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Unveiling the ecological and nutraceutical riches of sustainable aquatic lotus plant and its microbial allies

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Abstract
Sustainable aquatic, lotus plant (*Nelumbo nucifera* Gaertner), the national flower of India with cosmopolitan distribution is true symbol of purity (sacred), beauty, knowledge and immortality. It has surface floating, large peltateorbicular leaves with beautiful pink or purple colour flowers. Almost all of its parts from roots to seeds has numerous nutritional and medicinal importance. Now a days, it is considered as most sustainable fabric obtained from its stem part as long threads that is interwoven to popularly called as "Lotus Silk". It is a nano-fibre with silk like properties, utilized for making eco-friendly fabric with anti-bacterial, self-cleaning and super- hydrophobic potential. It is one of the plants with religious and cultural importance too. Keeping in view the above facts in mind, thisreview paperprimarily emphasizes on the ecological, nutraceutical, economic and sustainable fibre yielding potential of lotus plant, in addition to its role in wastewater management. Its rhizobiome inhabit numerous microbes that create a positive and eco-friendly relationship between these microbes and lotus root, thus providing a sustainable solution to support microbial diversity in aquatic lotus rhizobiome. This eco-friendly relationship between sacred lotus plant with nature can together be utilised for human welfare.

Keywords: Ecological, economic, lotus, nutraceutical, rhizobiome, sustainable.

Introduction

Lotus (*Nelumbo nucifera* Gaertner), is an aquatic perennial plant, belongs to monogeneric family- Nelumbonaceae (2n = 16). In India, *N. nucifera*, commonly known as lotus in English and Kamal or Padma in Hindi language. It is cosmopolitan in distribution and found throughout India. Sacred Indian lotus is the flower of antiquity and truly symbolizes purity (sacred), beauty, knowledge and immortality. Besides its popularity as an ornamental flowering plant, it has nutraceutical, ecological, aesthetic, religious, spiritual and economic importance too (Goel *et al*.2001 [13], Acharya*et al*. 2014 [1], Liu *et al*. 2016 [20], Lin *et al*. 2019 [15], Man *et al*. 2012) [22]. Owing to its very long association with history, religion, craft, art and culture, *Nelumbo nucifera* is chosen as national flower of India (Sharma *et al*. 2001) [39]. Being the national flower of India, it is highly esteemed for its sanctity (Goel *et al*. 2001) [13]. There are four types of lotus plant based on petals colour, one has white flowers and is commonly called 'sweitkamal' symbolizes beauty, grace, purity of mind, wealth, knowledge, fertility and faith; the other has pink flowers called 'rakta kamal' (Fig. 1) associated with compassion (Mandal and Bar 2013) [23], blue petalous (Fig. 2) known as 'Neel Kamal' in hindi language and is associated with a victory of the spirit over that of wisdom, intelligence and knowledge. The yellow-coloured lotus is associated with mental clarity and wisdom (Swarup 1983).

Origin and distribution

It is native of India, Japan and China, but it widely grows, cultivated and consumed in temperate, sub- temperate, tropical and sub- tropical regions of South-East Asian countries like Sri Lanka, Myanmar, Indonesia, Korea, Thailand, Vietnam, Cambodia as well as Australian and American continents (Qi and Zhou 2013 [31], Lin *et al*. 2019). China is considered as one of the cultivation centres of lotus (Deng *et al*. 2015) [10]. It is pictorial represented in the culture and architectural design of many countries like China, Korea, Japan, India, Australia pacific and Egypt (Paudel and Panth 2015 [30], Zhu *et al*. 2019) [48, 49]. It symbolizes perfection, purity, beauty and divinity.

Two important species of genera *Nelumbo*are *N. lutea*, the American lotus or water chinquapin or yellow lotus, growing in Eastern, Southern, Northern regions of America and *N. nucifera* which is widely distributed from tropical and sub-tropical Asia to Australia (Chen *et al*. 2013) [8]. Another species is *Nelumbo flavescens* has strongly scented lemon-yellow coloured and *Nelumbo alba*, white coloured, bold and beautiful were also reported by Mukherjee *et al*. 2009 [25], Min *et al*. 2019 [24].

In India, it is cosmopolitan in distribution showing enormous thermoplasticity and phenotypic diversity with a large number of racial variants in different shapes, sizes and shades (Goel*et al*. 2001 [13], Sharan and Haldar 2021) [38]. It is commercially very important and highly profitable for floriculture industry of the world. Lotus is exported from India to various countries like United States, Canada, Australia and United Kingdom in the form of cut flowers, flower buds, dry flowers, fresh flowers (lotus garland/ loose) in several kilograms, while China and Vietnam also have a well-established export industry of lotus (Seair Exim Solutions 2022) [35]. So, lotus business is of national and international repute.

