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EFFECTS OF WATER DEPTH ON THE GROWTH OF *NELUMBO NUCIFERA* GAERTN. SEEDLINGS

MD. ALMUJADDADE ALFASANE, MONIRUZZAMAN KHONDKER AND Z. N. TAHMIDA BEGUM

Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh

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Abstract

Water depth showed significant effect on the growth of *Nelumbo nucifera* Gaertn. in deep and shallow water culture pits. In deep water culture pit, the leaf area showed its highest growth rate of 21.84 ± 2.89 cm^2/day in summer and petiole length showed highest growth rate of 0.34 ± 0.10 cm/day in monsoon. The plantlets grown in shallow water culture pit showed highest growth rate of leaf area of 8.75 ± 0.91 cm^2/day in summer and the length of the petiole was highest in monsoon (0.25 ± 0.03 cm/day). Comparatively highest growth was observed in deep water culture pit rather than that of shallow water. Highest growth of the plant and flowering were found to be associated with higher water depth (100 cm) where the plant grew up to a height of about 1.5 m and maximum leaf diameter was 50 cm. Poor growth of the plant with no flowering was in shallow water depth (20 cm) where maximum height of the plant was about 0.5 m and leaf diameter was 25 cm. Although the concentrations of NO_3-N, soluble reactive phosphorus, soluble reactive silicate, planktonic chl *a* and phaeopigment were in higher amount in shallow water culture pit but due to shallow depthness plant showed poor growth and no flowering.

Introduction

Water depth has been considered as a regulatory factor for many water quality parameters. Water temperature and dissolved oxygen vary with depth as well as with the time of day. The depth of light penetration, which is influenced by turbidity, has an effect on the productivity of plants in an aquatic ecosystem. Various depths in a lake or river host different assemblages of benthic (bottom-dwelling) organisms. Plankton and fish move from one depth to another based on changing environmental conditions. In Bangladesh very few works on macrophytic vegetation have been carried out.[1-4] Recently Alfasane *et al*.[5-6] have studied the relationships between growth rate and limnological factors of *Nelumbo nucifera* Gaertn. and *Euryale ferox* Salisb. Biochemical compositions of the seeds of *E. ferox* and *N. nucifera* were also studied.[7-8] No research work has been carried out so far on the effects of water depth on the growth of *N. nucifera* seedlings in Bangladesh. However, similar researches had been carried out in other countries.[9-17] The present study has, therefore, been undertaken to carry out the effects of water depth on the growth of *N. nucifera* seedlings.

*Corresponding author.

Materials and Methods

The experiment was carried out in the culture pits of Department of Botany, University of Dhaka between 2005 and 2007. Seedlings of *Nelumbo nucifera* were obtained via seeds sown in 1 : 1 cow-dung compost and loamy soil. Collection and germination of seeds of *N. nucifera* were described by Alfasane *et al*.[5] Two experiments were conducted. For the first experiment which was described by Alfasane *et al*.[5], deep water culture pit measuring 3 × 2 m was filled with transparent underground water up to 100 cm for the first experiment and shallow water culture pit measuring 1.5 × 0.75 m was filled up to 25 cm for the second experiment. Eight young seedlings (3 months old) of *N. nucifera* were transferred to the deep water culture pit and immediately after transplantation some tap water was added in the tank in such a way that only the leaves of the plants remain afloat. The water depth was adjusted everyday looking at the growth of the plants. Eight plantlets were transferred to another shallow water culture pit and cultured to see the effect of depth on the plant and to compare the effects of water depth on the growth of *N. nucifera* in both the culture pits. The growth measurement was carried out on randomly selected petioles (n = 8) and leaves (n = 32) of the plants of both the culture pits.

During the experiments data on relative humidity, total rainfall, day length (sunshine hours), PAR (photosynthetic active radiation), air and water temperature, pH, DO (dissolved oxygen), soluble reactive silicate (SRS), alkalinity, nitrate-nitrogen (NO_3-N), SRP (soluble reactive phosphorus) and phytoplankton biomass were studied. Methods applied to measure these limnological parameters have been elaborated in Alfasane *et al*.[5] Seasonal mean values and ranges of the data of two culture pits are presented in Table 1. Pearson correlation study was made (SPSS program) to find the relationships between the measured limnological variables and the growth of petiole and leaf area of the plant of both the culture pits (Table 2).

