



Vegetative Propagation and Morphological Traits of Aquatic Weeds: Preliminary Assessment for Ecological Applications

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Abstract

Aquatic weeds are increasingly recognized for their ecological importance due to their rapid growth and biomass accumulation. However, limited information is available on their vegetative propagation and early growth performance under controlled conditions. The present study evaluated the propagation efficiency and morphological traits of four aquatic weed species, namely *Alternanthera philoxeroides*, *Juncellus alopecuroides*, *Physalis minima*, and *Portulaca oleracea*, collected from Pashan Lake, Pune, India. Stem cuttings (10 cm with 3–5 nodes) were propagated in coco-peat trays for 30 days under controlled conditions. Growth parameters including shoot length, root length, number of leaves, and fresh biomass were recorded and analysed using one-way ANOVA. Significant differences were observed among species for root length, leaf number, and biomass ($p < 0.05$), whereas shoot length did not differ significantly. Among the studied species, *Physalis minima* exhibited comparatively higher growth performance across most parameters, while *Portulaca oleracea* showed the lowest values. The results indicate species-specific variation in vegetative propagation efficiency and growth adaptability. These findings provide baseline information on morphological traits that may be relevant for ecological restoration and future phytoremediation studies. However, the absence of direct pollutant or heavy metal analysis limits the confirmation of phytoremediation potential, and further investigation is required.

Keywords: Aquatic weeds, Vegetative propagation, Morphological traits, Growth performance, Ecological restoration, Macrophytes.

Introduction

Understanding plant propagation and morphology is fundamental to scientific disciplines, including ecology, agriculture, conservation biology, and environmental science. Vegetative propagation plays a critical role in horticulture and ecological restoration by enabling rapid multiplication and maintenance of desirable plant traits¹. This technique, which uses vegetative structures such as stems, roots, or leaves, offers significant advantages for sustainable cultivation, ecosystem rehabilitation, and biodiversity conservation².

In ecological restoration, such propagation strategies enable rapid establishment of plant populations and enhance survival rates in disturbed or degraded environments³. Aquatic and semi-aquatic macrophytes have gained increasing attention due to their multifunctional ecological roles, including nutrient cycling, sediment stabilisation, and water purification. These plants possess unique physiological and morphological adaptations that allow them to thrive in waterlogged or nutrient-rich environments, making them potentially suitable for phytoremediation applications^{4,5}. Phytoremediation, a plant-based approach for pollutant removal, relies heavily on plant traits such as rapid growth, high biomass accumulation, and extensive root systems to facilitate the uptake, transformation, and sequestration of contaminants⁶.

Despite their recognised ecological significance, empirical research on the vegetative propagation capacity and morphological traits of aquatic and semi-aquatic weeds remains limited. A comprehensive review has identified aquatic weed species capable of removing specific heavy metals from contaminated environments⁷. However, experimental validation of their propagation efficiency and growth performance under controlled conditions is essential to confirm their applicability in phytoremediation systems.

The present study focuses on four aquatic weed species: *Alternanthera philoxeroides* (Mart.) Griseb. (alligator weed), *Juncellus alopecuroides* (Rottb.) C.B. Clarke (foxtail fountain grass), *Physalis minima* Linn. (pygmy ground cherry), and *Portulaca oleracea* L. (common purslane). These species, characterised by diverse ecological functions and socioeconomic importance, contribute to wetland health, biodiversity, and ecosystem services^{8,9}.

Vegetative reproduction, when optimised, can generate large numbers of viable propagules in confined spaces and short time periods, depending on the health and quality of the plant material used¹⁰. This is particularly important in phytoremediation systems, where plant establishment, survival, and biomass production directly influence pollutant uptake

efficiency. Aquatic weeds exhibiting rapid growth, high biomass accumulation, and well-developed root systems are considered effective in wastewater treatment and environmental remediation¹¹.