Plant description

Lotus is herbaceous, perennial and aquatic plant. The growth of lotus plant takes place by means of rhizome. Its rhizomes are 60–140 cm long, 0.5–2.5 cm in diameter,

whitish to yellowish brown in colour, smooth texture with long striations and patchy brown upper layer. Complete rhizome is divided into nodes and internodes. The rhizome bearing nodes, produces a leaf at each node by means of which it flourishes. The petioles and the rhizome contain channels filled with air assisting for floating in the aquatic system (Fatima *et al*. 2018) [12]. It has a creeping, rhizomatous, elongated and branched stem with ramal, alternate, simple, foliage aerial leaf with long petiole, stipulate (stipule ochereate) (Shad *et al*. 2011) [37]. The leaves are enormous, non-wettable, orbicular and 20–90 cm in diameter (Pal and Dey 2015) [27]. Broadly leaves are classified into two types: aerial and floating. It has cup-shaped aerial leaves while floating leaves are flat (Baghel and Dubey 2017 [4], Sridhar and Bhat 2007) [40]. Inflorescence is axillary, solitary and terminal with long pedicelled, ebracteate, hermaphrodite, actinomorphic, polypetalous, spirocyclic, hypogynous, pink coloured fragment flowers. Each flower is polysepalous which are small, greenish-pink and fragrant. The flowers are solitary, pink and having peduncles, each arising from the nodes of the rhizome with sheathing base. The sepals, petals and stamens are spirally arranged. Numerous spirally arranged stamens (polyandrous) with long, slender filaments and basifixed anther in which connective protrudes beyond anther as appendage. Gynoecium is multicarpellary, apocarpous in which carpels embedded at the top of a flattened thalamus. The green fruits of this plant are an aggregate indehiscent nutlets. Fruit bearing seeds are hard, ovoid, black in colour and are arranged in whorls, its ripened seeds are released as pod bend down to the water (Srivastava 2000 [41], Sharma 2021) [39].

Propagation

Lotus can be propagated either by cuttings of rhizomes or by sowing of seeds (Mandal and Bar 2013) [23]. Rhizomes with new sprouts are cut into small pieces having nodes and are planted horizontally 10 cm deep in the bed keeping the sprouts on upper side during February- March (Guo *et al*. 2009) [14]. The rhizomes are ready for harvesting during end of October. Lotus seeds have remarkable viability and survivability period. Lotus seeds have long viability period and its seeds can easily be stored for several years at room temperature. This is the reason that lotus is also called as 'the symbol of eternity' (Swarup 1983). It requires plenty of space and sunlight in order to thrive.The flowering of lotus starts from March and continues till October. Extreme hot summer and rainy days decreases the extent of flowering and fruiting. So, optimum growth and good flowering are promoted by moderate temperature i.e., 23-24 ^{0}C (Mandal and Bar 2013) [23]. Further, conservation of lotus and its sustainable utilization can help in keeping this religious and aesthetic flower alive, flourishing as well as for improving the economic condition of rural masses.

Nutraceutical value

Lotus is an ornamental, edible and medicinal plant. It is one of those plant who's each and every part i.e., the rhizome, young flower, dried petals, fruits and seeds are either edible as a vegetable or used for medicinal purposes in traditional medicinal system (Chen *et al*. 2012 [7], Chen *et al*. 2013) [8]. Hence, this crop can be considered to be a high nutraceutical value one.

a. Nutritional aspects

Looking towards the nutritional aspects of lotus plant, it is preferably grown and consumed as a vegetable in Asian, Australian and some African countries (Qi and Zhou 2013 [31], Shad *et al*. 2011 [37], Min *et al*. 2019).

Lotus is a wetland plant and its stem/rhizome is known as kamalkakri (Fig. 3) which is consumed as vegetable in Northern part of India (Sahu and Chandravanshi 2018 [34], Min *et al*. 2019). Table.1 clearly shows that it is a moderate calorific value root vegetable, being rich source of phyto-nutrients, vitamins especially Vitamin C as well as B complex, many minerals like zinc, copper, iron, magnesium and manganese, carbohydrates, proteins and fats, thus it serves as immunity booster (Bangar *et al*. 2022) [5].

Lotus rhizome is also eaten in roasted, dried and fried forms which is enriched with coarse fibre, vitamin (A, B_1, B_2, C) and minerals (K^+, Na^+, Ca^{+2}, P, Fe, Mg) as reported by Orozco-Obando 2012 [26], Shad *et al*. 2011 [37], Wang *et al*. 2015 [43] and Park *et al*. 2017 [28].

