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Assessing the potential adaptability of water lilies (*Nymphaea* sp.) under arid climatic conditions

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Abstract

The arid climatic conditions of Kuwait limits the range of plant species exploited in landscaping and in such environments, water gardening, which is suitable for a variety of climates including the desert climate, becomes significant. Hence, the relative growth rate and adaptability of 15 imported cultivars of water lilies (*Nymphaea* sp.) were assessed at the Urban Demonstration Garden Site (UDG) of the Kuwait Institute for Scientific Research (KISR). The cultivars were imported from Shanghai Xinhai Cultivation of Flowers Co., Ltd, China, and the experiment was conducted in Completely Randomized Design (CRD) with three replications. The cultivars were planted in one-gallon containers filled with sand:sphagnum peat moss (2:1 v/v) and placed in pond compartments filled with fresh water. The periodic data on the number of leaves, petiole length, leaf width, leaf area index, and number of flowers of water lily cultivars were analyzed using the statistical procedure, R method. The results of the study were very promising, indicating that using water lilies for greenery enhancement and in landscape beautification projects in Kuwait is a viable option. All the introduced water lily varieties from China were found suitable for growing under the climatic conditions of Kuwait as evidenced by the data on growth rate and survival percentage. All of the varieties exhibited a positive growth rate during the summer season and their growth was drastically reduced during the winter season. Further studies on the performance of water lilies are required to ascertain the long-term impact of prevailing environmental conditions on their growth and contribution to visual appeal.

Key words: *Nymphaea* sp., relative growth rate, survival percentage, seasonal fluctuations.

Introduction

The State of Kuwait is characterized by hyper arid to arid climate which limits the range of plant species exploited in landscaping with acceptable greenery impacts [5]. The major challenge of the agricultural sector in Kuwait is to maximize land and water productivity without depending on fertile soils and without degrading the environment and natural resource base. In such environments, water gardening, which is suitable for a variety of climates including the desert climate, becomes significant.

Water lilies (*Nymphaea* sp.) are commonly applauded for their beauty and aesthetic appeal and are the most popular and widely cultivated water garden plant in the world. Among the water plants, modern aquatic gardening places more emphasis on water lilies which form the showy centre piece of gardens and they have a thriving market in aquascaping with a brilliant prospective to become a multimillion-dollar product in the floriculture trade [4]. Water lilies are found adaptable to the climatic conditions of Kuwait [1, 2]. Therefore, the Arid Land Agriculture and Greenery Department (AAGD) at KISR conducted this study with the objective of evaluating the relative growth rate and adaptability of water lilies under the climatic conditions in Kuwait.

Materials and Methods

The study was conducted at the UDG site, Salmiya, using fifteen superior cultivars of water lily imported from Shanghai Xinhai Cultivation of Flowers Co., Ltd, China. The plants were selected after scientific appraisal of various plant morphological characteristics and color and size of the flowers. The cultivars studied were: *Nymphaea mexicana* (T1), *Nymphaea sumptuosa*(T2), *Nymphaea marliacea carnea*(T3), *Nymphaea texas* (T4), *Nymphaea rosea* (T5), *N.* Perry's Baby Red (T6), *Nymphaea odorata* (T7), *Nymphaea colorado* (T8), *Nymphaea* Almost Black (T9), *Nymphaea alba* (T10), *Nymphaea chromatella* (T11), *Nymphaea masaniello* (T12), *Nymphaea* Fabiola Pink (T13), *Nymphaea sunrise* (T14) *and Nymphaea odorata rosea* (T15). While importing, all the required quarantine and phytosanitary measures were advocated to avoid any seed-borne diseases from entering Kuwait.

A concrete pond of size 30 m x 10 m was constructed by a contracting company which was designed in such a way that the water in the tank can be pumped out at regular intervals in order to prevent dust accumulation and algal growth. The successful culture of rooted aquatic plants depends on the ability to absorb enough nutrients, light and inorganic carbon through the water to the plant shoots and different species may differ in their adaptability to a particular climatic condition [6]. The experimental plants were arranged in a completely randomized design (CRD) with three replications of each variety. One gallon containers were filled with a growing medium of sand: sphagnum peat moss in 2:1 (v/v) and the varieties were planted in pots during June 2009 and after planting the pots were backfilled to ensure that the plants were anchored with the crown of the plant at soil level. The pots were then placed in the pond compartments filled with fresh water. Whenever algal growth was noticed, it was controlled by sweeping the net in the initial stage itself, thus preventing its growth before it could reach dangerous levels. In order to prevent environmental hazards, pests were controlled manually whenever an infestation

was noticed in minor amounts. To maintain an optimum pH (in the range of 7 to 8) in the pond, care was taken to cover only 50 to 70% of the water surface with the plants and routine removal of sludge and decaying organic matter was carried out.