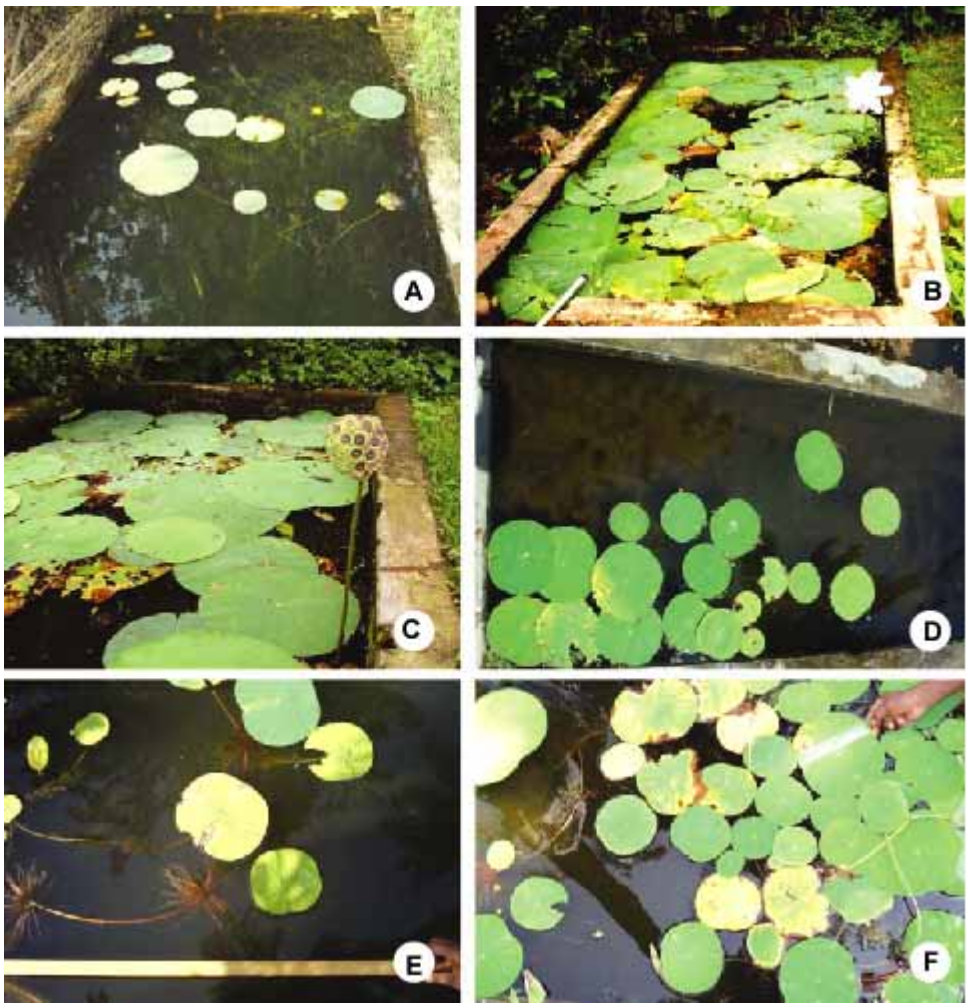
Results and Discussion

The present study showed that germination of the seeds occurred within the water depth of about 25 cm. Similar observation was found for the germination of the seeds of *Trapa bicornis* L. within the water depth of 20 - 25 cm.[13]

Results showing highest growth and flowering of *N. nucifera* in deep water culture pit associated with a water depth of 100 cm are presented in Figs. 1A-C. Poor growth of the plant with no flowering in shallow water culture pit is presented in Figs. 1D-F. In the deep water culture pit the plant grew up to a height of about 1.5 m and the leaves were as large as 50 cm in diameter. On the other hand, shallow water showed maximum height of the plant of about 0.5 m and leaves diameter of about 25 cm.

