response to salinity, with maximum values recorded at moderate salinity levels, indicating tolerance to mild salt stress. *Eucalyptus camaldulensis* showed superior growth performance across most parameters compared to *Syzygium cumini*, particularly under moderate salinity conditions, while high salinity levels resulted in growth reduction in both species. The findings suggest that *Eucalyptus camaldulensis* possesses greater tolerance to saline conditions and may be a suitable species for agroforestry practices in salt-affected soils.

Keywords: Salinity stress, agroforestry, *Eucalyptus camaldulensis*, *Syzygium cumini*, growth response, salt tolerance

Introduction

Interest in understanding salt stress has increased rapidly worldwide, as salinity has emerged as a major environmental factor limiting agricultural productivity and contributing to global food insecurity. Estimates indicate that approximately 45 million hectares of irrigated land worldwide are affected by salinity (World Bank, 2006; Hasanuzzaman et al., 2014). Pakistan ranks eighth globally in terms of land affected by salinity (FAO, 2005; Corbishley & Pearce, 2007). The extent of salinity continues to expand due to multiple interacting factors, and it is expected that increased attention will be directed toward research in this area in the future.

Salinity has become a major land degradation issue, particularly in regions with inefficient irrigation practices within canal command areas (Dagar & Krishi, 2018). High salt concentrations in soil adversely affect plant growth by disrupting key physiological processes, including photosynthesis, protein synthesis, energy metabolism, and lipid metabolism (Parida & Das, 2005). Salinity stress influences plants through several mechanisms, such as osmotic stress, ion toxicity, nutrient imbalance, oxidative stress, metabolic disruption, membrane instability, reduced cell division, inhibited growth, and genotoxic effects (Hasegawa & Bressan, 2000).

Plants employ various adaptive strategies to survive under saline conditions, including the exclusion or compartmentalisation of salt ions at the root surface. However, these mechanisms are metabolically expensive and energy intensive. Any factor that reduces the efficiency of these processes can negatively influence plant growth and stress tolerance. In addition, environmental stresses such as flooding can further exacerbate salinity effects by limiting oxygen availability in the soil, thereby restricting energy production and impairing root function (McFarlane et al., 1989). Under saline and waterlogged conditions, the ability of roots to exclude salts is reduced, leading to increased salt uptake and accumulation in plant tissues (Barrett-Lennard, 1986).

Certain plant species, particularly halophytes and stress-tolerant woody perennials, exhibit enhanced growth at low to moderate salinity levels, while growth declines at higher concentrations. This response reflects physiological adaptation to saline environments. Previous studies have demonstrated that moderate salinity can stimulate growth in salt-tolerant species, whereas excessive salinity results in growth inhibition. For example, *Eucalyptus camaldulensis* and *Syzygium cumini* have been reported to exhibit varying degrees of tolerance to saline conditions, with differences in growth performance, water relations, root architecture, and ion accumulation patterns (Geoff & Dickinson, 1995; Patil et al., 2015).

Agroforestry systems offer a promising approach for the productive use and rehabilitation of salt-affected lands. Identifying tree species capable of tolerating salinity while maintaining growth and biomass production is essential for sustainable land management. Therefore, the present study was undertaken to evaluate the growth potential of two agroforestry tree species, *Eucalyptus camaldulensis* and *Syzygium cumini*, under different salinity levels. The study aimed to assess their growth responses and tolerance mechanisms under saline soil conditions, with a focus on identifying species suitable for agroforestry practices in salt-affected regions.

Materials and Methods

Plant material and experimental site

The experiment was conducted using two agroforestry tree species, *Eucalyptus camaldulensis* and *Syzygium cumini*. Plant material was collected from the Forest Nursery and Experimental Area, Department of Forestry, Range and Wildlife Management, Bahawalpur, and from a Government Nursery near Karachi Mor, Bahawalpur, Pakistan. Healthy seedlings of uniform age and size were selected for the experiment.

A total of twenty-one healthy plants were selected for each species. Three individuals

Published online: 01 February 2026

of similar age and height were harvested at the beginning of the experiment to determine initial growth and biomass parameters, while the remaining plants were used for control and salinity treatments.

