EVALUATION OF AQUATIC PLANTS FOR WATER GARDENING

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled "**Evaluation of aquatic plants for water gardening**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis, entitled "Evaluation of aquatic plants for water gardening" is a record of research work done independently by Mr. Deviprasad. B.P. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Dedicated to My Parents, Brother, Friends & Baladi family

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Introduction

1. INTRODUCTION

Plants in their natural habitats live under a wide range of moisture conditions. At one extreme are members of family Cactaceae and at the other end are the members of various botanical families which complete their entire life cycle submerged beneath the ponds or lakes or streams. Plants which grow in wet places or in water, either partly or wholly submerged, are called aquatic plants (Banerjii, 2006). Cultivation of these beautiful and fascinating aquatic plants harmoniously in and around the pond is called as water gardening (Singh and Singh, 2002).

Water adds an appealing element to the garden. The reflections of the sky and the plants on the water surface, little waves passing in parade with gems of sunbeam on their crest, the movement of fishes in water, all gives us a very pleasant and happy feeling. Basically water garden is just a pool of water that is home to plants and possibly fish and other water creatures (Bose *et al.*, 1998). Water adds another new dimension to the landscape. Many are discovering the joys of the sound of running water, the unique shapes and textures of aquatic plants, and the accompanying wildlife inhabitants (Romanowski, 2000).

Thousands of years ago melting glaciers might have formed the very first water garden the world has seen, at an elevation of fourteen thousand feet from mean sea level. In areas that experience heavy rainfall, natural water gardens and ponds were formed. Fossil evidence proves that the water lily is one of the first flowering plants on the planet, in existence over 100 million years ago. Oldest reference of water gardening comes from the Buddhist period. Poet Ashwagosha (100 A.D) wrote that Buddha saw lotuses and flowering trees in Nandanavana (Amigos, 2006).

The soothing sound of a waterfall or cascade down rocks, or of a fountain lighted at night time; the beauty of a small pond with water lilies- these are some of the ways by which water can add beauty and peacefulness to gardens (Perry, 2007).The cooling images of reflecting pools and refreshing sounds of splashing water provide special appeal when used in desert gardens. Even small water features, such as barrel water gardens, can provide much needed psychological relief from our intense summer heat (Begeman, 2003). Water gardening refreshes your spirit and restores your sanity after a hard day's work (Randhawa and Mukhopadhyay, 2001).

One of the important considerations in water gardening is to choose the right spot. Most aquatic plants and fish need plenty of sun, so a site that gets 6-8 hours of direct sun is the best choice. Choose a site away from tall shrubs and trees for good light and to prevent the accumulation of leaf debris.

In India the Mughal rulers developed many water gardens with fountains and other adornments but they knew nothing about water plants such as water lily and lotus.

Water garden is increasing in popularity in ornamental landscapes across the country but in most of the modern gardens water gardening is generally neglected. Water gardens; no matter how tiny, are extremely effective in beautifying the landscape. Their effectiveness is rendered more striking by the addition of a distinct and delightful class of plants comprising of submerged or floating as well as the semi aquatics used in environmental plantings (Caurie and Ries, 2001). After planning and installing a water garden, one needs to determine the planting materials to be used in it. Basically, there are four types of plants suited to water gardens: deep water plants, bog plants or marginals, oxygenators, and floating plants. A mix of all four, properly planted, ensures a thriving, self-sustaining system (Relf, 1996). In water gardens, marginal and floating leaved plants typically are used more than the submerged, because of showy flowers and unique foliage (Worden and Sutton, 2005).

The presence of plants in water bodies is very important for the conversion of solar energy into chemical energy and for enriching these with fresh oxygen to support varied aquatic fauna. Even though a few books have been published on the aquatic and wetland flora of India, they are mostly concentrated on the forest areas. Hence they provide inadequate information on the floristic diversity of

India. In India aquatic plants have played fascinating roles in the life of people from primitive times in one way or the other (Ansari, 2007)

The diversity of wetland plants of West Bengal is richest in India (380 species). More than 44 species are important as food and vegetable, 21 species are significant for their medicinal use, 12 species are noteworthy for their biological filtering properties and 2 species are marketed for aesthetic values (Ghosh, 2004).

The presence of Western Ghats combined with North- East and South-West monsoon provide ideal conditions for the growth of aquatic plants in Kerala (Mathew and Satheesh, 1997). By virtue of its location, topography and high rainfall Kerala provides a wide variety of aquatic habitats like rivers, streams, ponds, lagoons and estuaries, harbouring unique types of vegetation of their own. In Kerala there are about 375 species of aquatic vascular plants of which 65 species are endemic (Ansari, 2004).

Since Kerala is blessed with vast diversity of aquatic angiosperms, there is a need to identify the plants which can be used for recreational purpose. Except for a few successful attempts in *Nymphaea* and *Nelumbo*, many of our aquatic angiosperms with ornamental values have not been exploited for use in water gardens. With this context an attempt has been made on the "Evaluation of aquatic plants for water gardening" with the following objectives

- To conduct survey, collection, classification and evaluation of aquatic plants for water gardening.
- To standardize the growing media for three varieties of water lily.

Review of Literature

2. REVIEW OF LITERATURE

Water feature is an irresistible attraction in any form of a garden. Creating a water garden provides habitat for a specific range of plants as well as attracting wild life.Water garden conveys a joy which is different from that of the land garden. An open sunny position away from hanging over trees provides the best condition for growing water plants. A water garden feature allows you to grow many plants that do not thrive under any other condition. Still water is valued for its properties of reflection and tranquility, while moving water either in the form of a classical fountain or rushing water falls add a delightful sound and a dynamic vitality to the garden (Brickell, 1989).

Water gardening can be defined as planting of aquatic and semi aquatic plants in a planned manner in and around the pool (Singh and Singh, 2002). It is by no means recommended that, collections of all aquatic or marsh or bog plants be planted but, the best and the most effective of them should be tastefully employed for picturesque effect (Watson, 1998).

Aquatic plants are among the earliest angiosperms. The plants like *Nymphaea lotus* and *Nymphaea caerulea* appeared as early as 2950-2770 BC. The "Imperial Garden" developed by the Han dynasty during, 206 BC is the first water garden. In the "Species Plantarum" Linnaeus named *Nymphaea alba* and *Nymphaea lotus* (Knots, 1998). Water gardening is one of the oldest arts of gardening in India. Oldest reference of water garden comes from Buddhist period. Lotus stem is referred as naval cord of Vishnu and lotus flower is described as the throne of Brahma. Water plants are mostly found in temples of South India and East India (Randhawa and Mukhopadhyay, 2001).

2.1. WORLD SCENARIO

China is the leading producer of aquatic plants in the world. During the year 1994 the global production of aquatic plants was 5.346 million tones with a value of 6.054 billion dollars (FAO, 1996).In global terms 99.8 percentage of cultured aquatic plants come from Asia and the Pacific. World aquatic plant production in 2004 reached 13.9 million tones with a value of 6.8 billion dollars of which 10.7 million tones originated from China, 1.2 million tones from Phillipines, 0.5 million tones from Republic of Korea and 0.48 million tones from Japan. The contribution from India was very negligible (FAO, 2006).

Rahman *et al.* (2007) collected a total of 44 species under 37 genera belonging to 25 families in his work on "Studies on the Aquatic Angiosperms of the Rajshahi University Campus" in Bangladesh. A brief taxonomic account of each species is given with the current nomenclature, local name, family and uses. Davies *et al.* (1999) discussed about the national collections of *Nymphaea* of United Kingdom and France. Riffle (1998) described the landscape uses of aquatic, bog and marsh plants. Fritz *et al.* (1992) reported that some aquatic plants are cultivated as vegetable crops mainly in subtropical or tropical regions of Germany. Morton (1976) reported that Florida is a home to the large exotic aquarium and ornamental foliage plant industry that imports millions of non native plants each year.

2.2. INDIAN SCENARIO

Cook *et al.* (1974) reported that there are about 660 species of aquatic vascular plants found in permanent or seasonal fresh water in India. In India there are more than 800 aquatic and wetland species (Ansari, 2007). In India the cultivation of significant non conventional wetland species like *Aeschynomene aspera, Cyperus pangorei, Eurayle ferox, Colocasia esculenta* and *Ipomoea aquatica* provide alternate source of food and income generation from the marketable products obtained by them in addition to conservation of wetlands (Ghosh, 2004).

In West Bengal the aquatic plants are widely distributed and there are about 380 species of aquatic plants. Nearly 2.5 million people in West Bengal are presently dependent on the wetland products for their subsistence, which is about

1-3 percent of state population. Lotus is extensively cultivated for its flowers in Medinipur district of West Bengal (Ghosh, 2005). *Rao et al.* (2002) conducted a survey on wetland flora of Uttara Kannada and reported that there are 167 species of aquatic plants from 32 families. *Schoenoplectus lateriflorus* was the most widely occurring species followed by *Cyperus halpan.* Maurya *et al.* (2004) reported that in India water chestnut (*Trapa bispinosa*) is an important food for many poor people. Half mature kernel is eaten as such or after frying, while the mature hard kernel is eaten after boiling. In India aquatic plant makhana (*Euryale ferox*) is cultivated in ponds and lakes in Bihar, Assam, West Bengal, Tripura, Manipur and Rajastan for its edible popped seeds.

2.3. SITUATION IN KERALA

Sabu and Bhaskaran (2007) reported that there are a total of 725 vascular plants belonging to 106 families in Kerala. The dominant families are *Cyperaceae, Poaceae, Scrophulariaceae* and *Fabaceae.* The aquatic situations in Kerala are reported to harbour about 150 aquatic species, of which about 35 species are seen only in Kerala. *Eriocaulon ansarii, Lagenandra nairii, Lagenandra keralensis, Nymphoides krishnakesara, Nymphoides sivarajinii, Rotala malabarica* and *Rotala malampuzhensis* are some of the very rare plants restricted only to Kerala (Ansari, 2007).

There are about 9 genera and 13 species of Podostemaceae in Kerala. Aquatic herbs of Podostemaceae are growing attached to rocks and other solid substrate in river rapids and water falls. The state of Kerala encompasses 80 percent of Podostemaceae of the country (Mathew and Satheesh, 1997). Due to heavy rains many ditches and small puddles are created and they can hold water for long time to allow water plants to grow (Rao *et al.*, 2002).

In Malabar Botanical Garden (Calicut) work has been done on the *ex situ* conservation of aquatic or wetland plants of India. An aquatic nursery (*Aquagene*) has been developed for growing the delicate aquatic plants in special germination pots filled with pH adjusted water. It has developed a conservatory for rare South Indian wetland plants. Works on identification and conservation of rare wet land plants is also carried out in Tropical Botanical Garden Research Institute, Palode. Three new species of *Ischaemum* L. (Poaceae), *I. wayanadense, I. abrahamii* and *I. fischeri* from India are described and illustrated (Ravi *et al.*, 2001).

Presannakumari *et al.* (2002) grouped 24 ecotypes of *Nelumbo* collected by her from different localities into 3 clusters by unweighted pair group method of cluster analysis based on anatomical and morphological characters. Minimol (2004) reported that the flower production in lotus started with the onset of monsoon and reached its peak in spring season and then declined with no flower production at all in summer season.

2.4. CLASSIFICATION OF AQUATIC PLANTS

It is generally recognized that the classification of aquatic plants is at present in a most confused condition, due partly to our ignorance of the factors controlling them, and partly to the variability and number of conditions which affect aquatic vegetation (Pearsall, 1918).

Sculthrope (1967) for the first time classified the aquatic plants based on the life form into attached and free floating. Emergent leaved attached plants, floating leaved attached plants and submerged- leaved aquatic plants are the three life forms within the attached type. Submerged leaved, floating leaved and emergent leaved aquatic plants are the three life forms within the floating types (Sculthrope, 1969). Cook *et al.* (1974) classified the water plants based on the growth forms into Ephydates, Haptophyte, Hyperhydate, Plankton, Pleustophyte free floating, Rosulate submerged, Tenagophyte and Vittate plants.

Brickell (1989) classified the water garden plants as deep water plants, submerged plants, free floaters, oxygenators, marginals and bog plants. Based on growth habits Riemer (1984) classified the water plants as emergent plants, floating attached plants, floating unattached plants and submersed plants. Plants which are suitable for growing in water gardens are divided into several groups such as surface flowering aquatics, oxygenators, floaters and marginals (Randhawa and Mukhopadhyay, 2001). Aquatic plants may be classified according to their habit of growth as marginal, floating leaved, floating and submerged (Worden and Sutton, 2005). Lynch (2006) classified the water garden plants into submerged plants, floating plants and emergent plants. There are many plants available for use in water garden. Aquatic plants for water gardening can be classified as marginal plants, bogplants, deep water marginals, floaters and oxygenators (Andrew, 2007). This large group of plants has different life forms and they have to be planted in the right zone to ensure their optimum growth (Rodriguez, 2007).

2.5. Water lilies and deep water plants

Deep water plants flourish under a depth range of 30.00 to 90.00 cm. This category includes plants such as Aponogeton, Hydrocleys along with water lilies, forming the largest group. Apart from their ornamental value, their floating leaves also help to reduce algae by cutting down the amount of light allowed to reach water (Brickell, 1989). Brock *et al.*, (1985) noticed that when light penetration is poor the floating leaved species such as *Nymphaea* produce sufficiently long petioles to colonize the greatest depths.

Nymphaea belongs to the family Nymphaeaceae. Historically, plants in family Nymphaeaceae are among the oldest groups of plants on the earth. Recently, botanists have agreed to split this family into two. Those with rigid petiole and peduncle are grouped under Nelumbonaceae. Others with soft petiole and peduncle are grouped under Nymphaeaceae (Chukiatman, 2006).The name *Nymphaea* is derived from the word 'Nymphe', one of the deities of mythology called water nymphs. They can be seen in luxuriant growth inhabiting ponds, lakes and quiet back waters (Everett, 1981).

Nymphaea is the most diversed genus in the family Nymphaeaceae (Woods *et al.*, 2005). Nymphaeales comprise 8 genera and approximately 70 species of aquatic plants with a world wide distribution in tropical and temperate regions (Gandolfo *et al.*, 2004). Detailed morphological studies have been carried out in family Nymphaeaceae (Khanna, 1967). *Nymphaea* is commonly known as water lily, pond lily and Egyptian lotus. A few species are grown in gardens for ornamental purposes (Banerjii, 2006).

Rodriguez (2007) reported that there are two types of water lilies, tropical and hardy. Tropical water lilies are divided into day and night bloomers. Hardy water lilies are all day bloomers and some of the hardy water lily flowers change colour shades over the life of the bloom. Genus *Nymphaea* consists of spectacular water plants with floating and large attractive flowers. *Nymphaea stellata* and *Nymphaea rubra* are native to India. With their numerous varieties and hybrids, having exquisite blooms of various colours and attractive foliage the water lilies are considered as "The Jewels of Water Garden" (Muthukulam, 2006).

Grob *et al.* (2006) reported that in *Nymphaea prolifera* the leaves arise from the rooted tuber consisting of petioles of upto 120 cm long. Hempstead and Leaves of *Nymphaea tetragona* are elliptic- oval and upto 5 inches long (Hulten, 1968).

The floral characters vary extensively among the genera, ranging from small, simple monocot like flowers of *Cabomba* to very large, showy, elaborate flowers of *Nymphaea* and *Victoria* (Soltis and Soltis, 2004). Schneider *et al.* (2003) reported that in *Nymphaea* and *Nuphar* each flower replaces a leaf in the ontogenetic spiral of the shoot apex with a Fibonacci angle of 137.5^0. *Nymphaea alba* produces floral primordia and leaf primordia as part of the same ontogenetic spiral (Grob *et al.*, 2006). The circadian rhythm of flower opening is seen in water lilies (*Nymphaea* sp.). In water lily same flower opens and closes for 3.0 to 4.0 consecutive days. The general phenomenon that the night blooming flowers are white in colour does not seem to be true in water lilies (Krishnan *et al.*, 2004). Schneider (1982) in his experiments on *Nymphaea elegans* observed that flowers open each morning for three successive days. *Nymphaea odorata* buds open in early morning exposing the spectacular white, waxy flowers which float on the surface of water. Some petals close during the afternoon and some petals remain open (Dalton and Novelo, 1983). In *Nymphaea prolifera* the rooted tubers produce mother flowers with flower stalk upto 80 cm long, but the stalks of daughter flowers are usually less than 20 cm long (Grob *et al.*, 2006).

The flowers of *Nymphaea rubra* are large, double red in colour and they open in night during summer (Muthukulam, 2006). *Nymphaea rubra* flowers are sweet scented, large, 4-10 inches across (Biswas and Calder, 1984). Muthukulam (2006) reported that *Nymphaea stellata* flowers are medium to large in size and pale blue in colour. *Nymphaea alba* is a white flowering species with yellow stigmatic disk (Jokla and Mussob, 2000). The four sepals are lanceolate as well as the 15–30 petals, which gradually turn into the stamens. There is a gradation in outward direction from conventional stamens to staminodes and petals. *Nymphaea odorata* flowers are upto 6 inch wide (Dalton and Novelo, 1983). Songpanich (2007) in his experiment on 'Flowering Habits of Hardy Water Lilies in the Tropics' revealed that the maximum number of flowers produced by *Nymphaea* (Gloriosa) was 163 blooms $year^{-1}$ and the minimum number of flowers by *Nymphaea* (Perry's Fire Opal) was 28 blooms $year^{-1}$.

Nymphaea stellata has 4 sepals which are narrow with fine purple lines. It has 8 petals and 15-29 stamens. Apices of the anthers foliacious with tongue shaped appendages and a 8 rayed stigma (Biswas and Calder, 1984). *Nymphaea odorata* flowers are white in colour with 4 petals, 56-100 stamens and upto 20 pistils (Dalton and Novelo, 1983). In *Nymphaea* the bractless flowers have mostly tetramerous calyces, whereas the other flower organs occur in whorls or rings. The petals are white, blue, red or yellow in various shades (Wieresma, 1987).

In *Nymphaea Mexicana* the anthesis is diurnal with flowers opening and closing for two consecutive days. Flowers on the first day of anthesis are functionally female (Capperino and Schneider, 1985). In *Nelumbo pentapetala* the anthesis occurs over 3 consecutive days. Flowers open each morning and close around noon (Schneider and Buchanan, 1980). Osborn et al. (1991) reported that the main difference between the lotus and water lily is the triaperturate pollen of *Nelumbo* and monoaperturate pollen grains of most Nymphaeles. In *Nymphaea* the pollen release takes place on the second day of flower opening (Wiersema, 1987). In *Nymphaea elegans* the first day flowers are protogynous with stigmata secreting a fluid which fills a perigynous cup. The pollinators are attracted and enter the first day flowers and land on inner stamens which bend and the insect falls into the stigmatic fluid. Stigmatic fluid washes pollen from the insects and pollination is achieved. Second and third day the flowers are functionally staminate (Schneider 1982).

Aponogeton is the only genus in Aponogetonaceae and all its members are aquatic (Grossi, *et al.* 2006). Fresh water monocotyledonous genus *Aponogeton* contains approximately 50 species of obligate aquatic plants that are distributed in the tropical and subtropical regions of the world. *Aponogeton* is important economically as it has long been regarded as a valuable source of species suitable for use as an aquarium plant (Hellquist and Jacobs, 1998). Pemberton (2000) reported that *Aponogeton distachyos* has been cultivated for more than two centuries, but mainly as an outdoor pond or water garden ornamental. Kasselmann (1995) reported that 15 species of *Aponogeton* from Australia, Asia and Madagascar are grown either widely or at least to a minor degree as aquatic ornamental plants. *Aponogeton* is an important genus whose species are cultivated widely as ornamental plants (Les *et al.*, 2005). *Aponogeton* is perennial, laticiferous and rhizomatous with emergent and floating leaves (Watson and Dalwitz, 2008).

Nymphoides peltata grows in such a way that a continuous field of flowers is maintained over a long period of season (Velde *et al.* 1982). Datta (1965) reported that in *Nuphar* growth is more vigorous than the water lilies and they grow luxuriantly in deeper and cooler water. *Nymphoides macrospermum* is a diocious aquatic herb endemic to Kerala and is found in deep water lagoons

(Ansari, 2007). *Nymphoides indica* is a typical heterostylous plant with dimorphic herkogamy (Shibayama and Kadono, 2007).

2.6. Shallow water plants

These plants root into mud like water lilies, but hold their leaves and flowers well above the water (Worden and Sutton, 2005). They prefer shallow water and can be grown from 60 -90 cm depth (Brickell, 1989). Lotuses are the shallow water plants that grow in submersed soil but their leaves, stems and flowers arise above the water surface. *Nelumbo* is a rhizomatous, aquatic, deciduous, perennial plant mostly grown for its foliage and flower (Banerjii, 2006). Nohara and Kimura (1997) reported that the maximum rate of petiole elongation in *Nelumbo nucifera* is 25 cm day^{-1}. Schneider and Buchanan (1980) reported that *Apis melifera* is the effective pollinating agent in *Nelumbo pentapetala*.

2.7. Free floating plants

Free floating plants, though not absolutely necessary, add the finishing touch to a natural appearing water garden. These plants move with the breeze and produce an ever changing appearance for the pond. Functionally, they add to the group of oxygenators and produce varying casts of shadow that the pond owner and the fish will appreciate (Neylon, 2006).

Floating aquatic plants enhance the appearance of the pond. Coverage of approximately 60 to 70 percentage of the water surface is generally recommended for algae control. Floating aquatics act as "biological sinks", that is, they utilize mineral salts dissolved in the water, thus effectively competing with algae for available nutrients (Cohen, 1993). Peterson and Lee (2005) reported that free floating plants produce group of roots which feed from the water rather than the soil. Floating plants are not attached to the soil and float freely in water. Plants may float on the surface like duckweeds or under the water like purple bladderwort (Worden and Sutton, 2005).

Eichhornia is a free floating aquatic plant (Singh and Gill, 1997). *Eichhornia crassipes* (water hyacinth), provides light bluish blossom and *Lemna minor* (duckweed), a spreading bed of small single leaf plants (Waples, 2007). Water hyacinth has vigorous growth and it reproduces at an alarming rate when conditions are favourable. Water hyacinth is used for wastewater treatment, food for humans and domestic animals, substitute for various raw materials (for fuel, fiber and carbon source) and in the cut flower industry (Quinones and Bravo, 1993). The beautiful water hyacinth (*Eichhornia crassipes*) is popular as an aquarium plant, but more so as a year-round decorative plant for ponds in warmer parts of the world.

Lemna minor is one of the world's smallest flowering plants. This plant is a free floating aquatic herb consisting of a single body called as frond or thallus. It is often purple beneath with a single root attached to each segment. Inflorescence is naked and enclosed in membranous spathe (Dalton and Novello, 1983). *Pistia stratiotes* is a favorite among water gardeners because of its hardiness and beauty (Fish, 2002).

Randhawa and Mukhopadhyay (2001) reported that *Azolla caroliniana, Eichornia speciosa, Lemna minor* and *Trapa natans* are the floating leaved plants which can be used in water garden. *Azolla* forms a crinkled surface carpet of mossy green colour and in temperate regions during the autumn it gets beautifully tinted with lilac and red colour. Florida hosts an early record of *Salvinia molesta* in the aquatic plant and water-garden market, during 1983 (Neylon, 2006).

Trapa natans belongs to the family Trapaceae and is commonly known as 'Singhara' or 'Paniphal' all over India (Maurya *et al.*, 1998). *Trapa natans* is a long day plant (Arima *et al.*, 1999) and is cultivated and harvested as supplementary vegetable and medicinal plant in West Bengal (Ghosh, 2004). Van (1969) reported that *Ceratopteris* is a group of floating ferns which is found in shallow waters and swamps.

2.8. Submerged or oxygenator plants

Submerged plants grow with most of their parts below the water surface although flowers and seed stalks may, at certain times of the year, extend above the surface to ensure pollination by wind and insects (Weigman and Helfish, 1997).

They get their nutrients directly from the water through their leaves rather than through their roots in the soil. Underwater plants play a vital role in water gardening. They provide the fish with some food. They help to oxygenate the water. They also provide hiding places for fish if they feel threatened. One bunch of submersed aquatic plant per square foot of water surface in a pond that is not overstocked with fish will keep the pond water clear (Jennings, 2004). Submerged plants receive most of their nutritional needs from the sediments in which they are growing (Worden and Sutton, 2005).

Many underwater aquatics are best adapted to cooler water temperatures and will not perform well when the surrounding temperature routinely exceeds 65° F (Cohen, 1993). Peterson and Lee (2005) reported that submerged plants can survive upto a maximum water depth of 10 to 12 feet in clear water.

Mukherjii (2000) reported that the submerged genus *Utriculària* consists of 120 species out of which 20 species are found in India. Datta (1965) reported that *Utricularia* is a rootless herb which can be grown in the aquaria as an insectivorous plant. Huang *et al.*, (2001) reported that *Najas marina* is a rooted, submerged annual with sub opposite leaves. *Cabomba* is a submersed annual plant that is characterized by slightly flattened stems that arise from base of the plant (Orgard, 1991). *Limnophila indica* bears pinnately dissected leaves when submerged in water (Ram and Rao, 1982).