Since water lily plants generally produce more biomass than submerged aquatic plants, they have proportionately greater demands for nutrients and hence fertilization is a must. Therefore, once the plants were established, three slow-release-aquatic fertilizer tablets, each weighing 5 g, were inserted in each container, about two inches from the rhizome. No incidences of pests or diseases were detected during the assessment period. Certain varieties started flowering within a month after planting. Both spent flowers and aging leaves were being removed periodically to reduce the nutrient load in the pond as they decompose. The rate of growth was measured on a monthly basis for petiole length, number of leaves, number of flowers, leaf width and relative growth rate to assess the performance of introduced water lily varieties during the period of study.

The average maximum and minimum day time temperatures and day-length data during the course of evaluation is presented in Table 1. The average maximum day time temperature at the time the plants were received in Kuwait was 48.5°C. During the study period, the maximum daytime temperatures varied between 46.5°C in August 2009 and 40.12°C in August 2010. The minimum daytime temperature recorded during December 2009 was 9°C.

Results and Discussion

The periodic data on the number of leaves, petiole length, leaf width, leaf area index, and number of flowers of water lily cultivars studied are presented in Tables 1 to 3. The data were analyzed using the statistical procedure, R method [3].

Table 1. Temperature and day-length conditions during the field study.

Month	Temperature (°C)			Day Length
	Maximum	Minimum	Average	(h:min)
2009				
July	45.9	31.1	39.0	9:28
August	46.5	31.0	38.4	10:25
September	42.7	27.3	34.7	9:29
October	37.5	21.6	28.9	7:32
November	26.0	15.0	21.0	8.03
December	20.0	9.00	14.5	7.0
2010				
January	17.87	16.86	17.37	8.02
February	19.33	18.13	18.73	8.91
March	24.31	22.87	23.59	9.05
April	28.42	26.95	27.69	9.55
May	33.02	31.39	32.21	10.13
June	37.36	35.52	36.44	10.51
July	38.35	36.63	37.49	10.92
August	40.12	38.22	39.17	11.31
September	36.40	34.71	35.56	10.32

Number of leaves: The number of leaves produced was significantly different among the different varieties during the study period. T8 (*N. colorado*) produced the highest number of leaves at 360 DAP (48.36) followed by T14 *(N. sunrise)* and T2 *(N. sumptuosa)* with values of 36.61 and 35.53, respectively. At 270 DAP, T1 (*N. mexicana*) produced the maximum number of leaves (15.71) followed by T7 (*N. odorata*) with a value of 14.44 and T3 (*N. marliacea carnea)* with a value of 12.31. At 180 DAP, variety *N. odorata* (T7) produced the maximum number of leaves (11.70) followed by T8 (*N. Colorado)* at 9.11. At 30 DAP, variety *N. chromatella* (T11) produced the maximum number of leaves (29.96) followed by T3 (*N. marliacea carnea*) (16.83). Differences between treatments were highly significant at P≤ 0.001 (Fig. 1).

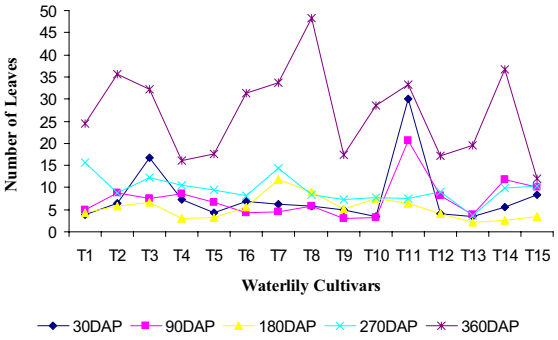

Figure 1. Average number of leaves produced.
T1-*Nymphaea mexicana*, T2-*Nymphaea sumptuosa*, T3-*Nymphaea marliacea carnea*. T4- *Nymphaea texas*, T5-*Nymphaea rosea*, T6-*N.* Perry's Baby Red. T7-*Nymphaea odorata*, T8-*Nymphaea colorado*, T9-*Nymphaea* Almost Black. T10-*Nymphaea alba*, T11-*Nymphaea chromatella*, T12-*Nymphaea masaniello*. T13-*Nymphaea* Fabiola Pink, *T14-Nymphaea sunrise,* T15-*Nymphaea odorata rosea.* DAP-Days After Planting.