The present study aims to evaluate vegetative propagation efficiency and morphological traits of selected aquatic weed species under controlled conditions. The study provides baseline information on growth performance and species adaptability, which may be useful for ecological restoration and future phytoremediation research. However, as the study focuses only on morphological parameters, direct conclusions regarding pollutant removal potential require further investigation.

Materials and Methods

Study area: Aquatic weed samples were collected from Pashan Lake, Pune, (Maharashtra, India), which is situated at 18°31'59"N, 73°47'24"E (Figure-1), and represents a key ecological wetland documented in the Asian Wetland Directory¹². This urban-proximate wetland supports diverse aquatic flora, including the weed species studied, while facing anthropogenic pressures typical of rapidly urbanising and scapes in Pune.

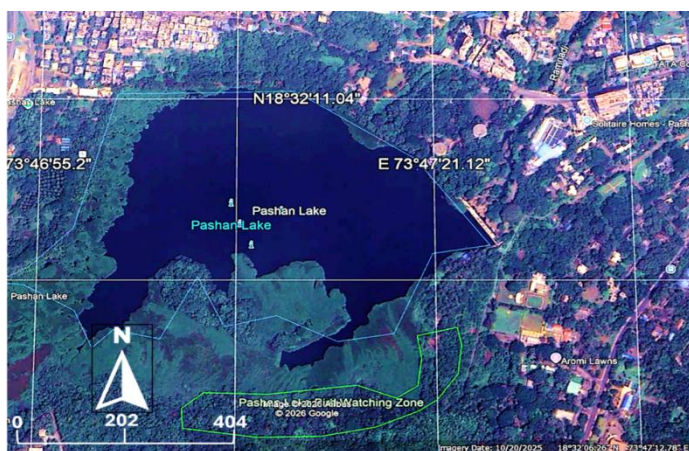


Figure-1: Location of the aquatic weed sampling site at Pashan Lake, Pune, Maharashtra, India

Figure-1 illustrates the geographical location and spatial context of the study area from where aquatic weed samples were collected. It highlights the sampling site within Pashan Lake, providing a clear reference for the ecological setting and field collection points.

Aquatic weed samples were collected from Pashan Lake, Pune, Maharashtra, India (18°31'59"N, 73°47'24"E), and an urban freshwater wetland known for its diverse aquatic vegetation¹².

Sample collection: The aquatic weed sample collection followed standardised field sampling protocols to ensure representative and diverse samples. Systematic sampling was employed in open-water areas to capture variation in the lake's

vegetation¹⁴. After collection, specimens were transported to the laboratory under controlled conditions to prevent mechanical damage and preserve their ecological integrity. Upon arrival, the weeds were placed in individual plastic bags, labelled carefully, and only healthy specimens were selected for vegetative propagation. Approximately 20–25 healthy individuals of each species were collected to ensure sufficient material for propagation experiments.

Vegetative propagation (stem cuttings) of selected weeds:

Vegetative propagation was carried out using stem cuttings to ensure uniformity and reproducibility in plant material. Cuttings measuring 10 cm in length and bearing three to five nodes were prepared with sterilised secateurs to prevent contamination and ensure consistency (Figure-2). Each species was propagated using 10 stem cuttings per replicate, with three replicates (n = 30 per species). Each cutting was weighed using a precision balance (± 0.001 g) to standardise the initial biomass. The cuttings were planted in multi-cellular trays containing an organic potting medium primarily composed of coco-peat, selected for its excellent moisture retention and aeration properties. The experiment was conducted under controlled conditions between August and October 2023, at Baburaoji Gholap College research centre, Pune-411027. The experiment was conducted at approximately $25 \pm 2^\circ\text{C}$ under natural photoperiod conditions. To maintain optimal moisture levels, the plants were irrigated daily with tap water under uniform conditions¹⁵ (Figure-3). This setup facilitated a reliable assessment of the vegetative growth potential of the selected aquatic weed species.



Figure-2: Preparation of stem cuttings used for vegetative propagation of selected aquatic weed species.

Figure-3 illustrates the establishment and growth of stem cuttings in multicellular trays containing coco-peat substrate. It highlights the uniform experimental setup adopted to assess propagation success and morphological development across different species.