In both the culture pits variation of different parameters were observed in different seasons such as in deep water culture pit[5], the leaf area showed its maximum average highest growth rate of 21.84 ± 2.89 cm^2/day in summer. A medium range growth rate was

observed during the monsoon (18.31 ± 0.98 cm^2/day). In winter the growth rate was 1.71 ± 0.55 cm^2/day whereas autumn showed poor growth of the plant (2.33 ± 0.29 cm^2/day; Fig. 2). Another aquatic macrophyte *Euryale ferox* also showed increased growth rate of leaf area in summer[6]. Petiole length showed highest growth rate of 0.34 ± 0.10 cm/day in monsoon. The summer season showed a medium growth in the length of the petiole (0.29 ± 0.05 cm/day). In autumn, the petiole length grew at a rate of 0.25 ± 0.07 cm/day. Least growth rate of the petiole was observed in winter (0.22 ± 0.05 cm/day; Fig. 2). Similar type of observation was also recorded in *E. ferox*[6].



Figs. 1A-F: A-C. Growing stage of seedlings of *Nelumbo nucifera* in the deep water culture pit with large leaves, flowering and fruiting stage. D-F. Plant grown in shallow water culture pit of *Nelumbo nucifera* with small leaves and no flowering and fruiting stage.

The plantlets grown in shallow water culture pit showed highest growth rate of leaf area of 8.75 ± 0.91 cm^2/day in summer. In monsoon the growth rate was medium (5.46 ± 0.67 cm^2/day). In autumn the growth rate was 1.15 ± 0.15 cm^2/day and the least growth was observed in winter (0.95 ± 0.26 cm^2/day). The length of the petiole was highest in monsoon (0.25 ± 0.03 cm/day). A medium growth of the petiole was observed in summer (0.20 ± 0.03 cm/day). The growth in the petiole length in autumn was 0.15 ± 0.01 cm/day. Lowest growth of the same was observed in winter (0.09 ± 0.02 cm/day; Fig. 2). In contrast to shallow water culture pit highest growth was observed in deep water culture pit. Highest growth and flowering were found to be associated with a water depth of 100 cm. That *Vallisneria natans* showed an optimal clonal growth at water depths of 110 - 160 cm was reported by Xiao *et al.*[9] Salter *et al.*[10] also examined the response of 5-month-old *Melaleuca ericifolia* Sm. (Swamp paperbark) seedlings to three water depths (exposed, waterlogged and submerged) at three salinities (2, 49 and 60 dS/m) and they found that

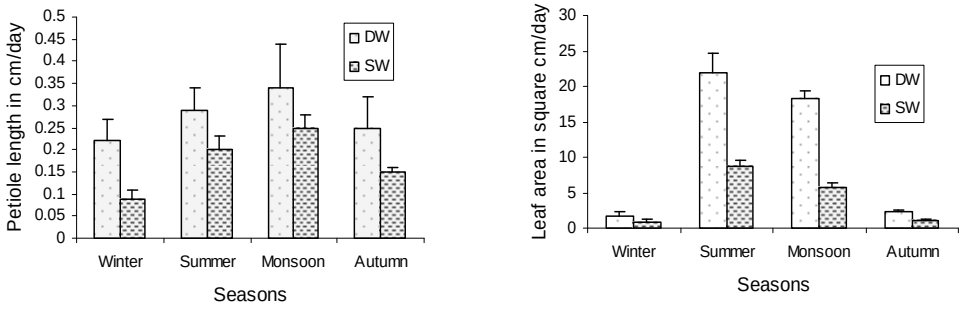


Fig. 2. Growth rate of *Nelumbo nucifera* in different seasons for deep water (DW, Alfasane *et al.*[5]) and shallow water (SW) culture pits (petiole length in cm/day, leaf area in cm^2/day).

increasing water depth at the lowest salinity did not affect survival, but strongly inhibited seedling growth. Strand and Weisner[12] reported that under deep water condition *Myriophyllum spicatum* exhibited increase in its height and branch length, and decreased branch number. Rea *et al.*[14] also showed that the area occupied by floating-leaved macrophytes increased from 3.2 to 19.9 ha, when macrophytes occupied 84.1% of the area ≤ 2 m deep and 56.3% of the area 3 m deep. The rates of macrophyte development were consistently slower in areas of greater water depth and greater fetch. *Myriophyllum variifolium* J. Hooker and *Eleocharis acuta* R. Br. showed morphological changes in different water depths.[16]

Throughout the study period, climatic data[5] showed that seasonal mean values of PAR were highest (776.83 μE/m^2/sec) in summer and lowest (620.28 μE/m^2/sec) in winter. The highest and lowest seasonal mean sunshine hour values were 12.84 and 10.74 hr in monsoon and autumn, respectively. The highest (213.19 mm) mean values of rainfall were recorded during monsoon and lowest (2.28 mm) were recorded during winter. On

the other hand, the highest (79.59%) mean values of humidity were recorded during monsoon and the lowest (55.83%) values were recorded during summer.