Experimental conditions

The experiment was conducted under a tree shade structure specifically prepared for this study. The experimental area measured 5.5 × 5.5 ft, with a height of approximately 2.5 ft above the ground surface. The shade structure protected plants from excessive solar radiation while allowing adequate air circulation. Pots were protected from rainfall to prevent leaching of salts. These conditions were maintained consistently throughout the experimental period.

Salinity treatments and experimental design

Three salinity treatments were applied using sodium chloride to evaluate the effect of salt stress on plant growth. The treatments consisted of control, moderate, and high salinity levels. Sodium chloride was applied at rates corresponding to control (0.07 g), moderate (0.14 g), and high (0.21 g) concentrations.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with a factorial arrangement, including species and salinity treatments as factors, and three replications per treatment.

Soil analysis

Soil samples were collected before planting and after completion of the experiment to determine changes in soil properties. Electrical conductivity (EC) of the soil was measured as an indicator of soil salinity. Soil electrical conductivity represents the concentration of soluble salts present in the soil and is an important parameter for assessing soil health, particularly in semi-arid and arid regions. The initial electrical conductivity of the soil was recorded as 184 millisiemens per meter.

Growth parameter measurements

Growth parameters were recorded after completion of the seventy-day experimental period. Plant height was measured from the soil surface to the apical tip of the plant. Stem diameter was measured using a digital vernier caliper. The number of leaves perplant was counted manually. Plants were harvested to determine total biomass, and fresh weights of stems and roots were recorded using a digital balance.

Statistical analysis

Data were analysed using analysis of variance (ANOVA) to evaluate the effects of species, salinity treatments, and their interaction on plant growth parameters. Mean values were calculated for each treatment, and standard errors were determined. Differences among treatments were considered statistically significant at $P \leq 0.05$.

Results

Effect of salinity on plant height

Salinity treatments significantly influenced plant height in both species. Plant height exhibited a non-linear response to salinity, with maximum values recorded at moderate salinity levels, indicating tolerance to mild salt stress. In *Eucalyptus camaldulensis*, the greatest mean plant height was observed under moderate salinity (64.1 cm), followed by control (37.8 cm), while the lowest height was recorded under high salinity (26.4 cm). In contrast, *Syzygium cumini* showed the highest plant height under control conditions (23.8 cm), followed by moderate salinity (17.6 cm), with the lowest values observed under high salinity stress. These results demonstrate that *Eucalyptus camaldulensis* exhibited greater tolerance to moderate salinity compared to *Syzygium cumini*, which showed a decline in plant height with increasing salinity.

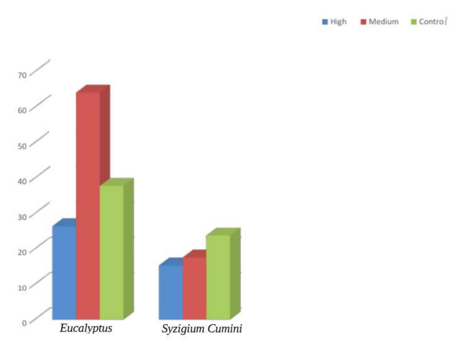

Figure 1: Effect of salinity treatments (control, moderate, and high) on plant height of *Eucalyptus camaldulensis* and *Syzygium cumini*. Error bars represent standard error of the mean.

Effect of salinity on stem diameter

The effect of salinity stress on stem diameter was statistically significant ($P < 0.001$). In *Eucalyptus camaldulensis*, the maximum stem diameter was recorded under high salinity conditions (35.7 mm), followed by moderate salinity (19.3 mm), while the minimum diameter was observed under control conditions (5.78 mm). In *Syzygium cumini*, stem diameter increased with increasing salinity, with the highest value recorded under high salinity (8.77 mm), followed by moderate (5.64 mm) and control conditions (3.95 mm).

Analysis of variance revealed significant effects of species, salinity treatment, and their interaction on stem diameter, indicating differential responses of the two species to salinity stress.