Oxygenators are the plants growing below the pond surface. They help to keep the water clean. They release oxygen, and absorb minerals and salts that encourage growth of algae. A secondary function of oxygenators is providing shelter for garden pond fish (Foster and Smith, 2008).

Oxygenators are submerged, fast growing plants which help to clean and oxygenate the water. They are essential for the growth of fishes in the pond. *Ceratophyllum demersum, Ceratopteris thalictroides, Myriophyllum aquaticum* and *Potamogeton filiformis* can be used in water garden as oxygenator plants (Brickell, 1989). Raymond (2006) reported that oxygenator plants can also be sown in pots or allowed to float submerged beneath the surface of the water. Anacharis (*Elodea*), *Cabomba* and dwarf *Sagittaria* are a few important plants belonging to the group of oxygenating plants.

To have the water in the pool clear and pure a number of oxygen releasing plants should find their place in the collection. Most of them do better when they are rooted in the soil, although some will live by floating on the water. *Elodea, Cabomba, Ceratophyllum* and *Myriophyllum* can be grown either by planting in soil or as floaters. *Ludwigia, Potamogeton* and *vallisnaria* do better when they are planted (Caurie and Ries, 2001). *Cabomba* is a very famous aquatic plant in Kolkatta (Ghosh, 2005). It is a feathery rich bright green plant requiring subtropical warmth and could be grown as an aquarium plant (Biswas and Calder, 1984; Caurie and Ries, 2001).

2.9. Marginal plants

Marginal plants are those that grow in shallow water not more than 2.00 to 6.00 inches deep. Many hardy ferns, grasses, rushes and sedges do well in pond margins and add fine textures to water gardens (Cohen, 1993; Perry, 2007). Marginal plants are the emergent plants that grow on saturated soil beyond the water edge (Whestone *et al.*, 2006). They may be found growing in the moist soils along the shoreline (Peterson and Lee, 2005). Marshall (2006) reported that Shallow water plants will help to create a beautiful and natural transition from more shallow water to the edge of the pond.

Marginal plants can be decorative, provide shelter from the wind, and offer a bit of shade. These plants do best in still to slow moving water (Rossow and Charboneau, 2006). They add informality to the edges of the pond and in garden ponds they could be planted in individual pots so that the depth can be adjusted as they grow (Foster and Smith, 2008). Marginal plants are valuable in the informal pond for breaking up the outline (Brickell, 1989). Marginal plants have their shoots above the water and portion of shoot and root below the water. In water garden marginal and floating leaved plants are used more than floating or submerged plants because of their showy flowers and unique foliage (Worden and Sutton, 2005).

Fischer (2005) reported that marginals are best suitable for tub gardens and some species thrive even in garden beds if the soil is amended with organic matter and kept constantly moist. Waples (2007) reported that marginal water plants add dimension and texture to the water gardens. Some marginals recommended for containers are *Cyperus haspan* (Dwarf Cyperus) and *Sagittaria japonica* (Japanese Arrowhead).

Ipomoea aquatica is a marginal aquatic plant which is also called as 'water spinach', 'chinese spinach' and 'swamp cabbage' (Tanaka, 1976). *Panicum repens* is another marginal species that occurs in and around shallow water and it is also called as torpedo grass (Schardt, 1994). *Eleocharis dulcis* is a tufted perennial with short rhizome and elongated stolons, most of these terminated by a globose tuber (Whistler, 1980).

2.10. Bog plants

Bog plants are the one which thrive in water logged soil and can withstand occasional flooding (Brickell, 1989). Dimmock (2007) reported that the main difference between the bog plants and marginal plants is based on the water depth at which the plant is most happy. Bog plants like to have their roots tapping into water, while marginals sit right in the water, some of them thriving upto 15cm of water above the soil level.

Evans (2000) reported that plants like *Acorus calamus, Pontederia cordata, Caltha palustris, Scirpus americanus* and *Schoenoplectus validus* can be used as bog plants in water garden. *Acorus* can be grown in shallow water or a marshy soil. It emits very pleasant smell and is used as an aromatic plant (Singh and Singh, 2002).

Brydon (2004) reported that *Marsilea* is an aquatic fern that prefers slow moving or still water, with fronds producing leaflets in the shape of four-leaf clovers, generally floating on the water surface. It is hardy and thrives in full sun to a semi-shade gradient. In natural habitats *Marselia quadrifolia* (Lin and Yang, 1999) produce different types of leaves above and below the water level. Youch (2008) reported that *Crinum companulatum* is a bog plant in which the first flower bud opens only on the 10^{th} day after the emergence of inflorescence. Initially the flower colour is pink which later turns into dark red colour.

Echinodorus macrophyllus has been increasingly used in landscape projects as bog plants for the beautiful effect of its foliage, when in groups and by the inflorescences that reach well above the foliage. Resistance to disease and fast growth rate also contribute to its increased popularity (Sobrinho and Silva, 2007). In *Echinodorous grandiflorus* the flowers are produced in rainy season (Vieira and Lima, 1997).

Sutton (1995) reported that *Sagittaria latifolia* can be used as an aquatic ornamental and for aquatic habitat restoration. Wilder (1974) reported that the upright vegetative axis of *Limnocharis flava* has sympodial growth and produces evicted branch primordia solely by meristematic bifrurcation. Kaul (1967) reported that the flowers of *Limnocharis flava* are borne in an intermediate umbel.

2.11. Growing environment for water plants

The strongest abiotic factors influencing the growth and distribution of aquatic plants are light, water temperature, substrate quality, altitude, pH, transparency and conductivity (Lacoul and Freedman, 2006). The abundance of sunshine and warm temperatures provide ideal growing conditions for many aquatic plant species (Worden and Sutton, 2005). *Nymphaea stellata* grows well in tropical and humid conditions. Factors such as water depth, amount of sunlight and how each species relates to its surroundings are to be considered while designing a water garden (Rodriguez, 2007). Temperature is one of the most important of the factors influencing the plant growth and is especially relevant to aquatic plants due to their close association with water and the moderating influence of water bodies on local temperatures (Burnett, *et al.*, 2007). Cook *et al.* (1974) studied the effects of temperature, photoperiod, light intensity and the emergence or submergence in water on the determination of leaf form.

2.11.1. Water lilies

Water lilies are tropical and is either day blooming or night blooming. Decorative water lilies add beauty to the pool. The shade formed by their leaves is very useful for reducing luxuriant growth of algae and provide shelter to fish (Brickell, 1989). Astle (2006) reported that Water lilies require full sunlight as the development of bud is dependent on the amount of sunlight. Day length and temperature are two main factors influencing the flower production of hardy water lilies when grown in the tropics (Songpanich, 2007). Factors changing during the whole day regulate the amplitude of the opening of the flower of *Nymphaea* and its immersion. Higher is the atmospheric pressure, longer is the day of *Nymphaea* The intensity of the bloom of the *Nymphaea* depends upon the temperature of the air and the water (Volkova *et al.*, 2001).

Henry (2008) reported that Water lilies are the most exquisite and colorful plants in the water garden which can give months of pleasure during the summer. Rossow and Charboneau (2006) reported that water lilies grow on the base of the pond and produce leaves and blooms to the surface. They also provide valuable leaf cover, which reduces algae growth.

Many floating leaved plants have increasingly longer petioles with increasing water depth (Wooten, 1986). In *Nymphaea odoarta* the petiole length varies according to the water depth (Dalton and Novelo, 1983). In *Nymphaea odorata* the growth of aerial petioles may be an adoptive response due to shading, allowing the aerial leaves to raise above the crowded water surface (Etnier and Villani, 2007).

Nash *et al.* (2003) reported that the most commonly recommended soil for planting aquatics is heavy garden loam. For hardy water lilies any heavy garden soil is suitable, but no peat moss, bark, or other floating materials should be used. Heavy clayey soils with bone meal and compost are the best media for growing water lilies (Sacher, 2006). According to Loehwing (1940) the relative growth and development of aquatic plants was greatest in the muck, second in clay and least in the sand. Dalton and Novelo (1983) reported that *Nymphaea odorata* grows well in stagnant and muddy water. *Nymphaea* plants have very high light requirement and develop well in medium salinity water (0.55 and 0,47mS cm^{-1}) (Pindel and Wozniak, 1998) and water lilies grow well in heavy clay soil free from organic matter (Molbak, 2002).

It is well known that water levels and flooding influence the composition of wetland communities (Blom *et al.*, 1990). Water depth has a pronounced regulatory effect on distribution and abundance of emergent plants (Squires and Valk, 1992). Water lilies require a minimum of six inches of water over the soil level in the pot; larger lilies can withstand 8 or 10 inches depth of water (Sacher, 2006). *Nymphaea alba* produces longer and thinner petioles when the water levels are high (Paillisson and Marion, 2006). *Nymphaea odorata* leaves growing at the pondward perimeter of beds were upto 74 percent larger than mid bed leaves. Both water depth and substrate nitrogen are instrumental in limiting the growth of *Nymphaea odorata* (Hempstead and Killingbeck, 1996). Solcum

(2005) reported that some *Nymphaea* spp. do not bloom during the period of high temperature.

Mean final potential leaf area also peaked in early July (146 cm^2) and then decreased. In *Nymphaea tetragona* the leaf life span reached an initial peak in June(38.6 days) and gradually decreased to a minimum (20.5 days) in late august and then increased suddenly to a maximum(52.9 days) in October. Annul mean life span was 31 days (Kunii and Aramaki, 1992). Many factors relate to the leaf life span (Chabot and Hicks, 1982) and many causes of decomposition can be recognized in the form of damage types and infection or decomposition patterns. In *Nymphaea alba* there was a highest rate of leaf decomposition in the warmer period of the year and under more alkaline conditions (Brock *et al.*, 1985). Velde *et al.* (1982) reported that grazing reduces the life span of floating leaves to a considerable extent.

2.11.2. Lotus

Lotus (*Nelumbo nucifera* Gaertn.) is a symbol of Indian cultural heritage, deeply associated with Hindu mythology, art and culture and has thus been accorded the status of the National Flower of India. It is one of the most attractive aquatic plant species in India with a large number of racial variants with different shapes, sizes and colours of the bloom ranging from white to dark pink and having 16-160 petals. The plants being highly ornamental are exploited for landscaping lakes and ponds (Goel *et al.*, 2001).

Nelumbo grows well in open sunny position with atleast 60 cm of water depth. Leaves with large petioles either floating or immersed and peltate leaves are 60.00 to 90.00 cm in diameter (Banerjii, 2006). Khedr and Hegazy (1998) reported that the most important environmental factor associated with the distribution of lotus is the fine sediments and organic carbon in soil. Yan *et al.* (1994) studied the effect of different culture media on leaf and flower growth and found that lotus plants grow better in soilless culture than in soil. Temporarily submerged leaves of aquatic plants can accommodate their petiole length to raising water levels and thus maintain the laminae at the water surface. Nohara (1991) reported that the distribution of *Nelumbo nucifera* is restricted to sites of water depth less than 1.5m. The maximum water depth at which *Nelumbo nucifera* can grow is 2.4 m (Nohara and Kimura, 1997).

Minimol (2004) reported that in *Nelumbo nucifera* rainy season favoured an increase in the size of the leaves and spring season increased the longevity of the leaves. Nohara and Kimura (1997) reported that the mean leaf area of emergent leaves of *Nelumbo nucifera* increased markedly with depth and mean leaf area of floating leaves increased with increasing water depth upto 1m, beyond which it was constant. The elongation rates of petioles of the floating and emergent leaves of *Nelumbo nucifera* just after unrolling were 2.6 and 3.4 cm day^{-1}, respectively (Tsuchiya and Nohara, 1989).

2.11.3. Other aquatic plants

Nymphoides indica is one of the species in which water level fluctuations affect the growth of juvenile plants (Mason and Valk, 1992). Tsuchiya (1988) reported that in *Nymphoides peltata* the stomata distribution was little influenced by the growth conditions. The leaf size of floating leaves was much larger than that of emerged leaves induced by terrestrial cultivation. The growth condition had a profound effect on the life span of these species; aerial leaves had a significantly longer life span than the normal floating leaves. *Nymphoides* are often found in shallow still water in lakes and ponds where they spread rapidly and form a floating carpet over the water (Mukherjii, 2000). Begon and Fitter (1994) reported that in aquatic environments oxygen shortage limits the growth of plants at higher temperature.

Sheldon and Boylen (1977) reported that *Elodea* can be grown at a maximum water depth of 12 m. Usually it is found in water depth between 4-8 m (Chapman *et al.*, 1974). *Myriophyllum spicatum, Potamogeton* and *Elodea* *canadensis* can be propagated rapidly. They prefer cool weather and enhance photosynthetic efficiency, which allow them to proliferate. They are deep water plants which develop in light intensity of less than 15% of full sunlight. They grow in water depth ranging from 1-4 m. None of these species thrive in shallow water of 0.5 m depth. Grace and Wetzel (1978) reported that *Elodea* is the most efficient in low light conditions and optimum temperature for maximum photosynthesis is 30-35^{0}C. *Ceratophyllum* can grow in deep water, so deep that it may not be evident from the surface of water (Smith and Kozlowski, 1996).

An experiment was conducted by Menzie (1979) on growth of *Myriophyllum spicatum* in an estuarine (0-6% salinity) littoral area. Standing crop of the plants ranged from 0 gm m^{-2} in winter to 60 gm m^{-2} (dry weight) in summer. A significant reduction of the standing crop was seen during the period of high temperature (upto 42^{0}C). Maximum standing of *Myriophyllum spicatum* in this study was less than that observed for this plant in some fresh water lakes and ponds. Lower standing of the crop was due to lower light penetration and more dynamic currents. Jones *et al*,. (2000) reported that increase in the surrounding water oxygen concentration produced a linear decline in photosynthesis and a linear increase in respiration of the plant *Elodea nuttalli.* The effect of reduced carbon dioxide level was substantial. The p^H below 6 and above 7 caused a decrease in photosynthesis. *Potamogeton* is a heterophyllic aquatic angiosperm (Gee and Anderson, 1998).

Karg (2006) reported that *Trapa natans* requires a warm temperature of 12-15^{0}C for the fruits to germinate and 20^{0}C for the development of the flowers. One stem will create upto 10 leaf rosette which float on water surface as carpet. The plant flowers during July-August and in autumn the leaf colour changes from green to purple brown. The impact of day length on flower bud formation differs in different species of Trapa (Arima *et al.*, 1999).

Tsuchiya and Iwakuma (1993) reported that in *Trapa natans* the leaf initiation rate, leaf loss rate and leaf life span were independent of nitrogen flux and ranged from 140-250 mg N m^{-2} day^{-1}. Leaf and rosette size were positively correlated with nitrogen flux. The net production was also positively correlated with nitrogen flux and ranged from 5 to 14 gm dry weight m^{-2} $day^{-1}$for all experimental trials.

Ber and Gaber (1989) reported that light and temperature determine the length of the vegetative period of *Eichhornia crassipes*. *Pistia stratiotes* prefers slightly acidic waters (6.5 - 7.2 p^H) and moderate hardness (5 - 20 KH). Neutral p^H is favorable for duckweed growth (Dalton and Novello, 1983). Sajna *et al.* (2007) reported that in *Pistia stratiotes* new stolons are formed at the end of the vegetation season and the flowers are seen during April to August.

Growth of *Rotala rotundifolia* is dependent on light and environmental condition. Under strong light leaves become wine red. It can be grown in shallow water and can withstand relatively cool temperature. It is a common aquarium plant which likes a lot of light to thrive. Losing its lower leaves means that it is not receiving enough light (Ansari, 2007). *Bacopa monnieri* is a perennial, creeping herb whose habitat includes wetlands and muddy shores (Huxley and Griffiths, 1999). Pindel and Wozniak (1998) reported that aquatic and bog ornamental plant species grow in water with pH varying between 5.6 and 8.3. *Limnocharis flava* which is commonly known as water cabbage grows well in wet, waterlogged, exposed lands and rice fields (Karthigeyan *et al.*, 2004).

Panicum repens is most often encountered as riparian species in wetland and marginal habitats. It grows well even after several days in standing water, but it is also drought-tolerant and can be found growing in heavy upland soils (Sayer and Lavieren, 1975). Low (1989) reported that *Eleocharis dulcis* grows well in marshes and shallow water and it prefers slightly acid soil conditions and a sunny position. *Sacciolepis interrupta* also grows well in marshes and shallow water (Biswas and Calder, 1984). *Typa latifolia* and *Typa domingensis* showed an increase in maximum height with the increasing water depth (Grace, 1989). Deegan and Harrington (2004) reported that salinity appears to be the most important factor limiting the downstream extension of *Schoenoplectus triqueter*.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation entitled "Evaluation of Aquatic Plants for Water Gardening" was carried out in Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, during the period 2007-08. The materials used and the methodology adopted for the investigation is dealt in this chapter.

3.1. Location

Geographically the area is situated at a latitude of 10^0 31'N and longitude of 76^0 13'E. The area lies 22-25 m above the mean sea level.

3.2. Climate

The climate is humid tropical. The weather parameters recorded during the period of observation is presented in Appendix 1.

3.3. Collection and evaluation of aquatic plants for water gardening

3.3.1. Collection

Survey was conducted and water plants were collected from different localities of Thrissur, Kozhikode and Palakkad Districts. The collected plants were classified into different groups based on their habitat and evaluated.

3.3.2. Evaluation

The plants collected were planted in containers filled with a mixture of clay and potting mixture. The water level was maintained as per their natural habitat and observations were recorded on vegetative and floral characters.

3.3.2.1. Vegetative characters

3.3.2.1.1. Plant height

Height of the plant was measured from base to the growing apex at 15 days interval and expressed in centimeters.

3.3.2.1.2. Surface spread

The spread of the plant was measured in north south and east west directions and expressed in centimeters.

3.3.2.1.3. Leaf length

Length of the fully opened leaf was measured and expressed in centimeters.

3.3.2.1.4. Leaf breadth

Breadth of the fully opened leaf was measured and expressed in centimeters.

3.3.2.1.5. Nature of growth

Growth pattern was observed and recorded as tall / spreading /creeping /spiral.

3.3.2.1.6. Nature of stem

The nature of the stem was studied and expressed as herbaceous / softwood / semi hardwood / hardwood.

3.3.2.1.7. Nature of leaf

The nature of the leaf was observed and recorded as spreading or not, glossy or blotched and plain or streaked.

3.3.2.1.8. Foliage colour

Foliage colour at Juvenile and mature stage was noted.

3.3.2.1.9. Shape of leaf

The shape of the fully matured leaf was observed and recorded as arrow / lance / clover like

3.3.2.1.10. Lobing of leaves

It was observed that whether the leaves were lobed or not and the lobes were overlapping or not.

3.3.2.2. Floral characters

3.3.2.2.1. Type of flower

It was observed that whether the flowers were Solitary or as inflorescence

3.3.2.2.2. Blooming period

Season of flowering in each plant was recorded.

3.3.2.2.3. Petal characters

Petal colour was observed and recorded in the plant description.

3.3.2.2.4. Value as commercial flower

By visual observation, the commercial value of the flowers was recorded i.e.; whether they are attractive and suitable for water gardening.

3.4. Standardization of growing media for three varieties of water lilies

3.4.1. Planting material

Uniform size planting materials of *Nymphaea alba*, *Nymphaea rubra* and *Nymphaea stellata* were collected from the local nursery and was used for planting. Cement containers of 45-50 cm depth and 75cm diameter were used for raising the crop (Plates 1-3).

3.4.2. Media

Four different combinations of media were tried

a) Sand + clay (1:2)

b) Sand + soil +clay (1:1:1)

c) Coir pith +soil + clay (1:1:1)

d) Coir pith +clay (1:2)

3.4.3. Planting

About 6 kg of the media combination was added to the pots and then filled with water upto 15 cm above the media. The media was puddled and was allowed to stand for two days. Planting was done at the centre of the pots at uniform depth during the evening hours.

Plate 1. *Nymphaea alba* in pot culture

Plate 2. *Nymphaea rubra* in pot culture

Plate 3. *Nymphaea stellata* in pot culture

3.4.4. General management aspects

After planting, the water level in the pots was increased. Water level of 16 cm above the media was maintained during the summer months. A polythene cover was spread over the bottom of the plots to control the weed menace. Removal of weeds, algae and dead plant parts from the pots were done at weekly intervals. Uniform amount of cow dung and groundnut cake were applied to all plants at monthly interval. The base of the pots was dusted with Chlorpyriphos to control ants.

3.4.5. Design of experiment

Completely randomized design with 3 replications and 12 treatments consisting of 3 species of water lilies and 4 media combinations.

3.4.6. Observations

In each variety 12 plants were used for recording biometric observations.

3.4.6.1. PLANT CHARACTERS

3.4.6.1.1. Surface spread

The spread of the plant was measured in North-South and East-West directions and expressed in centimeters.

3.4.6.2. LEAF CHARACTERS

3.4.6.2.1. Petiole length

Petiole length was measured from the point of leaf emergence to the base of the leaf lamina and was expressed in centimeters.

3.4.6.2.2. Length and breadth of leaf

Length and breadth of the fully opened leaf was measured and expressed in centimeters.

3.4.6.2.3. Leaf area

Length and breadth of 50 leaves was measured in each species and their leaf area was recorded by using the leaf area meter. By using this data the correction factor for each species was calculated. Leaf area was calculated for the three varieties by using the following formulae and expressed in cm^2.

Leaf area = Length × breadth × Correction factor

Nymphaea alba → Length × breadth × 0.79

Nymphaea rubra → Length × breadth × 0.76

Nymphaea stellata → Length × breadth × 0.94

3.4.6.2.4. Leaf production interval

Interval between the production of the two successive leaves was taken as the interval of leaf production and was expressed in days.

3.4.6.2.5. Longevity of leaves

The number of days from the emergence of the leaf bud to leaf abscission was taken as leaf longevity.

3.4.6.2.6. Total number of leaves

The total number of leaves present on the plant was recorded at weekly intervals.

3.4.6.2.7. Time for complete unfurling of leaves

Number of days from the emergence of the leaf bud to full opening of leaves was recorded.

3.4.6.3. FLOWER CHARACTERS

3.4.6.3.1. Days for emergence of first flower bud

The number of days from planting to the production of first flower bud was recorded in each plant.

3.4.6.3.2. Time taken for complete flower opening

The number of days from the emergence of the flower bud to full opening of the flower was recorded.

3.4.6.3.3. Interval of flower production

Interval between the opening of two successive flowers was recorded in days.

3.4.6.3.4. Number of flowers produced

Number of flowers produced by each plant during the entire growing period was recorded.

3.4.6.3.5. Bud length

Length of the flower bud was measured and expressed in centimeters

3.4.6.3.6. Pedicel length

Pedicel length was measured upto the base of flower bud and expressed in centimeters

3.4.6.3.7. Flower spread

Mean value of the flower spread in North-South and East- West direction was taken as the flower spread and was expressed in centimeters.

3.4.6.3.8. Flower longevity

The number of days from the opening of the flower to the submergence of closed flower in water is taken as flower longevity and is expressed in terms of days.

3.4.6.4. Number of propagules produced

The total number of propagules produced by each plant during the entire crop period was recorded.

3.4.6.5. Statistical analysis

The experimental data was analysed using MSTATC package available at the computer centre of College of Horticulture.

Results

4. RESULTS

The results of the investigation on "Evaluation of aquatic plants for water gardening" are presented under two major heads, viz., 'Collection and evaluation of water plants' and 'Standardization of growing media for *Nymphaea spp.*'

4.1. COLLECTION AND EVALUATION OF WATER PLANTS

4.1.1. Survey and collection

Survey was conducted in the districts of Thrissur, Palakkad and Kozhikode for collecting water plants. Plants were collected and the morphological characters observed in their original growing habitat are given below (Plates 4-47).

Plate 4.

Scientific name – *Acorus calamus*

Family - Araceae

Common name – Sweet flag

Habit - Aromatic marshy herb with creeping rootstock

Habitat – Bog plant

Place of collection – Vellanikkara, Thrissur

Stems are usually rhizomatic, horizontal and underground. Leaves are equitant, monofacial and glabrous. Inflorescence is a spadix, yellowish green in colour and flowers are hermaphrodite.

Plate 5.

Scientific name – *Alternanthera philoxeroides*

Family – Amaranthaceae

Common name – Alligator weed

Habit – Annual herb

Habitat – Bog plant

Place of collection - Vellanikkara, Thrissur

Stems are long, branched and hollow. Leaves are simple elliptic and have smooth margins. Flowering was seen in March and the flowers were white in colour with clover-like heads in the axils of the leaves.

Plate 6.

Scientific name – *Aeschynomene aspera*

Family - Fabaceae

Common name – Sola pith plant

Habit – Erect shrubby species

Habitat – Bog plant

Place of collection - Palakkad

Stem is stout and branches are erect. Leaves imparipinnate, leaflets small, linear, stipules lanceolate. Racemes are corymbose and 2-6 flowered. Flowers are pale yellow in colour.

Plate 7.

Scientific name – *Angelonia salicariaefolia*

Family – Scrophulariaceae

Common name – Angelonia

Habit – Herbaceous perennial shrub

Habitat – Marginal plant

Place of collection - Kozhikode

Plants have an erect growth with tender multiple stems growing from the base. Leaves are slender and about 3 inches long. Flowers are produced in spikes with white coloured flowers.

Plate 8.