Petiole length: Regarding petiole length, treatment T14 (*N. sunrise)* produced leaves with maximum petiole length (75.33 cm) at 360 DAP followed by T2 *(N. sumptuosa)* with a value of 68.83 and T1 (*N. mexicana*) recorded the lowest petiole length of 30.42. At 270 DAP the highest value of 33.17 was recorded in T5 (*N. rosea*) and the lowest value (10.88) was recorded in T7 *(N. odorata)*. At 180 DAP, the maximum petiole length of 7.56 was recorded in T2 (*N. sumptuosa*) and the lowest value of 2.06 was recorded for T14 (*N. sunrise*). The reduction in petiole length during this period can be attributed to the onset of the winter season. At 90 DAP, variety *N. sumptuosa* (T2) recorded the maximum petiole length of 64.43 and the lowest value of 41.00 was recorded for T5 (*N. rosea*). At 30 DAP, T3 (*N. marliacea carnea*) recorded maximum petiole length of 100.41 followed by T9 (*N.* Almost Black) and the lowest value of 26.28 was recorded in T13 (*N.* Fabiola Pink). After planting, rapid growth was observed during the summer season but with the onset of winter, growth slowed down significantly. Again in March, the indicator leaves started growing normally and the petiole length was found to increase. Statistical analysis of the data showed that the treatments differed significantly at 90, 180, 270, and 360 DAP at P≤ 0.001 but differences were nonsignificant at 30 DAP (Fig. 2).

Leaf width: T4 (*N. texas*) exhibited the maximum leaf width of 16.43 cm at 360 DAP followed by T2, *N. sumptuosa* (16.17 cm) and

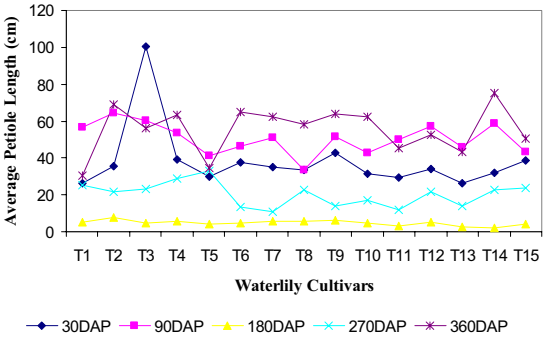

Figure 2. Average of petiole length.
T1-*Nymphaea mexicana*, T2-*Nymphaea sumptuosa*, T3-*Nymphaea marliacea carnea*. T4- *Nymphaea texas*, T5-*Nymphaea rosea*, T6-*N.* Perry's Baby Red. T7-*Nymphaea odorata*, T8-*Nymphaea colorado*, T9-*Nymphaea* Almost Black. T10-*Nymphaea alba*, T11-*Nymphaea chromatella*, T12-*Nymphaea masaniello*. T13-*Nymphaea* Fabiola Pink, *T14-Nymphaea sunrise,* T15-*Nymphaea odorata rosea.* DAP-Days After Planting.

the lowest value of 9.76 was recorded for T1 (*N. mexicana*). At 270 DAP, variety *N. rosea* (T5) recorded maximum leaf width of 11.23 cm and the lowest value of 4.14 cm was recorded for T11 (*N. chromatella*). The maximum and minimum values at 180 DAP were 34.80 cm and 4.06 cm, respectively, for T4 (*N. texas*) and T14 (*N. sunrise*). At 90 DAP, the highest value of 11.76 cm was recorded for T2 (*N. sumptuosa*) and the lowest value of 3.83 cm was recorded for T13 (*N.* Fabiola Pink). The differences between treatments were nonsignificant at 30 and 360 DAP and highly significant at 90, 180 and 270 DAP at $P \leq 0.001$ (Fig. 3).