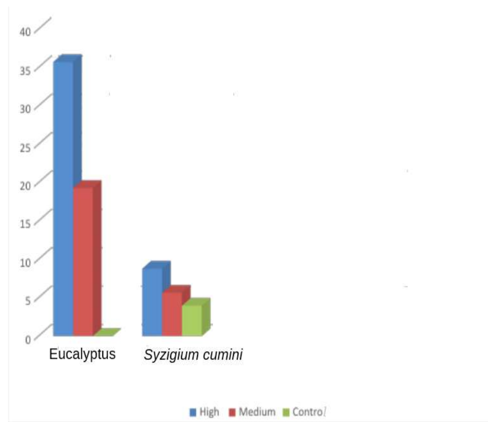

Figure 2: Effect of salinity treatments (control, moderate, and high) on stem diameter of *Eucalyptus camaldulensis* and *Syzygium cumini*. Error bars represent standard error of the mean.

Effect of salinity on number of leaves

The number of leaves per plant was significantly affected by salinity stress. In *Eucalyptus camaldulensis*, the highest number of leaves was recorded under control conditions (70.67), followed by moderate salinity (18.2), with the lowest number observed under high salinity stress (16.8). In *Syzygium cumini*, the maximum number of leaves was also recorded under control conditions (13.78), while moderate (4.56) and high salinity (7.56) treatments resulted in reduced leaf numbers. Analysis of variance indicated significant effects of species, salinity treatments, and species × treatment interaction on leaf production, demonstrating that increasing salinity generally reduced leaf number in both species.

Published online: 01 February 2026

,

Table 1: Effect of salinity treatments on growth parameters of two agroforestry tree species (mean ± SE)

Parameter	Species	Control	Moderate	High
Plant height (cm)	*Eucalyptus camaldulensis*	37.8 ± 1.19	64.1 ± 5.53	26.4 ± 1.24
	Syzygium cumini	23.8 ± 0.92	17.6 ± 0.67	19.0 ± 1.00
Stem diameter (mm)	*Eucalyptus camaldulensis*	5.78 ± 0.18	19.3 ± 8.97	35.7 ± 2.35
	Syzygium cumini	3.95 ± 1.32	5.64 ± 0.87	8.77 ± 2.17
Number of leaves (per plant)	*Eucalyptus camaldulensis*	70.67 ± 3.78	18.2 ± 1.89	16.8 ± 0.91
	Syzygium cumini	13.78 ± 2.41	4.56 ± 1.45	7.56 ± 0.35
Total biomass (g)	*Eucalyptus camaldulensis*	11.05 ± 0.61	5.56 ± 0.40	5.80 ± 0.45
	Syzygium cumini	5.65 ± 0.38	4.43 ± 0.27	3.71 ± 0.22

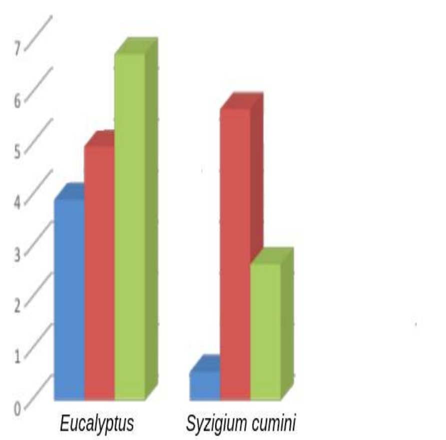

Figure 3: Effect of salinity treatments (control, moderate, and high) on total biomass of *Eucalyptus camaldulensis* and *Syzygium cumini*. Error bars represent standard error of the mean.