Scientific name – *Aponogeton monostachyon*

Family - Aponogetonaceae

Habit – Submerged aquatic herb

Habitat – Deep water plant

Place of collection - Kozhikode

Stems are rhizomatous, leaves linear, stalked and floating, blades linear to oblong. Petiole length varies with depth of water. Flowers are bisexual, borne in spikes, emerging above the water surface, bud enveloped by a caducous spathe and purplish white flowers.

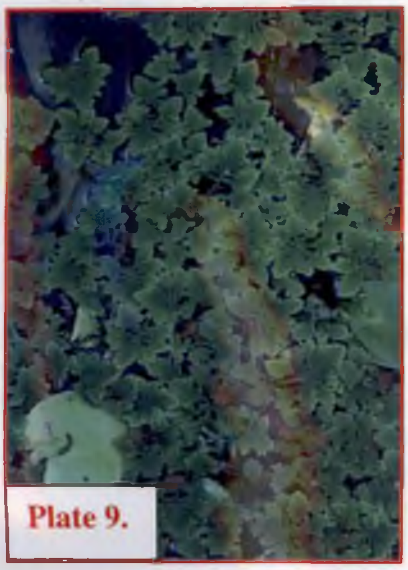


Plate 9.

Scientific name –*Azolla pinnata*

Family - Azollaceae

Common name – Azolla

Habit –Annual or perennial

Habitat – Free floating plant

Place of collection – Kodungallur, Thrissur

Stems floating covered with alternate leaves, roots are filamentous and feathered. Leaves are green in colour, sessile, alternate, imbricate and trapeziform.

Plate 10.

Scientific name - *Bacopa monnieri*

Family - Scrophulariaceae

Common name - Brahmi

Habit – Creeping aquatic herb

Habitat – Bog plant

Place of collection - Vellanikkara, Thrissur

Stem is herbaceous, leaves are sessile, decussate, succulent, relatively thick, and oblanceolate and arranged oppositely on the stem. Flowers are solitary, small with 4-5 white petals.

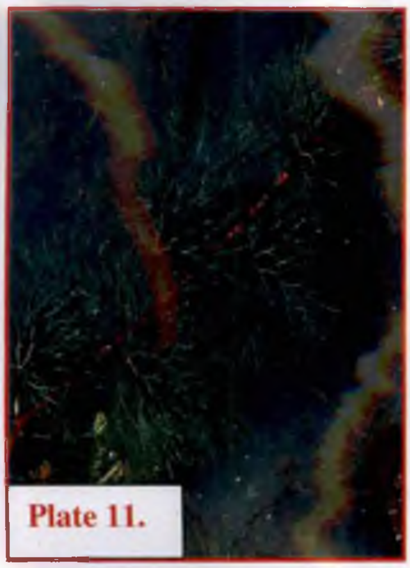


Plate 11.

Scientific name - *Cabomba caroliniana*

Family - Cabombaceae

Common name - Fanwort

Habit – Aquatic herb

Habitat – Submerged plant

Place of collection - Kodungallur, Thrissur

Freshwater perennial plant with short, fragile rhizomes. Leaves are dimorphic with palmately dissected submerged leaves and narrowly forked floating leaves. The Flowers are white coloured.

Plate 12.

Scientific name – *Ceratophyllum demersum*

Family - Ceratophyllaceae

Common name – Rigid hornwort

Habit – Perennial

Habitat – Submerged plant

Place of collection - Kozhikode

The stem has numerous side shoots and appears bushy. The leaves are produced in whorls of six to twelve, each leaf forked into two to eight thread-like segments edged with spiny teeth; they are stiff and brittle.

Plate 13.

Scientific name - *Ceratopteris thalictroides*

Family - Adiantaceae

Common name – Indian fern

Habit – Aquatic fern

Habitat – Bog plant

Place of collection- Kodungallur, Thrissur

A fern with tufted, thick, inflated stipes filled with air spaces, which helps in floating. Frond succulent in texture, slightly divided and 2-3 pinnate with rather narrow linear segments when fully developed.

Plate 14.

Scientific name - *Commelina benghalensis*

Family - Commelinaceae

Common name - Tropical spiderwort

Habit – Creeping perennial herb

Habitat – Marginal plant

Place of collection – Thrissur

Leaves ovate to ovate-oblong, subsessile to shortly petioled, with sheathing base, entire, acute to sub-round at apex. Upper cymes 2-3-flowered and lower 1-2-flowered. Flowers are blue in colour

Plate 15.

Scientific name – *Crinum viviparum*

Family - Amaryllidaceae

Common name - Visha moongil

Habit – Bulbous herb

Habitat – Bog plant

Place of collection - Kozhikode

Perennial herb with tunicated bulbous root stock. Leaves basal, linear with parallel nerves and terete. Flowers showy, pink to white and few to many in an umbel.

Plate 16.

Scientific name - *Desmostachya bipinnata*

Family - Poaceae

Common name - Darbha

Habit - Perennial

Habitat – Marginal plant

Place of collection - Palakkad

It is clumped densely. Leaves mostly basal. Leaf sheaths are as wide as blade at the collar, smooth, glabrous on surface. Leaf-blades are convolute, coriaceous, stiff and glaucous. Inflorescence composed of racemes having spikelets.

Plate 17.

Scientific name - *Echinodorus argentinensis*

Family - Alistamaceae

Common name - Argentine sword plant

Habit - Annual or perennial herb

Habitat – Bog plant

Place of collection - Palakkad

Stem erect and sparse. Leaves submerged, floating or erect, blade linear to broad ovate and base attenuate or cordate. Inflorescence is paniculate, broadly branched in the lower whorl, having 5 - 12 whorls containing 6 - 12 flowers each. Flowers are white in colour. After the flower is abscissed the next vegetative sucker grows from the same point.

Plate 18.

Scientific name - *Eichhornia crassipes*

Family - Pontederiaceae

Common name - water hyacinth

Habit - Annual or perennial floating aquatic

Habitat – Free floating plant

Place of collection - Thrissur

The stems are floating, creeping and often stoloniferous. The leaves are glossy green, leather and with long blades. Leaves are attached to petioles which are often spongy and inflated. The inflorescence is a loose terminal spike with showy light blue to violet flowers (bluish petals). One central petal bears a yellow spot.

Plate 19.

Scientific name – *Eleocharis dulcis*

Family - Cyperaceae

Common name – Chinese water chestnut

Habit – Tuberous, perennial sedge

Habitat – Marginal plant

Place of collection - Kozhikode

Tufted perennial with short rhizome and elongated stolons, most of these terminated by a globose tuber; culms terete, 50-200 cm tall and shining deep green. Inflorescence is a solitary terminal spikelet.

Plate 20.

Scientific name – *Eleocharis rectroflexa*

Family - Cyperaceae

Common name – Spiral scaled spike sedge

Habit – Annual or perennial

Habitat – Marginal plant

Place of collection – Kozhikode

Plant is a slender herb. Stems are erect and trigonous. Spikelets globosely ovoid rounded at the apex with pale brown colour. Leaves are absent.

Plate 21.

Scientific name - *Elodea canadensis*

Family - Hydrocharitaceae

Common name – Water weed

Habit – Perennial

Habitat – Submerged plant

Place of collection – Chetakulam, Thrissur

A submerged plant with long, slender and branched stem. Leaves arranged in whorls of three, but opposite on lower portion of stem, finely toothed along the edges. Flowers were not produced.

Plate 22.

Scientific name – *Hygrophila difformis*

Family - Acanthaceae

Common name – Water wisteria

Habit - Perennial

Habitat – Submerged plant

Place of collection – Kozhikode

Stem creeping and rooting at lower nodes. Leaves opposite, decussate and sessile. Leaf blade dissected to various degrees, lanceolate to ovate, margins serrate, highly heterophyllous between submersed and emergent forms. Submersed leaves deeply pinnate but emerged leaves are small, lobed instead of pinnate.

Plate 23.

Scientific name - *Hygroryza aristata*

Family – Poaceae

Common name – Nirvallipullu

Habit – Perennial stoloniferous

Habitat – Marginal plant

Place of collection – Kodungallur, Thrissur

A glabrous floating grass with long spongy stem and feathery whorled roots at the nodes. Leaf blade ovate to oblong, ligules absent, leaf sheaths open, usually strongly inflated. Inflorescence is a panicle.

Plate 27.

Scientific name – *Limnophila heterophylla*

Family – Scrophulariaceae

Common name – Indian ambulia

Habit – Annual or perennial

Habitat – Submerged plant

Place of collection – Thrissur

It is annual or perennial. Stems ascending or creeping, leaves caulescent, decussate or whorled, sessile or petiolate, distinctly heterophyllous between submersed and emersed forms. Flowers are solitary producing terminal spikes or leafy racemes with white petals.

Plate 28.

Scientific name - *Ludwigia adscendens*

Family – Onagraceae

Common name – Creeping water primrose

Habit – Submersed, floating, emergent and erect stemmed

Habitat – Bog plant

Place of collection – Thrissur

Stems creeping, erect or ascending, rooting at lower nodes, floating stems with spongy aerenchyma and white pneumatophores. Leaves are cauline, opposite or in floating rosette. Flowers are solitary, sessile or borne on short pedicels with white colour flowers.

Plate 29.

Scientific name – *Marsilea quadrifolia*

Family – Marsiliaceae

Common name – Water clover

Habit – Amphibious widely creeping or floating herbs

Habitat – Marginal plant

Place of collection – Vellanikkara

It is a perennial water fern. Rhizome creeping or floating and rooted at nodes. Fronds (leaves) scattered along rhizome, submersed, floating or emergent. Long and upright petioles terminate into a divided blade of 4 leaflets.

Plate 30.

Scientific name – *Monochoria vaginalis*

Family – Pontederiaceae

Common name – Pickerel weed

Habit – Attached, floating or emergent rosette plants

Habitat – Marginal plant

Place of collection – Pudunagaram, Palakkad

Annual or perennial. Stem floating, creeping or erect with spongy root stock. Leaves radical from the stem and solitary from the flowering stems. Leaf heart shaped, sheathed at base and linear to petiolate with distinct blade. Inflorescence a raceme or umbel-like, enveloped in broad leaf sheaths (i.e. lower spathe).

Plate 31.

Scientific name – *Najas minor*

Family – Najadaceae

Common name – Naiad

Habit – Annual or perennial

Habitat – Submerged plant

Place of collection – Kozhikode

It is an attached perennial or annual. Stems slender and much-branched. Leaves alternate, appearing whorled and linear, margin serrate to toothed.

Plate 32.

Scientific name – *Nelumbo nucifera*

Family – Nelumbonaceae

Common name – Sacred lotus

Habit – Attached, floating or emergent, broad-leaved plant

Habitat – Shallow water plant

Place of collection – Chetakulam, Thrissur

It's a perennial with milky latex present. Stems are dimorphic, slender, horizontal stolons or rhizomes. Leaves floating or emergent and peltate. Petiole are elongate (up to 3 m), bearing numerous small spines. Leaf blade is large, up to 1 m in diameter. Inflorescence a large, solitary flower borne on an elongate, axillary, spineless pedicel.

Plate 33.

Scientific name – *Nymphaea alba*

Family – Nymphaeceae

Common name – water lily

Habit – Perennial

Habitat – Deep water plant

Place of collection – Kozhikode

It is a floating leaved plant. Leaves are petiolate, glossy and oval to orbicular in shape with a radial slit. Flowers produced are white in colour with yellow centres.

Plate 34.

Scientific name – *Nymphoides indica*

Family – Menyanthaceae

Common name – Water snowflake

Habit – Perennial

Habitat – Deep water plant

Place of collection – Chetakulam, Thrissur

It's a floating leaved plant. Leaf lamina is almost circular with a radial slit, to 30 cm diameter, margins entire and shortly petiolate. White flowers are produced through radial slit of leaves.

Plate 35.

Scientific name - *Nymphoides peltata*

Family – Menyanthaceae

Common name – Fringed Water-lily

Habit – Annual or perennial

Habitat – Deep water plant

Place of collection – Kozhikode

Stem is compact or ascending. Submersed leaves petiolate, reniform to orbicular but floating leaf blade is ovate and chevron shaped. Clusters of solitary flowers produced either from base of floating leaves or on separate lateral branches.

Plate 36.

Scientific name – *Panicum repens*

Family – Poaceae

Common name – Torpedo grass

Habit – Annual or perennial herb

Habitat – Marginal plant

Place of collection – Pudunagaram, Palakkad

Plant has elongated rhizomes. Stolons absent or present. Culms erect or geniculately ascending. Leaves distichous and ligule a ciliate membrane. Leaf-blades are erect, flat or convolute, coriaceous, stiff and glaucous. Leaf-blade apex is acuminate or attenuate. Inflorescence is a panicle with many spikelets.

Plate 37.

Scientific name – *Pistia stratiotes*

Family – Araceae

Common name – Water lettuce

Habit – Stoloniferous rosette plant.

Habitat – Floating plant

Place of collection – Vellanikkara, Thrissur

It is a perennial, stoloniferous and free-floating plant. Leaves are in rosette, sessile or short-petiolate. Leaf blade obovate, emarginate and sometimes undulate apically, densely pubescent, filled with aerenchyma for floatation and with parallel venation. Roots are numerous, long and pinnately branched.

Plate 38.

Scientific name – *Polygonum barbata*

Family – Polygonaceae

Habit – Annual or perennial herb

Habitat – Marginal plant

Place of collection –Thrissur

It is an erect, creeping or floating plant. The stem nodes are swollen, completely surrounded by a scarious sheath. Leaves are alternate, always distinctly longer than width and usually entire.

Plate 39.

Scientific name – *Polygonum persicaria*

Family – Polygonaceae

Common name – Spotted ladysthumb

Habit – Perennial herb

Habitat – Bog plant

Place of collection – Kozhikode

A thin membranous sheath called an ocrea encircles the stem at the base of each leaf petiole. Fibrous roots with a shallow taproot. Leaves are arranged alternately along the stem and lanceolate to elliptic in outline. Flowers are pink in colour and they are clustered in terminal spikes at the ends of stems.

Plate 40.

Scientific name – *Potamogeton praelongus*

Family – Potamogetonaceae

Common name – White stemmed pond weed

Habit – Floating stem plant

Habitat – Submerged plant

Place of collection – Kozhikode

Perennial or annual plants in which stem is whitish, zigzag and branching towards the top. Leaves are submerse, alternate or rarely opposite. Submerged leaves thin, linear to lanceolate, margin entire and sometimes undulate. Floating leaves are thick, leathery, ovate, elliptic and oblong.

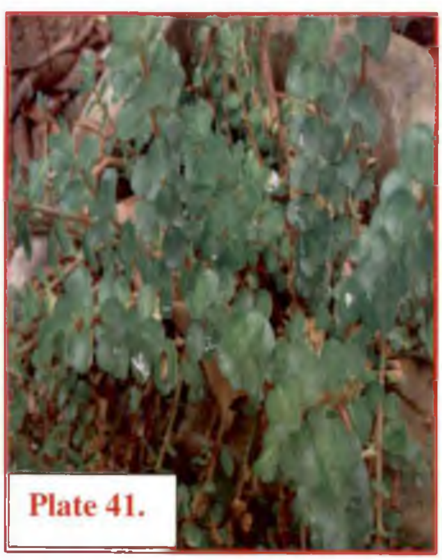


Plate 41.

Scientific name – *Rotala macrandra*

Family – Lythraceae

Common name – Dwarf rotala

Habit – Annual glabrous herb

Habitat – Marginal plant

Place of collection – Kozhikode

Stem is erect or creeping. Leaves opposite, decussate, sometimes whorled and usually sessile. Leaf blade shape is variable, capillary, oblong to ovate, green to dark red and distinctly heterophyllous. Submersed leaf is typically narrow and thinner than emergent leaves.

Plate 42.

Scientific name – *Sacciolepis interrupta*

Family – Poaceae

Habit – Grass

Habitat – Marginal plant

Place of collection – Thrissur

Vigorous aquatic perennial. Culms are rooting and floating in water, spongy, succulent, hollow, smooth and glabrous. Leaf sheaths loose and papery. Leaf blades linear, flat, soft, base abruptly rounded and apex acuminate. Panicle is spike like and 10–30 cm long. Spikelets light green, asymmetrically oblong and lightly dorsally compressed.

Plate 43.

Scientific name – *Salvinia molesta*

Family – Salviniaceae

Common name – Kariba weed

Habit – Perennial

Habitat – Floating plant

Place of collection – Thrissur

A free-floating perennial aquatic fern with stems just below water surface and floating leaves (fronds). Upper surfaces of floating leaves bear eggbeater-shaped hairs. Primary growth form has small, flat leaves; tertiary growth form is a mat of crowded leaves.

Plate 44.

Scientific name – *Schoenoplectus articulatus*

Family – Cyperaceae

Habit – Perennial sedge

Habitat – Bog plant

Place of collection- Thrissur

It is a slender annual with terete stem upto 4 m high. Stem contains numerous air canals. They are often leaf less. Inflorescence is a spikelet with many flowers.

Plate 45.

Scientific name – *Thalia geniculata*

Family – Marantaceae

Common name – Water canna

Habit – Perennial, Emergent broad leaved plant.

Habitat – Bog plant

Place of collection – Kozhikode

Stem is narrow. Leaves alternate, petiole narrow and sheathed. Leaf blade is broad ovate. Inflorescence is a bracteate panicle. Flowers are purple in colour.

Plate 46.

Scientific name – *Trapa natans*

Family – Trapaceae

Common name – Water chestnut

Habit – Attached stem plant with apical, floating rosette.

Habitat – Floating plant

Place of collection – Kozhikode

Annual plant with stem attached to substrate, submersed, elongate and relatively unbranched. Leaves are dimorphic and arranged in rosette. Leaf blade is rhombic and margin serrate. Inflorescence is solitary and Flowers are yellow in colour

Plate 47.

Scientific name – *Utricularia australis*

Family – Lentibulariaceae

Common name – Bladder wort

Habit – Free-floating below water surface, rootless, submersed stem plant.

Habitat – Floating plant

Place of collection – Chetakulam, Thrissur

Perennial or annual. Submersed, free-floating or fixed by root-like rhizoids, often tangled with other plants. Leaves are alternate or whorled, dimorphic. Emergent leaves peltate, entire, linear, obovate and reniform but submersed leaves usually highly dissected with bladder-like traps. Inflorescence a raceme supported on a whorl of inflated leaves or floats. Flowers are showy and yellow in colour.

4.1.2. Field evaluation

The water plants collected during the survey were grown as in their natural habitat and evaluated for six months under Vellanikkara conditions.

4.1.2.1. Plant characters

All types of plants ranging from tall, erect perennial as in *Sacciolepis interrupta* to very minute as in *Hygroriza aristata* were observed. The growth habits ranged from tall erect to creeping. There were trailing, free floating and submerged plants also. The stem characters also varied. The stems were creeping, herbaceous, spongy, woody, cladode, terete and hollow, bulbous etc. Variation was also observed in characters like plant height, plant spread, nature of growth and nature of stem (Table1). Plant height varied from 12.26 cm (*Hygroryza aristata*) to 162 cm (*Sacciolepis interrupta*). There were plants having a spread of 260.45 cm (*Commelina benghalensis*).

4.1.2.2. Leaf characters

The variations observed in the leaf characters viz., nature of leaf, leaf arrangement, shape of leaves, lobing of leaves, foliage colour, leaf length and leaf breadth under Vellanikkara conditions are presented in Table 2.

Wide variation was seen in the leaf characters. *Eleocharis dulcis, Eleocharis rectroflexa* and *Schoenoplectus articulatus* did not produce leaves during the entire observation period, whereas plants like *Utricularia australis, Najas minor*, *Ceratophyllum demersum* and *Cabomba caroliniana* produced finely dissected submerged leaves. *Azolla pinnata, Lemna minor* and *Salvinia molesta* produced minute floating leaves, whereas *Nymphoides* spp. and *Nelumbo nucifera* produced large size floating leaves. *Hygrophila difformis, Limnophila heterophylla, Marsilea quadrifolia* and *Nelumbo nucifera* produced dimorphic leaves.

Azolla pinnata and *Ceratopteris thalictroides* are the only plants which produced lobed leaves. The maximum leaf length was recorded in *Acorus calamus* (71.50 cm) followed by *Crinum viviparum* (54.50 cm). The minimum leaf length was

Table 1. Variation in plant characters among the aquatic plants grown under Vellanikkara conditions

Sl. no	Scientific name	Plant height (cm)	Plant spread in N-S direction (cm)	Plant spread in E-W direction (cm)	Narure of growth	Nature of stem
1	*Acorus calamus*	80.52	10.50	25.50	Tall rhizomatic	Rhizomatic
2	*Aeschynomene aspera*	62.23	54.25	15.14	Erect shrub	Creeping or floating
3	*Alternanthera philoxeroides*	40.25	35.56	40.25	Emersed	Herbaceous
4	*Angelonia salicariaefolia*	50.82	20.00	72.56	Tall	Herbaceous
5	*Aponogeton monostachyon*	*	35.45	30.00	Spreading aquatic herb	Stoloniferous
6	*Azolla pinnata*	*	30.00	30.00	Free floating herb	Herbaceous, floating
7	*Bacopa monnieri*	30.53	54.38	40.25	Creeping herb	Herbaceous
8	*Cabomba caroliniana*	*	32.00	26.50	Submerged	Herbaceous
9	*Ceratophyllum demersum*	*	35.50	35.00	Submerged	Herbaceous and branched
10	*Ceratopteris thalictroides*	18.50	146.51	90.25	Aquatic fern	Inflated stipe
11	*Commelina benghalensis*	30.25	260.45	100.12	Slender creeping herb	Herbaceous
12	*Crinum viviparum*	60.84	80.25	52.00	Perennial herb	Basal bulbaceous
13	*Desmostachia bipinnata*	160.0	50.00	21.50	Tall, caespitose	Spongy
14	*Echinodorus argentinensis*	31.45	140.25	100	Emergent marsh plants	Rhizomatic
15	*Eichhornia crassipes*	35.00	40.52	40.52	Floating	Creeping and spongy
16	*Eleocharis dulcis*	90.12	150.12	35.00	Erect and tall	Terete and hollow
17	*Eleocharis rectroflexa*	35.52	65.86	69.00	Erect and tall	Terete with air canals
18	*Elodea canadensis*	*	34.25	34.00	Submerged aquatic herb	Filiform and stoloniferous
19	*Hygrophila difformis*	90.00	90.20	85.00	Submerged and emerged	Herbaceous, pubescent
20	*Hygroryza aristata*	12.26	16.25	80.00	Floating, spreading grass	Spongy with roots at node
21	*Ipomoea aquatica*	15.13	75.28	40.45	Trailing	Herbaceous
22	*Lemna minor*	*	30.00	30.00	Free floating herb	Cladode (flat floating stem)
23	*Limnocharis flava*	83.45	38.50	72.56	Erect herb	Stout rhizome
24	*Limnophila heterophylla*	12.00	25.50	25.00	Submerged aquatic herb	Herbaceous and creeping
25	*Ludwigia adscendens*	20.78	110.25	100.50	Ascending or creeping herbs	Soft wood (spongy)

26	***Marsilea quadrifolia***	34.72	40.45	42.50	Floating herb	Herbaceous and creeping
27	***Monochoria vaginalis***	30.30	90.42	65.35	Marsh herb	Suberect and spongy
28	***Najas minor***	*	34.54	34.00	Submersed	Slender
29	***Nelumbo nucifera***	36.50	120.20	120.25	Rhizomatic	Dimorphic and horizontal
30	***Nymphaea alba***	*	75.34	72.55	Deep water	Submerged rhizome
31	***Nymphoides indica***	*	29.30	22.46	Deep water plants	Submerged rhizome
32	***Nymphoides peltata***	*	35.28	58.64	Deep water plants	Submerged rhizome
33	***Panicum repens***	85.20	250.00	100.00	Errect creeping grass	Spongy with roots at node
34	***Pistia stratiotes***	*	35.00	35.00	Free floating	Floating rhizome
35	***Polygonum barbatum***	60.21	120.25	80.25	Emergent and spreading	Erect, creeping or floating
36	***Polygonum persicaria***	54.78	90.00	57.24	Erect or creeping	Herbaceous
37	***Potamogeton praelongus***	34.50	45.45	60.00	Submersed	Herbaceous white stem
38	***Rotala macrandra***	17.25	33.50	54.00	Spreading herb	Herbaceous
39	***Sacciolepis interrupta***	162.0	220.15	80.20	Marshy, tall and emergent	Hollow, Succulent stem
40	***Salvinia molesta***	*	30.00	30.50	Floating aquatic fern	Horizontal rhizome
41	***Schoenoplectus articulatus***	40.92	15.00	15.50	Tall	Triquetrous or terete
42	***Thalia geniculata***	52.56	28.52	30.00	Tall marsh plant	Thick rhizome
43	***Trapa natans***	*	35.00	35.50	Submerged and floating	Herbaceous, and bottom rooted
44	***Utricularia australis***	*	30.45	30.47	Submerged and floating	Filiform and stoloniferous

* Floating and submerged plants

Table 2. Variation in leaf characters among the aquatic plants grown under Vellanikkara condition