Dry lotus seeds are a good source of protein (15.4 g), unsaturated fatty acids, vitamins (vitamin B_1, vitamin B_2, vitamin B_6 and Vitamin E), minerals, starch, sugar, other amino acid and ions (Rai, *et al*. 2006 [33], Li 2020, Zhu *et al*. 2016) [48, 49]. Roasted seeds are rich in saponins, phenolics and carbohydrates. Lotus seeds also contain water-soluble polysaccharides which enhances the immune function by increasing lymphocyte number. Polyphenols show strong antioxidant potential with an ability to scavenge free radicals, break radical chain reactions as well as acting as metal chelators (Lobo *et al*. 2010) [21].

b. Pharmaceutical use

Lotus is gaining popularity among masses due to its nutraceutical importance too as it is used as a medicinal herb and folk medicine in Eastern Asia, particularly in China, Japan and India (Tian *et al*. 2009) [42]. Lotus produces a number of important secondary metabolites, like alkaloids, flavonoids, steroids, triterpenoids, glycosides and polyphenols (Mukherjee *et al*. 2009 [25], Bangar *et al*. 2022 [5], Fatima *et al*. 2018) [12]. Different classes of phytochemicals have been isolated from various parts of *N. nucifera* including rhizome, leaf, seed and flower etc. Various pharmacological activities shown by the whole plant of lotus includes antioxidant, anti-pyretic, antiviral activity, immunity booster, anti-inflammatory, atherosclerotic, anti-diabetic, anti-ageing, hepatoprotective, anti-obesity, anticancer and cardiotonic activity (Mukherjee *et al*. 2009 [25], Deng *et al*. 2013 [9], Huang *et al*. 2010 [16], Paudeland Panth 2015). Decoction prepared from lotus has been used as an antidote for mushroom poisoning as well as teas, tonics and astringents. It is believed that lotus plant possesses the secret to cure ageing (Huang *et al*. 2010) [16].

The rhizomes are traditionally used for treating leukoderma, cough, small pox, dysentery and diarrhoea. The lotus rhizome is also used with other herbs to treat fever and sunstroke. Phenolic substances provide the lotus rhizome different properties like antioxidant, anti-mutagenic, anti-ageing, anti-inflammatory and anti-microbial. Polyphenolic extracts of lotus rhizome provide defence against herbivores, has antibacterial as well as antifungal activities and also involved in fruit colouring, pollination and other plant processes. Coloured anthocyanins, flavonoids, flavanols, phenolic acids, isoflavones etc are complex

secondary metabolites in this plant (Chen *et al*. 2013 [8], Deng 2013 [9], Deng *et al*. 2015) [10].

In ayurvedic system of medicines, the stem is used to treat nervous exhaustion, leprosy and skin diseases (Chen *et al*. 2012) [7]. Mixed honey and seed powder is useful in treating cough. Lotus leaves are beneficial as natural home remedy for summer heat and obesity in Asian countries like Japan and China.

Lotus seeds also has antimicrobial potential (Liu *et al*. 2015) [19] and are used as a diuretic, cooling agent, treatment of tissue inflammation and cancer. Chinese drug is prepared by using embryo of lotus seed which is useful in insomnia, various cardiovascular diseases, nervous disorders and high fevers. Phenolic compounds are secondary metabolites that have high antioxidant potential. The major secondary metabolites present in the seeds are alkaloids such as dauricine, lotusine, nuciferine, pro-nuciferine, liensinine, isoliensinine, roemerine, neferine and armepavine (Wu *et al*. 2017). Seeds alsocontains water-soluble polysaccharides, alkaloids, flavonoids and other bioactive components which enhances the immune function by increasing lymphocyte number (Chen *et al*. 2012 [7], Liu *et al*. 2015) [19]. The functional components i.e. polyphenols in seeds can help combating high blood pressure, diabetes and gallstones. Polyphenols show strong antioxidant potential with an ability to scavenge free radicals, break radical chain reactions as well as acting as metal chelators (Lobo *et al*. 2010) [21].

Processed food products from lotus plants

Due to high dietary content of lotus, almost all of its parts are used in preparing different cuisines in different parts of the world. Lotus tubers are rich source of starch. The tubers can be consumed as sliced, pickled, cooked, candied or stir-fried. In China, the starches obtained from lotus plant are consumed as fast food and food additives (Man *et al*., 2012). Lotus root chips are produced and consumed in United States and India due to its crispy texture (Sridhar *et al*. 2007) [40]. Lotus leaf are used to wrap rice which give aroma of the leaf on steaming, other than this, they are also used as biodegradable wrappers. The lotus flower stem can be eaten raw or in fried form or used in making Thai soups. The flower is used both as a savoury topping after being dried and also used for making tea. In Asian countries, the dried petals are used for garnish. The stamens are also used as flavouring agent in the tea in Asian countries. Lotus seeds are embedded in young pods of plant. They are sold in Indian markets named ‘kamalgatta’ (Fig. 4). The seeds are eaten both in raw like popcorn and in roasted form. Lotus seeds are eaten when green having sweet taste and also consumed on turning brown with nuttier taste. It can also be grounded and used in making bread and pastries. They are also the main ingredient in many South Asian curries. Lotus seeds are rich source of protein, unsaturated fatty acids, minerals, saponins, phenolics and carbohydrates (Rai *et al*. 2006 [33], Zhu *et al*. 2016) [48, 49]. Lotus leaves having super hydrophobicity and self-cleaning nature are used for wrapping and serving food (Rahi *et al*, 2022) [32].