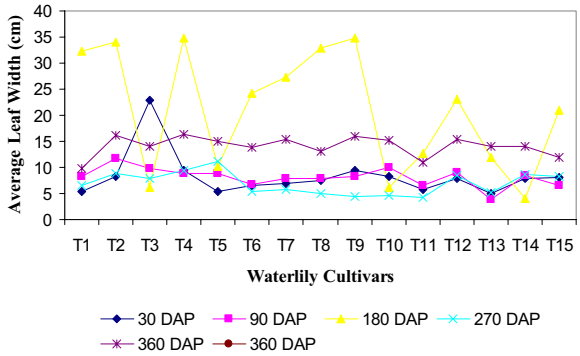

Figure 3. Average of leaf width.
T1-*Nymphaea mexicana*, T2-*Nymphaea sumptuosa*, T3-*Nymphaea marliacea carnea*.
T4- *Nymphaea texas*, T5-*Nymphaea rosea*, T6-*N.* Perry's Baby Red. T7-*Nymphaea odorata*, T8-*Nymphaea colorado*, T9-*Nymphaea* Almost Black. T10-*Nymphaea alba*, T11-*Nymphaea chromatella*, T12-*Nymphaea masaniello*.T13-*Nymphaea* Fabiola Pink, *T14-Nymphaea sunrise,* T15-*Nymphaea odorata rosea.* DAP-Days After Planting.

Leaf area index: T7 (*N. odorata*) produced maximum leaf area of 131.03 cm^2 at 420 DAP followed by T12 (130.05 cm^2) and the lowest value of 22.98 cm^2 was recorded for T15 (*N. odorata rosea*). At 330 DAP, variety *N. rosea* (T5) recorded the maximum leaf area of 101.80 cm^2 and the lowest value of 13.43 cm^2 was recorded for T15 (*N. odorata rosea*). The maximum and minimum values at 240 DAP were 20.46 cm^2 and 3.90 cm^2, respectively for T3 (*N. marliacea carnea*) and T9 (*N.* Almost Black). At 150 DAP, the highest value of 42.05 cm^2 was recorded for T3 (*N. marliacea carnea*) and the lowest value of 10.47 cm^2 was recorded for T15 (*N. odorata rosea*). The differences between treatments were highly significant during the period of study at $P \leq 0.001$ (Fig. 4).

Number of flowers: Among the 15 water lily varieties tried, the varieties *N. sunrise, N. texas, N. odorata,* and *N. colorado* produced flowers within 30 DAP. T4 (*N. texas)* produced the highest number of flowers (1.33) at 30 DAP. At 60 DAP, T14 *(N. sunrise)* produced the highest number of flowers followed by T4 (*N. texas),* T11 *(N. chromatella*), T12 *(N. masaniello)*.and T15 (*N. odorata rosea*). During this period, T2 (*N. sumptuosa*), T6 (*N.* Perry's Baby Red), T8 (*N. colorado)* and T10 (*N. alba)* produced the same number of flowers (0.67). T11 *(N. chromatella)* produced maximum number of flowers at 90 DAP (1.42). At 120 DAP T7 *(N. odorata),* T2 *(N. sumptuosa)* and T3 (*N. marliacea carnea)* produced the same number of flowers (0.33). T8 (*N. colorado)* also produced a significant number of flowers from 30 to 90 DAP. Statistical analysis (R Method) showed that differences between the treatments were significant at 30, 60, and 90 DAP and nonsignificant at 120 DAP. Flower production ceased with the onset of winter and resumed with the onset of summer. From 150 to 240 DAP flower production completely stopped due to the cold climate. At 270 DAP, in March, flower-bud production resumed and the treatments were found to be highly significant. At 300,

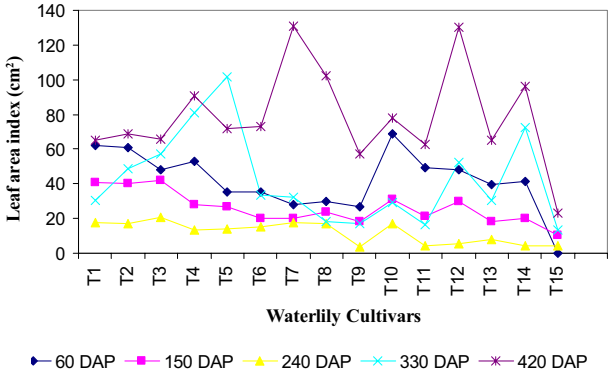

Figure 4. Leaf area index.
T1-*Nymphaea mexicana*, T2-*Nymphaea sumptuosa*, T3-*Nymphaea marliacea carnea*.
T4- *Nymphaea texas*, T5-*Nymphaea rosea*, T6-*N.* Perry's Baby Red. T7-*Nymphaea odorata*, T8-*Nymphaea colorado*, T9-*Nymphaea* Almost Black. T10-*Nymphaea alba*, T11-*Nymphaea chromatella*, T12-*Nymphaea masaniello*. T13-*Nymphaea* Fabiola Pink, *T14-Nymphaea sunrise,* T15-*Nymphaea odorata rosea.* DAP-Days After Planting.