Sl. no	Scientific name	Nature of leaf	L.A	Shape of leaves	L.L	Foliage colour (J)	Foliage colour (M)	Leaf length (cm)	Leaf breadth (cm)
1	***Acorus calamus***	Monofacial and glabrous	Basal, cauline	Sword shaped	NL	Dark green	Dark green	71.50	2.10
2	***Aeschynomene aspera***	Light green and unipinnate	Alternate	Linear	NL	Light green	Greenish yellow	14.25	2.50
3	***Alternanthera philoxeroides***	Succulent	Opposite	Elliptic	NL	Green	Green	2.50	1.00
4	***Angelonia salicariaefolia***	Leathery and glabrous	Opposite	Arrow shaped or lanceolate	NL	Light green	Greenish yellow	8.50	1.00
5	***Aponogeton monostachyon***	Floating, glossy and dark green	Basal spiral	Linear oblong	NL	Light green	Dark green	11.01	1.50
6	***Azolla pinnata***	Sessile and imbricate	Alternate	Trapeziform	BL	Dark green	Reddish brown	×	×
7	***Bacopa monnieri***	Succulent and thick	Opposite	Lanceolate	NL	Light green	Dark green	2.50	0.80
8	***Cabomba caroliniana***	Dimorphic	Whorled	Brush like	NL	Light green	Light green	×	×
9	***Ceratophyllum demersum***	Rigid, forked with rows of minute teeth	whorled, 6-8 at a node	Brush like	NL	Dark green	Greenish brown	×	×
10	***Ceratopteris thalictroides***	Succulent and dissected	Alternate or spiral	Fern shaped (finely divided)	L	Light green	Greenish brown	40.00	17.98
11	***Commelina benghalensis***	Subsessile	Alternate	Linear to lanceolate	NL	Dark green	Light green	8.00	2.00
12	***Crinum viviparum***	Thick ,Flat or terete	Alternate	Sword shaped	NL	Dark green	Dark green	54.50	2.15
13	***Desmostachia bipinnata***	Leaf sheath smooth, glabrous	Opposite decussate	Elliptic to ovate, obtuse at both ends	NL	Dark green	Greenish yellow	110	0.55
14	***Echinodorus argentinensis***	Submerged or erect	Basal	Linear to broad	NL	Dark green	Dark green	12.50	10.00
15	***Eichhornia crassipes***	Thick, glossy, waxy green	Arranged in rosette	Ovate, rounded and elliptic	NL	Dark green	Dark green	10	9.50
16	***Eleocharis dulcis***	*	*	*	*	*	*	*	*
17	***Eleocharis rectroflexa***	*	*	*	*	*	*	*	*

18	***Elodea canadensis***	Glossy and dark green	Opposite or in whorls of 3	Oval in outline with teeths in margin	NL	Bright green	Bright green	1.70	0.40
19	***Hygrophila difformis***	Dimorphic and serrated	Opposite	leaves pinnately divided and cauline	NL	Dark green	Dark green	9.00	4.50
20	***Hygroryza aristata***	Glossy and smooth	Alternate or spiral	Linear or ovate to oblong	NL	Light green	Greenish yellow	5.50	2.50
21	***Ipomoea aquatica***	Long stalked and smooth	Alternate	Triangular, lanceolate or linear	NL	Dark green	Light green	9.00	3.50
22	***Lemna minor***	Flat green fronds	Whorled	Elliptic, obovate	NL	Light green	Light green	1	0.30
23	***Limnocharis flava***	Light green colour and waxy	Arranged in rosette	ovate to orbicular	NL	Dark green	Greenish yellow	22.50	19.00
24	***Limnophila heterophylla***	Polymorphic and pinnatifid	Opposite and whorled	Laciniate	NL	Light green	Light green	1.50	1.00
25	***Ludwigia adscendens***	Glossy and cauline	Alternate or opposite	Obovate	NL	Dark green	Greenish yellow	3.50	2.00
26	***Marsilea quadrifolia***	Dimorphic with 4 leaflets	Symmetric	Obdeltate to ovate	NL	Light green	Light green	3.00	3.00
27	***Monochoria vaginalis***	Glossy and dark green	Alternate	Cordate or reniform	NL	Dark green	Dark green	5.80	3.00
28	***Najas minor***	Simple, linear with toothed margins	Opposite, pseudo whorled	Filiform	NL	Dark green	Dark green	×	×
29	***Nelumbo nucifera***	Waxy and floating	Basal	Orbiculate	NL	Dark green	Dark green	28.87	38.67
30	***Nymphaea alba***	Waxy	Basal	Ovate to orbicular	NL	Dark green	Light green	16.28	13.50
31	***Nymphoides indica***	Waxy, green above and dark below	Basal spiral	broadly ovate to orbicular	NL	Reddish brown	Green	6.50	3.50
32	***Nymphoides peltata***	Waxy, and peltate	Basal spiral	ovate to orbicular	NL	Reddish brown	Green	9.50	7.00
33	***Panicum repens***	Hairy above and smooth below	Alternate	Linear, flat to folded	NL	Dark green	Greenish yellow	21.25	0.74
34	***Pistia stratiotes***	Sessile and pubescent	Arranged in rosette	Obovate to ovate	NL	Light green	Greenish yellow	3	2.87
35	***Polygonum barbatum***	Entire long leaf	Alternate	Lanceolate	NL	Light green	Light green	14.50	3.50

36	***Polygonum persicaria***	Dark green with purple petioles	Alternate	Lanceolate	NL	Dark green	Dark green	9.00	2.00
37	***Potamogeton praelongus***	Glossy and wavy	Alternate	Lance shaped	NL	Dark green	Greenish yellow	6.75	1.75
38	***Rotala macrandra***	Dark green and sessile	Opposite, whorled	Linear to ovate	NL	Light green	Light green	1.50	1.00
39	***Sacciolepis interrupta***	Glossy, long, flat or rolled	Alternate or spiral	Linear to lanceolate	NL	Dark green	Greenish yellow	32.95	0.60
40	***Salvinia molesta***	Glossy with unwettable hairs	In whorls of 3 leaves	Elliptic, entire and folded	NL	Light green	Purple	1.5	0.50
41	***Schoenoplectus articulatus***	*	*	*	*	*	*	*	*
42	***Thalia geniculata***	Simple, basal and cauline	Alternate or spiral	Lance shaped or Ovate to lanceolate	NL	Dark green	Greenish yellow	18.26	7.25
43	***Trapa natans***	Dimorphic and caducous	Opposite or alternate	Rhomboidal reniform	NL	Dark green	Light green	1.5	0.50
44	***Utricularia australis***	Entire and capillary	whorled	Rhomboidal reniform	NL	Dark green	Light green	×	×

× Plants with very minute leaves, * Plants with no leaves, L.A – Leaf arrangement, L.L – Leaf lobe, NL - Not lobed, BL – Bilobed, L - Lobed recorded in *Lemna minor* (1.00 cm). The leaf width ranged from 0.30 cm (*Lemna minor*) to 38.67 cm (*Nelumbo nucifera*).

4.1.2.3. Floral characters

The variations observed in the floral characters of aquatic plants under Vellanikkara conditions are presented in Table 3. Flowers are borne either solitary or in inflorescence. The flower colour varied with respect to different species. In most of the species the blooming period ranged from July to September. *Azolla pinnata, Ceratopteris thalictroides, Cabomba caroliniana, Hypolytrum nudicaule, Lemna minor, Marsilea quadrifolia, Najas minor, Pistia stratiotes* and *Polygonum barbatum* did not produce flowers during the period of observation.

4.1.2.4. Classification of collected aquatic plants

The collected aquatic plants were grouped into the following six groups based on their growth habit (Table 4 and Fig. 1).

4.1.2.4.1. Deep water aquatics

Deep water aquatic plants root strongly in bottom of pond. Stem is below water and leaves float on water surface. Depth of water is more than 60 cm. Plants like *Nymphaea alba, Nymphoides indica, Nymphoides peltata* and *Aponogeton monostachyon* are included in this group.

4.1.2.4.2. Shallow water aquatics

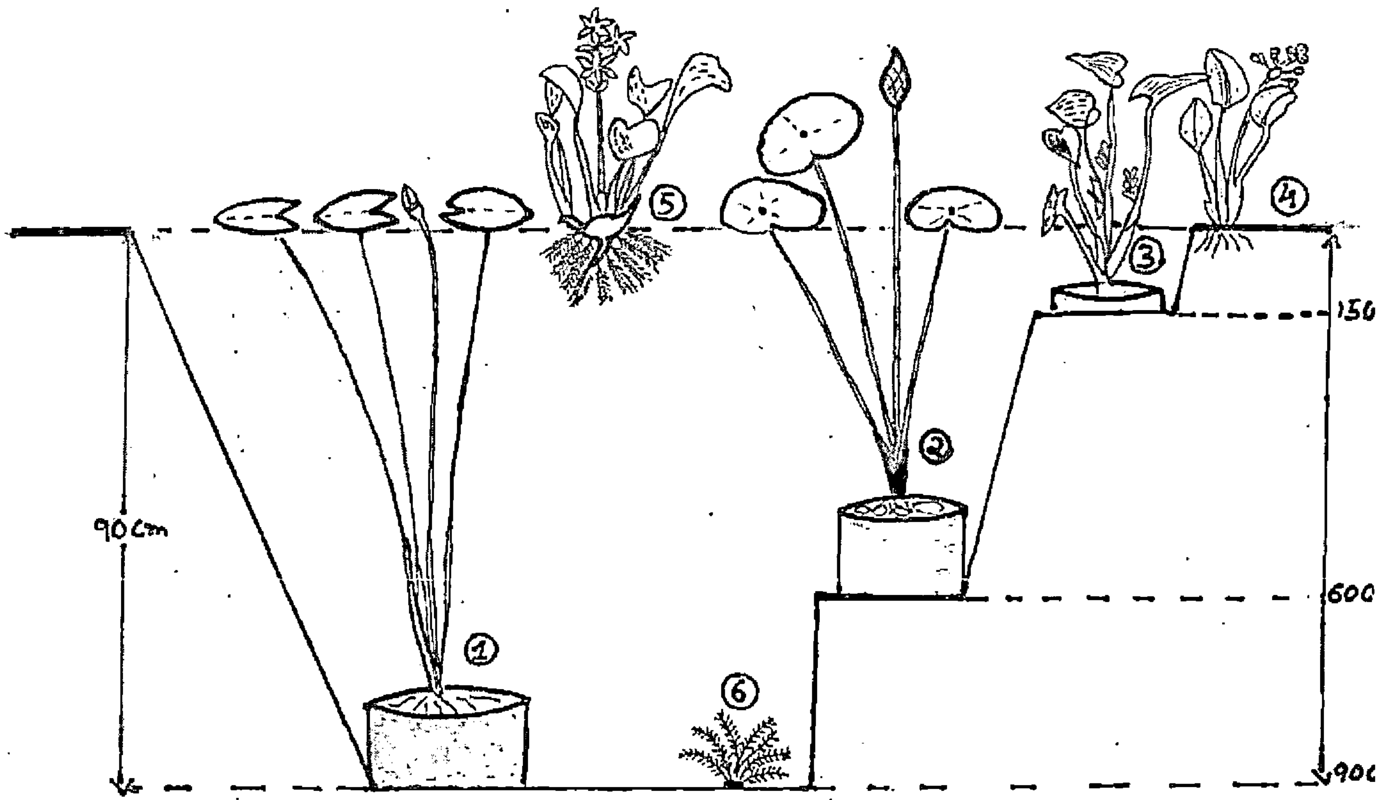
These plants root into mud like water lilies, but hold their leaves and flowers well above the water. They prefer shallow water and can be grown upto 90 cm depth.

Nelumbo nucifera comes under this group.

4.1.2.4.3. Submerged aquatic plants

They are totally submerged under water and can never exist out of water. They are known as oxygenators and help to keep the water clean and provide shelter for pond fish. Collected plants included under this group are *Utricularia australis, Najas minor, Limnophila heterophylla, Rotala macrandra, Hygrophila difformis, Cabomba*

Fig. 1. Classification of aquatic plants based on their habitat



1. Deep water plants – eg. *Nymphaea ,Nymphoides* and *Nuphar spp.*
2. Shallow water plants – eg. *Nelumbo nucifera*
3. Marginal plants– eg. *Monochoria vaginalis* and *Ipomoea aquatica*
4. Bog plants– eg. *Limnocharis flava* and *Crinum viviparum*
5. Floating plants – eg. *Eichhornia, Pistia* and *Lemna*
6. Submerged plants – eg. *Ceratophyllum, Cabomba* and *Najas*

Table 3. Variation in the floral characters among the aquatic plants grown under Vellanikkara conditions

Sl.no	Scientific name	Solitary/ Inflorescence	Flower colour	Blooming period
1	*Acorus calamus*	Inflorescence	Yellowish green	June
2	*Aeschynomene aspera*	Solitary	Yellow	October
3	*Angelonia salicariaefolia*	Inflorescence	Lavender	March to May
4	*Aponogeton monostachyon*	Inflorescence	Pink to pale blue	Rainy season
5	*Azolla pinnata*	*	*	*
6	*Alternanthera philoxeroides*	Solitary	White	March to May
7	*Bacopa monnieri*	Solitary	White	February to May
8	*Cabomba caroliniana*	*	*	*
9	*Ceratophyllum demersum*	Solitary	Greenish brown	January to March
10	*Ceratopteris thalictroides*	*	*	*
11	*Commelina benghalensis*	Inflorescence	Blue	June - September
12	*Crinum viviparum*	Inflorescence	Pink to White	Sep - Oct
13	*Desmostachya bipinnata*	Inflorescence	Yellow with red	Sep - Nov
14	*Echinodorus argentinensis*	Inflorescence	White	April - August
15	*Eichhornia crassipes*	Inflorescence	Pink to light	Jan –Apr , Aug - Oct
16	*Eleocharis dulcis*	Inflorescence	Straw colour	May - Oct
17	*Eleocharis rectroflexa*	Inflorescence	Pale brown	July - October
18	*Elodea canadensis*	Solitary	white	July- September
19	*Hygrophila difformis*	Inflorescence	Lavender	March- April
20	*Hygroryza aristata*	Inflorescence	Grey colour	July - Oct
21	*Ipomoea aquatica*	Solitary	White to purple	Feb- April , Sep-Nov
22	*Lemna minor*	*	*	*
23	*Limnocharis flava*	Inflorescence	Yellow	Throughout year
24	*Limnophila heterophylla*	Inflorescence	White	March - October
25	*Ludwigia adscendens*	Solitary	White	February to April
26	*Marsilea quadrifolia*	*	*	*
27	*Monochoria vaginalis*	Inflorescence	Blue	Feb-Mar ,Jul-Oct
28	*Najas minor*	*	*	*
29	*Nelumbo nucifera*	Solitary	Pink	April- August
30	*Nymphaea alba*	Solitary	white	Juy-Sept, Nov- Mar
31	*Nymphoides indica*	Solitary	White	Sep-Nov, Feb-May
32	*Nymphoides peltata*	Solitary	Yellow	June
33	*Panicum repens*	Inflorescence	Greenish yellow	July - August
34	*Pistia stratiotes*	*	*	*
35	*Polygonum barbatum*	*	*	*
36	*Polygonum persicaria*	Inflorescence	Pink	May - October
37	*Potamogeton praelongus*	Inflorescence	Green	June - July
38	*Rotala macrandra*	Inflorescence	Pink	Spring to Autumn
39	*Sacciolepis interrupta*	Inflorescence	Light green	July- October
40	*Salvinia molesta*	*	*	*
41	*Schoenoplectus articulatus*	Inflorescence	Brown	Feb-May
42	*Thalia geniculata*	Inflorescence	Purple	April - August
43	*Trapa natans*	Solitary	Yellow	February - April
44	*Utricularia australis*	Inflorescence	Yellow	April- August

*No flowers

Table 4. Classification of aquatic plants collected into different groups

Sl. No	Deep water aquatics	Shallow water aquatics	Submerged aquatic plants	Floating water plants	Marginal water plants	Bog plants
1	*Nymphaea alba*	*Nelumbo nucifera*	*Utricularia australis*	*Azolla pinnata*	*Ipomoea aquatica*	*Acorus calamus*
2	*Aponogeton monostachyon*		*Najas minor*	*Eichhornia crassipes*	*Polygonum barbatum*	*Bacopa monnieri*
3	*Nymphoides indica*		*Limnophila heterophylla*	*Pistia stratiotes*	*Monochoria vaginalis*	*Crinum viviparum*
4	*Nymphoides peltata*		*Hygrophila difformis*	*Salvinia molesta*	*Panicum repens*	*Schoenoplectus articulates*
5			*Cabomba caroliniana*	*Trapa natans*	*Commelina benghalensis*	*Ceratopteris thalictroides*
6			*Ceratophyllum demersum*	*Lemna minor*	*Sacciolepis interrupta*	*Ludwigia adscendens*
7			*Elodea canadensis*		*Eleocharis dulcis*	*Echinodorus argentinensis*
8			*Potamogeton praelongus*		*Hygroryza aristata*	*Thalia geniculata*
9					*Desmostachia bipinnata*	*Marsilea quadrifolia*
10					*Angelonia salicariaefolia*	*Polygonum persicaria*
11					*Rotala macrandra*	*Aeschynomene aspera*
12						*Limnocharis flava*
13						*Alternanthera philoxeroides*

caroliniana, Ceratophyllum demersum, Elodea canadensis and *Potamogeton praelongus*.

4.1.2.4.4. Floating water plants

Plants which move freely on the surface of water. They do not need soil for growing. Among the collected plants *Azolla pinnata, Eichhornia crassipes, Pistia stratiotes, Salvinia molesta, Trapa natans* and *Lemna minor* were free floating plants.

4.1.2.4.5. Marginal water plants

The plants grown at the edge of the pond with their roots in soil but with most of the foliage above the soil and out of water. Most of them like to be in soil that is few centimeters under water (5 – 15 cm). Plants like *Ipomoea aquatica, Polygonum barbatum, Monochoria vaginalis, Panicum repens, Commelina benghalensis, Sacciolepis interrupta, Eleocharis dulcis, Hygroryza aristata, Desmostachya bipinnata* and *Angelonia salicariaefolia* are included in this group.

4.1.2.4.6. Bog plants

These are the plants growing in wet mud. *Acorus calamus, Bacopa monnieri, Crinum viviparum, Schoenoplectus articulatus, Ceratopteris thalictroides, Ludwigia adscendens, Echinodorous argentinensis, Thalia geniculata, Marsilea quadrifolia, Polygonum persicaria, Aeschynomene aspera, Limnocharis flava and Alternanthera philoxeroides* are the collected plants which are included in this group.

4.1.2.5. Plants suitable for water gardening

Based on the evaluation 22 aquatic plants were selected for different uses in water gardens.

4.1.2.5.1. Deep water plants

a) *Nymphaea alba* – It produces large solitary white coloured flowers.

b) *Nymphoides indica* – Produces white flowers with fringed petals which appear to be floating in water with dark green and attractive heart shaped leaves.

c) *Nymphoides peltata* – Produces yellow coloured flowers with attractive floating leaves.

d) *Aponogeton monostachyon* – They produce floating leaves and attractive purple coloured spikes.

4.1.2.5.2. Shallow water plants

a) *Nelumbo nucifera* – It commands admiration and a good deal of attention because of large solitary flowers borne high above the water surface against the background of silvery bluish leaves on the stem.

4.1.2.5.3. Oxygenators

a) *Utricularia australis* – Yellow coloured spikes and feather like submerged leaves are the main attractive features.

b) *Najas minor, Limnophila heterophylla, Hygrophila difformis, Cabomba caroliniana, Ceratophyllum demersum* and *Elodea canadensis* can also be used as oxygenator plants. Due to their attractive foliage they can be used as aquarium plants.

4.1.2.5.4. Floating water plants

a) *Azolla pinnata* and *Lemna minor* – Both receive a good deal of attention because of their minute floating leaves.

b) *Eichhornia crassipes* – It is a free floating plant with glossy leaves and terminal violet coloured spikes.

c) *Pistia stratiotes* – It is very attractive because of the cabbage head like floating leaves.

d) *Trapa natans* – This is a very attractive floating plant which has a rosette arrangement of leaves and yellow coloured flowers.

4.1.2.5.5. Marginal water plants

a) *Angelonia salicariaefolia* – It produces white coloured flowers which are very attractive.

b) *Ipomoea aquatica* – It is a marginal plant with creeping branches and attractive white flowers.

c) *Hygroriza aristata* – Its glossy and smooth leaves are very attractive.

4.1.2.5.6. Bog plants

a) *Crinum viviparum* - The main attractive feature is the large white flowers which are intensively fragrant.

b) *Limnocharis flava* – Leaves are velvety, broad and heart shaped flowers are produced throughout the year.

4.2 STANDARDISATION OF GROWING MEDIA FOR *NYMPHAEA* SPECIES

Data generated from the experiment on the effect of media combinations on different species of *Nymphaea* for various months are presented under the two main heads, viz., plant characters and floral characters

4.2.1 Plant characters

The influence of species, growing media and their interactions on plant characters, viz., surface spread of plants, petiole length, leaf length, leaf width, leaf area, number of leaves, leaf production interval, longevity of leaf and time for complete leaf opening in different months are presented in Tables 5 to 8.

4.2.1.1. Surface spread in North – South direction

The effect of *Nymphaea spp*., media and their interactions on the surface spread in North – South direction is given in Table 5. In all the three species there was no significant difference in the surface spread during the initial three months but from December to June a significant difference in surface spread was noticed. *Nymphaea stellata* recorded the maximum surface spread in February (79.43cm) followed by *Nymphaea alba* (75.54cm). Surface spread decreased from February to April and it was significantly lower in the month of April and *Nymphaea rubra* recorded the minimum surface spread (64.79 cm) in April. The surface spread increased during May – June.

All the four media combinations showed significant differences in the surface spread from December to June. The maximum plant surface spread (80.47 cm) was found in M1in the month of February. Surface spread was significantly lower in April.

Table 5. Surface spread in North – South direction in *Nymphaea* spp. as influenced by different media combinations

Treatments	Surface spread (cm)									
	Months									
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Nymphaea spp.										
N1	52.38	61.81	66.06	68.22	70.51	72.66	69.29	64.79	65.61	69.54
N2	50.52	60.22	66.77	70.60	76.18	75.54	71.31	66.2	66.58	70.50
N3	48.00	58.11	68.04	73.20	77.50	79.43	74.12	69.33	70.75	74.54
SE ±	2.408	2.160	1.497	1.1578	0.8869	0.6013	0.5590	0.4621	0.4336	0.4465
C.D (0.05)	**N.S**	**N.S**	**N.S**	4.55*	**2.59****	**1.76****	**1.63****	**1.35****	**1.27****	**1.30****
Media										
M1	47.63	58.95	66.05	70.69	76.13	80.47	76.47	71.11	72.70	76.50
M2	48.00	61.33	70.69	74.88	76.42	77.41	72.58	68.13	68.66	72.94
M3	50.37	58.05	64.58	67.86	71.23	73.33	69.19	64.58	65.18	69.11
M4	55.22	61.94	66.50	69.27	71.00	72.30	68.05	63.27	64.03	67.55
SE ±	2.780	2.494	1.729	1.3369	1.0241	0.6943	0.6455	0.5336	0.5007	0.5156
C.D (0.05)	**N.S**	**N.S**	**N.S**	**3.90****	**2.99****	**2.03****	**1.88****	**1.56****	**1.46****	**1.50****
Spp x Media										
N1M1	46.33	59.00	63.83	66.41	69.33	73.08	71.50	68.16	69.88	72.33
N1M2	51.77	65.83	70.75	72.25	73.60	74.41	70.50	66.00	66.11	71.83
N1M3	52.77	59.08	63.08	66.08	69.40	71.66	69.00	64.00	64.44	68.83
N1M4	58.66	63.33	66.58	68.16	69.73	71.50	66.16	61.00	62.00	65.16
N2M1	49.11	60.66	66.50	71.66	77.13	81.00	76.50	70.16	73.11	77.08
N2M2	42.66	56.00	66.83	73.16	74.00	76.58	71.75	66.25	65.77	70.25
N2M3	54.00	60.00	66.16	69.00	71.53	72.66	68.50	64.83	64.88	69.33
N2M4	56.33	64.25	67.58	68.58	70.06	71.58	68.50	63.58	62.55	65.33
N3M1	47.44	57.20	67.83	74.00	81.93	87.00	81.41	75.00	75.11	80.08
N3M2	49.55	62.16	74.50	79.25	81.66	81.25	75.50	72.16	74.11	76.75
N3M3	44.33	55.08	64.50	68.50	73.23	75.66	70.08	64.91	66.22	69.16
N3M4	50.66	58.25	65.33	71.08	73.20	73.833	69.500	65.25	67.55	72.16
SE ±	4.816	4.321	2.995	2.3155	1.7739	1.2026	1.1180	0.9242	0.8672	0.8930
C.D (0.05)	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**3.51****	**3.62***	**2.70***	**2.53****	**2.61****

* Significant at 0.05 level, ** Significant at 0.01 level, N.S – Non Significant, N1 – *Nymphaea rubra,* N2 – *Nymphaea alba*, N3 – *Nymphaea stellata,* M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2)

M4 produced the minimum surface spread (63.27 cm) followed by M3 (64.58 cm) in April.

The combined effect of species and media were significant only during February to June (Table 5). The surface spread was significantly higher in the month of February. *Nymphaea stellata* recorded the maximum surface spread (87.00cm) in M1 which was significantly superior to all other treatment combinations. Minimum plant spread (71.50 cm) was recorded by *Nymphaea rubra* in M4.