Aesthetic and ecological role

Lotus is an important and attractive wetland plant species in India. It has a beautiful flower which creates the spotlight view in any pond. Lotus has an important feature of growing in dirty ponds or water bodies with self-cleaning and water repellent properties (Li *et al*.2020). A pond full of lotus plants in blooming stage shows a captivating effect (Fig. 5). It extensively covers the large surface area of aquatic body and provides excellent cover for aquatic wildlife. Together inhabiting lotus, *Trapa*, *Euryale ferox* (makhana/Gorgon nut) and fishes in an aquatic body is highly suggested for high ecological and economic benefits. Lotus plant has aesthetically pleasing flower. Growing of lotus in pond gives aesthetically pleasing sight to viewers and adds beauty to the water garden. Its petals are used to extract colour (Pal and Dey 2015) [27] and to attract pollinators (Fig. 6).

Lotus silk- a sustainable fibre

Lotus fibre extracted from the stems of lotus which grow naturally on Burma lakes. A lotus textile is a popular industry in Thailand and Myanmar (Aishwariya *et al*. 2020) [2]. Although, production of lotus thread/lotus silk is extremely tedious and labour intensive**,** but it is considered as an act of great merit and enormous significance due to the special place of lotus in Hindu and Buddhist mythology.

Now a days, the silk is made from long strands of fibres that are stretched out from the stems of the lotus plant. Botanically, lotus fibres are the helical thickenings in xylem tracheid and primitive vessel elements of lotus petioles”. Lotus silk is purely of plant origin, so it is called vegan silk as worn by vegans and is also considered the most luxurious vegan fabric on earth. The thread from lotus silk fibre is used for weaving special robes for Buddha images called lotus robe. Lotus fibre is usually extracted from stems of two species of *Nelumbo; Nelumbo nucifera* and *Nelumbo lutea* (Wang *et al*. 2015) [43]. Natural fibres are 100% organic and bio-degradable. It has antibacterial properties and gives the feeling of calmness and peacefulness to people wearing it. It mainly consists of cellulose, hemicellulose, lignin, ash, pectin, amino acids and so on. Extracting fibre or lotus silk from stem part which is a renewable source is a sustainable approach of yielding fibre. It is finest aquatic fibre, breathable, comfortable, soft as well as crease resistance. Lotus fibre has good elasticity, piling resistance, has a texture like normal silk, colour of lotus fibre is milky yellow with moisture absorption potential, antibacterial, self-cleaning and eco-friendly nature (Aishwarya 2020). Due to self-cleaning natural mechanism of lotus plant water doesn't stick to lotus leaves called the "Lotus effect" (Escaray *et al*. 2012) [11].

Wu *et al*. 2014 stated that due to growing environmental concerns in the world, demands for environment friendly, fully biodegradable products has substantially increased among people. Since, no chemical is needed for its cultivation, as grown in naturally occurring muddy water and hence, making it is the most eco-friendly material in the world. Being most ecological fibre in the world it also serves the purpose of providing the employment to tribal and rural people (Patil 2018) [29]. Further, clothes of lotus fibre give the feeling of coolness in summer and warmness in winter. It has good tearing and tensile strength and is perfectly suited to make dresses, tunics or scarves. In addition, it is handmade or handcrafted and has UV resistance property, air permeability, free radicals absorbing potential that are generated by body, ability to inhibit fat production, being soft, light and comfortable to wear. Lotus fibre is a soft and fragrant natural fibre which shows perfect

moisture absorption and good ventilation potential other than cultural meaning (Yadav *et al*. 2019). *Li et al*. 2020 also stated that lotus textile surface has special wettable quality with self-cleaning, self-healing, UV-blocking, antibacterial and flame-retardant potential. It is believed that wearing this fabric provides healing effects which is peaceful, calm and meditative.

Being free from chemicals and pesticides during its cultivation process, the extracted fabric is hand-crafted, so it is considered among luxury fabric. For making weaving scarf from lotus fibre which can take the 9,200 plants to make a single lotus silk scarf. Due to long duration of extraction, processing and weaving, it prices upto 10 times than that of a traditional silk scarf. Reason behind its high selling price is its highly labour intensive and time-consuming production duration.

Advantages of lotus fabric and future scope of lotus silk fibre

A waste (lotus stems) used to extract and interwove a quality textile/product without use of any chemicals or generating toxic waste by simply hand woven and hand spun method is a traditional Cambodian practice. By supporting and encouraging people to work in this field will give an income generation option to local people while working in their original environment and will become the means to support future generations, thus allowing this art to survive as well. By producing more such eco-friendly fibres, we can increase the market of natural fibres around the globe with a step towards the direction of sustainability. So, it is economical also.

