

Original Research Paper

Pollution Potential Assessment of *Nymphaea alba* in Nigeen Basin of Dal Lake, Kashmir (J&K), India

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Abstract: The present study was conducted to investigate the biochemical attributes of *Nymphaea alba* (also known as the European White Water lily or Nenuphar), an annual or perennial aquatic flowering plant at three study sites viz., site I (Nagoo Mohalla, near residential area); site II (Ashaibagh-adjacent to floating gardens) and site III (Marzibagh-Nigeen boat club) in Nigeen Basin of Dal Lake, Kashmir. The sampling was done on monthly basis and the entire study period was divided into two phases i.e., the active growth phase (summer-June, July and August) and the senescence phase (early winter-September, October and November). Comparative biochemical assessment of three sites revealed chlorophyll 'a' ranging from 2.371 $\mu\text{g mL}^{-1}$ (site-III) to 3.266 $\mu\text{g mL}^{-1}$ (site-I); chlorophyll 'b'- 0.382 $\mu\text{g mL}^{-1}$ (site-III) to 0.588 $\mu\text{g mL}^{-1}$ (site-I); total chlorophyll, 3.184 $\mu\text{g mL}^{-1}$ (site-III) to 4.262 $\mu\text{g mL}^{-1}$ (site-I), while as carotenoids varied between 0.438 $\mu\text{g mL}^{-1}$ (site-III) to 1.083 $\mu\text{g mL}^{-1}$ (site-I). Proteins and amino acids elevated from a range of 0.328 mg mL^{-1} (site-III) to 0.578 mg mL^{-1} (site-I) and 2.884 mg mL^{-1} (site-III) to 3.823 mg mL^{-1} (site-I) respectively. The starch and carbohydrate content obtained a concentration range of 8.486 mg mL^{-1} (site-III) to 10.302 mg mL^{-1} (site-I) and 10.009 mg mL^{-1} (site III) to 12.769 mg mL^{-1} (site-I) respectively. The results revealed that the biosynthesis of various biomolecules accelerated during the active growth phase at Site-I (June) due to optimum physico-chemical parameters of water such as temperature (27°C); pH (8.9); free carbon dioxide (20.0 mg L^{-1}); and high concentrations of nitrate-nitrogen (427.3 $\mu\text{g L}^{-1}$) and total phosphorous (226.8 $\mu\text{g L}^{-1}$) while as, low range of biomolecules was observed at site-III in the senescence phase (November) due to decrease in various physico-chemical parameters of water (temperature, 5.0°C; pH,7.2; free carbon dioxide, 16.4 mg L^{-1} ; nitrate-nitrogen, 201.7 $\mu\text{g L}^{-1}$; and total phosphorous, 203.5 $\mu\text{g L}^{-1}$) from summer to early winter season. The study concludes that high nutrient load owing to various anthropogenic activities during active growth phase enhanced the growth of *Nymphaea alba* at site I as it increased biosynthesis of its various biomolecules in comparison to site III (control site) which is attributed to various clean-up activities taken up around this site. The study, thus recommends urgent scientific measures including proper management, conservation and restoration of lake. Furthermore, human habitation around the lake catchment demands sustainable protection measures to limit further degradation of the lake.

Keywords: Nigeen Lake, Water, Macrophytes, White Water Lily

Introduction

The vale of Kashmir is a Lucastrine basin of the inter montane depression existing between the Lesser and the Greater Himalaya. It is of Pleistocene origin and is formed because of tectonic activity (Khan, 1978). The Kashmir valley in India is famous for its high mountains reaching to a height of about 6,000 m and their elevations and depressions have created numerous, natural high altitude lakes (Kousarnag, Alipather, Kishansar, Vishansar, Tarsar, Marsar, Gangabal and Sheshnag- all above 3,800 m above sea level) and low flat lakes (Wular lake, Dal lake, Manasbal lake, Anchar lake and Nigeen Lake- all lie between 1,580-1,600 m) while, Nilnag is intermediate in altitude (2,000 m above sea level). Kashmir valley is generally referred to as "land of lakes and rivers" and the natural lakes of Kashmir Himalaya have been categorized into three different types, viz Glacial Mountain Lakes (between 3,000-4,000 m in altitude); Pine Forest lakes (at an altitude of 2,000-2,500 m) and Valley lakes (about 1,510-1,600 m above sea level) based on their origin, altitudinal situation and nature of the biota they contain (Zutshi *et al.*, 1972; Kaul *et al.*, 1978; Pandit, 1996).

Dal Lake (urban valley lake), known for its historical and cultural importance continues to be a famous scenic spot for tourists from all over the world visiting the valley and has remained the focus of considerable limnological research. The lake is located on the North-East of Srinagar city at the foot of Zabarwan mountains and is situated at an altitude of 1587 m (mean sea level) and lies between 34°5'-34°6'N latitude and 74°8'-74°9'E longitude and has the total water surface area of 11.45 km² and the total volume is estimated to be 9.83×10⁶ m³. The four functional basins of Dal Lake are Hazratbal, Bod-Dal, Gagribal and Nigeen. Morphologically, the four basins of the saucer shaped lake differ markedly (Kaul *et al.*, 1978) with regard to their areas, volumes, depths and indices of shoreline development. The Hazratbal basin is the largest in the area and the smallest is the Nigeen basin, but the Nigeen basin is the deepest (6 m) and the Gagribal basin is the shallowest one (2.5 m). The present study was carried out in Nigeen Basin of Dal Lake, which is situated to the north of Srinagar city at a distance of 9 km and at an elevation of 1584 m above sea level with Hari Parbat on its West. It has the surface area of 0.89 km² and the total volume is estimated to be 1.22×10⁶ m³ with the maximum depth of 6 m (minimum depth - 1.37 m). The limnological type of Nigeen is warm monomictic with an unstable thermocline. It has the catchment area of 3.5 km and is connected to Hazratbal basin via a narrow strip of marshy land.

Macrophytes are an important part of lake ecosystems and are often regarded as indicators of environmental changes in the lake by playing an

important role in maintaining the structure and function of lake ecosystems (Jun *et al.*, 2008; Luo *et al.*, 2016).

Macrophytes are the primary producers of aquatic ecosystems, apart from being a major food source of many kinds of fish and other aquatic animals (Guan *et al.*, 1987; Lan *et al.*, 2010). Furthermore, they can regulate the lake water body, degrade various pollutants and improve the transparency (Mânzatu *et al.*, 2015; Rezanian *et al.*, 2016).