4.2.1.2 Surface spread in East – West direction

Data regarding the effect of *Nymphaea spp.* and growing media on surface spread in East-West direction is presented in Table 6. The surface spread in different species of *Nymphaea* differed significantly during December to June. From December to June *Nymphaea stellata* recorded maximum surface spread and was significantly superior when compared to other species. Maximum surface spread (80.08cm) was recorded by *Nymphaea stellata* in February and it decreased during March-April and reached the minimum (71.77 cm) in April. *Nymphaea rubra* recorded the minimum surface spread (65.06cm) in April. This was on par with *Nymphaea alba* (66.72cm). During May – June the surface spread started increasing gradually.

The influence of media on surface spread of plants was evident. Plants raised in M1 recorded maximum surface spread in February (81.41 cm) and was. significantly superior to the other treatments. Minimum plant spread was reached by M4 (65.30 cm) which was on par with M3 (66.25 cm) in April.

The differential effect between *Nymphaea spp.* and media combinations on the surface spread in East- West direction during the observation period was not significant except February, March and June. *Nymphaea stellata* recorded the maximum (87.50 cm) in M1during February and was significantly superior to all the treatment combinations. The same trend was also noticed in March and June. Minimum plant spread was noticed by *Nymphaea alba* in M4 in February and June (69.41 and 65.58 cm respectively).

Table 6. Surface spread in east – west direction in *Nymphaea* spp. as influenced by different media combinations

Surface spread (cm)										
Treatments	**Months**									
	Sep	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Nymphaea spp.										
N1	54.44	62.02	65.47	68.06	71.26	73.06	68.65	65.06	66.31	69.81
N2	52.33	59.87	66.97	71.08	73.81	75.27	71.83	66.72	67.83	71.27
N3	55.45	61.84	69.22	73.87	77.38	80.08	75.66	71.77	72.60	75.35
SE ±	2.469	2.097	1.654	1.1400	0.9302	0.6759	0.5250	0.6278	0.5943	0.5571
C.D (0.05)	**N.S**	**N.S**	**N.S**	**3.33****	**2.72****	**1.97****	**1.53****	**1.83****	**1.73****	**1.63****
Media										
M1	51.87	60.66	67.08	71.58	77.26	81.41	77.61	72.25	74.20	76.55
M2	50.59	60.48	68.97	73.91	76.60	77.25	71.55	67.61	68.91	72.72
M3	54.85	60.58	66.63	70.27	73.55	74.83	70.18	66.25	66.50	70.30
M4	59.00	63.25	66.22	68.25	69.20	71.66	69.25	65.30	66.22	69.00
SE ±	2.851	2.422	1.910	1.3164	1.0741	0.7805	0.6062	0.7249	0.6862	0.6433
C.D (0.05)	**N.S**	**N.S**	**N.S**	**3.84***	**3.14****	**2.28****	**1.77****	**2.12****	**2.00****	**1.88****
Spp x Media										
N1M1	47.00	57.33	62.33	64.50	70.000	74.08	71.91	69.58	71.66	73.50
N1M2	55.44	68.00	71.16	72.25	73.200	73.66	69.08	64.16	65.75	69.66
N1M3	55.55	60.66	64.16	68.83	72.600	73.50	67.66	64.16	64.83	69.41
N1M4	59.77	62.08	64.25	66.66	69.267	71.00	67.16	62.33	63.00	66.66
N2M1	60.00	67.08	71.00	75.33	79.333	82.66	78.66	71.50	74.33	77.00
N2M2	44.44	54.33	66.66	73.41	76.133	78.00	72.00	66.83	67.58	72.33
N2M3	51.33	57.66	65.83	69.25	71.933	72.83	69.25	65.83	66.00	70.16
N2M4	53.55	60.41	64.41	66.33	67.867	69.41	67.41	62.75	63.41	65.58
N3M1	48.61	57.58	67.91	74.91	82.467	87.50	82.25	75.66	76.08	79.16
N3M2	51.89	59.12	69.08	76.08	80.467	80.08	73.58	71.83	73.41	76.16
N3M3	57.66	63.41	69.91	72.75	76.133	78.16	73.66	68.75	68.66	71.33
N3M4	63.66	67.25	70.00	71.75	70.467	74.58	73.16	70.83	72.25	74.75
SE ±	4.939	4.195	3.309	2.2800	1.8604	1.351	1.0500	1.2555	1.1885	1.1141
C.D (0.05)	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**3.95****	**3.07***	**N.S**	**N.S**	**3.25***

* Significant at 0.05 level, ** Significant at 0.01 level, N.S – Non Significant, N1 – *Nymphaea rubra,* N2 – *Nymphaea alba*, N3 – *Nymphaea stellata,* M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2)

4.2.1.3. Petiole length

Nymphaea spp. recorded significant difference with regard to the petiole length in all the months except September. It showed an increasing trend from September to November and there was a decrease during the period of December to February. From March onwards again there was a steady increase and it reached the peak value in June (Table 7). During the entire growing period, *Nymphaea stellata* was significantly superior to all other species, with regard to the petiole length. In *Nymphaea rubra* the petiole length was short. *Nymphaea stellata* recorded maximum petiole length (36.39 cm) in June.

The media combinations also showed significant difference in the petiole length during October – June. During this period the minimum petiole length was recorded in M3. Plants grown in M2 recorded maximum length during October to December, February March and June, but it was on par with M1in April and May. The minimum petiole length was recorded in M3 in February (22.61 cm).

The combined effect of *Nymphaea spp.* and growing media was significant in all the months except January. *Nymphaea stellata* in M1 recorded maximum petiole length during the entire period except in February. *Nymphaea stellata* in M1 recorded maximum petiole length (40.04 cm) in June and was significantly superior to all other combinations except M2 (38.50 cm) in *Nymphaea stellata*. *Nymphaea rubra* in M3 recorded the minimum petiole length in February (21.58 cm).

4.2.1.4. Leaf characters

The data pertaining to the effect of *Nymphaea spp.* and growing media on the leaf characters viz., length, width, area, number of leaves produced, production interval, longevity and time for complete unfurling are given in Table 8.

4.2.1.4.1. Leaf length

The effect of *Nymphaea* spp. on leaf length was clearly evident. *Nymphaea rubra* recorded the maximum leaf length (13.36 cm) which was on par with *Nymphaea stellata* (13.18 cm) and *Nymphaea alba* recorded the minimum (12.22 cm).

Table 7. Petiole length in *Nymphaea* spp. as influenced by different media combinations

Treatments	Petiole length (cm)									
	Months									
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
***Nymphaea* spp.**										
N1	25.58	26.74	27.79	25.10	23.65	23.40	26.35	27.60	28.50	30.49
N2	26.48	27.31	28.03	26.10	25.31	24.39	26.38	27.32	28.76	30.99
N3	25.73	28.92	30.01	29.67	28.63	27.99	30.86	32.45	34.16	36.39
SE ±	0.3619	0.4504	0.3665	0.3557	0.3639	0.4415	0.3795	0.3119	0.340	0.3610
C.D (0.05)	**N.S**	**1.31****	**1.07****	**1.04****	**1.06****	**1.29****	**1.11****	**0.91****	**0.99****	**1.05****
Media										
M1	26.18	28.31	29.47	27.79	26.96	26.53	28.96	30.53	32.06	33.74
M2	26.32	28.65	29.73	28.37	26.63	26.59	29.20	30.20	31.19	35.27
M3	24.92	25.63	26.68	24.69	24.62	22.61	26.15	27.40	28.40	29.64
M4	26.31	28.03	28.80	26.98	25.62	25.30	27.13	28.36	30.24	31.83
SE ±	0.4179	0.5201	0.4220	0.4107	0.4202	0.5098	0.4382	0.3602	0.3972	0.4169
C.D (0.05)	**N.S**	**1.52****	**1.23****	**1.20****	**1.23****	**1.49****	**1.28****	**1.05****	**1.16****	**1.21****
Spp x Media										
N1M1	23.94	25.45	26.91	25.08	24.09	25.85	25.62	28.66	29.00	30.25
N1M2	26.51	27.96	29.16	26.33	23.81	23.52	28.62	28.87	29.16	33.16
N1M3	24.88	25.79	26.79	23.98	23.45	21.58	25.54	26.54	27.50	28.66
N1M4	27.00	27.75	29.04	25.01	23.27	22.66	25.61	26.33	28.36	29.87
N2M1	26.05	27.41	27.91	26.16	25.70	24.75	26.68	27.36	29.16	30.95
N2M2	26.56	27.75	28.45	27.09	26.91	26.05	27.75	28.33	29.16	34.16
N2M3	25.88	26.00	27.29	25.16	23.72	23.09	24.93	26.58	27.54	28.92
N2M4	27.44	28.09	28.45	26.00	24.93	23.66	26.16	27.00	28.41	29.91
N3M1	28.54	32.07	33.58	32.13	31.08	29.00	34.58	35.56	38.04	40.04
N3M2	25.88	30.25	31.58	31.70	29.16	30.21	31.25	33.41	34.50	38.50
N3M3	24.00	25.11	25.98	24.93	26.70	23.16	28.00	29.09	30.16	31.33
N3M4	24.50	28.25	28.91	29.93	27.59	29.58	29.63	31.74	33.95	35.70
SE ±	0.7239	0.9008	0.7309	0.7114	0.7278	0.8830	0.7590	0.6238	0.6880	0.7220
C.D (0.05)	**2.11****	**2.63***	**2.13****	**2.07****	**N.S**	**2.58***	**2.22****	**1.82****	**1.95****	**2.25****

* Significant at 0.05 level, ** Significant at 0.01 level, N.S – Non Significant, N1 – *Nymphaea rubra*, N2 – *Nymphaea alba*, N3 – *Nymphaea stellata*, M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2)

Table 8. Leaf characters in *Nymphaea* spp. as influenced by different media combinations

Treatments	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Number of leaves	Leaf production interval (days)	Leaf longevity (days)	Days for complete leaf unfurling
Nymphaea spp.							
N1	13.36	11.65	122.80	8.4	4.0	33.5	11.3
N2	12.22	10.62	99.65	6.3	4.3	32.3	11.5
N3	13.18	11.79	146.34	18.4	3.6	32.2	9.8
SE ±	0.2241	0.2647	4.8972	0.4764	0.1632	0.5248	0.1863
C.D (0.05)	**0.65****	**0.77****	**14.29****	**1.4****	**0.5***	N.S	**0.5****
Media							
M1	12.87	11.98	123.41	10.2	3.9	32.3	10.0
M2	13.48	11.48	133.74	11.1	3.8	30.8	10.7
M3	12.34	10.63	111.37	11.0	4.2	33.8	11.9
M4	13.00	11.31	123.23	11.9	3.9	33.7	10.7
SE ±	0.2588	0.305	5.6536	0.5501	0.1884	0.6060	0.2152
C.D (0.05)	**0.76***	**0.89***	N.S	N.S	N.S	**1.8****	**0.6****
Spp x Media							
N1M1	13.75	12.50	135.59	6.2	4.2	31.0	11.7
N1M2	14.20	12.45	157.86	8.6	4.3	32.3	11.3
N1M3	13.37	11.41	120.24	9.0	4.1	36.7	12.5
N1M4	13.12	11.25	116.49	8.9	3.3	34.0	12.0
N2M1	12.04	10.41	95.33	6.4	4.4	31.7	11.0
N2M2	13.87	12.54	132.16	7.1	4.0	31.0	11.0
N2M3	10.62	9.00	72.05	5.4	4.4	33.3	12.0
N2M4	12.41	10.54	99.06	6.3	4.3	33.0	11.0
N3M1	12.83	11.54	139.31	17.2	3.3	31.3	9.0
N3M2	13.35	11.95	150.16	17.7	2.9	29.2	9.7
N3M3	13.08	11.50	141.43	18.4	4.0	33.7	11.7
N3M4	13.45	12.16	154.13	20.5	4.1	31.5	9.5
SE ±	0.4484	0.5294	9.792	0.9529	0.3263	1.0497	0.3727
C.D (0.05)	**1.31***	**1.54***	**28.57***	N.S	N.S	3.1*	**1.1***

* Significant at 0.05 level, ** Significant at 0.01 level, N.S – Non Significant, N1 – *Nymphaea rubra,* N2 – *Nymphaea alba*, N3 – *Nymphaea stellata,* M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2)

Noticeable differences could be observed among the media combinations with regard to leaf length. The maximum leaf length was recorded in M2 (13.48 cm) which was on par with all media combinations except M3 (12.34 cm).

The combined effect of species and media on leaf length was significant. Maximum leaf length (14.20 cm) was recorded in *Nymphaea rubra* in M2 which was on par with all media combinations in *Nymphaea stellata* except M1 (12.83 cm). This was also on par with *Nymphaea alba* in M2 (13.87 cm). *Nymphaea alba* recorded the minimum leaf length (10.62 cm) in M3.

4.2.1.4.2. Leaf breadth

The effect of species on leaf breadth was highly significant. *Nymphaea stellata* recorded maximum leaf breadth (11.79 cm) which was on par with *Nymphaea rubra* (11.65 cm) and *Nymphaea alba* recorded the minimum (10.62 cm).

Appreciable differences were noticed among the media combinations with respect to leaf breadth (Table 8). M1 (11.98 cm) recorded the maximum leaf width and was on par with all media combinations except M3. M3 (10.63 cm) recorded the minimum leaf breadth.

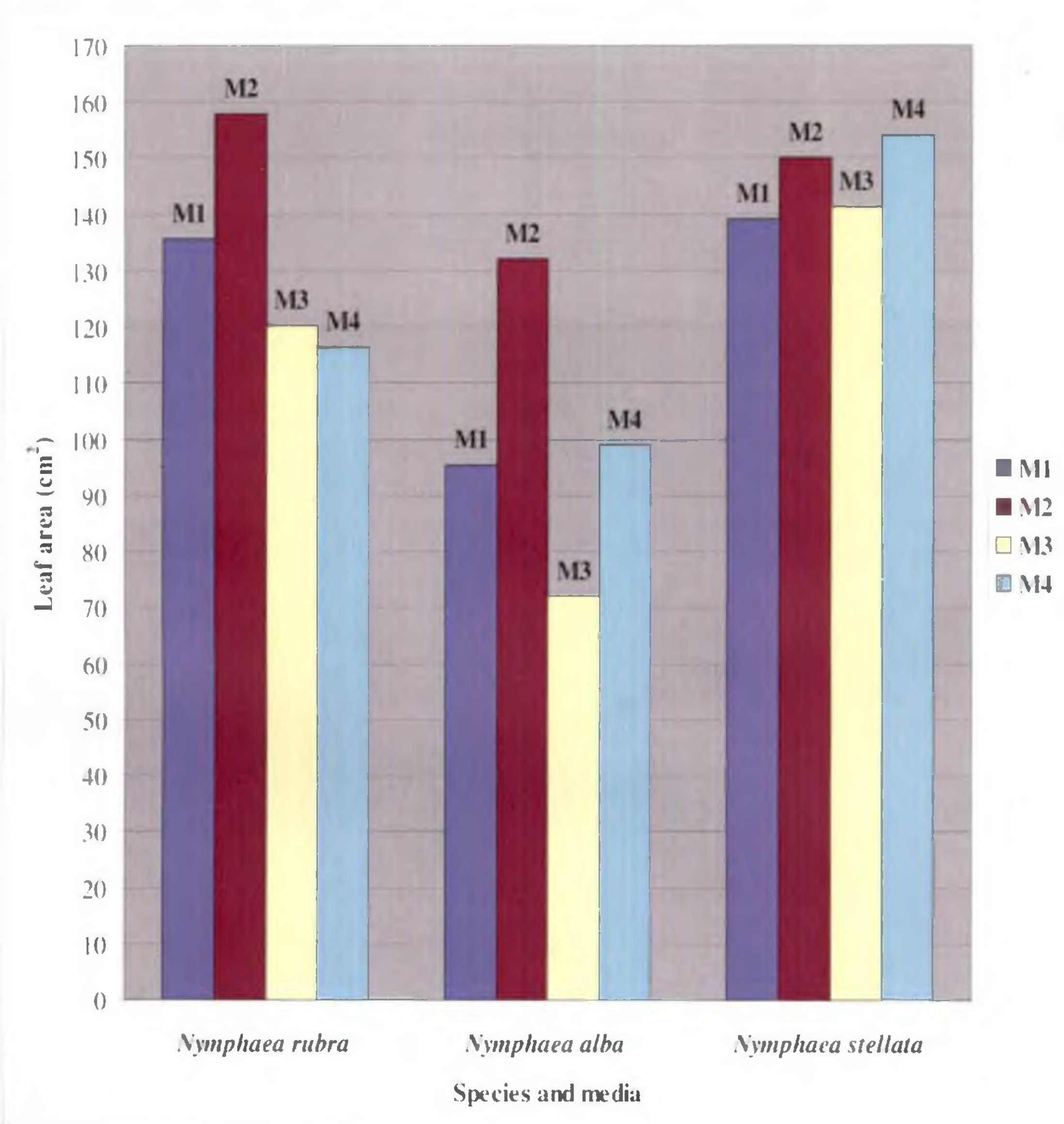
Differential effect between *Nymphaea* spp. and media combinations with respect to leaf width was significant. *Nymphaea rubra* recorded the maximum leaf breadth in M2 (12.54 cm) which was on par with all the combinations except M1, M3 and M4 in *Nymphaea alba*. *Nymphaea alba* recorded the minimum leaf breadth (9.0 cm) in M3.

4.2.1.4.3. Leaf area

Significant difference in the leaf area was noticed among the three species (Table 8). Maximum leaf area (146.34 cm^2) was recorded in *Nymphaea stellata* which was significantly superior over other species and the minimum (99.65 cm^2) was recorded in *Nymphaea alba*. The influence of growing media on leaf area was not significant.

The combined effect of *Nymphaea* spp. and growing media on leaf area was appreciable. *Nymphaea rubra* recorded the maximum (157.86 cm^2) in M2 which was

Fig. 2. Leaf area in different *Nymphaea* species in different growing media



on par with all media combinations in *Nymphaea stellata*, M2 (132.16 cm^2) in *Nymphaea alba* and M1 (135.59 cm^2) in *Nymphaea rubra*. The minimum leaf area (72.05 cm^2) was recorded in M3 which was on par with M1 and M4 in *Nymphaea alba* (Table 8 and Fig.2).

4.2.1.4.4. Number of leaves

Nymphaea spp. exhibited significant differences in the number of leaves produced. The maximum number of leaves (18.4) was recorded in *Nymphaea stellata* and was significantly superior among the three species. This was followed by *Nymphaea rubra* (8.4) and *Nymphaea alba* (6.3).

The effect of media and the differential effect between *Nymphaea* spp. and media combinations on the number of leaves produced were not significant.

4.2.1.4.5. Leaf production interval

The leaf production interval among the three species varied significantly. *Nymphaea stellata* recorded the minimum (3.6 days) which was on par with *Nymphaea rubra* (4.0 days) and *Nymphaea alba* recorded the maximum leaf production interval (4.3 days).

The effect of media and the differential effect between *Nymphaea* spp. and media combinations on leaf production interval were not significant.

4.2.1.4.6. Leaf longevity

The effect of *Nymphaea* spp. on leaf longevity was not significant, whereas the effect of different media combinations was highly significant. M3 recorded the maximum (33.8 days) which was on par with M4 (33.7 days) and M1 (32.3 days). The minimum leaf longevity (30.8 days) was recorded in M2.

The differential effect between *Nymphaea* spp. and media combinations with respect to leaf longevity was appreciable. The leaf longevity ranged from 29.2 days (N3M2) to 36.7 days (N1M3). *Nymphaea rubra* in M3 recorded the maximum leaf longevity (36.7 days) which was on par with M4 (34.0 days) in *Nymphaea rubra.* Nymphaea stellata in M2 recorded minimum leaf longevity (29.2 days).

4.2.1.4.7. Time for complete leaf unfurling

There are different stages of leaf development in water lilies (Plate 48). The effect of species on the time required for complete leaf unfurling was significant. *Nymphaea stellata* recorded the minimum time (9.8 days) for complete leaf unfurling and was significantly superior over other species. *Nymphaea alba* recorded the maximum (11.5 days) and this was followed by *Nymphaea rubra* (11.3 days).

The effect of media on the time for complete leaf unfurling was significant. M1 recorded the minimum time (10.0 days) for complete leaf unfurling, which was significantly superior over the other media combinations and M3 recorded the maximum time (11.9 days). This was followed by M2 and M3.

The differential effect between *Nymphaea* spp. and media combinations had a significant effect on the time for complete leaf unfurling. The time for complete leaf unfurling ranged from 9.0 days (N3M1) to 12.5 days (N1M3). *Nymphaea stellata* recorded the minimum (9.0 days) in M1which was on par with M2 (9.7 days) and M4 (9.5 days) in *Nymphaea stellata.*

4.2.2 Floral characters

Nymphaea rubra, Nymphaea alba and *Nymphaea stellata* produced red, white and blue coloured flowers respectively. Wide variations were observed in the floral and leaf characters of *Nymphaea* spp. (Plate 49- 54). The effect of different species of *Nymphaea* and growing media on floral characters is presented in Tables 9 to 17.

4.2.2.1 Days taken for the emergence of first flower bud

'The effect of *Nymphaea* spp. and growing media on the days taken for the emergence of first flower bud is given in Table 9.

Appreciable differences were noticed among the *Nymphaea* spp. with respect to the days taken for first bud emergence. *Nymphaea stellata* recorded the minimum

Plate 48. Different stages of leaf development in water lilies (*Nymphaea stellata*)

Variations in the floral and leaf characters of *Nymphaea* species

Plate.49 *Nymphaea alba* leaf

Plate.52 *Nymphaea alba* flower

Plate. 50 *Nymphaea rubra* leaf

Plate. 53 *Nymphaea rubra* flower

Plate. 51 *Nymphaea stellata* leaf

Plate. 54 *Nymphaea stellata* flower

Table 9. Days taken for the emergence of first flower bud in *Nymphaea* spp. as influenced by different media combinations

Media	Days taken for the emergence of first bud			Mean
	NI	N2	N3	
M1	48.0	28.7	35.0	37.2
M2	41.7	72.0	30.3	48.0
M3	43.7	43.7	32.3	39.9
M4	42.0	36.3	30.0	36.1
Mean	43.9	45.1	32.0	
SE ±	6.47			
C.D for comparing				
Nymphaea spp.	9.45			
Media	N.S			
N XM	18.89			

N.S – Non Significant, N1 – *Nymphaea rubra,* N2 – *Nymphaea alba*, N3 – *Nymphaea stellata,* M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2).

duration (32.0 days) and was significantly superior to all other species. *Nymphaea alba* recorded the maximum duration (45.1 days) and this was on par with *Nymphaea rubra* (43.9 days). Influence of growing media on the days taken for first bud emergence was not significant.

Differential effect between *Nymphaea* spp. and growing media combinations was evident. *Nymphaea alba* in M1 recorded the minimum duration for the emergence of first flower bud (28.7 days), this was followed by *Nymphaea stellata* in M4 and M2 (30.0 and 30.3 days, respectively).

4.2.2.2 Days taken from bud emergence to complete flower opening

Data pertaining to monthly variation in the days taken from the bud emergence to complete flower opening in *Nymphaea* sp. as influenced by growing media is given in Table 10. Noticeable differences could be observed among species in the days taken from bud emergence to complete flower opening. The duration differed in different months also. However, the duration was maximum (13.5 days) in *Nymphaea rubra* which was on par with *Nymphaea alba* (13.1 days) in June. Minimum duration was recorded in *Nymphaea stellata* (10.0 days) in January.

The growing media also significantly influenced the days taken from bud emergence to complete flower opening during all the months except October and January. (Table 10). The duration from bud emergence to complete flower opening was minimum in M3 in all the months and it reached its minimum (7.1 days) in February. Maximum duration (13.6 days) was recorded in June in M2, which was on par with M1 (13.5 days). During March to June, M2 recorded the maximum duration from bud emergence to complete flower opening and M3 recorded the minimum.

The combined effect of species and growing media on days taken from bud emergence to complete flower opening in *Nymphaea* was significant during all the months except November, February and June. Among the treatment combinations involving *Nymphaea rubra,* the duration ranged from 7.3 days to 13.8 days and in *Nymphaea alba* and *Nymphaea stellata* it ranged from 7.7 days to 13.9 days and 9.5 to 13.0 days respectively.