Wastewater management and phytoremediation potential of lotus plant

Lotus is cosmopolitan in distribution in Indian water bodies like wetlands, ponds, lakes, canals etc. (Fatima *et al*. 2018) [12]. *Lotus* species has shown great potential of revegetation and reclamation of a heavy metal-contaminated soil with adaptability to various stresses. *It also* protects the soil from natural and anthropogenic erosion. It has great potential to counteract water eutrophication. The floating leaf reduces sunlight intensity down the water body. This suppresses algal bloom in lotus inhabited aquatic ecosystems and adds on oxygen to pond ecosystem for better ecological cycles (Fig. 7). Due to surface run off containing nitrogen and phosphorus rich chemical fertilizers in agricultural practices, water pollution is major cause of concern in aquatic ecosystem. To mitigate it, the strength of lotus to assimilate both chemicals can be significantly utilized. Through rhizo-filtration by lotus rhizome, heavy metals including arsenic, copper and cadmium can be efficiently removed. So, it can be recommended to be planted in ponds containing discharged agricultural effluents for water purification in the most natural manner (Fig. 8). There is an interesting phenomenon that this plant maintains a microclimate, thus it helps the insect pollinators with a warm and equable environment (Sharan and Hakdar 2021 [38], Seymour *et al*. 2009 [36], Orozco-Obando 2012) [26].

Fish food rich in nitrogen get deposited at the bottom of pond in ponds that may choke the aquatic animals, thus threatening their life other than polluting a water body and creating a cause of water pollution through eutrophication. Ammonia and nitrite, the by-product of nitrogen metabolism is bio-toxic to fishes inhabiting pond. Lotus roots are reported to significantly to reduce and metabolise total nitrogen, total phosphorus and assimilate ammonia content in sediments of an aquatic body via active participation of microbes in its microbiome like *Thiobacillus denitrificans.* Hence, Lotus cultivation has significant contribution in both the ecological and economic perspectives (Rahi *et al*, 2022 [32]; Yang *et al*, 2022) [47].

Table 1: Nutrients content in Lotus plant

S.No.	Contents	Amount
A. Nutrient content in 100 g fresh rhizome of lotus		
1.	Starch	15– 26.25 g
2.	Protein	1–3.86 g
3.	Fat	0.1 g
B. Nutrient content in 100 g dry material of lotus		
4.	Coarse fibre	0.5 g
5.	Vitamin A	0.02 mg
6.	Vitamin B_1	0.11 mg
7.	Vitamin B_2	0.14 mg
8.	Vitamin C	15–79.39 mg
9.	K^+	49.7 mg
10.	Na^+	49.7 mg
11.	Ca	19 mg
12.	P	51 mg
13.	Fe	0.5 mg
14.	Mg	16.4 mg

(Source: Bangar *et. al.*, 2022, Bishayee *et. al*. 2022; Awal *et. al.*, 2020, Hajela *et. al*., 2019, Zhang *et. al*., 2015 and Li, 2007)

Fig 1: Dark pink Lotus in flowering stage

Fig 2: Purple-pink Lotus in flowering stage

Fig 3: A view of edible lotus rhizome (Kamal Kakri)

Fig 4: A general view of the fruits of pink Lotus having seeds

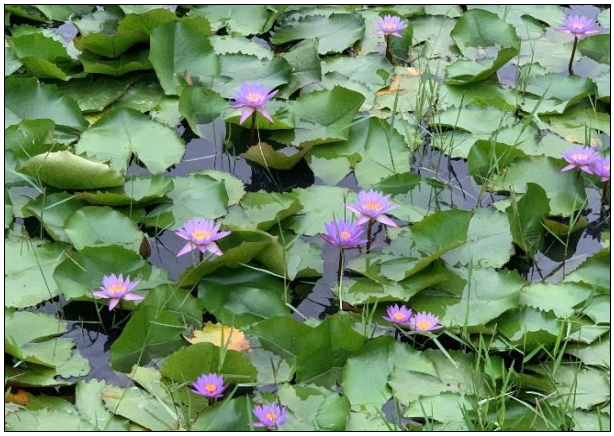

Fig 5: Magnificent view of purple-blue lotus plant

Fig 6: Well bloomed flower of blue lotus with pollinator

Fig 7: An overview of blue lotus pond

Fig 8: Artificially made pond of blooming lotus

Conclusion

This literature clearly reveals that the lotus being aquatic plant are grown in different continents of the world for their aesthetic and ornamental values, as a staple food, in nutraceutical industries, in sacred offerings having religious values, so, its flowers are in great demand for above mentioned purposes. Its commercial cultivation has good income generation option by promoting floriculture industry. Here, the sustained efforts need to be made for its conservation, documentation, multiplication and dissemination. In today's scenario of climate change, water bodies are degrading day by day. The neglected water bodies and existing ones should be maintained properly. Further, it is also required to develop more such water bodies. Simultaneously, a sustainable approach and concerted efforts are the need of the hour towards the conservation of this valuable aquatic plant. So, to conserve this highly esteemed aquatic plant, the modern cultural practices are needed to be practiced. Conservation of this plant and its sustainable utilization can help in keeping this marvellous species alive, flourishing as well as for improving the economic condition of the rural masses. Lotus rhizobiome inhabiting microbes play a sustainable and beneficial coordinated interaction in maintaining its microbial diversity and integrity in aquatic zone. Thus, lotus is not only highly esteemed aquatic ornamental plant for its sanctity with cultural and economic importance but it has a crucial nutraceutical, ecological, aesthetic and wastewater management potential too, adding sustainability to environment and life. Hence, its value to be honoured as well as its cultivation must be supported and promoted.