The Nigeen Lake is infested with different types of macrophytic vegetation (e.g., emergents, rooted floating leaf type, free-floating types and submerged types). Like other primary producers, macrophytes respond to the quality of the water in which they grow and are beneficial to the working of aquatic systems. Aquatic weeds, as for example scavenge inorganic and some organic compounds from water, incorporating the dissolved materials into their own structure and thus act as "Biological Sinks" for large quantities of minerals, which could otherwise cause "Algal Blooms". Thus, the presence and dominance assemblages of macrophytes in the lake reflect its trophic status, therefore, being very good indicators of water quality. However, from past few years Nigeen Lake witnessed intense and multiple changes in its ecology due to the changes in nutrient loading brought about by the agricultural practices and sewage arrangements. The Nigeen Lake has been extensively encroached to form artificial floating gardens or islands (locally called as *Raadhs*) separated by canals which on maturity are subjected to vegetable cultivation, construction of shop-sites, residential houses and hotels etc. resulting in the formation of innumerable side water channels which get colonized by the obnoxious *Salvinia-Lemna* weed complex which interrupts the hydrological flow patterns and are long identified potential threats to the Lake existence (ENEX, 1978). The present study is an attempt to investigate the pollution potential assessment of *Nymphaea alba* in Nigeen Basin of Dal Lake.

Description of Experimental Plant, *Nymphaea alba*

Classification:

- Kingdom - Plantae
- Division - Magnoliophyta
- Class - Magnoliopsida
- Order - Nymphaeales
- Family - Nymphaeaceae
- Genus - *Nymphaea*
- Species - *alba*.

Species Distribution

Nymphaea alba (also known as the European White Waterlily, White Lotus, or Nenuphar) is found all over Europe and in parts of North Africa and the Middle East in fresh water. In India, the nomenclature of *Nymphaea*

has been very confusing; however, *Nymphaea alba* has been recorded from the Himalayas. Besides *Nymphaea alba*, following species of *Nymphaea* recorded from the Himalayas include; *Nymphaea odorata*, *Nymphaea candida*, *Nymphaea tetragona*, *Nymphaea tuberosa*. *N. candida* is sometimes considered as sub-species of *N. alba*. The red variety, which is in cultivation, came from Lake Fagertarn (Fair tarn) in the forest of Tiveden, Sweden, where they were discovered in the early 19th century.

Morphology

N. alba is an aquatic flowering plant. It is perennial or annual, grows in water from 30-150 cm deep, likes large ponds and lakes and is abundantly found in Nigeen Lake, Srinagar, Kashmir. These are aquatic plants without spines. Stems, a slender or stored rhizome, a corm or a tuber. The leaves can be up to 30 cm in diameter and they take up a spread of 150 cm per plant. Petiole smooth, mature leaf blades, mostly floating, ovate or orbicular, leathery, if submerged usually sagittate, filmy and delicate. Flowers borne above the water surface are white in colour and are strongly protogynous. Sepals (4) green or streaked with red. Petals numerous, showy, sometimes passing into stamens. Stamens numerous with or without appendaged connectives. Carpels (3-35) united or partially united fruit a berry ripening below water. Seeds with bell-shaped arils dispersed by animals, insects and by water, some species spread by specialized buds. The juveniles are submerged; the adults are submerged or floating.

Uses

The rhizomes, flower buds and seeds are eaten for food, medicinal purposes or to cause hallucination. It contains active alkaloids nupharine and nymphaeine, resin, glycosides and tannins and is a sedative and an aphrodisiac/anaphrodisiac depending on the sources. Although the roots and stalks are used in traditional herbal medicine along with the flower, the petal and other flower parts are the most potent (Robin, 2000). Alcohol (Both Methanol as well as Ethanol) can be used to extract the active alkaloids and it boosts the sedative effects. The rhizomes are used as a mordant in dyeing and tanning. They are also widely used for ornamental purposes.

Materials and Methods

The present study was carried out in Nigeen Basin of Dal Lake for the period of six months. The entire study period was divided into two phases i.e., the peak growth phase (June, July and August) and the senescence phase (September, October and November). The water samples and the experimental plant material (leaf) were collected on monthly basis from the designated sampling sites in

Nigeen Basin of Dal Lake to assess the physico-chemical parameters of the sampled water and the biological characteristics of plant material of *Nymphaea alba*.

Study Sites

The sites were selected based on the availability of the experimental plant i.e., *Nymphaea alba* and the brief description of the sites are as follows

Site-I

This is a densely populated area and is situated in Khoj Yarbhal part of Nigeen Lake. Due to heavy nutrient inputs from the houses and nearby floating gardens, the site is occupied with heavy macrophytic vegetation of both submerged as well as floating forms such as; *Nymphaea alba*, *Nelumbo nucifera*, *Lemna sp.*, *Salvinia sp.*, *Potamogeton sp.*, *Azolla sp.* etc.

Site-II

This site is located near Ashaibagh Bridge i.e. inlet of the lake and is characterized by a vast area of floating gardens. The site has a depth of (2-2.5 m) and submerged, emergent as well as floating forms of macrophytes are present at this site.

Site-III

This site is located at Nigeen Boat club and has a scanty vegetation of *Nymphaea alba* and various other forms of submerged macrophytes due to nutrient loading from the boat club and the surrounding houseboats.

Methods

A. Physico-Chemical Parameters

The physico-chemical parameters of water samples were analyzed using the methods of A.P.H.A. (2005) and Golterman and Clymo (1969). Water samples were collected in plastic bottles of 1.5 litre capacity and parameters of Temperature, Hydrogen Ion Concentration (pH), Nitrate-Nitrogen and Total Phosphorus were analyzed in the laboratory.

B. Biochemical Parameters

For biochemical analysis, the plant material i.e. *Nymphaea alba* was collected in transparent polythene bags (after decanting water) and analyzed for biochemical characteristics using the methods derived by Strain *et al.* (1971); Duxbury and Yentech (1956); Lowry *et al.* (1951); Lee and Takahashi (1966); Agarwal *et al.* (1998); Montgomery (1982).

Preparation of Homogenate

A 10% (W/V) homogenate was prepared by homogenizing a weighed sample of plant leaves in a measured volume of distilled water using pestle and

mortar. The homogenate was centrifuged at 5000rpm for 10 minutes. The supernatant thus obtained was used for estimation of Pigments [Chlorophyll (a, b), Total Chlorophyll and Carotenoids]; Proteins; Amino Acids; Starch and Carbohydrates (Free sugars).

Results

Observations recorded during the present study pertaining to various water samples and biochemical characteristics of *Nymphaea alba* in Nigeen Basin of Dal Lake were as.

A. Water Analysis

The physio-chemical characteristics of the analyzed water samples are as under.

Water Temperature (°C)

Water temperature varied between (4.0-27°C, site-I); (5.0-27°C, site-II); (5.0-28°C, site-III) with lowest recorded temperature i.e., 4°C observed at site-I in November and highest temperature i.e., 28°C at site-III in June (Fig. 1).