Table 10. Days taken from bud emergence complete flower opening in *Nymphaea* spp. as influenced by different media combinations

Days taken from bud emergence to complete flower opening									
Treatments	Months								
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
***Nymphaea* spp.**									
N1	10.9	11.4	13.20	10.7	10.2	12.01	12.0	13.12	13.5
N2	10.2	12.0	12.37	10.8	0.0	12.58	10.3	12.79	13.1
N3	11.4	11.2	11.33	10.0	12.0	11.31	11.0	11.58	12.1
SE ±	0.9709	0.1474	0.2207	0.1442	0.8637	0.2324	0.5537	0.1867	0.1661
C.D (0.05)	**2.8***	**0.4****	**0.6****	**0.4****	**2.5****	**0.7****	**N.S**	**0.5****	**0.5****
Media									
M1	10.1	11.6	12.3	10.5	12.8	12.2	11.7	12.7	13.5
M2	10.7	12.1	13.0	10.6	12.2	13.0	12.4	13.0	13.6
M3	10.5	10.9	11.5	10.5	7.1	11.1	8.6	11.2	12.1
M4	11.0	11.5	12.0	10.3	10.5	11.6	11.6	12.3	12.6
SE ±	1.1211	0.1702	0.2548	0.1665	0.9973	0.2684	0.6394	0.2156	0.1918
C.D (0.05)	**N.S**	**0.5****	**0.7****	**N.S**	**2.9***	**0.8****	**1.9****	**0.6****	**0.6****
Spp x Media									
N1M1	11.2	11.9	15.0	7.7	9.0	13.2	12.1	13.8	12.9
N1M2	10.8	11.8	13.7	7.3	0.0	12.8	12.7	12.8	13.8
N1M3	11.0	11.7	12.7	10.7	0.0	11.5	11.7	11.7	12.7
N1M4	9.8	10.3	11.5	9.9	7.7	10.6	11.7	11.2	12.7
N2M1	11.3	11.6	12.1	10.0	0.0	12.0	12.0	12.1	12.5
N2M2	0.0	12.5	13.0	10.5	0.0	13.3	12.5	13.9	13.7
N2M3	7.7	11.8	12.0	11.3	0.0	12.3	13.7	12.2	12.3
N2M4	11.4	11.8	12.2	11.2	0.0	12.7	13.0	13.0	13.7
N3M1	11.8	11.4	11.3	10.1	11.3	11.4	11.1	11.7	12.5
N3M2	12.4	12.0	12.3	10.5	12.6	12.8	11.9	12.2	13.0
N3M3	9.7	10.9	9.6	9.5	10.5	9.6	10.5	9.8	11.4
N3M4	11.8	10.6	12.1	9.8	13.5	11.4	10.2	12.6	11.5
SE ±	1.9417	0.2948	0.4413	0.2883	1.7273	0.4649	1.1075	0.3734	0.3323
C.D (0.05)	**3.7***	**N.S**	**1.3****	**0.8****	**N.S**	**1.4****	**3.2****	**1.1****	**N.S**

* Significant at 0.05 level, ** Significant at 0.01 level, N.S – Non Significant, N1 – *Nymphaea rubra*, N2 – *Nymphaea alba*, N3 – *Nymphaea stellata*, M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2).

Fig. 3. Longevity of flower on the plant in different *Nymphaea* species

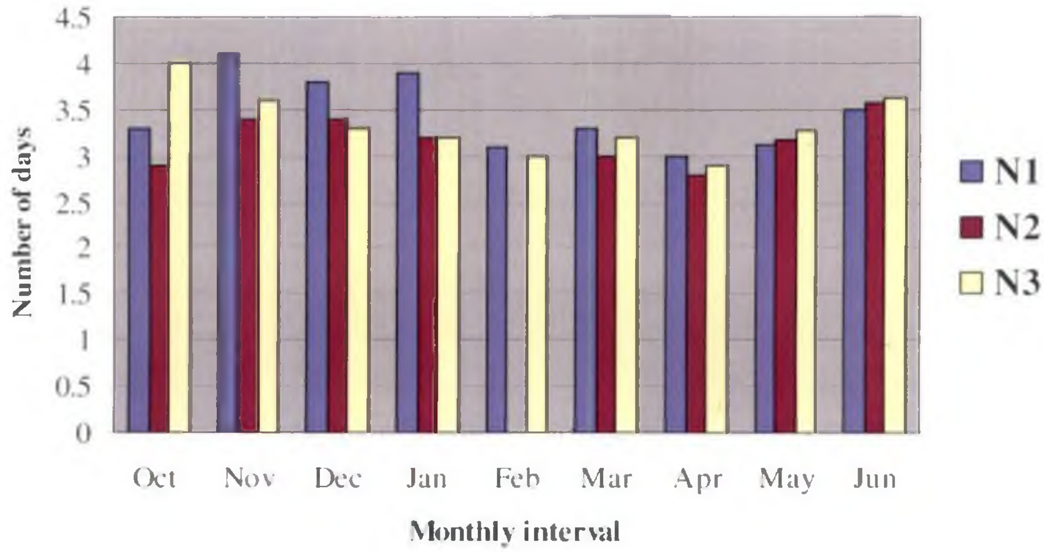
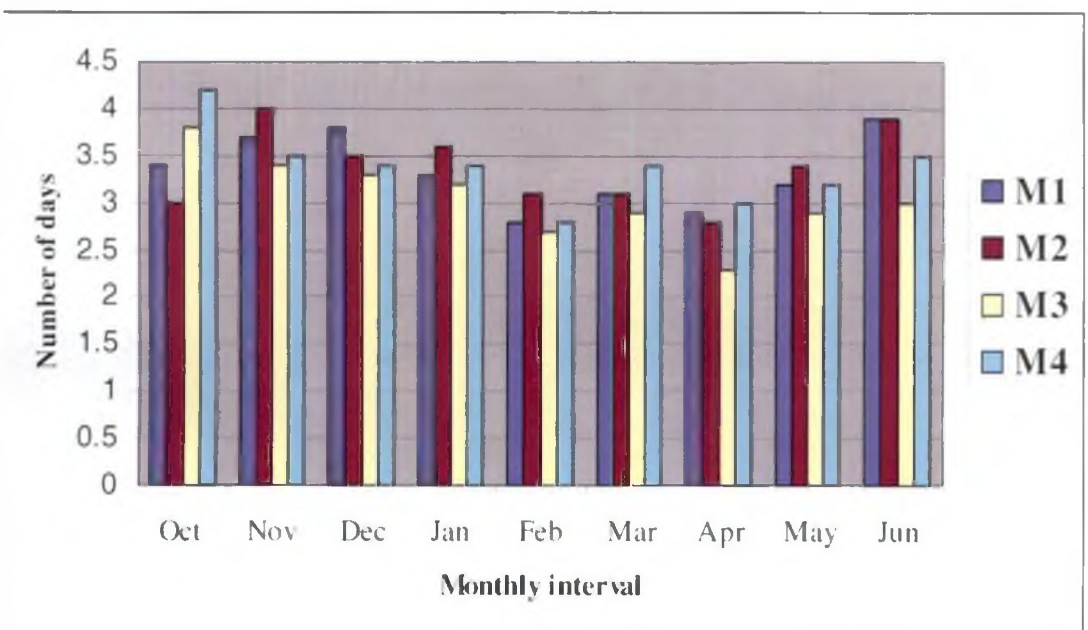


Fig. 4. Longevity of flower on the plant in different media combinations



4.2.2.3 Longevity of flower on the plant

Data pertaining to the longevity of the flower (days taken from flower opening till the flower retains its freshness) on the plant in *Nymphaea sp.* as influenced by the growing media is given in Table 11. The effect of species on longevity of flower was significant during the entire observation period, except December and May. Maximum flower longevity (4.1 days) was recorded in *Nymphaea rubra* in November and the minimum in *Nymphaea alba* (2.8 days) in April (Fig. 3).

The media combinations also recorded significant differences with regard to the longevity of flower in all the months except December and January. The flower longevity was maximum in October in M4 (4.2 days) which was on par with all treatments except M2 (Fig. 4). The longevity of flower on the plant ranged from 2.3 days (M3 in April) and 4.2 days (M4 in October).

The combined effect of *Nymphaea* spp. and media combinations had a significant effect on flower longevity during October – November and March – June. *Nymphaea rubra* recorded the maximum flower longevity (4.5 days) in M4 in October which was on par with all treatment combinations except N1M1, N1M2 and N2M2. During March to June also, the flower longevity was maximum in *Nymphaea rubra* in M4 and was significantly superior to all other treatment combinations. *Nymphaea stellata* recorded the minimum flower longevity (2.3 days) in M3 in April.

4.2.2.4 Bud length

The effect of *Nymphaea* spp., growing media and their interactions on bud length is presented in the Table 12. The *Nymphaea* spp. differed significantly with regard to the bud length. *Nymphaea rubra* recorded the maximum bud length during the period of observation and was significantly superior to the other species. It recorded maximum bud length (6.89 cm) in January and *Nymphaea stellata* recorded the minimum (5.71 cm). The bud length reduced during March to May and the minimum bud length (4.19 cm) was recorded in *Nymphaea stellata* in April.

Influence of growing media on bud length was evident during the entire observation period (October – June). It varied in different months. M4 recorded the maximum bud length during October-November and M2 in December, January, May and June whereas M1 in March-April.

Table 11. Longevity of flower on the plant in *Nymphaea* spp. as influenced by different media combinations

Treatments	Longevity of flower on the plant (Days)								
	Months								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
***Nymphaea* spp.**									
N1	3.3	4.1	3.8	3.9	3.1	3.3	3.0	3.12	3.50
N2	2.9	3.4	3.4	3.2	0.0	3.0	2.8	3.16	3.58
N3	4.0	3.6	3.3	3.2	3.0	3.2	2.9	3.27	3.62
SE ±	0.2721	0.0914	0.1202	0.0072	0.2164	0.0326	0.0340	0.0573	0.0340
C.D (0.05)	**0.8***	**0.3****	**N.S**	**0.02****	**0.6****	**0.1****	**0.1***	**N.S**	**0.1***
Media									
M1	3.4	3.7	3.8	3.3	2.8	3.1	2.9	3.2	3.9
M2	3.0	4.0	3.5	3.6	3.1	3.1	2.8	3.4	3.9
M3	3.8	3.4	3.3	3.2	2.7	2.9	2.3	2.9	3.0
M4	4.2	3.5	3.4	3.4	2.8	3.4	3.0	3.2	3.5
SE ±	0.3142	0.1056	0.1388	0.0892	0.2499	0.0377	0.0393	0.0662	0.0393
C.D (0.05)	**0.9****	**0.3****	**N.S**	**N.S**	**0.7***	**0.1****	**0.1****	**0.2****	**0.1****
Spp x Media									
N1M1	2.5	4.0	4.0	3.8	3.0	3.0	3.0	3.2	4.0
N1M2	2.7	4.2	3.7	3.9	0.0	3.0	3.0	3.3	4.0
N1M3	3.7	3.5	3.5	3.7	0.0	3.0	3.0	3.0	3.0
N1M4	4.5	4.4	3.8	4.0	0.0	4.0	4.0	4.0	4.2
N2M1	3.4	3.2	3.3	3.0	0.0	3.0	2.8	3.0	3.7
N2M2	0.0	4.0	3.3	3.5	0.0	3.0	3.0	3.3	3.7
N2M3	4.0	3.3	3.3	3.1	2.1	2.8	2.7	3.0	3.0
N2M4	3.9	3.0	3.5	3.2	0.0	3.0	3.0	3.3	4.0
N3M1	4.4	4.0	4.0	3.2	3.1	3.3	3.0	3.5	4.0
N3M2	4.2	3.9	3.6	3.4	3.2	3.2	3.0	3.6	4.0
N3M3	3.8	3.3	3.0	3.0	2.7	3.0	2.3	2.7	3.0
N3M4	3.6	3.1	3.0	3.2	3.1	3.2	3.0	3.4	3.5
SE ±	0.5441	0.1829	0.2404	0.1544	0.4329	0.0653	0.0680	0.1147	0.0680
C.D (0.05)	**1.6****	**0.5****	**N.S**	**N.S**	**N.S**	**0.2****	**0.2****	**0.3***	**0.2****

* Significant at 0.05 level, ** Significant at 0.01 level, N.S – Non Significant, N1 – *Nymphaea rubra,* N2 – *Nymphaea alba*, N3 – *Nymphaea stellata,* M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2).

The interaction between *Nymphaea* spp. and media on bud length was significant in all the months except February and June. *Nymphaea rubra* in M2 recorded maximum bud length during Dec-Jan and in M1 during November and March- May (Table 12). *Nymphaea rubra* in M2 recorded maximum bud length (7.66 cm) and was significantly superior when compared to other treatments but was on par with M1 (7.5 cm). The minimum bud length (3.08 cm) was recorded by *Nymphaea alba* in M3 in October.

4.2.2.5 Pedicel length

The data pertaining to the effect of *Nymphaea* spp., growing media and their interactions on the pedicel length is given in Table 13. *Nymphaea* spp. showed marked difference in pedicel length during October – November, February and April – June and it varied among species. *Nymphaea stellata* recorded the maximum pedicel length during Oct-Nov and Feb-March whereas *Nymphaea rubra* recorded the maximum pedicel length during April-June. *Nymphaea stellata* recorded the maximum pedicel length (22.49 cm) in November and was significantly superior to the other species. During the period of observation the minimum pedicel length was recorded in *Nymphaea alba* (13.48 cm) during October which was on par with *Nymphaea rubra* (15.22 cm).

The influence of growing media on pedicel length of flowers was clearly evident only in October, December, April and May. The effect of growing media on pedicel length varied in different months. Plants grown in M2 was significantly superior with regard to the pedicel length but was on par with M1 and M4 in December and June and with M1 in May.

The differential effect between *Nymphaea* spp. and growing media with respect to pedicel length showed significant differences in Oct-Dec and May. *Nymphaea rubra* in M2 recorded maximum pedicel length (24.75 cm) in December and was significantly superior to other treatment combinations except *Nymphaea rubra* in M1 (24.08 cm), *Nymphaea alba* in M2 and M4 (23.66 and 23.33 cm, respectively) and *Nymphaea stellata* in M4 (23.33 cm). Minimum pedicel length (12.33 cm) was recorded by *Nymphaea rubra* in M3 in October.

Table 12. Bud length in *Nymphaea* spp. as influenced by different media combinations

Treatments	Bud length (cm)								
	Months								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Nymphaea spp.									
N1	4.29	5.65	6.47	6.89	1.91	5.80	5.21	5.69	6.08
N2	3.47	5.52	5.97	6.10	0.0	5.14	4.72	5.02	5.20
N3	4.98	5.20	5.16	5.71	4.93	4.58	4.19	4.60	4.92
SE ±	0.4556	0.0741	0.0695	0.0858	0.3957	0.0799	0.0685	0.0515	0.2599
C.D (0.05)	N.S	**0.22****	**0.20****	**0.25****	**1.16****	**0.23****	**0.20****	**0.15****	**0.76***
Media									
M1	4.33	5.62	5.86	6.36	2.92	5.48	5.00	5.39	5.71
M2	2.94	5.28	6.13	6.52	1.63	5.37	4.89	5.41	5.79
M3	4.50	5.23	5.38	5.62	1.55	4.68	4.35	4.68	4.59
M4	5.22	5.69	6.12	6.43	3.03	5.17	4.58	4.94	5.513
SE ±	0.5261	0.0855	0.0802	0.0990	0.4570	0.0900	0.0791	0.0595	0.3001
C.D (0.05)	**1.54***	**0.25****	**0.23****	**0.29****	**1.33***	**0.26****	**0.23****	**0.17****	**0.88***
Spp x Media									
N1M1	3.50	5.94	7.00	7.50	4.00	6.53	6.33	6.62	6.75
N1M2	4.08	5.66	7.16	7.66	0.0	6.00	5.44	6.06	6.32
N1M3	4.83	5.00	5.25	5.58	0.0	5.00	4.41	5.00	5.50
N1M4	5.16	6.00	6.50	6.83	3.66	5.66	4.66	5.10	5.75
N2M1	4.91	5.66	5.60	5.91	0.0	5.33	4.60	5.16	5.66
N2M2	0.0	5.33	6.05	6.33	0.0	5.50	5.04	5.52	6.00
N2M3	3.08	5.50	5.75	6.00	0.0	4.58	4.50	4.50	3.50
N2M4	5.50	5.58	6.25	6.41	0.0	5.16	4.75	4.91	5.66
N3M1	5.01	532	4.98	5.67	4.76	4.58	4.08	4.39	4.73
N3M2	4.75	4.85	5.14	5.58	4.89	4.61	4.21	4.66	5.07
N3M3	5.16	5.19	4.90	5.54	4.66	4.46	4.13	4.55	4.77
N3M4	5.00	5.50	5.64	6.06	5.43	4.69	4.34	4.81	5.13
SE ±	0.9113	0.1481	0.1390	0.1715	0.7915	0.1559	0.1370	0.1030	0.5198
C.D (0.05)	**2.66***	**0.43***	**0.41****	**0.50****	N.S	**0.46****	**0.40****	**0.300****	N.S

* Significant at 0.05 level, ** Significant at 0.01 level, N.S – Non Significant, N1 – *Nymphaea rubra,* N2 – *Nymphaea alba*, N3 – *Nymphaea stellata,* M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2).

Table 13. Pedicel length in *Nymphaea* spp. as influenced by different media combinations

Pedicel length (cm)									
Treatments	Months								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Nymphaea spp.									
N1	15.22	21.38	22.20	21.41	16.25	20.55	20.33	21.49	21.49
N2	13.48	20.33	21.58	21.10	0.0	19.48	18.59	17.58	21.38
N3	21.16	22.49	21.09	20.64	20.99	20.99	19.41	19.91	20.52
SE ±	1.7263	0.5592	0.3952	0.6159	1.3008	0.4397	0.4130	0.9648	0.2604
C.D (0.05)	5.03*	1.63*	N.S	N.S	3.80**	N.S	1.21*	2.82*	0.76*
Media									
M1	18.39	22.81	22.43	21.16	11.12	20.81	19.22	20.72	21.33
M2	17.78	20.41	22.59	20.89	6.96	20.04	20.65	21.81	21.74
M3	11.59	20.60	19.97	20.59	6.88	20.55	18.43	15.73	20.61
M4	19.21	21.78	21.51	21.56	11.35	20.40	19.47	20.38	20.86
SE ±	1.9934	0.6457	0.4563	0.7112	1.5020	0.5078	0.4769	1.1140	0.3007
C.D (0.05)	5.82*	N.S	1.33**	N.S	N.S	N.S	1.39*	3.25**	N.S
Spp x Media									
N1M1	13.08	24.33	24.08	23.16	12.66	22.10	20.67	22.09	21.16
N1M2	18.66	22.16	24.75	21.16	0.0	20.44	22.66	22.22	22.16
N1M3	12.33	19.16	19.33	21.00	0.0	20.66	19.16	21.00	21.33
N1M4	16.83	19.86	20.66	20.33	12.33	19.00	18.83	20.66	21.33
N2M1	21.66	21.50	21.66	19.43	0.0	19.72	17.86	20.33	22.05
N2M2	0.00	17.33	23.66	20.83	0.0	18.83	19.69	21.66	21.83
N2M3	14.16	20.33	19.66	20.83	0.0	19.33	17.33	16.00	20.66
N2M4	19.53	22.16	23.33	23.33	0.0	21.50	19.50	20.33	21.00
N3M1	20.44	22.61	21.54	20.90	20.69	20.61	19.13	19.75	20.78
N3M2	22.44	21.75	21.36	20.69	20.89	20.85	19.61	19.56	21.23
N3M3	20.52	22.30	20.93	19.94	20.64	21.79	18.80	20.20	19.83
N3M4	20.54	21.25	23.33	21.02	21.73	20.70	20.09	20.15	20.26
SE ±	3.4526	1.1183	0.7904	1.2318	2.6015	0.8795	0.8260	1.9296	0.5208
C.D (0.05)	4.07*	3.26*	2.31**	N.S	N.S	N.S	N.S	5.63**	N.S

* Significant at 0.05 level, ** Significant at 0.01 level, N.S – Non Significant, N1 – *Nymphaea rubra,* N2 – *Nymphaea alba,* N3 – *Nymphaea stellata,* M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2).

4.2.2.6 Flower spread / size

The data pertaining to the effect of *Nymphaea* spp., growing media and their interactions on the flower spread is given in Table 14. The effect of *Nymphaea* spp. on flower spread was significant in all the months except October. *Nymphaea rubra* recorded the maximum flower spread (13.79 cm) during January and was significantly superior over the other species. This was followed by *Nymphaea rubra* (12.20 cm). *Nymphaea stellata* recorded the minimum flower spread in all the months (Table 14).

The growing media markedly influenced the flower spread during the entire observation period. M2 recorded the maximum flower spread during Dec-Feb and May-June. The maximum flower spread (13.05 cm) was recorded in M2 in January and was significantly superior to M3 (11.25) but was on par with M4 (12.87 cm) and M1 (12.73 cm). The minimum flower spread was recorded in M3 in all the months except October. M3 recorded the minimum flower spread (4.11 cm) in February.

The combined effect of species and media on the flower spread was significant during all months except February (Table 14). Maximum flower spread (15.33cm) was recorded by *Nymphaea rubra* in M2 in January and it excelled all other treatment combinations except M1 (15.00 cm) which was on par. *Nymphaea rubra* and *Nymphaea stellata* in M3 recorded minimum spread during October and March-June, respectively.

4.2.2.7 Number of flowers produced

Data pertaining to the monthly variation in flower production is given in Table 15. The number of flowers produced increased as the time progressed upto November. From December to February there was a decreasing trend, this was followed by an increasing trend during March to May. The maximum number of flowers was produced during March- April (Fig. 5). *Nymphaea* spp. differed significantly with regard to the flower production during the entire observation period (Oct-Jun). In all the months *Nymphaea stellata* recorded the maximum number of flowers. Flower production was the maximum (7.5) in *Nymphaea stellata* in April and was significantly superior over the other species.

Table 14. Flower spread in *Nymphaea* spp. as influenced by different media combinations

Flower spread (cm)									
Treatments	Months								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Nymphaea spp.									
N1	8.58	11.30	12.95	13.79	0.0	11.60	10.42	11.39	12.16
N2	6.95	11.04	11.95	12.20	0.0	10.29	9.44	10.05	11.25
N3	9.96	10.40	10.33	11.43	9.87	9.17	8.38	9.20	9.85
SE ±	0.9113	0.1481	0.1390	0.1715	0.7915	0.1559	0.1370	0.1030	0.1246
C.D (0.05)	N.S	0.43**	0.41**	0.50**	2.31**	0.46**	0.40**	0.30**	0.36**
Media									
M1	8.67	11.24	11.72	12.73	5.84	10.97	10.00	10.79	11.43
M2	5.88	10.56	12.24	13.05	6.26	10.74	9.79	10.83	11.59
M3	9.00	10.46	10.76	11.25	4.11	9.36	8.70	9.36	10.29
M4	10.44	11.38	12.26	12.87	6.06	10.35	9.17	9.88	11.03
SE ±	1.0523	0.1710	0.1605	0.1981	0.9139	0.1800	0.1582	0.1189	0.1438
C.D (0.05)	3.07*	0.50**	0.47**	0.58**	1.67*	0.53**	0.46**	0.35**	0.42**
Spp x Media									
N1M1	9.66	11.88	14.00	15.00	8.00	13.07	12.66	13.25	13.50
N1M2	8.16	11.33	14.33	15.33	0.0	12.00	10.88	12.13	12.64
N1M3	6.16	10.00	10.50	11.16	0.0	10.00	8.83	10.00	11.00
N1M4	10.33	12.00	13.00	13.66	7.33	11.33	9.33	10.20	11.50
N2M1	9.83	11.33	11.21	11.83	0.0	10.66	9.20	10.33	11.33
N2M2	0.0	10.66	12.10	12.66	0.0	11.00	10.08	11.05	12.00
N2M3	7.00	11.00	11.50	12.00	0.0	9.16	9.00	9.00	10.33
N2M4	11.00	11.16	12.50	12.83	0.0	10.33	9.50	9.83	11.33
N3M1	10.02	10.52	9.96	11.35	9.52	9.16	8.26	8.78	9.46
N3M2	9.50	9.70	10.28	11.16	9.78	9.22	8.43	9.32	10.14
N3M3	10.33	10.38	9.80	11.08	9.33	8.92	8.16	9.10	9.54
N3M4	10.00	11.00	11.29	12.13	10.87	9.38	8.68	9.62	10.26
SE ±	1.8226	0.2962	0.2780	0.3430	1.5829	0.3118	0.2740	0.2060	0.2491
C.D (0.05)	1.32*	0.87*	0.81**	1.00**	N.S	0.91**	0.80**	0.60**	0.73**

* Significant at 0.05 level, ** Significant at 0.01 level, N.S – Non Significant, N1 – *Nymphaea rubra*, N2 – *Nymphaea alba*, N3 – *Nymphaea stellata*, M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2).