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Conflicts of interest

The authors declare no conflict of interest.

References

1. Acharya CVK, Srikanth K. Second Generation Biofuels from *Nelumbo nucifera* (lotus) Seeds. IJEDR,2014:2(4):3693-3696. Available from: https://www.ijedr.org/papers/IJEDR1404050.pdf
2. Aishwariya S, Thamima S. Sustainable textiles from Lotus. Asian Textile Journal,2020:28(10):56-59. Available from: https://www.researchgate.net/publication/340279701_Sustainable_textiles_from_lotus
3. Awal R, Rahmatullah SM, Nasrin S. Nutrient composition of lotus (*Nelumbo nucifera*) fruits. Asian Australas J Biosci Biotechnol,2020:5(3):115-120. Available from: https://www.researchgate.net/publication/360223529_Asian_Australasian_Journal_of_Bioscience_and_Biotechnology_Nutrient_composition_of_lotus_Nelumbo_nucifera_fruits
4. Baghel SS, Dubey S. Pharmacological Importance of *Nelumbo nucifera*: A Review. Asian J Pharm Educ Res,2017:6(1):60-71. Available from: http://www.ajper.com/admin/assets/article_issue/1485337910.pdf
5. Bangar SP, Dunno K, Kumar M, Mostafa H, Maqsood S. A comprehensive review on lotus seeds (*Nelumbo nucifera* Gaertn.): Nutritional composition, health-related bioactive properties, and industrial applications. J Funct Foods,2022:89:104937. Available from: https://doi.org/10.1016/j.jff.2022.104937
6. Bishayee A, Patel PA, Sharma P, Thoutireddy S, Das N. Lotus (*Nelumbo nucifera* Gaertn.) and Its Bioactive Phytocompounds: A Tribute to Cancer Prevention and Intervention. Cancers,2022:14:529. Available from: https://doi.org/10.3390/cancers14030529
7. Chen J, Ma X, Gao K, Wang Y, Zhao H, Wu H, *et al*. Study of the *Nelumbo nucifera* alkaloids and their main bioactive metabolites. Molecules,2012:17:9855-9867. Available from: https://doi:10.3390/molecules17089855
8. Chen S, Zheng Y, Fang JB, Liu YL, Li S. Flavonoids in Lotus (*Nelumbo*) leaves evaluated by HPLC–MS at the germplasm level. Food Res Int,2013:54(1):796-803. Available from: https://agris.fao.org/agris-search/search.do?recordID=US201900109083
9. Deng J. Systematic qualitative and quantitative assessment of anthocyanins, flavones, and flavanols in the petals of 108 lotus (*Nelumbo nucifera*) cultivars. Food Chem,2013:139(1-4):307-312. Available from: https://doi:10.1016/j.foodchem.2013.02.010
10. Deng J, Fu Z, Chen S, Damaris RN, Wang K, Li T, *et al*. Proteomic and Epigenetic Analyses of Lotus (*Nelumbo nucifera*) Petals Between Red and White cultivars. Plant Cell Physiol,2015:56(8):1546-1555. Available from: https://doi:10.1093/pcp/pcv077
11. Escaray FJ, Menéndez AB, Gárriz A, Pieckenstain FL, Estrella MJ, Castagno LN, *et al*. Ecological and agronomic importance of the plant genus Lotus. Its application in grassland sustainability and the amelioration of constrained and contaminated soils. Plant Sci,2012:182:121-133. Available from: https://doi:10.1016/j.plantsci.2011.03.016
12. Fatima T, Iftikhar F, Hussain SZ. Ethno-medicinal and pharmacological activities of lotus rhizome. Pharma Innov J,2018:7(4):238-241. Available from: https://www.thepharmajournal.com/archives/2018/vol7issue4/PartD/7-3-98-850.pdf
13. Goel A, Sharma SC, Sharga AN. The conservation of the diversity of *Nelumbo nucifera* (Lotus) at the National Botanical Research Institute. Lucknow India, Botanic Garden Conserv News,2001:3:52-54.
14. Guo HB. Cultivation of Lotus (*Nelumbo nucifera* Gaertn. sp. *nucifera*) and its utilization in China. Genet Resour Crop Evol,2009:56:323-330. Available from: https://doi.org/10.1007/s10722-008-9366-2
15. Hajela M, Srivastava R, Kaur J. A Review on Health Benefits of Lotus Seeds (*Nelumbo nucifera*). J Appl Sci Comput,2018:5(4):92.
16. Huang B, Ban X, ShengHe J, Tong J, Tian J, Wang Y. Hepatoprotective and antioxidant activity of ethanolic extracts of edible lotus (*Nelumbo nucifera* Gaertn.) leaves. Food Chem,2010:120(3):873-878. Available from: https://agris.fao.org/agris-search/search.do?recordID=US201301793853
17. Li Y, Zhu FL, Zheng ZW, Hu ML, Dong C, Diao Y, *et al*. Comparative population genomics reveals genetic divergence and selection in lotus: *Nelumbo nucifera*.