Table 2: Analysis of variance (ANOVA) for growth parameters of two agroforestry tree species

Parameter	Source of variation	SS	DF	MS	F-value	P-value
Stem diameter	Species	76.1558	4	19.039	125.719	< 0.001
	Treatment	4.6513	1	4.6513	30.713	< 0.001
	Species × Treatment	2.2738	4	0.5684	3.754	0.011
	Error	6.0576	40	0.1514		
Number of leaves	Species	42886.72	3	8499.08	128.21	< 0.001
	Treatment	2022.66	2	1132.88	17.09	< 0.001
	Species × Treatment	1146.31	3	264.28	3.99	0.008
	Error	1912.40	36	66.29		
Total biomass	Species	398.292	4	99.573	56.854	< 0.001
	Treatment	14.574	1	14.574	8.321	0.006
	Species × Treatment	44.774	4	11.194	6.391	< 0.001
	Error	70.055	40	1.751		

Effect of salinity on total biomass

Total biomass was significantly affected by salinity treatments ($P < 0.05$). In *Eucalyptus camaldulensis*, the maximum total biomass was recorded under control conditions (11.05 g), followed by high (5.80 g) and moderate salinity (5.56 g). In *Syzygium cumini*, the highest biomass was also observed under control conditions (5.65 g), while moderate (4.43 g) and high salinity (3.71 g) treatments resulted in lower biomass values. The analysis of variance showed significant effects of species, salinity treatments, and their interaction on total biomass, indicating species-specific variation in biomass allocation under salinity stress.

Discussion

The present study evaluated the growth responses of two agroforestry tree species, *Eucalyptus camaldulensis* and *Syzygium cumini*, under varying salinity levels and revealed species-specific differences in tolerance to salt stress. Salinity significantly affected all measured growth parameters, including plant height, stem diameter, number of leaves, and total biomass, indicating that salt stress plays a critical role in regulating early growth performance of agroforestry species.

Plant height exhibited a non-linear response to salinity, particularly in *Eucalyptus camaldulensis*, where maximum height was recorded at moderate salinity levels. This response suggests a stimulatory effect of mild salt stress, reflecting physiological adaptation and tolerance mechanisms. Similar reductions in plant height under increasing salinity stress have been reported by Punyawardena and Yapa (1991) and Kayambo et al. (1986), who observed that elevated salt concentrations generally suppress plant growth. However, the enhanced growth observed at moderate salinity in the present study supports the concept that certain woody species can exhibit adaptive responses under mild stress conditions. In contrast, *Syzygium cumini* showed a decline in plant height with increasing salinity, indicating comparatively lower tolerance.

Stem diameter responses further demonstrated adaptive growth strategies under salinity stress. In both species, stem diameter increased with increasing salinity levels, particularly under high salinity conditions. This response may represent a stress-induced structural adjustment rather than true growth enhancement, as plants under stress often allocate resources toward stem thickening to improve mechanical stability and stress resistance. Similar observations of reduced elongation accompanied by increased stem thickness under stress conditions have been reported by Kayambo et al. (1986). However, Gill and Aulakh (1990) suggested that changes in soil physical properties, such as bulk density, may also influence stem diameter, which could partially explain variation in the present study.

The number of leaves declined significantly with increasing salinity in both species, indicating reduced photosynthetic surface area under salt stress. These findings are consistent with those of Ngunjiri

Published online: 01 February 2026

and Siemens (1993), who reported that stress conditions, including salinity and moisture deficiency, significantly reduce leaf production. Reduced leaf number under salinity stress is a common adaptive response aimed at minimizing transpirational water loss and ion accumulation.
Total biomass accumulation was highest under control conditions for both species, with a marked decline under moderate and high salinity treatments. Biomass reduction under salinity stress has been widely reported in woody and herbaceous species and is attributed to osmotic stress, ion toxicity, and impaired metabolic activity (Turner, 1979). However, the relatively higher biomass retention observed in *Eucalyptus camaldulensis* compared to *Syzygium cumini* indicates greater tolerance and adaptive capacity. Similar species-specific variation in salinity tolerance has been reported in other agroforestry and tree species (Abbas et al., 2013). Overall, the differential responses of growth traits suggest that salinity tolerance is trait-dependent and influenced by physiological, morphological, and environmental factors. Variations in light availability, soil properties, and microclimatic conditions may have further contributed to the observed responses during the short experimental period. The results highlight the potential of *Eucalyptus camaldulensis* to tolerate moderate salinity levels and maintain growth under saline conditions, supporting its suitability for agroforestry systems in salt-affected regions.