Table 15. Number of flowers produced in *Nymphaea* spp. as influenced by different media combinations

Treatments	Number of flowers produced									
	Months									
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Nymphaea spp										
N1	0.0	1.0	1.9	1.4	2.0	0.4	1.9	2.7	1.7	1.7
N2	0.0	1.4	1.8	1.5	1.9	0.0	1.6	2.2	1.5	1.2
N3	0.5	3.0	4.4	5.0	6.1	6.0	6.3	7.5	6.2	6.5
SE ±	0.083	0.192	0.212	0.230	0.136	0.166	0.198	0.186	0.159	0.245
C.D (0.05)	**0.2****	**0.6****	**0.6****	**0.7****	**0.4****	**0.5****	**0.6****	**0.5****	**0.5****	**0.7****
Media										
M1	0.1	2.1	2.8	2.8	3.3	2.1	3.5	4.7	4.2	4.0
M2	0.0	1.8	2.6	2.5	4.0	2.6	3.4	4.8	3.5	3.2
M3	0.2	1.4	2.3	2.4	3.0	2.0	3.0	3.1	2.1	2.3
M4	0.2	2.4	3.0	2.7	3.1	1.7	3.2	4.0	2.7	3.1
SE ±	0.096	0.222	0.248	0.266	0.157	0.192	0.229	0.215	0.184	0.283
C.D (0.05)	**N.S**	**0.7****	**N.S**	**N.S**	**0.5****	**0.6***	**N.S**	**0.6****	**0.5****	**0.8****
Spp x Media										
N1M1	0.0	0.6	2.3	2.0	1.6	0.6	2.6	3.6	3.0	2.6
N1M2	0.0	1.0	1.6	1.3	2.6	0.0	2.0	3.0	2.0	1.3
N1M3	0.0	1.0	1.3	1.0	2.0	0.0	1.3	2.0	1.0	1.6
N1M4	0.0	1.6	2.3	1.3	1.6	1.0	1.6	2.3	1.0	1.3
N2M1	0.0	2.3	2.3	2.0	2.3	0.0	2.0	2.6	2.0	2.3
N2M2	0.0	2.3	1.0	1.0	2.3	0.0	2.0	3.6	2.0	1.0
N2M3	0.0	1.0	2.0	1.6	1.3	0.0	1.3	1.0	0.6	0.6
N2M4	0.0	2.3	2.0	1.6	1.6	0.0	1.3	1.6	1.3	1.0
N3M1	0.3	3.3	4.0	4.6	6.0	5.6	6.0	8.0	7.6	7.0
N3M2	0.0	3.0	5.3	5.3	5.0	6.3	6.3	9.0	6.6	7.3
N3M3	0.6	2.3	3.6	4.6	5.6	6.0	6.3	6.3	4.6	4.6
N3M4	0.6	3.3	4.6	5.3	6.0	4.3	6.6	8.0	6.0	7.0
SE ±	0.116	0.384	0.430	0.461	0.272	0.333	0.396	0.372	0.319	0.490
C.D (0.05)	N.S	N.S	N.S	N.S	N.S	1.0**	N.S	5.4*	N.S	N.S

* Significant at 0.05 level, ** Significant at 0.01 level, N.S – Non Significant, N1 – *Nymphaea rubra,* N2 – *Nymphaea alba,* N3 – *Nymphaea stellata,* M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2).

Fig. 5. Monthly flower production in *Nymphaea* species

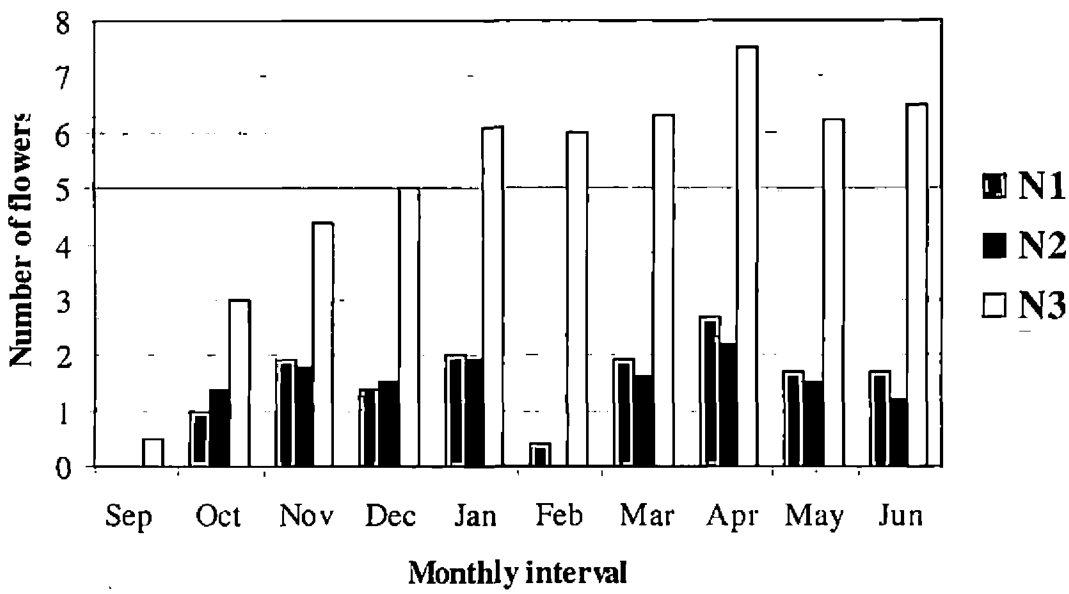
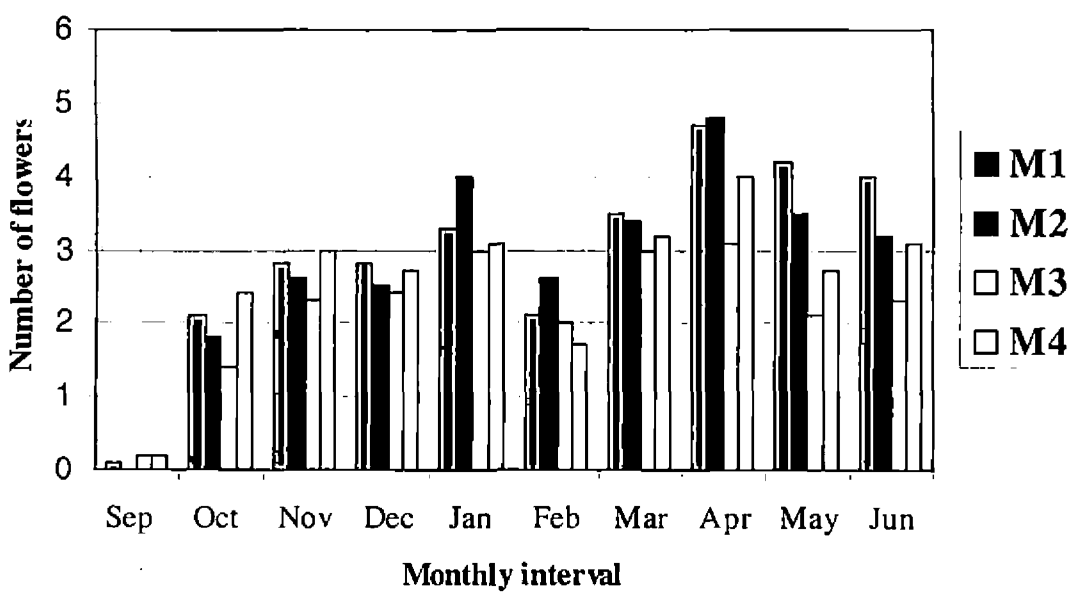


Fig. 6. Effect of media on monthly flower production



The growing media also significantly influenced the flower production in different months. Flower production was maximum (4.8) in M2 in April (Fig. 6) and was significantly superior to other media except in M1 (4.7) which was on par. M3 produced the minimum number of flowers (1.4) in October and this was on par with M2 (1.8).

The combined effect of *Nymphaea* spp. and media combinations with respect to the number of flowers produced was significant only during February and April (Table 15). *Nymphaea stellata* in M2 recorded the maximum number of flowers (9.0) in April and was significantly superior to all other combinations except M1 (8.0), M3 (6.3) and M4 (8.0), which was on par. During February, in *Nymphaea alba* there was no flowers and in *Nymphaea rubra* the flowers were produced in M1 and M4. However, regular flowering was seen in *Nymphaea stellata*.

4.2.2.8 Flower production interval

Nymphaea spp. recorded significant differences in the flower production interval (Table 16 and Fig. 7). Among the *Nymphaea* spp., *Nymphaea stellata* was significantly superior and recorded the minimum (4.9 days). *Nymphaea alba* recorded the maximum (17.9 days), this was followed by *Nymphaea rubra* (16.9 days).

The growing media also showed significant differences in flower production interval. Minimum flower production interval (10.5 days) was recorded in M1 and was significantly different from others. M3 recorded the maximum (17.4 days) which was followed by M4 (13.4 days) and M2 (11.6 days).

The combined effect of species and media on flower production interval was noticeable. The maximum interval for flower production was recorded in *Nymphaea alba* and *Nymphaea rubra in* M3 (23.8 and 23.1 days, respectively) and were significantly more when compared to other treatment combinations. *Nymphaea stellata* recorded the minimum flower production interval in M2 (4.4 days) which was on par with M1 (4.7 days), M3 (5.4 days) and M4 (4.9 days).

Table 16. Flower production interval and Annual flower production in *Nymphaea* spp. as influenced by different media combinations

Media	Flower production interval (days)			Mean	Annual flower production (days)			Mean
	NI	N2	N3		N1	N2	N3	
M1	12.0	14.7	4.9	10.5	18.7	17.3	52.3	29.4
M2	15.8	14.6	4.4	11.6	15.0	13.0	58.7	28.9
M3	23.1	23.8	5.4	17.4	10.7	9.7	48.7	23.0
M4	16.7	18.7	4.9	13.4	14.7	13.3	52.7	26.9
Mean	16.9	17.9	4.9		14.8	13.3	53.1	
SE ±	0.57				0.69			
C.D for comparing								
Nymphaea spp.				0.83	1.01			
Media				0.97	1.17			
N XM				1.68	2.02			

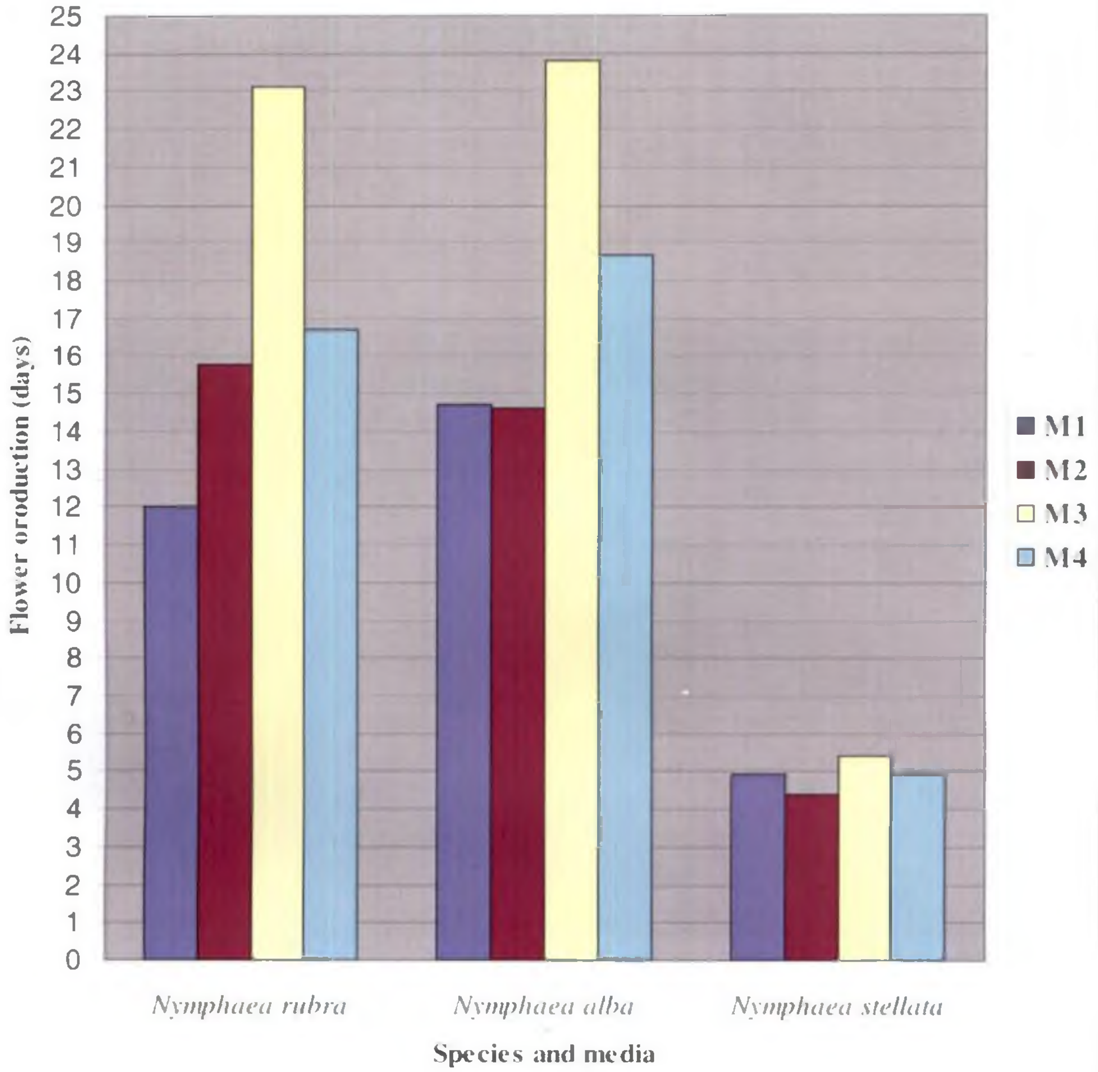
N1 – *Nymphaea rubra,* N2 – *Nymphaea alba,* N3 – *Nymphaea stellata,* M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2).

Table 17. Total number of propagules produced in *Nymphaea* spp. as influenced by different media combinations

Media	Total number of propagules produced			Mean
	NI	N2	N3	
M1	7.7	8.0	5.0	6.9
M2	5.3	4.7	2.7	4.2
M3	9.7	11.3	8.7	9.9
M4	7.7	9.3	6.0	7.7
Mean	7.6	8.3	5.6	
SE ±	0.66			
C.D for comparing				
Nymphaea spp.		1.0		
Media		1.12		
N XM		N.S		

N.S – Non Significant, N1 – *Nymphaea rubra,* N2 – *Nymphaea alba,* N3 – *Nymphaea stellata,* M1 - Sand + clay (1:2), M2 - Sand + soil +clay (1:1:1), M3 - Coir pith +soil + clay (1:1:1), M4 - Coir pith +clay (1:2).

Fig. 7. Flower production interval in *Nymphaea* species in different growing media



4.2.2.9 Annual flower production

Appreciable differences could be noticed among species in the annual flower production (Table 16). *Nymphaea stellata* recorded the maximum number of flowers (53.1) and was significantly superior when compared to other species. This was followed by *Nymphaea rubra* (14.8) and *Nymphaea alba* (13.3) and were on par. Plants raised in M1 and M2 produced significantly more number of flowers (29.4 and 28.9, respectively) and were statistically similar whereas in M3 they recorded the minimum (23.0).

Differential effect between *Nymphaea* spp. and media combinations was evident (Table 16). *Nymphaea stellata* in M2 markedly influenced the flower production and produced the maximum number of flowers (58.7). This was followed by *Nymphaea stellata* in M4 (52.7) and M1 (52.3).

4.2.3 Total number of propagules produced

Data pertaining to the total number of propagules produced in *Nymphaea sp.* as influenced by the media is given in Table 17. *Nymphaea* spp. showed significant difference in the total number of propagules produced. Maximum number of propagules was produced in *Nymphaea alba* (8.3) which was on par with *Nymphaea rubra* (7.6) and the minimum was produced in *Nymphaea stellata* (5.6).

The effect of media on total number of propagules produced was evident. M3 produced the maximum number of propagules (9.9) and was significantly superior when compared to other media combinations. M2 recorded the minimum production of propagules (4.2). The interaction of *Nymphaea* spp. and media was not significant (Table 17).

Discussion

5. Discussion

The results generated from the study of the "Evaluation of Aquatic Plants for Water Gardening" carried out at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period from 2006-2008 are briefly discussed here under.

The performance of any plant depends on the growing environment and its genetic character. Most of the aquatic plants are suitable for growing under humid tropical conditions. However the differences in the plant type, nature of growth and floral characters make each and every species different from one another. Thus it becomes a primary requisite to evaluate the different aquatic plants based on their growth and other characters which directly contribute to their use as ornamental plants for water gardening.

. 5.1. COLLECTION AND EVALUATION OF WATER PLANTS

In the present study plants belonging to different genera and species having varying growth pattern were evaluated. This included the aquatic plants which are commonly available in Thrissur, Kozhikode and Palakkad districts. A total of 44 species of aquatic plants were evaluated. The plants collected for the study were morphologically described with respect to their vegetative and floral characters.

5.1.1. Plant characters

Under open field conditions plant characters like height, spread, nature of growth and nature of stem were recorded and used to compare the species.

Height is an important genetic character of the plant, which can be influenced by the growing conditions. Since the plant belonged to different genera and species, the basic morphological difference among the species was the height. Plant height varied from one species to another. The plant height ranged between a minimum in *Hygroryza aristata* and a maximum in *Thalia geniculata.* Cook *et al.* (1974) reported that *Thalia geniculata* can grow upto a height of 1.5 to 2.0 mt. *Eleocharis* is a perennial growing upto 1 m tall (Whistler, 1980).

The plant spread was measured in N-S and E-W direction and the spread was maximum in creepers. Maximum surface spread in North-South direction was seen in *Commelina benghalensis* and the minimum was seen in tall growing plants like *Acorus* and *Schoenoplectus*. *Acorus calamus* is a perennial plant which has a spread of 2.5 to 12.5 cm (Periera, 1985). The spread in the East-West direction was maximum in *Nelumbo nucifera* and the minimum in *Hypolytrum nudicaule*. Banerjii (2006) in *Nelumbo nucifera* supported this finding.

The growth habits ranged from tall erect to creeping. *Acorus calamus, Angelonia saliacriaefolia, Crinum viviparum, Eleocharis dulcis, Eleocharis rectroflexa, Thalia geniculata, Limnocharis flava* and *Schoenoplectus articulatus* showed tall erect growth as reported by Randhawa and Mukhopadhyay (2001). *Limnocharis flava* is a perennial erect herb growing upto 60 cm tall (Karthigeyan, *et al.*, 2004).

Commelina benghalensis, Bacopa monnieri and *Panicum repens* showed creeping growth. *Bacopa monnieri* is a creeping aquatic herb used as an aquarium plant (Huxley and Griffiths, 1999). Sayer and Lavieren (1975) reported that *Panicum repens* could be grown as perennial creeping grass.

Plants like *Azolla pinnata, Lemna minor, Pistia stratiotes* and *Salvinia molesta* were found to be free floating. *Pistia stratiotes* is a free floating fresh water macrophyte and a perennial herb widely distributed in tropical and subtropical regions (Sajna *et al.*, 2007). *Aponogeton Monostachyon, Trapa natans, Utricularia australis* and *Nymphoides* spp. exhibited both floating and submerged growth. *Potamogeton praelongus, Najas minor, Limnophila heterophylla, Hygrophila difformis, Elodea canadensis, Cabomba caroliniana* and *Ceratophyllum demersum* showed a submerged growth habit. Smith and Kozlowski (1996) reported that *Najas, Cabomba* and *Ceratophyllum* are submerged annual plant that has many branched stems.

The stem characters also varied from creeping herbaceous, spongy, cladode, terete and hollow. Herbaceous stems were common in most of the plants. Spongy stems were recorded in *Eichorrnia, Ludwigia* and *Monocharia*. Such results were also reported by Biswas and Calder (1984). Cladode was recorded only in *Lemna minor*, whereas terete and hollow stems were seen in *Ceratopteris thalictroides, Eleocharis dulcis, Eleocharis rectroflexa* and *Schoenoplectus articulatus*. This was in accordance of the findings of Cook *et al.* (1974) who reported that *Schoenoplectus articulatus* has triquetrous and terete stem.

5.1.2. Leaf characters

Variations were observed in the leaf characters with respect to nature of leaf, leaf arrangement, lobing of leaves, foliage colour, leaf length and width. *Eleocharis dulcis, Eleocharis rectroflexa* and *Schoenoplectus articulatus* did not produce leaves during the entire growing period. Cook *et al.* (1974) reported that leaves are rarely produced in *Eleocharis* and *Schoenoplectus.*

Some plants like *Utricularia australis, Najas minor, Ceratophyllum demersum* and *Cabomba caroliniana* produce highly dissected leaves. Such differences were also recorded by Smith and Kozlowski (1996). *Azolla pinnata* and *Lemna minor* produced very minute floating leaves, whereas *Nelumbo* and *Nymphoides* produced large size leaves floating or above the water level. Riemer (1984) also identified *Azolla pinnata* as a fern with tiny leaves of 0.5 mm long. *Azolla pinnata* and *Certopteris thalictroides* were the only plants producing lobed leaves.

Hygrophila difformis, Limnophila heterophylla, Marsilea quadrifolia and *Nelumbo nucifera* produced different types of leaves above and below the water level. This is due to the change in water level and the activity of growth regulators. Gee and Anderson (1998) reported that *Potamogeton nodosus* produces morphologically distinct leaves above and beneath the surface of water. *Limnophila heterophylla* bears pinnately dissected leaves arranged in whorls, under water and entire, ovate and opposite decussately arranged leaves on aerial shoots (Ram and Rao, 1982). In natural habitats *Marsilea quadrifolia* produces different types of leaves above and below the water level. The application of either blue light or an optimal concentration of ABA induced the development of aerial type of leaves (Lin and Yang, 1999).

The leaf length and width varied among the different plant species. The length was maximum in *Desmostachia bipinnata* followed by *Acorus calamus ,Crinum viviparum, Ceratopteris thalictroides, Nelumbo nucifera* and *Panicum repens.* It was minimum for *Lemna minor* followed by *Limnophila heterophylla, Salvinia molesta, Rotala macrandra* and *Trapa natans.* The width was maximum in *Nelumbo nucifera* followed by *Limnocharis flava* and *Echinodorous argentinensis.* It was minimum in

Lemna minor followed by *Elodea canadensis, Panicum repens* and *Bacopa monnieri.* Such wide differences in length and width of different aquatic plant species was also observed by Cook *et al.* (1974) in his works on the identification of all genera of aquatic macrophytes.

5.1.3. Floral characters

Wide variations were observed in the floral characters of collected aquatic plants. The flowers were borne solitary or in inflorescence. Flower colour varied from one species to another. The most common flower colours recorded were white, yellow, lavender, blue, brown and green. Most attractive flowers were produced in *Angelonia salicariaefolia, Bacopa monnieri, Eichorrnia crassipes, Nymphoides peltata, Nymphoides indica, Nelumbo nucifera, Ipomoea aquatica, Monochoria vaginalis, Aponogeton Monostachyon* and *Thalia geniculata. Nelumbo nucifera* produces a spectacular bloom, soft pink in colour upto 20 cm across opening on top of a stiff stalk emerging directly from below the water (Banerjii, 2006). Waples (2007) reported that Water hyacinth is a popular aquarium and pond plant which produces beautiful flowers when in full bloom. In *Ipomoea aquatica* the flowers are showy, funnel form like morning glory blooms (Ghosh, 2004).

In *Limnocharis flava* and *Echinodorous argentinensis* the new vegetative bud developed from the old flower bud. Wilder (1974) reported that in *Limnocharis flava* the ultimate bud of the inflorescence develops into a vegetative bud which forms a new vegetative shoot after the fruits have fallen and ultimately forms a new erect plant.

5.1.4 Classification of aquatic plants

The classification of the collected plants was done based on their growth habit. They were classified into bog, marginal, deep water, submerged, oxygenators and free floating plants as done by Brickell (1989). Later Randhawa and Mukhopadhyay (2001), Worden and Sutton (2005), Lynch (2006) and Andrew (2007) also followed an almost similar classification of aquatic plants based on their habitat.

5.1.5 Plants suitable for water gardening

Based on the evaluation of qualitative and quantitative characters the following plants were found suitable for water gardening.

Angelonia salicariaefolia produced white coloured flowers which were very attractive. This plant can be planted on the border of the pond as a marginal plant. *Crinum viviparum* produced large white flowers which are intensively fragrant and can be used as a bog plant. Singh (2006) reported that *crinum viviparum* is a bog plant which can be seen in rocky shallow river beds. *Limnocharis flava* is another bog plant which produced broad heart shaped velvety leaves and yellow flowers throughout the year and could be grown as a bog plant in water gardens (Andrew, 2007).

Ipomoea aquatica produced creeping branches and white flowers. It can be used as a marginal plant in water gardens. In *Ipomoea aquatica* the flowers are showy, funnel like as in morning glory blooms (Ghosh, 2004). *Nelumbo nucifera* commands admiration and a good deal of attention because of large solitary flowers borne high above the water against the background of silvery bluish leaves on stem. *Nelumbo nucifera* is a deep water plant and can be used in water garden for its large showy blooms. This was also suggested by Caurie and Ries (2001). *Hygrorhiza aristata* can be used as marginal aquatic plant because of its glossy and smooth leaves which were very attractive.

Aponogeton monostachyon produced floating leaves and attractive purple colour spikes emerging above the water surface. *Nymphoides indica* blooms were white in colour with fringed petals which appear to be floating in water with dark green and attractive heart shaped leaves. *Nymphoides peltata* produces yellow coloured flowers with attractive floating leaves. All the three plants can be used as deep water plants in water gardens. Brickell (1989) reported that *Aponogeton* and *Nymphoides* can be used in water gardens as deep water plants.

Azolla pinnata and *Lemna minor* receives a good deal of attention because of their minute floating leaves. *Eichhornia crassipes* which produced glossy leaves and terminal violet colour spikes are very attractive when in full bloom. *Pistia stratiotes* is very attractive and suitable for water gardens because of the Cabbage head like floating leaves. In *Trapa natans* the rosette arrangement of leaves and yellow coloured flowers are very attractive. *Azolla, Lemna, Pistia, Eichhornia* and *Trapa* can be used as free floating plants in water gardens. Peterson and Lee (2005) reported that *Azolla, Lemna, Pistia* and *Eichhornia* can be grown as free floating plants in water gardens.