330, and 360 DAP, T7 (*N. odorata*) produced the maximum number of flowers followed by T6 (*N.* Perry's Baby Red) and the variety T15 (*N. odorata rosea*) recorded the lowest number of flowers. Statistical analysis (R Method) showed that differences between the treatments were highly significant at $P \leq 0.001$ during the period of study except at 120 DAP (Fig. 5).

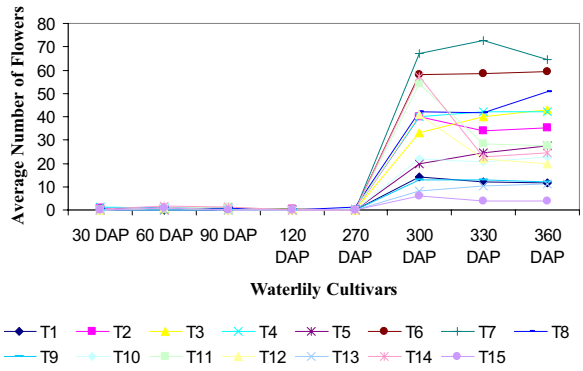

Figure 5. Average number of flowers produced.
T1-*Nymphaea mexicana*, T2-*Nymphaea sumptuosa*, T3-*Nymphaea marliacea carnea*.
T4- *Nymphaea texas*, T5-*Nymphaea rosea*, T6-*N.* Perry's Baby Red. T7-*Nymphaea odorata*, T8-*Nymphaea colorado*, T9-p*Nymphaea* Almost Black. T10-*Nymphaea alba*, T11-*Nymphaea chromatella*, T12-*Nymphaea masaniello*. T13-*Nymphaea* Fabiola Pink, *T14-Nymphaea sunrise,* T15-*Nymphaea odorata rosea.* DAP-Days After Planting.

Relative growth rate (RGR) under different seasons*:* The relative growth rate calculated using the following equation is summarized in Table 2.

$$\text{Growth Rate} = \frac{\text{Final Plant Height - Initial Plant Height x 100}}{\text{Initial Plant Height}}$$

Table 2. Relative growth rate (RGR %) of water lilies during summer and winter seasons.

Varieties	Relative Growth Rate (%)		
	Summer 2009	Winter 2009	Summer 2010
Nymphaea mexicana	65.08	17.19	41.68
Nymphaea sumptuosa	104.74	19.39	105.29
Nymphaea marliacea carnea	85.69	18.52	92.82
Nymphaea texas	31.79	06.12	53.59
Nymphaea rosea	69.27	15.97	56.98
N. Perry's Baby Red	38.80	27.12	84.93
Nymphaea odorata	92.15	11.88	102.14
Nymphaea colorado	72.25	05.92	79.27
Nymphaea Almost Black	41.18	17.49	54.19
Nymphaea alba	89.26	12.30	92.27
Nymphaea chromatella	59.03	20.97	77.24
Nymphaea masaniello	40.00	13.82	64.58
Nymphaea Fabiola Pink	53.43	29.41	60.95
Nymphaea sunrise	83.80	05.82	100.51
Nymphaea odorata rosea	32.76	16.25	41.61

Table 3. Survival rate of plant species at various time periods.

Variety	60 DAP	120 DAP	180 DAP	240 DAP	300 DAP	360 DAP	420 DAP	480 DAP
N. mexicana	100.00	93.75	93.75	81.25	81.25	81.25	81.25	81.25
N. sumptuosa	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
N. marliacea carnea	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
N. texas	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
N. rosea	100.00	92.85	92.85	92.85	92.85	92.85	92.85	92.85
N. Perry's Baby Red	100.00	93.33	93.33	93.33	93.33	93.33	93.33	93.33
N. odorata	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
N. colorado	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
N. Almost Black	100.00	88.88	88.88	88.88	88.88	88.88	88.88	88.88
N. alba	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
N. chromatella	100.00	85.00	85.00	75.00	75.00	75.00	75.00	75.00
N. masaniello	100.00	92.85	92.85	92.85	92.85	92.85	92.85	92.85
N. Fabiola Pink	100.00	80.00	80.00	70.00	70.00	70.00	70.00	70.00
N. sunrise	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
N. odorata rosea	100.00	57.14	57.14	42.85	42.85	42.85	42.85	42.85

DAP: Days After Planting.