BMC Genomics,2020:21:146. Available from: https://doi.org/10.1186/s12864-

18. Lin Z, Zhang C, Cao D, Damaris RN, Yang P. The Latest Studies on Lotus (*Nelumbo nucifera*)-an Emerging Horticultural Model Plant. Int J Mol Sci,*2019:20:3680. https://doi.org/10.3390/ijms20153680*.
19. Liu Y, Ma SS, Ibrahim SA, Li EH, Yang H, Huang W. Identification and antioxidant properties of polyphenols in lotus seed epicarp at different ripening stages. *Food Chem*,2015:185:159-164. https://doi.org/10.1016/j.foodchem.2015.03.117.
20. Liu Z, Zhu H, Liu Y, Kuang J, Zhou K, Liang F, *et al*. Construction of a high-density, high-quality genetic map of cultivated lotus (*Nelumbo nucifera*) using next-generation sequencing. *BMC Genomics*,2016:17:466. https://doi.org/10.1186/s12864-016-2781-4.
21. Lobo V, Patil A, Phatak A, Chandra N. Free radicals, antioxidants and functional foods: Impact on human health. *Pharmacogn Rev*,2010:4(8):118-126. https://doi.org/10.4103/0973-7847.70902.
22. Man J, Cai J, Cai C, Xu B, Huai H, Wei C. Comparison of physicochemical properties of starches from seed and rhizome of Lotus. *Carbohydr Polym*,2012:88:676–683. Elsevier. https://doi.org/10.1016/j.carbpol.2012.01.016.
23. Mandal RN, Bar R. The Sacred Lotus an Incredible Wealth of Wetlands. *Resonance*,2013:732-736.
24. Min T, Bao Y, Zhou B, Yi Y, Wang L, Hou W, *et al*. Transcription Profiles Reveal the Regulatory Synthesis of Phenols during the Development of Lotus Rhizome (*Nelumbo nucifera* Gaertn). *Int J Mol Sci*,2019:20:2735. https://www.ias.ac.in/article/fulltext/reso/018/08/0732-0737.
25. Mukherjee PK, Mukherjee D, Majia AK, Rai S, Heinrichb M. The Sacred Lotus (*Nelumbo nucifera*) – phytochemical and therapeutic profile. *J Pharm Pharmacol*,2009:61:407–422. https://doi.org/10.1211/jpp/61.04.0001.
26. Orozco-Obando WSO. Evaluation of Sacred Lotus (*Nelumbo nucifera* Gaertn.) as an Alternative Crop for Phyto-remediation. *Ph.D Dissertation Graduate Faculty of Auburn University Auburn Alabama*, 2012. https://www.semanticscholar.org/paper/Evaluation-of-Sacred-Lotus-(Nelumbo-nucifera-as-an-OrozcoObando/e21b9b4af28b23c25000f527da5d876866aa688a.
27. Pal I, Dey P. A Review on Lotus (*Nelumbo nucifera*) Seed. *Int J Sci Res*,2015:4(7):2319-7064. https://www.ijsr.net/archive/v4i7/SUB156738.pdf.
28. Park E, Gyoung DK, Go MS, Kwon D, Jung IK, Auh JH, *et al*. Anti-inflammatory effects of Nelumbo leaf extracts and identification of their metabolites. *Nutr Res Pract*,2017:1(4):265-274. https://doi.org/10.4162/nrp.2017.11.4.265.
29. Patil K. Lotus Fibre: A new facet in textile and fashion. *Int J Humanit Soc Sci Invention*,2018:7(12):71-75. https://www.ijhssi.org/papers/vol7(12)/Ver-2/K0712027175.pdf.
30. Paudel KR, Panth N. Phytochemical Profile and Biological Activity of *Nelumbo nucifera*. *Evid Based Complement Alternat Med*, 2015. http://doi.org/10.1155/2015/789124.
31. Qi S, Zhou D. Lotus seed epicarp extract as potential antioxidant and anti-obesity additive in Chinese Cantonese Sausage. *Meat Sci*,2013:93(2):257-262. https://doi.org/10.1016/j.meatsci.2012.09.001.
32. Rahi P, Chaudhari D, Choudhary A, Silveira K, Narwade N, Dhotre D, *et al*. Prokaryotic communities adapted to microhabitats on the Indian lotus (*Nelumbo nucifera*) growing in the high-altitude urban Dal Lake. *Research Square*,2022. https://doi.org/10.21203/rs.3.rs-1421588/v1.
33. Rai S, Wahile A, Mukherjee K, Saha BP, Mukherjee PK. Antioxidant activity of *Nelumbo nucifera* (sacred lotus) seeds. *J Ethnopharmacol*,2006:104(3):322-327. https://doi.org/10.1016/j.jep.2005.09.025.
34. Sahu R, Chandravanshi SS. Lotus Cultivation under Wetland: A Case Study of Farmers Innovation in Chhattisgarh, India. *Int J Curr Microbiol Appl Sci*,2018:7:4635-4640. https://www.ijcmas.com/special/7/Rajeshwari%20Sahu%20and%20S.%20S.%20Chandravanshi.pdf.
35. Seair Exim Solutions. Lotus Flower Export Data of India with HS Code and Price. *Seair Exim Solutions*, 2022. https://www.seair.co.in/lotus-flower-export-data.aspx.
36. Seymour E, Graham P, Agcopra C, Willows K, Herbert B. Assessing Lotus for Wastewater Bioremediation. *RIRDC Publ*,2009:09/089. Australian Government. Rural Industries and Development Corporation. http://era.daf.qld.gov.au/id/eprint/2395/1/RIRDC_Final Report09-089.pdf.
37. Shad MA, Nawaz H, Hussain M, Yousuf B. Proximate composition and functional properties of rhizomes of Lotus (*Nelumbo nucifera*) from Punjab. *Pak J Bot*,2011:43(2):895-904. http://www.pakbs.org/pjbot/PDFs/43(2)/PJB43(2)0895.pdf.
38. Sharan M, Haldar S. Lotus (*Nelumbo nucifera*) - An Exploration of Hygro-waste for Textile Applications. *Acta Sci Agric*,2021:5(5):119-126. https://actascientific.com/ASAG/pdf/ASAG-05-0997.pdf.
39. Sharma OP. Selected families of dicotyledons. In: Plant Taxonomy,2nd ed. McGraw Hill Education Private Limited (India), 2021,229-230.
40. Sridhar KR, Bhat R. Lotus - A potential nutraceutical source. *J Agric Technol*. https://www.researchgate.net/profile/Rajeev-Bhat/publication/237669013_Lotus_A_potential_nutraceutical_source/links/0046352f5192a5741a000000/Lotus-A-potential_nutraceutical-source.pdf.
41. Srivastava HN. Practical Botany. 7th ed. Jalandhar (India): Pradeep Publications: 2000. p. 62-63.
42. Tian D, Tilt KM, Sibley JL, Woods FM, Dane F. Response of Lotus (*Nelumbo nucifera* Gaertn.) to Planting Time and Disbudding. *HortScience*,2009:44(3):656–659. https://doi.org/10.21273/HORTSCI.44.3.656.
43. Wang K, Deng J, Damaris RN, Yang M, Xu L, Yang P. Lotus-DB: an integrative and interactive database for *Nelumbo nucifera* study. *Database (Oxford)*,2015:1-8. http://lotus-db.wbgcas.cn.
44. Wu HM, Kao CL, Huang SC, Li WJ, Li HT, Chen CY. Secondary metabolites from the stems of *Nelumbo*