Utricularia australis produced yellow coloured spikes and feather like submerged leaves which were very attractive. *Najas minor, Limnophila heterophylla, Hygrophila difformis, Ceratophyllum demersum and Elodea canadensis* produced attractive feather like foliage submersed in water which can be used as aquarium plants. Such results were also reported by Cook *et al.* (1974), Worden and Sutton (2005) and Lynch (2006).

Utricularia australis, Najas minor, Limnophila heterophylla and *Hygrophila difformis* can be used as submerged plants, whereas *Ceratophyllum demersum* and *Elodea canadensis* can be used as oxygenator plants in water gardens as reported by Randhawa and Mukhopadhyay (2001).

5.2. Standardization of growing media for *Nymphaea* species

As the second part of the study the effect of *Nymphaea* spp. viz., *Nymphaea rubra, Nymphaea alba, Nymphaea stellata,* media and their interactions on the vegetative and the floral characters were evaluated.

5.2.1. Plant characters

Under open field conditions the plant characters like surface spread and petiole length were recorded at monthly intervals and were used to compare with different species and media. Leaf characters like leaf length, breadth, area, number of leaves, leaf production interval, leaf longevity and days for complete unfurling of leaves were also recorded.

Spread of a plant gives the area occupied by the plant under the growing environmental conditions. It determines the number of plants that could be accommodated in a given area. The plant spread was measured separately in North-South and East-West direction. Surface spread in North-South and East-West direction showed a similar trend. In both the cases the plant spread was maximum in *Nymphaea stellata* during February and minimum in *Nymphaea rubra*. This may be due to the individual genetic character of each species. Among the media combinations M1 recorded the maximum and M4 recorded the minimum surface spread. The combined effect of species and media showed that *Nymphaea stellata* in M1 recorded maximum and *Nymphaea rubra* in M4 recorded minimum surface spread. This may be due to the presence of coir pith (M3 and M4) which is very light and floats in water and not suitable for aquatic plants. Sacher (2006) reported that peat moss, bark and other floating materials are not suitable for growing water lilies.

The leaves in *Nymphaea* arise from the rooted tuber with long petioles. The petiole length increases as the water depth increases. Nohara and Tsuchiya (1990) also reported that petioles elongate 4-6 times longer under water than in air. Grob *et al.* (2006) also reported that the leaves of *Nymphaea* arise from rooted tuber. Among the three species *Nymphaea stellata* recorded the maximum petiole length. M3 recorded the minimum and M2 recorded maximum followed by M1, whereas *Nymphaea stellata* in M1 recorded maximum in June and *Nymphaea rubra* in M3 recorded minimum petiole length in February. Petiole length was maximum during the month of June when the mean monthly temperature ranged from 23.5 - 29.9^{0}C and minimum in the month of February when the mean monthly temperature ranged from 22.9 - 33.6^{0}C. Decomposition of the petiole is faster during high temperature and hence the petiole length is low during the hot conditions (Kunii and Aramakii, 1992).

5.2.2. Leaf characters

The leaf length and breadth of leaves varied significantly with respect to different species of *Nymphaea*. Such difference was also reported by Solcum (2005) in different cultivars of water lilies. *Nymphaea rubra* and *Nymphaea stellata* recorded maximum leaf length and breadth respectively, whereas *Nymphaea alba* recorded the minimum. The effect of media on leaf length and breadth was significant. M2 recorded maximum leaf length followed by M4, whereas M1 recorded the maximum leaf breadth which was on par with M2 and M4. Length and width width of leaves was the minimum in M3. When the interaction effect was studied, it showed that *Nymphaea rubra* in M2 recorded maximum leaf length and breadth, whereas *Nymphaea alba* recorded minimum in M3. The poor performance of M3 and M4 may be attributed to the higher content of coir pith in the media. Nash *et al.* (2003)

reported that heavy clay subsoil found beneath the top soil is not suitable for growing aquatic plants.

Leaf area among the three species varied significantly. *Nymphaea* stellata recorded the maximum and was on par with *Nymphaea rubra*, whereas *Nymphaea alba* recorded the minimum. Difference in the leaf area was also observed by Solcum (2005) in different species of genus *Nymphaea*.The effect of media on leaf area was not significant. This may be due to the fact that temperature plays an important role in leaf expansion as compared to the soil factors. Begon and Fitter (1994) reported that as temperature increases the rate of leaf expansion increases. The interaction of species and media were significant. *Nymphaea rubra* recorded maximum leaf area in M2 which was on par with all media combinations in *Nymphaea stellata*, M2 in *Nymphaea alba* and M1 in *Nymphaea rubra*. Minimum leaf area was recorded in M3 which was on par with M4 in *Nymphaea alba*. Kunii and Aramaki (1992) reported that seasonal maximum leaf area index for *Nymphaea tetragona* is 1.5 to 2.04 $m^2 m^{-2}$ and mean potential leaf area ranged from 73.6 to 146 cm^2.

The effect of *Nymphaea* spp. on the number of leaves produced was significant, whereas the effect of media and interaction of species and media was not significant. *Nymphaea stellata* recorded minimum leaf production interval with maximum number of leaves. This may be due to the fact that *Nymphaea stellata* grows well in tropical and humid conditions compared to the other species as reported by Astle (2006).

The effect of *Nymphaea* spp. on leaf longevity was not significant, whereas its effect on the days for complete leaf unfurling was significant. *Nymphaea stellata* recorded the minimum number of days for complete unfurling of leaves. The effect of media on leaf longevity and the days for complete unfurling of leaves was significant. Leaf longevity was maximum in M3 with maximum number of days for complete unfurling of leaves. The number of days for complete unfurling of leaves was minimum in M1. This may be due to a lower nutrient level in M3 when compared to the other media combinations. Chabot and Hicks (1982) reported that under poor nutrition, leaves live longer in order to improve nutrient use efficiency per unit carbon gain. The interaction of *Nymphaea* spp. and media with respect to leaf longevity was appreciable. *Nymphaea rubra* in M3 recorded the maximum leaf longevity with maximum number of days for complete unfurling of leaves. This was also on par with

M4. *Nymphaea stellata* recorded minimum leaf longevity and minimum number of days for complete unfurling of leaves in M2 and M1 respectively. The annual mean leaf life span of *Nymphaea tetragona* is 31 days (Kunii and Aramaki, 1992). In general, the leaf life span of floating leaves ranged from 13 to 35 days (Tsuchiya, 1991).

5.2.3. Floral characters

In Nymphaeaceae family the floral characters vary extensively among the genera, ranging from simple monocot to the elaborate flowers in *Nymphaea*. Schneider *et al.* (2003) reported that in *Nymphaea* each flower replaces a leaf in the ontogenetic spiral of the shoot apex with a Fibonacci angle of 137.5^0. *Nymphaea rubra, Nymphaea alba* and *Nymphaea stellata* produced pink, white and blue coloured flowers respectively.

Effect of *Nymphaea* spp. on the days taken for the emergence of first flower bud was significant. Early flowering was seen in *Nymphaea stellata* which was superior to all other species. Late flowering was seen in *Nymphaea alba*. The effect of media was not significant whereas, the interaction of species and media was significant. *Nymphaea alba* in M1 recorded the minimum duration and this was followed by *Nymphaea stellata* in M4 and M2. This may be due to the fact that *Nymphaea stelllata* flowers regularly under humid tropic conditions, whereas *Nymphaea alba* is hardy water lily which requires warm days for flower initiation. Solcum (2005) reported that warm days initiate flower opening earlier than cooler ones in hardy water lilies.

The *Nymphaea* spp. followed a circadian rhythm in flower opening. In *Nymphaea stellata* the flowers open during 8.30 am. and closes at 6.0 pm. In *Nymphaea rubra* and *Nymphaea alba* the flower opening period was from 8 pm. to 10 am. Such differences were also observed by Krishnan *et al.* (2004) in his studies on the phenology of water lily flowers. Volkova (2001) reported that the change of solar radiation activity is the main natural factor which causes the rhythmic cycle of the floral behavior of *Nymphaea*.

The growing media also significantly influenced the days taken from bud emergence to complete flower opening during all the months except October and

January. The duration from bud emergence to complete flower opening was minimum in M3 in all the months and it reached its minimum in February. Maximum duration was recorded in June in M2 which was on par with M1. The combined effect of species and growing media on days taken from bud emergence to complete flower opening in *Nymphaea* was significant during all the months except November, February and June. The duration was minimum in *Nymphaea rubra* in M2 during January. As the sunshine hours increased the days taken from bud emergence to complete flower opening decreased. Such differences were also observed by Songpanich (2007) in the flowering habits of hardy water lilies. Days for complete flower opening in *Nelumbo nucifera* ranged from 12 to 21 days (Minimol, 2004).

Longevity of flower refers to the days taken from flower opening till the flower retains its freshness on the plant. Among the species the maximum flower longevity was recorded in *Nymphaea rubra* in November and the minimum in *Nymphaea alba* in April. The media combinations also recorded significant differences with regard to the longevity of flower in all the months except December and January. In *Nymphaea* the flowers open and close for 3.0 to 4.5 days consecutively (Krishnan *et al.*, 2004). Schnieder and Buchanan (1980) reported that the flowers of *Nelumbo pentapeatla* opens and closes for 3 consecutive days. Minimol (2004) in her experiments on morphogenesis and floral biology of sacred lotus reported that the longevity of lotus flowers was 3 days.

The *Nymphaea* spp. differed significantly with regard to the bud length. *Nymphaea rubra* recorded the maximum bud length during the period of observation and was significantly superior to the other species. This is mainly due to its genetic superiority in bud length over the other two species. Such differences were also reported by Solcum (2005) in his description of different water lily cultivar. Maximum bud length was recorded in *Nymphaea rubra* in January and *Nymphaea stellata* recorded the minimum. The bud length reduced during March to May and the minimum bud length was recorded in *Nymphaea stellata* in April. Influence of growing media on bud length was evident during the entire observation period. M4 recorded the maximum bud length during October-November and M2 in December, January, May and June whereas M1 in March-April. However, M2 recorded the maximum bud length in January and M3 recorded the minimum in April. The interaction between *Nymphaea* spp. and media on bud length was significant in all the months except February and June. *Nymphaea rubra* in M2 recorded maximum bud length in January and was on par with M1. The minimum bud length was recorded by *Nymphaea alba* in M3 in October. Minimol (2004) reported that the bud length in *Nelumbo nucifera* ranged from 1.40 to 12.38 cm.

The length of the flower stalk is termed as the pedicel length. *Nymphaea* spp. showed marked difference in pedicel length during October – November, February and April – June and it varied among species. According to Krishnan *et al.* (2004) in *Nymphaea* species the pedicel length ranged from 15 to 30 cm. The influence of growing media on pedicel length of flowers was clearly evident only in October, December, April and May. The effect of growing media on pedicel length varied in different months. Plants grown in M2 was significantly superior with regard to the pedicel length but was on par with M1 and M4 in December and June and with M1 in May. Volkova (2001) reported that higher the atmospheric pressure lower will be the flower stalk length.

The interaction effect of *Nymphaea* spp. and growing media with respect to pedicel length showed significant differences in Oct-Dec and May. *Nymphaea rubra* in M2 recorded maximum pedicel length in December and was significantly superior to other treatment combinations. Minimum pedicel length was recorded by *Nymphaea rubra* in M3 in October. Grob *et al.* (2006) reported that in *Nymphaea prolifera* the pedicel length in daughter flowers was around 20 cm.

Flower size refers to the average of the flower diameter in North-South and East-West direction. Among the three species *Nymphaea rubra* recorded the maximum flower spread. Solcum (2005) reported that Flower spread in *Nymphaea rubra* ranged from 12 to 25 cm. *Nymphaea stellata* recorded the minimum number of flowers in all the months. In *Nymphaea stellata* the flower spread ranges from 5 to 13 cm (Solcum, 2005). Maximum flower spread was recorded in M2 in January and was on par with M4 and M1, whereas M3 recorded the minimum flower spread. The combined effect of species and media were significant in all the months except February. *Nymphaea rubra* recorded the maximum flower spread in M2 in January which was on par with M1. *Nymphaea stellata* in M3 recorded the minimum flower spread. Variations in flower size in *Nymphaea* spp. was also recorded by other scientists in this field (Solcum, 2005, Banerjii, 2006 and Muthukulam, 2007).

The number of flowers produced in each species varied significantly. *Nymphaea stellata* recorded the maximum number of flowers during March-April, whereas minimum number of flowers was recorded during September. In September the flower production was less due to the early growth phase of the plant. *Nymphaea rubra* and *Nymphaea alba* recorded maximum flowering in April and minimum during February. This may be due to the higher difference in Minimum and maximum temperature recorded during February. Such differences were also recorded by Songpanich (2007) in his works on the flowering habits of water lilies. Growing media also had a significant effect on the number of flowers produced. The flower production was maximum in M2 in April which was on par with M1. The minimum number of flowers was recorded in M3 during February.

The interaction of species and media on the number of flowers produced was significant only during February and April. *Nymphaea stellata* in M2 recorded the maximum number of flowers in April which was on par with M1 and M4. In *Nymphaea alba* no flowers were produced in February, whereas in *Nymphaea rubra* flowers were produced in M1 and M4 during February. However, regular flowering was seen in *Nymphaea stellata* supporting the findings of Astle (2006) as the species produces regular flowering under humid tropical conditions

Interval of flower production is indicative of the flower yield. Among the three species *Nymphaea stellata* produced flowers with minimum flower production interval and was superior over the other two species. Flower production interval was maximum in *Nympahaea alba*. M1 recorded the minimum flower production interval and was significantly superior when compared to other media combinations. M3 recorded the maximum flower production interval and was on par with M4. The interaction of species and media was also significant. *Nymphaea stellata* in M2 recorded the minimum and was on par with M1, M4 and M3. Maximum flower production interval was recorded by *Nymphaea alba* in M3.

Among the *Nymphaea* spp. the maximum annual flower production was recorded in *Nymphaea stellata* which was highly superior compared to the other two species. Minimum number of flowers was recorded in *Nymphaea alba* which was on par with *Nymphaea rubra*. Plants raised in M1 and M2 recorded maximum number of flowers, whereas M3 recorded minimum number of flowers. The combined effect of species and media on the annual flower production was significant. *Nymphaea stellata* in M2 recorded the maximum number of flowers. This was followed by *Nymphaea stellata* in M1 and M4. Songpanich (2007) reported that the annual flower production in *Nymphaea* varieties Mayla and Odorata were 43 and 54 respectively.

5.2.4 Number of propagules produced

Maximum number of propagules was produced in *Nymphaea alba* which was on par with *Nymphaea rubra*. M3 recorded the maximum number of propagules and was significantly superior over other media combinations. M2 recorded the minimum number of propagules.

Many workers have done extensive research work in lotus and water lilies due to their wide distribution all over India and their attractive colour and form, while majority of the other aquatic plants remain neglected. So, attempts must be made for further investigation on the floriculturaly curious under investigated aquatic plants belonging to different families. Research on the phylogeny and molecular characterisation of aquatic plants will help in their proper identification. Conducting research on the medicinal value of aquatic plants will serve the pharmaceutical industry to a great extent. *Acorus calamus, Bacopa monnieri, Centella asiatica* and *Monochoria vaginalis* are frequently used as medicinal plants. There will be many other plants having such values yet to be exploited. Many of the aquatic plants like *Aponogeton natans, Azollla pinnata, Nelumbo nucifera* and *Trapa natans* are edible and they can be used as a good source of food. Aquatic plants like *Azolla pinnata* and *Aeschynomene aspera* can also be used as good source of manure. *Echhornia crassipes* can be used as a water purifier. Some aquatic plants like *Aponogeton appendiculatus, Rotala malabarica* and *Rotala malampuzensis* are in a danger of extinction. So, emphasis must be given on the conservation of these plants.

Summary

6. SUMMARY

The study entitled "Evaluation of aquatic plants for water gardening" was carried out at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur during 2006 - 2008. The salient findings of the study are summarised below.

1. About 44 aquatic plants were collected and evaluated for vegetative and floral characters. Wide variations were observed in the vegetative and floral characters of the aquatic plants.

2. Based on their growth habit the aquatic plants were classified into deep water plants, shallow water plants, submerged plants, floating plants, marginal plants and bog plants.

3. Based on the evaluation of qualitative and quantative characters, the following plants were found suitable for water gardening.

   a. Deep water plants - *Nymphaea alba, Nymphoides indica, Nymphoides peltata* and *Aponogeton monostachyon*

   b. Shallow water plants - *Nelumbo nucifera*

   c. Oxygenators - *Utricularia australis, Najas minor, Limnophila heterophylla, Hygrophila difformis, Cabomba caroliniana, Ceratophyllum demersum* and *Elodea canadensis*

   d. Floating water plants - *Eichhornia crassipes, Pistia stratiotes, Trapa natans, Azolla pinnata* and *Lemna minor*

   e. Marginal water plants - *Angelonia salicariaefolia, Ipomoea aquatica* and *Hygroriza aristata*

   f. Bog plants - *Crinum viviparum* and *Limnocharis flava*

4. Among the three *Nymphaea* species studied, the maximum surface spread was observed in *Nymphaea stellata* in the M1 [sand + clay (1:2)], whereas it was the minimum in M4 [coir pith +clay (1:2)].

5. *Nymphaea rubra* recorded the maximum leaf length (13.36 cm), but leaf breadth (11.79), leaf area (146.34 cm^2), petiole length (36.39 cm) and number of leaves (18.4) were maximum in *Nymphaea stellata*. The time for complete unfurling of leaf and leaf production interval were minimum in *Nymphaea stellata*. Among the media combinations, M2 recorded the maximum leaf length (13.48 cm) and petiole length (35.27 cm), but M1 produced maximum leaf breadth (11.98 cm) and minimum time for complete leaf unfurling (10.0 days). Among the leaf characters studied, maximum leaf production was observed in *Nymphaea stellata*. The size of the leaves with respect to breadth, area and petiole length was also high in the species. M1 was found to be a better medium for leaf production. *Nymphaea rubra* in M2 recorded the maximum leaf length (14.20 cm), leaf breadth (12.54 cm) and leaf area (157.86 cm^2). *Nymphaea stellata* in M1 recorded maximum petiole length (40.04 cm). The time for complete unfurling of leaf (12.5 days) and leaf longevity (36.7 days) was maximum for *Nymphaea rubra* grown in M3.

6. Early flowering was observed in *Nymphaea stellata* (32.0 days) where the duration from bud emergence to complete flower opening was minimum (10.0 days) and late flowering was seen in *Nymphaea alba* (45.1 days) where the flower longevity was minimum (2.8 days). Flower longevity (4.1 days) and the duration from the bud emergence to complete flower opening (13.5 days) was maximum in *Nymphaea rubra*.

7. Among the treatment combinations involving *Nymphaea rubra*, the duration from bud emergence to complete flower opening ranged from 7.3 days to 13.8 days and in *Nymphaea alba* and *Nymphaea stellata*, it ranged from 7.7 days t o13.9 days and 9.5 to 13.0 days, respectively. *Nymphaea rubra* recorded the maximum flower longevity (4.5 days) in M4 and *Nymphaea stellata* in M3 recorded the minimum (2.3 days) in April.

8. *Nymphaea rubra* recorded the maximum bud length (6.89 cm) and flower spread (13.79 cm). *Nymphaea stellata*, which produced minimum bud length and flower spread, recorded the maximum (22.49 cm) pedicel length. Among the media combinations M2 recorded the maximum bud length, pedicel length and flower spread and M3 recorded the minimum. When the effect of the interactions was studied it was found that *Nymphaea rubra* in M2 recorded maximum bud length (7.66 cm), pedicel length (24.75 cm) and flower spread (13.79 cm).

9. *Nymphaea stellata* recorded maximum flower production (7.5) and minimum flower production interval (4.9 days). Among the media combinations M2 produced the maximum number of flowers (4.8). When the combined effect was studied, *Nymphaea stellata* in M2 was the best combination in which the flower production was maximum (9.0) due to the low flower production interval (4.4 days).

10. Annual flower production was maximum in *Nymphaea stellata*(53.1), which was followed by *Nymphaea rubra* (14.8) and *Nymphaea alba* (13.3). Plants raised in M1 and M2 produced significantly more number of flowers (29.4 and 28.9, respectively). M3 (23.0) recorded the minimum number of flowers. *Nymphaea stellata* in M2 produced the maximum number of flowers (58.7).

11. Maximum number of propagules was produced in *Nymphaea alba* (8.3) and the minimum was in *Nymphaea stellata* (5.6). M3 produced the maximum number of propagules (9.9) and M2 the minimum (4.2).

12. The study on *Nymphaea* spp. and the media combinations revealed that *Nymphaea stellata* which produced the maximum number of flowers is the most suitable species for growing under Vellanikkara conditions and M1 [Sand + clay (1:2)] and M2 [Sand + soil +clay (1:1:1)] are the most suitable media combinations for growing water lilies.

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Appendix

Appendix - 1

Mean monthly weather data from August 2007 to July 2008

Months	Temperature (^0C)		Relative humidity (%)		Wind speed (km/hr)	Sunshine (hrs)	Rainfall (mm)	No.of rainy days	Evaporation (mm)
	Max	Min	Max	Min					
August	29.0	22.8	92	76	3.3	3.2	549.7	19.0	83.8
September	29.4	22.9	93	78	3.0	2.5	735.9	23.0	72.5
October	30.5	22.5	91	69	3.2	4.4	383.8	14.0	80.6
November	31.7	21.7	80	54	4.5	8.0	24.8	3.0	129.5
December	31.6	22.7	74	45	8.6	6.7	8.7	1.0	163.8
January	32.3	21.7	78	40	6.9	9.4	0.0	0.0	170.0
February	33.6	22.9	80	41	4.5	8.2	29.7	3.0	153.1
March	33.2	23.4	78	49	4.9	6.9	205.3	7.0	155.6
April	33.2	25.0	89	60	3.2	6.3	65.6	3.0	116.8
May	33.0	24.7	87	58	4.1	6.1	11.5	2.0	126.5
June	29.9	23.5	93	77	3.0	2.0	632.3	24.0	90.5
July	29.3	23.2	93	75	3.1	2.7	405.3	19.0	0.0

EVALUATION OF AQUATIC PLANTS FOR WATER GARDENING

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The present investigation on the ***Evaluation of aquatic plants for water gardening*** was carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur during the period 2006 – 2008 with the objectives of evaluating the aquatic plants suitable for water gardening and standardizing the growing media for three species of water liliy, viz., *Nymphaea rubra, N. alba* and *N. stellata.*

Survey was conducted across Thrissur, Kozhikode and Palakkad districts and 42 aquatic plants were collected. Evaluation of the collected aquatic plants revealed that, wide variation existed in the vegetative and floral characters. Based on their growth habit these plants were classified into deep water aquatics, shallow water aquatics, submerged or oxygenator plants, floating plants, marginal plants and bog plants. Twenty two aquatic plants suitable for water gardening at different levels were identified.

Angelonia salicariaefolia, Crinum viviparum and *Limnocharis flava* were found suitable to be grown as bog plants. The marginal areas of the water gardens can be planted with *Ipomoea aquatica* and *Hygroriza aristata* etc. *Aponogeton monostachyon, Nymphaea alba, Nymphoides indica* and *Nymphoides peltata* are suitable for deep water areas. In shallow water areas *Nelumbo nucifera* can be used. *Azolla pinnata, Lemna minor, Eichhornia crassipes, Pistia stratiotes* and *Trapa natans* could be used as free floating plants. *Utricularia australis, Najas minor, Limnophila indica, Cabomba caroliniana, Ceratophyllum demersum, Elodea canadensis* and *Hygrophila difformis* can be grown as submerged plants. They can also be used as aquarium plants.

Studies on three *Nymphaea spp.* revealed that *Nymphaea stellata* was superior to the other two in all the vegetative parameters, except leaf length and leaf longevity which were higher in *Nymphaea rubra.* Early flowering and maximum flower production were also observed in *Nymphaea stellata* in which the duration from bud emergence to complete flower opening was the minimum. Length of the bud, flower size and longevity of flower were found to be the maximum in *Nymphaea rubra.*

Among the media combinations studied, M1 [sand + clay (1:2)] was superior over others with respect to all vegetative parameters, except leaf length, which was maximum in M2 [sand + soil +clay (1:1:1)]. When the floral characters were studied it was found that M2 [sand + soil +clay (1:1:1)] was superior to the other media combinations. M3 [coir pith +soil + clay (1:1:1)] produced the maximum number of propagules.

The study on the interaction effect of *Nymphaea spp.* and media revealed that *Nymphaea rubra* in M2 [sand + soil +clay (1:1:1)] recorded the maximum leaf length, leaf breadth, leaf area, pedicel length, bud length and flower spread. In *Nymphaea stellata,* M1 [sand + clay (1:2)] recorded maximum petiole length and M2 [sand + soil +clay (1:1:1)] recorded maximum flower production. In *Nymphaea rubra* the time for complete unfurling of leaf and leaf longevity was maximum in M3 [coir pith +soil + clay (1:1:1)] but, the flower longevity were maximum in M4 [coir pith +clay (1:2)].