Hydrogen Ion Concentration (pH)

pH varied between (7.4-8.9, site-I); (7.4-8.7, site-II); 7.2-8.2, Site-III) with the lowest value of 7.2 being recorded in November at site-III and the highest of 8.9 in June at site-I (Fig. 2).

Nitrate-Nitrogen (µg/l)

The value of nitrate-nitrogen varied between (235.1-427.3 µg L⁻¹, site-I); (223.5-424.0 µg L⁻¹, site-II); (201.7-405.3 µg L⁻¹, site-III) with the lowest value i.e., 201.7 µg L⁻¹ recorded at site-III and the highest value i.e., 427.3 µg L⁻¹ at site-I in November and June respectively (Fig. 3).

Total Phosphorus (µg/l)

The concentration of total Phosphorus varied between (206.1-226.8 µg L⁻¹, site-I); (205.7-223.5 µg L⁻¹, site-II); (203.5-221.1 µg L⁻¹, Site-III). On site wise comparison, the lowest value of 203.5 µg L⁻¹ was recorded at site-III and the highest value of 226.8 µg L⁻¹ at site-I in November and June respectively (Fig. 4).

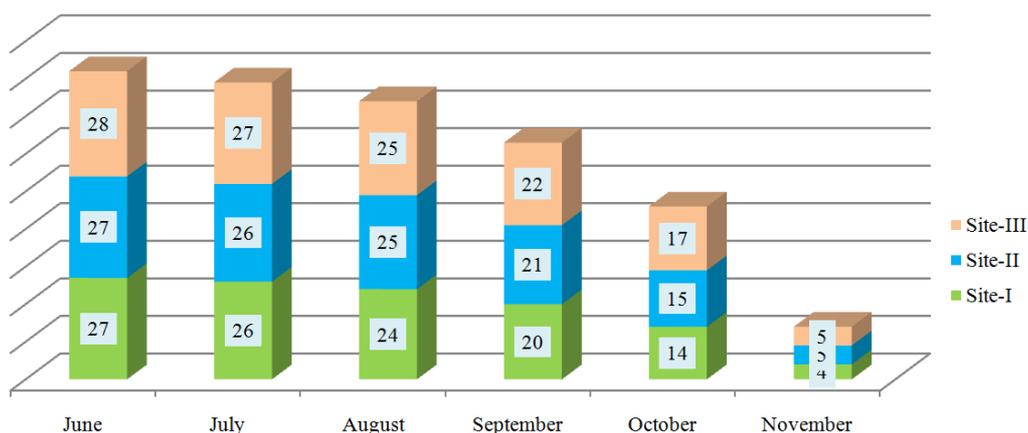


Fig. 1: Water temperature (°C) recorded at three study sites

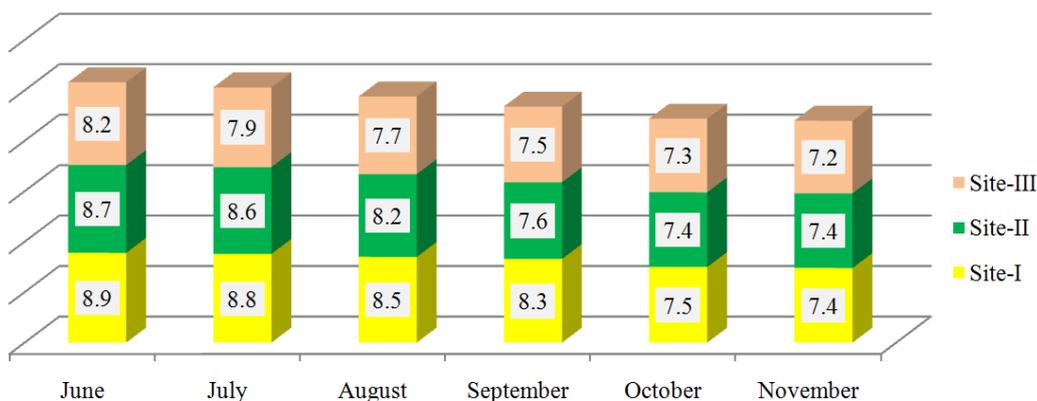


Fig. 2: pH of Water recorded at three study sites

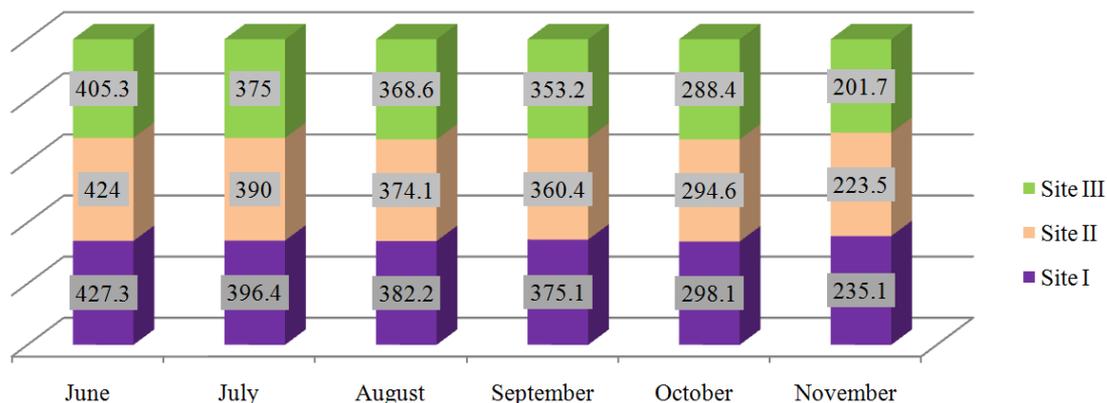


Fig. 3: Nitrate nitrogen (µg/l) of water recorded at three study sites

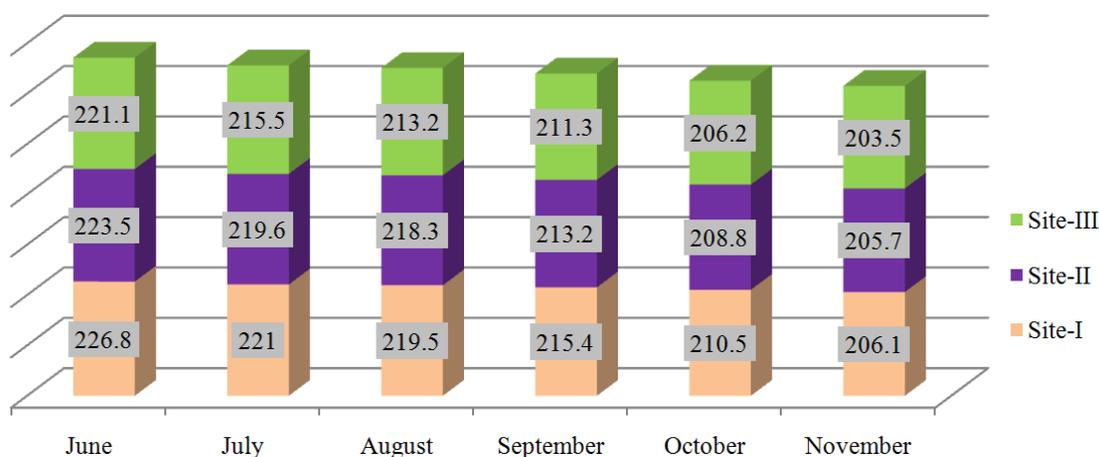


Fig. 4: Total phosphorus (µg/l) of water recorded at three study sites

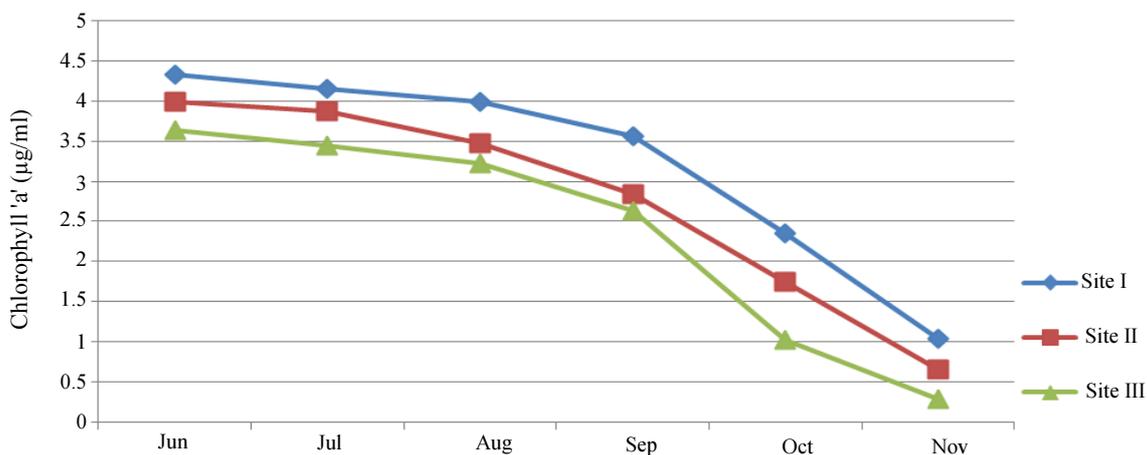


Fig. 4: Chlorophyll a (µg/ml) of *Nymphaea alba* recorded at three study sites

Biochemical Analysis of *Nymphaea alba*