Statistical Analysis: All statistical analyses were performed using Microsoft Excel 2016. Data are presented as mean \pm standard deviation (SD). One-way analysis of variance (ANOVA) was used to determine significant differences among species. Prior to analysis, data were checked for normality and homogeneity of variance. Tukey’s Honestly Significant Difference (HSD) test was applied as a post hoc analysis to identify significant differences between species at $p < 0.05$.

Results and Discussion

Morphological Analysis: A systematic morphological assessment of the selected aquatic weed species revealed clear interspecific variation in growth attributes following 30 days of vegetative propagation (Table-1). Among the species, *Physalis minima* showed comparatively higher values across most parameters, while *Portulaca oleracea* exhibited the lowest growth performance. Such variation in growth traits reflects differences in physiological efficiency and adaptability among species. Previous studies have reported that plant morphological traits play a crucial role in determining ecological performance and survival under different environmental conditions^{16,17}.

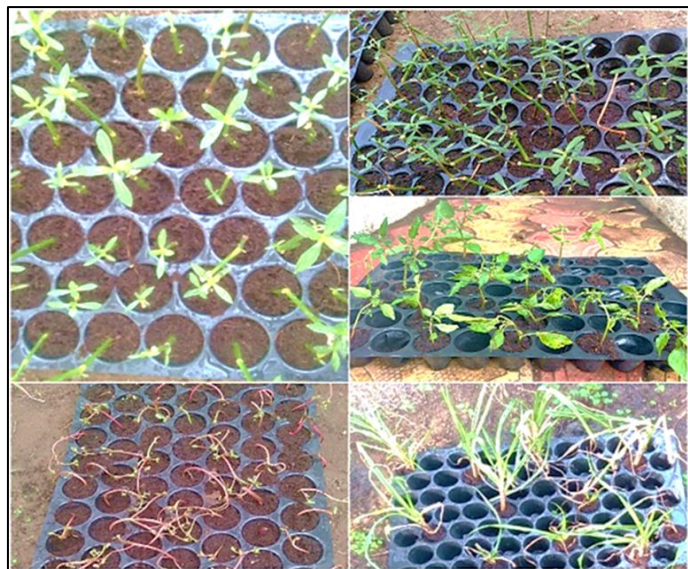


Figure-3: Vegetative propagation of selected aquatic weed species under controlled experimental conditions.

Shoot length: Shoot length varied among species, with *Physalis minima* recording the highest mean value (9.1 ± 1.00 cm), followed by *Alternanthera philoxeroides* (8.7 ± 1.45 cm) and *Juncellus alopecuroides* (7.3 ± 0.85 cm), while *Portulaca oleracea* showed the lowest value (6.5 ± 1.25 cm) (Table-1). However, the variation was not statistically significant ($p > 0.05$). The non-significant variation suggests that shoot growth may be influenced more by environmental conditions than intrinsic species characteristics. Similar observations have been reported in aquatic plants, where shoot elongation is affected by external factors such as light availability and water conditions¹⁸.

Therefore, the non-significant variation in shoot length observed in this study is consistent with both classical and contemporary ecological understanding.

Table-1: Measured morphological characters of selected weeds.

Name of Weed	Sets	Shoot Length (cm)	Root Length (cm)	No. of Leaves	Biomass (gm)
<i>Alternanthera philoxeroides</i>	1	7.1	5.3	14	14.2
	2	9	5	10	13.3
	3	10	5.3	12	16
	Mean \pm SD	8.7 ± 1.45	5.2 ± 0.17	12.0 ± 2.00	14.5 ± 1.37
<i>Juncellus alopecuroides</i>	1	6.4	4.6	11	13.2
	2	8.1	4.2	11	11.3
	3	7.4	4.7	8	12.1
	Mean \pm SD	7.3 ± 0.85	4.5 ± 0.26	10.0 ± 1.73	12.2 ± 0.95
<i>Physalis minima</i>	1	10.1	6.1	13	16.3
	2	8.1	5.5	15	17.9
	3	9.1	6.4	17	16.2
	Mean \pm SD	9.1 ± 1.00	6.0 ± 0.46	15.0 ± 2.00	16.8 ± 0.95
<i>Portulaca oleracea</i>	1	7.8	3.8	9	10.8
	2	6.4	3.7	7	10.3
	3	5.3	3.9	8	9.8
	Mean \pm SD	6.5 ± 1.25	3.8 ± 0.10	8.0 ± 1.00	10.3 ± 0.50