The results presented in Table 1 showed that the highest and lowest seasonal mean air temperatures were 33.92 and 25.49ºC in summer and winter, respectively. The highest seasonal mean water temperature was 31.58ºC for two culture pits in summer. The lowest seasonal mean temperature was 24.28 and 24.07ºC for deep water and shallow water culture pits, respectively. The mean pH fluctuated from 6.67 - 7.09 and 6.68 - 7.04 for deep water and shallow water culture pits, respectively in different seasons of the present study. The highest seasonal mean values of alkalinity recorded were 4.10 and

Table 1. Seasonal mean values of different limnological parameters for *Nelumbo nucifera* in deep water (DW, Alfasane *et al.*[5]) and shallow water (SW) culture pits.

Parameters	Winter (late November-February)		Summer (March-May)		Monsoon (June-early October)		Autumn (late October- November)	
	DW	SW	DW	SW	DW	SW	DW	SW
Air temp. (ºC)	25.49 ± 4.02	25.49 ± 4.02	33.92 ± 2.30	33.92 ± 2.30	32.00 ± 2.24	32.00 ± 2.24	33.50 ± 2.01	33.50 ± 2.01
Water temp. (ºC)	24.28 ± 3.89	24.07 ± 4.05	31.58 ± 1.95	31.58 ± 2.14	29.93 ± 1.99	30.11 ± 1.66	30.75 ± 1.15	30.75 ± 1.53
pH	6.95 ± 0.22	7.04 ± 0.13	6.67 ± 0.07	6.68 ± 0.12	6.94 ± 0.24	6.92 ± 0.09	7.09 ± 0.06	6.83 ± 0.12
Alkalinity (meq/l)	3.86 ± 0.27	3.67 ± 0.39	4.10 ± 0.61	3.84 ± 0.80	2.97 ± 0.47	1.80 ± 0.41	3.45 ± 0.34	2.84 ± 0.37
DO (mg/l)	11.08 ± 0.94	7.67 ± 0.77	10.00 ± 1.72	8.65 ± 0.76	5.65 ± 0.97	4.87 ± 1.67	10.26 ± 1.15	8.02 ± 0.15
NO_3-N (µg/l)	95.28 ± 65.17	197.43 ± 66.40	108.72 ± 43.13	135.84 ± 47.18	60.97 ± 41.93	106.02 ± 55.57	58.55 ± 37.54	80.39 ± 54.41
SRP (µg/l)	132.93 ± 49.49	287.56 ± 75.03	113.46 ± 65.34	599.93 ± 178.21	87.96 ± 60.05	268.15 ± 64.35	138.81 ± 29.04	292.22 ± 43.69
SRS (mg/l)	85.22 ± 25.08	82.85 ± 23.74	80.76 ± 37.33	49.46 ± 18.95	74.52 ± 25.29	15.36 ± 5.48	77.12 ± 10.47	50.59 ± 17.06
Chl *a* (µg/l)	35.25 ± 29.85	55.38 ± 30.73	102.34 ± 130.95	165.50 ± 113.04	24.32 ± 24.93	60.75 ± 96.57	24.99 ± 8.85	66.53 ± 70.35
Phaeo. (µg/l)	6.85 ± 5.65	10.54 ± 6.15	24.89 ± 36.98	27.83 ± 29.00	5.67 ± 5.64	16.21 ± 30.92	5.67 ± 2.57	8.13 ± 9.90

DW - Deep water culture pit, SW - Shallow water culture pit.