The following biochemical parameters were analyzed during the study.

Pigments (µg/ml)

The results revealed that the concentration of Chlorophyll 'a' varied between (1.029 to 4.325 µg mL⁻¹,

site-I); (0.645 to 3.987 $\mu\text{g mL}^{-1}$, site-II); (0.277 to 3.634 $\mu\text{g mL}^{-1}$, site-III). However, the lowest concentration of 0.277 $\mu\text{g mL}^{-1}$ was recorded at site-III in November and the highest value of 4.325 $\mu\text{g mL}^{-1}$ at site-I in June (Fig. 5).

The value of chlorophyll 'b' varied between (0.017 to 1.472 $\mu\text{g mL}^{-1}$, site-I); (0.009 to 1.375 $\mu\text{g mL}^{-1}$, site-II); (0.004 to 1.201 $\mu\text{g mL}^{-1}$, site-III). Overall, lowest concentration of 0.004 $\mu\text{g mL}^{-1}$ was observed at site-III

in November and the highest concentration of 1.472 $\mu\text{g mL}^{-1}$ at site-I in June (Fig. 6).

The total chlorophyll concentration varied between (2.427 to 5.796 $\mu\text{g mL}^{-1}$, site-I); (1.739 to 5.362 $\mu\text{g mL}^{-1}$, site-II); (1.112 to 4.845 $\mu\text{g mL}^{-1}$, site-III) showing the lowest concentration of 1.112 $\mu\text{g mL}^{-1}$ at site-III in November and highest concentration of 5.796 $\mu\text{g mL}^{-1}$ at site-I in June (Fig. 5).

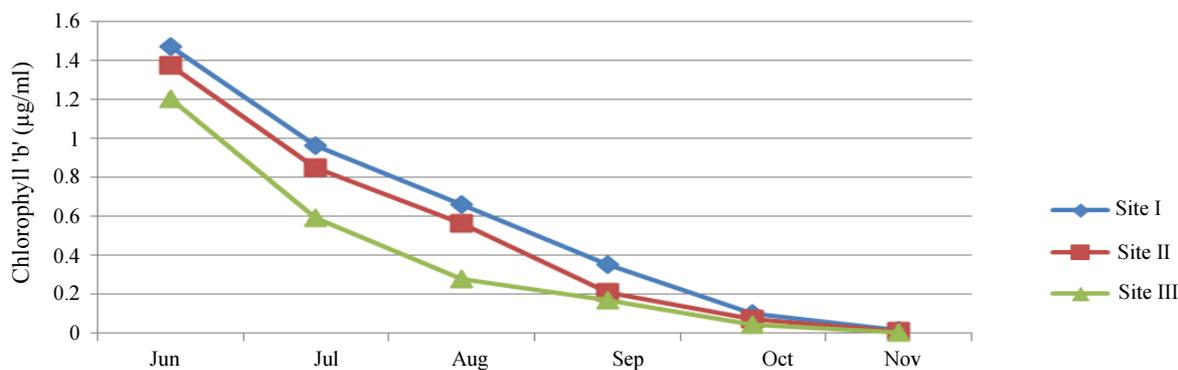


Fig. 5: Chlorophyll 'b' ($\mu\text{g/ml}$) of *Nymphaea alba* recorded at three study sites

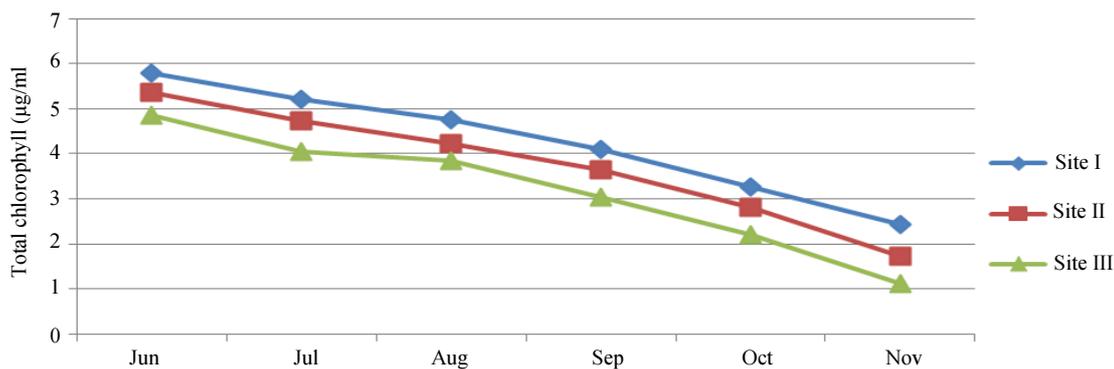


Fig. 6: Total Chlorophyll ($\mu\text{g/ml}$) of *Nymphaea alba* recorded at three study sites