Root length: Root length showed highly significant variation among species ($F = 33.34, p < 0.001$), with *Physalis minima* exhibiting the highest root length (6.0 ± 0.46 cm), followed by *Alternanthera philoxeroides* (5.2 ± 0.17 cm) and *Juncellus alopecuroides* (4.5 ± 0.26 cm), while *Portulaca oleracea* recorded the lowest value (3.8 ± 0.10 cm) (Table-1). Root development is a critical factor influencing nutrient uptake and plant establishment. Previous studies have demonstrated that well-developed root systems enhance the ability of plants to absorb nutrients and adapt to environmental conditions^{19,20}. In the context of phytoremediation, roots play a major role in pollutant uptake and stabilization processes⁶.

Number of leaves: The number of leaves varied significantly among species ($F = 8.92, p = 0.006$), with *Physalis minima* showing the highest leaf count (15.0 ± 2.00), followed by *Alternanthera philoxeroides* (12.0 ± 2.00) and *Juncellus alopecuroides* (10.0 ± 1.73), whereas *Portulaca oleracea* recorded the lowest value (8.0 ± 1.00) (Table-1). Leaf production is directly associated with photosynthetic capacity and biomass accumulation. Studies have shown that increased leaf area enhances energy capture and supports plant growth and productivity^{21,17}.

Biomass: Biomass accumulation differed significantly among species ($F = 24.05, p < 0.001$), with *Physalis minima* recording the highest biomass (16.8 ± 0.95 g), followed by *Alternanthera philoxeroides* (14.5 ± 1.37 g) and *Juncellus alopecuroides* (12.2 ± 0.95 g), while *Portulaca oleracea* exhibited the lowest biomass (10.3 ± 0.50 g) (Table-1). Higher biomass production is often associated with improved growth efficiency and ecological adaptability. Previous research indicates that plants with higher biomass have greater potential for nutrient accumulation and environmental applications^{22,5}.

Comparison of growth parameters: The comparative analysis highlights that *Physalis minima* consistently exhibited higher growth performance across all measured parameters, followed by *Alternanthera philoxeroides* and *Juncellus alopecuroides*, while *Portulaca oleracea* showed comparatively lower growth. This variation indicates species-specific differences in growth strategies and adaptability. However, it is important to note that morphological performance alone cannot fully determine phytoremediation efficiency, as factors such as pollutant uptake capacity and environmental interactions also play a crucial role¹¹.