3.84 meq/l during summer for deep water and shallow water culture pits, respectively and the lowest (2.97 meq/l in deep water and 1.80 meq/l in shallow water culture pits) were recorded during monsoon. Dissolved oxygen concentration of the studied habitats ranged from 5.65 - 11.08 mg/l and 4.87 - 8.65 mg/l for deep water and shallow water culture pits, respectively. The concentration of NO_3-N varied from 58.55 - 108.72 µg/l and

80.39 - 197.43 µg/l for deep water and shallow water culture pits, respectively. The soluble reactive phosphorus exhibited highly fluctuating pattern over the study period and among the culture pits. The concentration ranged from 87.96 - 138.81 µg/l and 268.15 - 599.93 µg/l, for deep water and shallow water culture pits, respectively. In the deep water culture pit, SRS ranged from 74.52 - 85.22 mg/l and in shallow water culture pit from 15.36 - 82.85 mg/l. The concentration of planktonic chl *a* varied from 24.32 - 102.34 µg/l and 55.38 - 165.50 µg/l for deep water and shallow water culture pits, respectively. Phaeopigment concentration varied from 5.67 - 24.89 µg/l and 8.13 - 27.83 µg/l for deep water and shallow water culture pits, respectively. Emergent macrophyte (*Cladium mariscus*) showed significant differences in the limnological environment in deeper (1.0 m) and in shallower (0.4 m) water zones of the Spanish National Park, Las Tablas de Daimiel.[11]

Correlation studies between the growth and limnological variables for deep water culture pit [5] showed that the petiole length relates positively with rainfall, humidity and pH and leaf area showed positive correlation with PAR, day length, rainfall, humidity, air temperature, water temperature, NO_3-N, planktonic chl *a* and phaeopigment. Among these parameters positive correlation between leaf area and day length was found to be significant at 5% level (Table 2). On the other hand, shallow water culture pit for *N. nucifera* showed that the petiole length positively correlated with PAR, day length, rainfall, humidity, air temperature, water temperature and SRP and leaf area showed positive correlation with PAR, day length, rainfall, humidity, air temperature, water temperature, alkalinity, SRP and planktonic chl *a* (Table 2).

Table 2. Pearson correlation between limnological parameters and growth rate of *Nelumbo nucifera* (data extracted from SPSS programme).

Limnological parameters	Growth rate				Limnological parameters	Growth rate			
	Petiole length		Leaf area			Petiole length		Leaf area	
	DW	SW	DW	SW		DW	SW	DW	SW
PAR	−0.818	+0.388	+0.682	+0.811	Alkalinity	−0.904	−0.637	−0.019	+0.072
Day length	−0.195	+0.872	+0.976*	+0.910	DO	−0.569	−0.595	−0.567	−0.006
Rainfall	+0.452	+0.921	+0.673	+0.482	NO_3-N	−0.853	−0.568	+0.269	−0.120
Humidity	+0.811	+0.689	+0.238	+0.009	SRP	−0.233	+0.205	−0.383	+0.801
Air temp.	−0.229	+0.656	+0.565	+0.563	SRS	−0.501	−0.955	−0.807	−0.491
Water temp.	−0.248	+0.649	+0.619	+0.513	Chl *a*	−0.951*	−0.087	+0.624	+0.563
pH	+0.797	−0.806	−0.776	−0.282	Phaeopigment	−0.935	−0.777	+0.663	−0.539

*Correlation is significant at the 0.05 level (2- tailed). DW = Deep water culture pit (Alfasane *et al*.[5]), SW = Shallow water culture pit.

The present study reveals that pH, alkalinity and dissolved oxygen were in higher range in deep water culture pit rather than that of shallow water culture pit. On the other hand, the concentration range of NO_3-N, SRP, planktonic chl *a* and phaeopigmet were in higher range in shallow water culture pit rather than that of deep water culture pit. The

concentration of maximum mean values of SRS in the two culture pits were nearly same. These results clearly indicate that higher range of NO_3-N, SRP and SRS did not influence positively in petiole length and leaf size of *N. nucifera* and failed to produce flowering and fruiting in shallow water culture pit. But in contrast to the deep water culture pit showed highest growth and flowering under lower concentrations of NO_3-N, SRP, SRS, planktonic chl *a* and phaeopigment rather than that of shallow water culture pit.

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