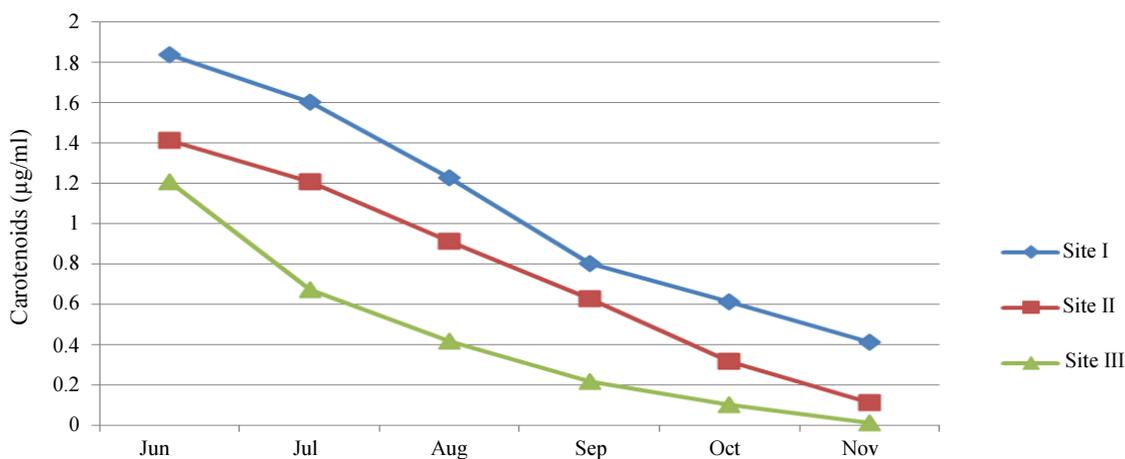


Fig. 7: Carotenoids ($\mu\text{g/ml}$) of *Nymphaea alba* recorded at three study sites

Carotenoid concentration depicted the variation between (0.411 to 1.836 $\mu\text{g mL}^{-1}$, site-I); (0.112 to 1.412 $\mu\text{g mL}^{-1}$, site-II); and (0.012 to 1.209 $\mu\text{g mL}^{-1}$, site-III). Out of three sites, the lowest value of 0.012 $\mu\text{g mL}^{-1}$ was observed at site-III in November and the highest value of 1.836 $\mu\text{g mL}^{-1}$ was observed at site-I in June (Fig. 7).

Proteins (mg/ml)

The concentration of Proteins varied between (0.056 to 1.281 mg mL^{-1} , site-I); (0.033 to 1.119 mg mL^{-1} , site-II) and (0.021 to 1.069 mg mL^{-1} , site-III) with the lowest concentration of 0.021 mg mL^{-1} observed in November at site-III and highest of 1.281 mg mL^{-1} in June at site-I (Fig. 8).

Amino Acids (mg/ml)

The concentration of amino acids varied between (2.484 to 4.948 mg mL^{-1} , site-I); (1.411 to 4.822 mg mL^{-1} , site-II); (1.315 to 4.291 mg mL^{-1} , site-III) with the lowest concentration of 1.315 mg mL^{-1} at site-III

observed in November and the highest concentration of 4.948 mg mL^{-1} at site-I in June (Fig. 9).

Starch (mg/ml)

The concentration of starch varied between (7.432 to 13.209 mg mL^{-1} , Site-I); (6.751 to 12.709 mg mL^{-1} , site-II) and (6.168 to 11.764 mg mL^{-1} , site-III) with minimum concentration of 6.168 mg mL^{-1} at site-III in November and corresponding maximum concentration of 13.209 mg mL^{-1} at site-I observed in June (Fig. 10).

Carbohydrates (Free Sugars) (mg/ml)

Carbohydrate concentration varied between (10.991 to 14.317 mg mL^{-1} , site-I); (9.821 to 13.561 mg mL^{-1} , site-II); (7.510 to 12.812 mg mL^{-1} , site-III) with the minimum concentration of 7.510 mg mL^{-1} in November at site-III and the maximum concentration of 14.317 mg mL^{-1} in June at site-I (Fig. 11).

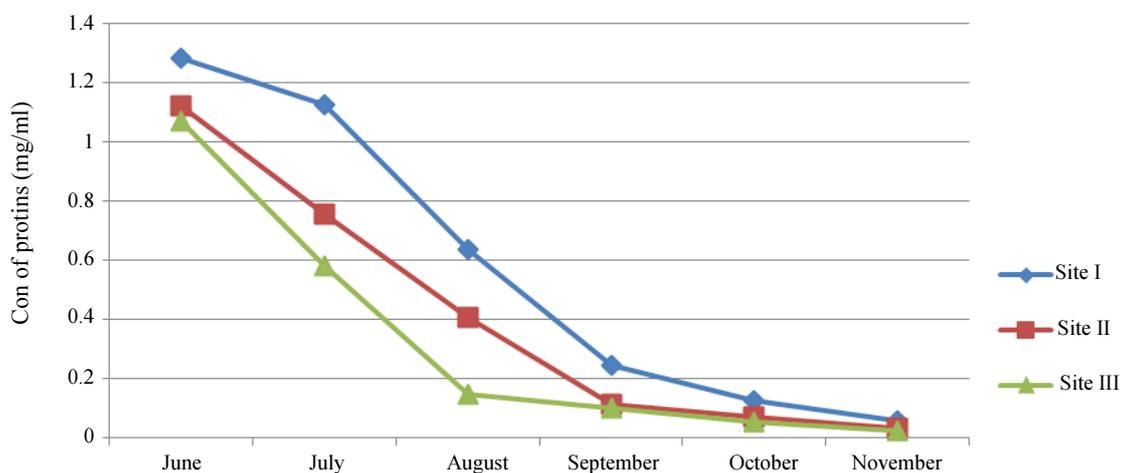


Fig. 8: Proteins estimation (mg/ml) of *Nymphaea alba* recorded at three study sites