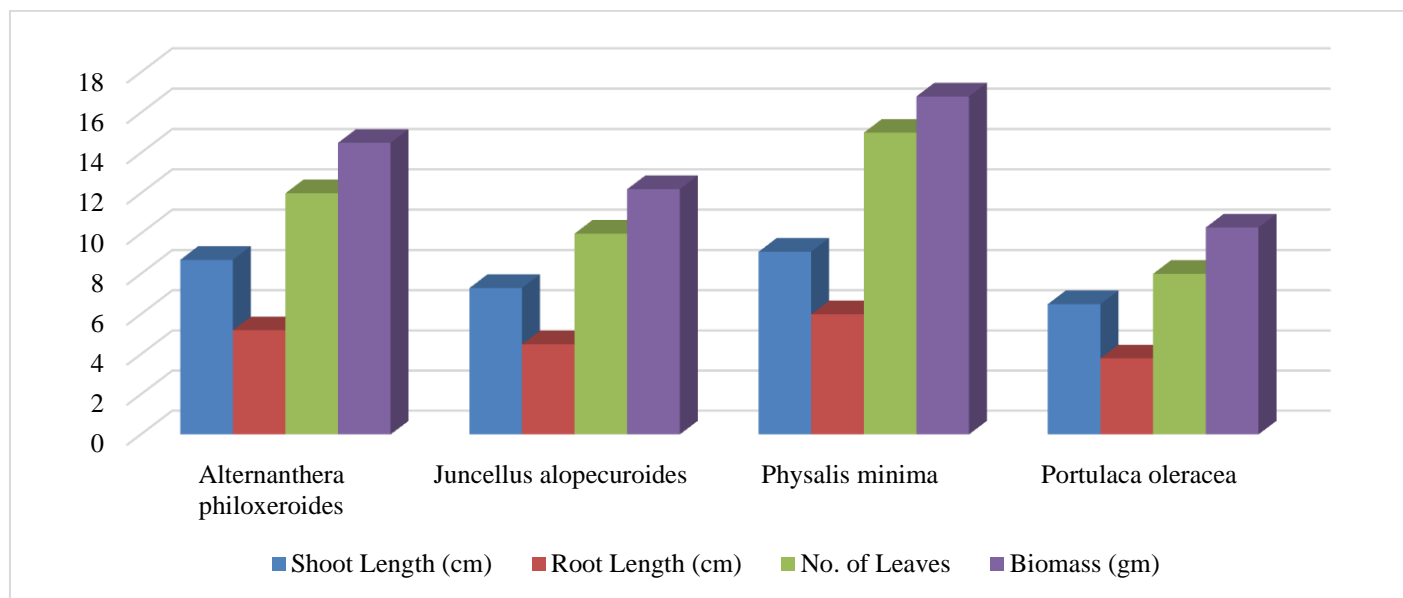


Figure-4: Comparative analysis of mean growth parameters of selected aquatic weed species following 30 days of vegetative propagation.

Table-2: One-Way ANOVA results for morphological parameters of aquatic weeds.

Morphological Parameter	F-value	df (Between, Within)	P-value	Significance/Difference
Shoot Length (cm)	3.22	(3, 8)	0.083	Not significant (ns)
Root Length (cm)	33.34	(3, 8)	< 0.001	Significant (p < 0.001)
Number of Leaves	8.92	(3, 8)	0.006	Significant (p < 0.01)
Biomass (g)	24.05	(3, 8)	< 0.001	Significant (p < 0.001)

Note: Significance was evaluated at $\alpha = 0.05$. df = degrees of freedom.

Post hoc analysis (Tukey HSD) indicated that *Physalis minima* differed significantly from *Portulaca oleracea* in root length and biomass ($p < 0.05$).

The present study is limited to morphological assessment under controlled conditions and does not include direct measurement of pollutant or heavy metal uptake. Therefore, any inference regarding the applicability of these species in phytoremediation remains preliminary. Future studies should focus on evaluating contaminant removal efficiency and field-based validation of the selected species.

Conclusion

The present study demonstrates that vegetative propagation through stem cuttings is an effective method for the rapid multiplication of selected aquatic weed species under controlled conditions. Significant interspecific variation was observed in key morphological parameters, particularly root length, leaf number, and biomass, while shoot length did not differ significantly. Among the studied species, *Physalis minima* exhibited comparatively higher growth performance, followed by *Alternanthera philoxeroides* and *Juncellus alopecuroides*, whereas *Portulaca oleracea* showed lower growth values. The findings highlight the importance of morphological traits such as root development, leaf production, and biomass accumulation in determining early growth performance and species adaptability. These traits can be useful indicators for selecting suitable plant species for ecological restoration and related environmental applications. However, the study is limited to morphological assessment under controlled conditions and does not include direct evaluation of pollutant or heavy metal uptake. Therefore, conclusions regarding phytoremediation potential remain preliminary. Future studies should focus on contaminant removal efficiency, physiological responses, and field-based validation to establish the practical applicability of these species in phytoremediation systems.

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