Conclusion

The present study demonstrated that salinity significantly influences the growth performance of agroforestry tree species, with responses varying between species and growth traits. *Eucalyptus camaldulensis* exhibited greater tolerance to salinity stress, particularly under moderate salinity levels, where enhanced plant height indicated adaptive growth responses. In contrast, *Syzygium cumini* showed greater sensitivity to increasing salinity. These findings suggest that *Eucalyptus camaldulensis* is a suitable candidate for agroforestry practices in salt-affected soils. Further long-term studies are recommended to assess physiological mechanisms and field-level performance under varying environmental conditions.

Received: 10 October 2025 **Revised:** 04 December 2025 **Accepted:** 05 December 2025 **Published:** 31 January 2026

References

Abbas, G., Saqib, M., Akhtar, J., & Basra, S. M. A. (2013). Salinity tolerance potential of two Acacia species at early seedling stage. *Pakistan Journal of Agricultural Sciences*, 50, 683–688.

Barrett-Lennard, E. G. (1986). Effect of waterlogging on the growth and ion relations of plants. *Plant and Soil*, 92, 187–196. https://doi.org/10.1007/BF02372633

Corbishley, D., & Pearce, F. (2007). *Salinity: A growing problem*. FAO Land and Water Bulletin. Food and Agriculture Organization of the United Nations, Rome.

Dagar, J. C., & Krishi, M. (2018). Managing saline soils for sustainable agriculture. *Indian Journal of Agricultural Sciences*, 88, 1–15.

FAO (2005). *Global network on integrated soil management for sustainable use of salt-affected soils*. Food and Agriculture Organization of the United Nations, Rome.

Geoff, M., & Dickinson, G. (1995). Growth responses of tree species under saline conditions in tropical environments. *Australian Journal of Experimental Agriculture*, 35, 471–478. https://doi.org/10.1071/EA9950471

Gill, K. S., & Aulakh, M. S. (1990). Effect of soil physical properties on plant growth. *Soil Science*, 150, 853–860.

Hasanuzzaman, M., Nahar, K., Alam, M. M., Bhowmik, P. C., & Fujita, M. (2014). Potential use of halophytes to remediate saline soils. *BioMed Research International*, 2014, 1–12. https://doi.org/10.1155/2014/589351

Hasegawa, P. M., & Bressan, R. A. (2000). Plant cellular and molecular responses to high salinity. *Annual Review of Plant Physiology and Plant Molecular Biology*, 51, 463–499. https://doi.org/10.1146/annurev.arplant.51.1.463

Kayambo, B., Lal, R., & Calhoun, F. G. (1986). Effects of salinity stress on plant growth parameters. *Journal of Agronomy and Crop Science*, 156, 123–130. https://doi.org/10.1111/j.1439-037X.1986.tb00016.x

McFarlane, D. J., Barrett-Lennard, E. G., & Davidson, N. J. (1989). Waterlogging and salinity effects on plant growth. *Australian Journal of Agricultural Research*, 40, 497–507. https://doi.org/10.1071/AR9890497

Ngunjiri, G. M., & Siemens, J. C. (1993). Effects of soil moisture stress on plant height and leaf production. *Agricultural Water Management*, 24, 37–46. https://doi.org/10.1016/0378-3774(93)90014-G

Parida, A. K., & Das, A. B. (2005). Salt tolerance and salinity effects on plants: A review. *Ecotoxicology and Environmental Safety*, 60, 324–349. https://doi.org/10.1016/j.ecoenv.2004.06.010

Patil, S., Chavan, R., & Jadhav, B. (2015). Growth performance of tree species under saline soil conditions. *Journal of Environmental Biology*, 36, 1209–1215.

Punyawardena, B. V. R., & Yapa, P. A. J. (1991). Effects of salinity on growth and yield of crops. *Journal of Agronomy and Crop Science*, 166, 1–8. https://doi.org/10.1111/j.1439-037X.1991.tb00882.x

Turner, N. C. (1979). Drought resistance and adaptation to water deficits in crop plants. *Plant and Soil*, 52, 399–414. https://doi.org/10.1007/BF02184196

World Bank (2006). *Reengaging in agricultural water management: Challenges and options*. World Bank, Washington, DC.

Published online: 01 February 2026