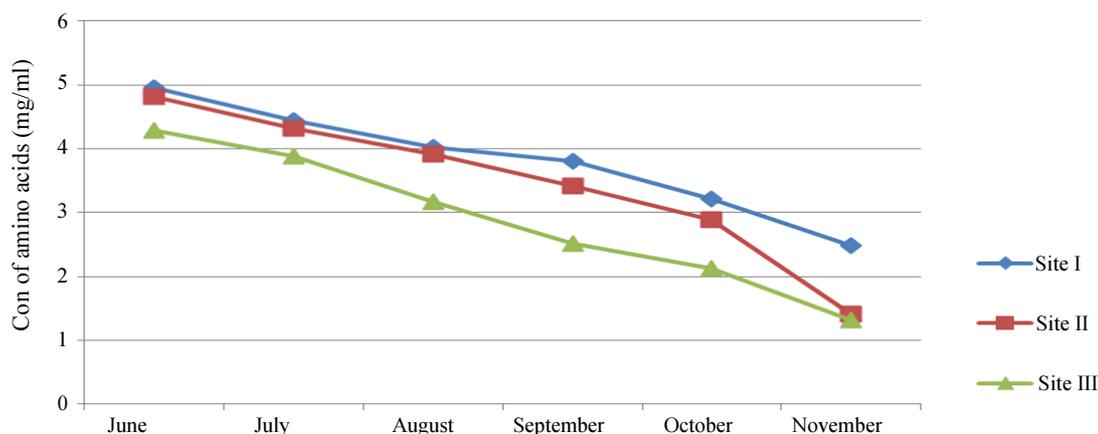


Fig. 9: Amino acids estimation (mg/ml) of *Nymphaea alba* recorded at three study sites

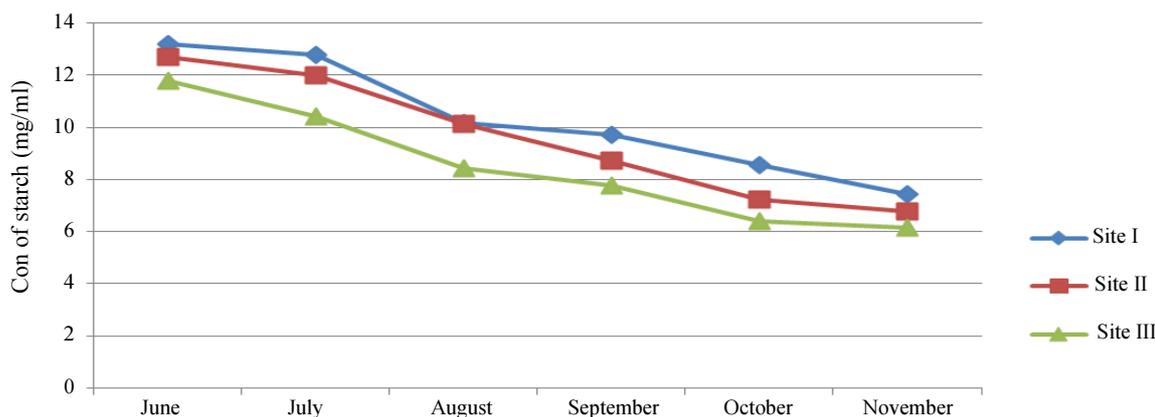


Fig. 10: Starch estimation (mg/ml) of *Nymphaea alba* recorded at three study sites

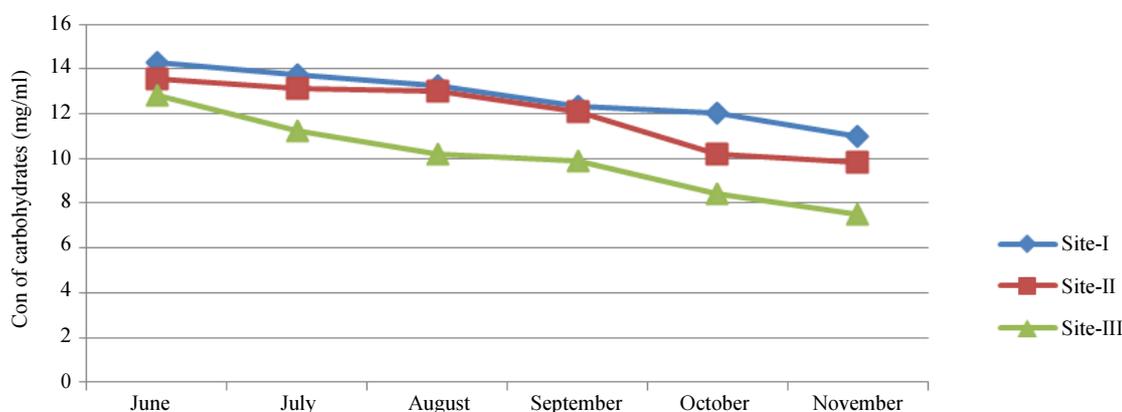


Fig. 11: Carbohydrates estimation (mg/ml) of *Nymphaea alba* recorded at three study sites

Discussion

Macrophytes form an integral part in Lake Ecosystem and grows in or near water bodies such as lakes, ponds, ditches etc, either partially or fully submerged. A set of environmental factors govern the presence and abundance of macrophytes in any aquatic habitat which include physical factors such as light intensity, temperature and flow rate (Barko and Smart, 1981; Singh and Srivastava, 1985; Wetzel and Bruce, 1975) whereas, the oxygen, carbon-dioxide, pH (Vass and Zutshi, 1979), nitrogen and phosphorus content of waters are the most important chemical factors (Fig. 3 and 4). The hydrological factors such as water depth and its associated influences are also opined to influence the occurrence and extent of individual plant species, while sediment type and nutrient composition have little importance in controlling macrophytic distribution. Macrophytes form a basic source of food chain, acts as bio indicators of water pollution and reduce the nutrients from nutrient sediment pool (Pandit, 1984), but when these macrophytes grow in excess, the water body becomes

unaesthetic, the fish population is affected and the entire ecological balance of the lake ecosystem is disturbed.

Water Temperature, is of prime importance as the same regulates the various physico-chemical as well as biological activities and has been considered as a profound and primary environmental condition determining photosynthesis, metabolism and growth processes as is evident from the studies of Barko and Smart (1981), Zieman and Wetzel, (1980); Singh and Srivastava (1985). Temperature has been reported as a primary factor in controlling growth and enhanced production rates are attributed to increased temperature and light conditions, during longer summer days as observed by Kopezynka (1980). During the present study, temperature has shown a decreasing trend from the peak growth phase towards the senescence phase.