Relative growth rate is determined by a number of physiological, morphological, and biological components and a high RGR reduces the time between vegetative growth and reproduction. The growth rate of water lily varieties ranged from 31.79 to 104.74% during the summer of 2009. Out of the 15 varieties, five varieties namely *N. sumptuosa, N. marliacea carnea, N. odorata, N. alba* and *N. sunrise* performed well with a growth rate of above 75%. All the varieties exhibited a positive growth rate which indicates that they can tolerate the harsh climatic conditions of Kuwait.

During winter season, the growth was drastically reduced and the range of growth rate varied from 5.92 to 29.41%. Even though there was a drastic reduction in growth, none of the varieties showed a negative growth rate thus indicating that they can tolerate the winter climatic conditions of Kuwait and resume growth after winter.

The range of growth rate of experimental plants during the summer of 2010 was from 41.61 to 105.29%. A good growth rate of more than 40% was shown by all varieties. Five varieties namely *N. sumptuosa, N. marliacea carnea, N. odorata, N. alba* and *N. sunrise* performed exceptionally well with a growth rate of above 90%. The varieties that exhibited an exceptionally high growth rate were selected for further study on the effect of water quality and pot size on the growth of water plants under the climatic conditions of Kuwait.

Survival and regrowth of plants after severe summer and winter seasons: All the varieties survived in spite of the extreme climatic conditions during the period of study (Table 3). Seven water lily species namely, *N. sumptuosa, N. marliacea carnea, N. texas, N. odorata, N. colorado, N. alba* and *N. sunrise* recorded 100% survival rates. All these varieties were found to be tolerant to the severe winter and summer seasons of Kuwait. *N. mexicana* recorded a survival rate of 93.75% at 120 DAP and 81.25% at 240 DAP. Varieties such as *N. rosea, N.* Perry's Baby Red, *N.* Almost Black and *N. masaniello* recorded survival rates of 92.85, 93.33, 88.88, and 92.85%, respectively, at 120 DAP. *N. chromatella* recorded 85.00% survival at 120 DAP which was reduced to 75.00% at 240 DAP. Among the 15 varieties studied, *N. odorata rosea* recorded the lowest survival rate of 57.14% at 120 DAP and it further reduced to 42.85% at 240 DAP.

During the very hot climates of June, July, and August, even though flower production was more, scorching of the petals was noticed. The plants bloom well from July to October; they became dormant from November to February. When the weather becomes cold and days grow shorter indicator leaves remain submerged under water at the base of the plant. In the month of March when the weather became warm, the plants resumed their growth activities and increased in size and started blooming. During dormant stage no fertilizers were applied, but when they started developing some floating leaves, fertilizer tablets were inserted into the pots.

Conclusions

The results of the study were very promising; indicating that using water lilies for greenery enhancement and landscape beautification projects in Kuwait is a viable option. All the 15 water lily varieties introduced from China were found adaptable for growing under the climatic conditions of Kuwait as evidenced by the data on growth rate and survival percentage. All of the varieties exhibited a positive growth rate during the summer season and their growth was drastically reduced during winter. Five varieties namely, *N. sumptuosa, N. marliacea carnea, N. odorata, N. alba,* and *N. sunrise* performed exceptionally well with a growth rate above 90% during the summer of 2010. Regarding the survival and regrowth of the plants after severe summer and winter seasons, all the varieties survived in spite of the extreme conditions prevailed during the period of study. Seven water lily species namely, *N. sumptuosa, N. marliacea carnea, N. texas, N. odorata, N. colorado, N. alba* and *N. sunrise* recorded 100% survival. Results revealed that the intensity of flower production under Kuwait's conditions was very high for varieties such as *N. odorata*, *N. texas*, *N. sunrise*, *N. colorado*, *N. rosea*, *N. sumptuosa*, *N.* Perry's Baby Red and *N. marliacea carnea*. They were found to be excellent heavy-flowering varieties and can be used for greenery enhancement and in landscape beautification projects. However, further continuous monitoring of performance of water plants is needed to ascertain the long-term impact of prevailing environmental conditions on their growth and contribution to visual appeal.

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