nucifera cv. Rosa-plena. *Chem Nat Compd*,2017:53(4). https://doi.org/10.1007/s10600-017-2126-9.
45. Wu M, Shuai H, Cheng Q, Jiang L. Bioinspired Green Composite Lotus Fibres. *Angew Chem Int Ed Engl*,2014. https://doi.org/10.1002/anie.201310656.
46. Yadav N, Tomar S. Lotus Fibre: An eco-friendly textile fibre. *Int Arch Appl Sci Technol*,2019:10(2):209-215. https://doi.org/10.15515/iaast.0976-4828.10.2.209215.
47. Yang Z, Yao Y, Sun M, Li G, Zhu J. Metagenomics. Reveal Microbial Effects of Lotus Root–Fish Co-Culture on Nitrogen Cycling in Aquaculture Pond Sediments. *Microorganisms*,2022:10:1740. https://doi.org/10.3390/microorganisms10091740.
48. Zhu HH, Yang JX, Xiao CH, Mao TY, Zhang J, Zhang HY. Differences in flavonoid pathway metabolites and transcripts affect yellow petal colouration in the aquatic plant Nelumbo nucifera. BMC Plant Biology,2019:19:277a. https://doi.org/10.1186/s12870-019-1886-8.
49. Zhu M, Liu T, Guo M. Current Advances in the Metabolomics Study on Lotus Seeds. Frontiers in Plant Science,2016:7:891. https://doi.org/10.3389/fpls.2016.00891.