The pH can be considered as an ecological factor of major importance in controlling the activities and distribution of aquatic flora and fauna (Liu *et al.*, 2015). Peak values of pH observed in active growth phase of *Nymphaea alba* are related to its increased

photosynthetic activity. In the present study, comparative analysis of three sites revealed minimum pH range of 7.2-8.2 observed at site-III and maximum range of 7.4-8.9 at site-I which can be attributed to increased anthropogenic pressure in Nagoo Mohalla (residential area - Site-I), which is in agreement with Zutshi *et al.* (1972) associated higher pH values with primary production and biogenic calcification and lower values with decomposition of organic matter.

The inorganic carbon source for photosynthetic activity of macrophytes (aquatic autotrophs) that can be assimilated and incorporated into the living matter is provided by the free CO₂ in water (Olesen and Madsis, 2000), while studying the growth and physiological acclimation to temperature and inorganic C availability observed up to 4.5 times increased growth of macrophytes with increase in temperature and carbon and the present investigations revealed the same.

Chlorophyll is a green photosynthetic pigment. A whole series of chlorophyll called Chlorophyll a, b, c, d and e are known. In the present investigation chlorophyll (a, b), total chlorophyll and carotenoid have been investigated. Chlorophyll a is widely distributed in nature and is called primary photosynthetic pigment since it is responsible for the emission of electrons during cyclic and non-cyclic photophosphorylation. Chlorophyll b and carotenoid on the other hand are accessory pigments as they transfer the energy absorbed to the chlorophyll a. The chlorophyll estimation of macrophytes is an important parameter for analyzing their growth performance. The present investigation revealed the recorded chlorophyll content peaked during the active growth phase and decline with decrease in growth activity in the senescence phase. This declining trend can be attributed to the changes in temperature and pH. Besides, strong positive correlations have been observed between concentration of N and P and the overall photosynthetic pigment Salisbury and Ross (2005). Comparative analysis of the three sites revealed high range of total chlorophyll at site-I (2.427 to 5.796 µg mL⁻¹) and low range of 1.112 to 4.845 µg mL⁻¹ at site-III which is due to high concentrations of nitrogen and phosphorous at site-I during the peak growth phase which resulted into high chlorophyll content as compared to the senescence phase (Fig. 4-6).

Proteins, the most abundant intercellular macromolecules constitute over half of the dry weight of most living organisms. Amino acids are the building blocks of proteins. The spatial and temporal variation recorded in the protein and amino acid content during the present study revealed a declining trend due to the reduction of total phosphorus and nitrate-nitrogen content (Salisbury and Ross, 2005) from summer to autumn to early winter season. This finding is in agreement of the study conducted earlier by

Taheruzzaman and Kushari (1989). Maximum concentration of proteins and amino acids were recorded at site-I (0.56 to 1.281 mg mL⁻¹ and 2.484 to 4.948 mg mL⁻¹) and this elevated concentration in pollution level is mainly due to nutrient enrichment by intense human activities. However, minimum concentration of 0.021 to 1.069 mg mL⁻¹ and 1.315 to 4.291 mg mL⁻¹ was observed at site-III which can be accredited to restoration measures taken around Nigeen Boat Club that mirror the significance of conservation measures for the betterment of water quality and productivity of lake (Fig. 9).

Carbohydrates, based on mass are the most abundant biomolecules in nature and starch is the most important reserve food of plants. Best and Visser (1987) found that non-reducing carbohydrates predominate in summer and reduce during winter, similar observations has been made during the present investigation as starch concentration has been highest during the peak growth phase and lowest during the senescence phase. Such decline can be attributed to decreased rate of photosynthesis. The contribution of N and P in the synthesis of carbohydrates has been reported by Salisbury and Ross (2005). Similarly, Biudes and Camargo (2006) concluded that high N and P availability in water is probable cause of higher carbohydrates. The carbohydrate concentration showed variation with highest range of 10.991 to 14.317 mg mL⁻¹ at site-I due to heavy nutrient inputs to the lake from the residential area as compared to the lowest range of 7.510 to 12.812 mg mL⁻¹ at Site-III i.e., Nigeen boat club area (Fig. 11).

In nutshell, physico-chemical evaluation revealed the water near site-I i.e., Nagoo Mohalla (residential area) to be more polluted compared to site-II i.e., Floating Garden Area while as site-III (Nigeen Boat Club) has been found to be least polluted out of the three sites. In response to the variations in the ecological conditions, macrophytic community at three different sites also exhibited differences in growth conditions, biomolecular composition and metabolic stage or age. The growth of *Nymphaea alba* was especially luxuriant in areas additionally fertilized by human induced eutrophication for the major mineral nutrients of N & P (Fig. 3 and 4).

Conclusion and Future Prospects

From the present investigation, it can be inferred that high nutrient loading accelerates the growth of aquatic macrophytes as it increases the biosynthesis of various biomolecules, thereby having a positive impact on the productivity of the Lake. The macrophytes are regarded as biological indicators, which determine the extent of water pollution as they scavenge large proportions of nutrients from the lake waters thereby preventing the formation of algal blooms (eutrophication), but the excessive growth of macrophytes result in imbalances in

the aquatic food chain and affect the fish population adversely. In addition, it decreases the aesthetic value of the lake by converting it into a Stinking Drain. Thus, proper management and conservation measures are of utmost importance and more stress should be given to lake restoration programmes such as selective phased de-weeding programmes can work wonders towards managing the water quality of a lake. Besides various conservation measures, concerted efforts from the local people can play a vital role in the proper management and restoration of the water bodies.

The future prospective of this work includes the study of various other related plant species and their interactions with the micro biota and local water bodies, so that a comprehensive programme could be started to save our wetlands from being polluted.

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Author's Contributions

Hina Mushtaq: Participated in all experiments, coordinated the data-analysis and contributed to the writing of the manuscript.

S.A. Shameem: Participated in experimental planning and data-analysis interpretation.

Mumtaz Mohd Bhat: Participated in all experiments, coordinated the data-analysis and helped in manuscript writing.

Abdul Hai: Participated in all experimental planning and data interpretation and contributed to the writing of the manuscript

K.R. Hakeem: Participated in coordinated the critical data-analysis and contributed to the writing of the manuscript.

Ethics

Authors declare no conflict of interest

References

- A.P.H.A., 2005. Standard methods for examination of water and wastewater.
- Agarwal, S.B., Agarwal and P.K. Nandi, 1998. Impact of cement kiln emissions on vegetation: An ecological assessment. *Indian J. Environ. Health*, 30: 340-347.
- Barko, J.W. and R.M. Smart, 1981. Comparative influences of light and temperature on the growth and metabolism of selected submersed freshwater macrophytes. *Ecol. Mono.*, 51: 219-235.
DOI: 10.2307/2937264

- Best, P.H. and H.W.C. Visser, 1987. Seasonal growth of the submerged macrophyte *Ceratophyllum demersum* L. in mesotrophic lake vechten in relation to insolation, temperature and reserve carbohydrates. *Hydrobiologia*, 148: 231-243.
DOI: 10.1007/BF00017526
- Biudes, J.F. and A.F. Camargo, 2006. Changes in biomass, chemical composition and nutritive value of spartina alterniflora due to organic pollution in the itanhaém river basin.
- Duxbury, A.C. and C.S. Yentech, 1956. Plankton pigment monographs. *J. Mar Res.*, 15: 19-101.
- ENEX, 1978. Study of the pollution of the dal lake, Srinagar, Kashmir. ENEX Consortium.
- Golterman, H.L. and R.S. Clymo, 1969. Methods for physical and chemical analysis of freshwaters. IBP, Handbook No. 8. Blackwell Scientific Publications.
- Guan, S., Q. Lang and B. Zhang, 1987. Aquatic vegetation of poyang lake. *Acta Hydrobiologica Sinica*.
- Jun, H., G. Xiaohong and L. Guofeng, 2008. Aquatic macrophytes in East Lake Taihu and its interaction with water environment. *J. Lake Sci.*, 20: 790-795.
- Kaul, V., C.L. Trisal and J.K. Handoo, 1978. Distribution and Production of Macrophytes in Some Water Bodies of Kashmir. In: *Glimpses of Ecology*, Singh, J.S. and B. Gopal (Eds.), Intern. Sci. Publ. Jaipur, India, pp: 313-334.
- Khan, M.A., 1978. Limnological studies of some Kashmir lakes.
- Kopozynka, E.E., 1980. Seasonal variations in phytoplankton in the Grand river month area of lake Michigan. *Poll Arch. Hydrobiol.*, 21: 95-123.
- Lan, C., Y. Shen and B. Wang, 2010. Investigation of aquatic plants and benthic macro invertebrates of lakes in inner mongolia- xinjiang plateau. *J. Lake Sci.*, 6: 888-893.
- Lee, Y.P. and T. Takahashi, 1966. An improved colorimetric determination of amino acids with the use of ninhydrin. *Anal. Biochem.*, 14: 71-77.
- Liu, W., J. Liu, D. Yin and X. Zhao, 2015. Influence of ecological factors on the production of active substances in the anti-cancer plant *Sinopodophyllum hexandrum* (Royle) T.S Ying. *Plos One*, 10: 1-4.
DOI: 10.1371/journal.pone.0122981
- Lowry, O.H., N.J. Rosebrough, A.L. Farr and R.J. Randall, 1951. Protein measurement with Folin-phenol reagent. *J. Biol. Chem.*, 193: 265-275.
- Luo, J., X. Li, R. Ma, L. Fei and D. Hongtao, 2016. Applying remote sensing techniques to monitoring seasonal and interannual changes of aquatic vegetation in taihu lake, China. *Ecol. Indic.*, 60: 503-513. DOI: 10.1016/j.ecolind.2015.07.029

- Mânzatu, C., B. Nagy, A. Ceccarini, R. Iannelli and S. Giannarelli, 2015. Laboratory tests for the phytoextraction of heavy metals from polluted harbor sediments using aquatic plants. *Mar. Poll. Bull.*, 101: 605-611. DOI: 10.1016/j.marpolbul.2015.10.045
- Montgomery, R., 1982. Determination of glycogen by phenol-sulphuric acid method. *Arch. Biochem. Biophys.*, 67: 378-386.
- Olesen, B. and T.V. Madsen, 2000. Growth and physiological acclimation to temperature and inorganic carbon availability by two submerged aquatic macrophyte species, *Callitriche cophocarpa* and *Elodea canadensis*. *Funct. Ecol.*, 14: 252-260. DOI: 10.1046/j.1365-2435.2000.00412.x
- Pandit, A.K., 1984. Role of macrophytes in aquatic ecosystems and management of fresh water resources. *J. Environ. Manage.*
- Pandit, A.K., 1996. Lakes in Kashmir Himalaya. In: *Ecology, Environment and Energy*, Khan, A.H. and A.K. Pandit (Eds.), The University of Kashmir, Srinagar, J&K, India, pp: 140-140.
- Rezania, S., S.M. Taib, M.F. Md Din, F.A. Dahalan and H. Kamyab, 2016. Comprehensive review on phytotechnology: heavy metals removal by diverse aquatic plants species from wastewater. *J. Hazard Mat.*, 318: 587-599. DOI: 10.1016/j.jhazmat.2016.07.053
- Robin, D., 2000. Nymphaeaeodorata: White pond lily. *Medical Herbalism*, 11: 6-7
- Salisbury, F.B. and C.W. Ross, 2005. *Plant physiology*. Asia Printograph, Shahdara.
- Singh, A. and O.N. Srivastava, 1985. Effect of light intensity on the growth of *Azolla pinnata* R. Brown at Ranchi, India. *Hydrobiologia*, 126: 49-52. DOI: 10.1007/BF00008386
- Singh, A. and O.N.H. Srivastava, 1985. Effect of photoperiod on the growth of *Azolla pinnata* R. brown. *Hydrobiologia*, 123: 211-214. DOI: 10.1007/BF00034380
- Strain, H.H., T.C. Bengavin and A.S. Walter, 1971. Analytical Procedure for Isolation, Identification, Estillation, Investigation of Chlorophyll. In: *Methods in Enzymology*, Pietro, A.S. (Ed.), Academic Press, New York, pp: 452-476.
- Taheruzzaman, Q. and D.P. Kushari, 1989. Evaluation of some common aquatic macrophytes cultivated in enriched water as possible source of protein and biogas. *Hydrobiol. Bullet.*, 23: 207-121. DOI: org/10.1007/BF02256739
- Vass, K.K. and D.P. Zutshi, 1979. Limnological studies of dal lake, kashmir, morphometry and physical features, *J. Ind. Fish. Soc. India.*, 9: 13-21.
- Wetzel, R.G. and A.M. Bruce, 1975. Secretion of dissolved organic carbon and nitrogen by aquatic macrophytes. *Int. Verein. Theoret. Angewandte Limnol. Verhan.*, 18:162-170. DOI: 10.1080/03680770.1971.11895979
- Zieman, J.C. and R.G. Wetzel, 1980. Productivity in Seagrasses, Methods and Rates. *Handbook of Seagrass Biology, an ecosystem Perspective*, Phillips, R.C. and C.P. McRoy (Eds.), Garland STPM press, New York, pp: 87-116.
- Zutshi, D.P., 1978. Ecology of some kashmir lakes. PhD Thesis, University of Kashmir (Unpublished),
- Zutshi, D.P., V. Kaul and K.K. Vass, 1972. Limnology of high altitude Kashmir lakes. *Int. Vereinig. Theoret. Angewandte Limnol. Verhandlu.*, 18: 599-604. DOI: 10.1080/03680770.1972.11899514