Water chestnut - an aquatic crop of high nutritional and economicalimportance: A Conceptual Note

Abstract

The global food problem would be resolved to some extent by the production of water chestnuts. Moreover, waterlogging developed due to global warming would be better utilized by the cultivation of water chestnut. The cultivation of water chestnuts takes place in water bodies or ponds with depths ranging from 1.20 to 1.80 m as well as in shallow agricultural fields with depths of 0.30 to 0.45 m. The fruit of the water chestnut has considerable nutritional and economic significance. The entire herb and fruit of the water chestnut have been acknowledged in traditional medicine for their medicinal properties, serving as remedies for various diseases.

Introduction

Water chestnut (*Trapa natans*) is an annual aquatic angiosperm found in tropical and subtropical regions of the world such as India, China, and Italy. China has been emerged as the largest exporter of water chestnut in the world and accounts for about 42% (1.35 lakh crores) of total global export market value i.e. Rs 3.22 lakh crores. In India, it is extensively and commercially grown in states like Bihar, Uttar Pradesh, Madhya Pradesh, Odisha, Jharkhand, Karnataka, Rajasthan and Jammu Kashmir where commonly known as water chestnut in English and *Singhara* or *Paniphal* in Hindi. Madhya Pradesh alone has a credit of growing water chestnut in an area of approximately 5,000 hectares which fetches 20 to 25 crores of rupees annually. According to an estimate, the total area under cultivation of water chestnut in Uttar Pradesh has been recorded to be 918 hectares [1-3]. The total area sown under water chestnut in Bihar during 1998-99 was reported around 14,000 hectares; out of 14,000 ha, approximately 10% was used for Singhara-cum-fish culture. In 20222, India exported 185 tonnes of raw water chestnut fruit and earned Rs 1.45 crores only. The reason behind very slow pace of expansion of water chestnut cultivation is that not only in India, it is treated as a neglected crop but in whole world the aquatic plants are considered as a weed only which are found to be grown in eutrophicated water bodies [4-6]. Simultaneously, it has also been found that the aquatic crop can be used for the bioremidiation of aquatic bodies which have become massively polluted with heavy metals. But now a days, it has drawn the attention of the masses as a crop of immense industrial and medicinal importance. It is grown in ponds, land depressions, swamps, oxbow lakes, and ditches having depth of sweet water ranging from 0.30 m to 1.50 m. It does not grow well in acidic or saline water and soils [7,8]. Cultivation of water chestnut in cropping system mode with makhana and fisheries is a good option, especially for resource-poor farmers of north Bihar. In the wake of the growing demand of consumers for natural foods, having good therapeutic values, water chestnut offers excellent opportunities. Fishermen communities use this fruit as a substitute for cereals. The dried fruit contains about 11.2% moisture, 76.7% carbohydrate, 7.3% protein, 0.8% fat, 3% mineral elements and plenty of iodine including significant amounts of vitamins such as thiamine, riboflavin, nicotinic acid, vitamin C and vitamin A. The possibility of water chestnut cultivation in agricultural fields having a 45-60 cm depth of water has been standardized by the National Research Centre for Makhana, Darbhanga. This system is very easy to operate and provides an

opportunity to cultivate makhana, fodder and rabi crops in the same piece of land. It raises the crop intensity by 200-300%. The productivity potential of the high-yielding strain under field conditions is 16 to 20 t/ha whereas under pond conditions productivity goes up to 10-12 t/ha which further needs to be doubled i.e. 20 to 24 t/ha through the adoption of scientific methods of cultivation under pond condition. The growth and productivity potential of most aquatic plants differ on the depth of water and type of soil, water, and climate.

Habitat, Cultivation and Distribution

Water chestnut requires full sun, sluggish, nutrient-rich, fresh waters, and soft substrate. Water chestnut grows in waters 0.3 to 3.6 m deep but is most abundant in sheltered bodies of water about 2 m deep with soft, muddy bottoms. In areas where water chestnut is cultivated, farmers collect the seed and store the seed in water before planting in March of the following year. Following seed germination, lateral roots grow down from the hypocotyl to anchor the young seedlings. The adventitious roots that develop at the nodes of the main stem and its branches contain photosynthetic pigments, particularly chlorophyll, and perform both photosynthesis and the absorption of nutrients.

Fig 1. One whorl of leaves of water chestnutplant

Fig 2. Water chestnut growing in aquatic habitat

The flowers are few, white in colour with four petals and four green sepals. The inflorescence is solitary and axillary the pedicels being shorter than the petioles. The flowers are bisexual, perigynous with a disc above the stamen. The calyx is gamosepalous, four-lobed, and pubescent; two lobes persist and become spines of the fruit. The corolla is polypetalous, about twice as long as the calyx-tube, crenulated on the margin, pure white or slightly purple in colour. The androecium consists of four, two-celled, dorsifixed anthers that dehisce longitudinally. The gynaecium is half-inferior, pendulous and two-celled, with a solitary ovule in each cell.

Fig 3. White coloured Water chestnut flower

Pollination apparently occurs in the air; however, the pollen vector is unknown. Self-pollination possibly occurs before the flower opens. After pollination, the flower stalks droop downward beneath the water surface to facilitate fruit formation.

Cultivation techniques of water chestnut

Water chestnut is cultivated either in water bodies/ponds having water depth of 1.20-1.80 m or in 30-45 cm deep shallow agricultural fields.Traditionally it is grown in naturally formed high organic matter-rich ponds/ditches where seed sowing is not required, since leftover seeds of previous crops serve as planting materials for subsequent crops. However, its cultivation in new water bodies (ponds) requires an addition of FYM @ 15 t/ha followed by two to three wet ploughings of the field after that the fields must be filled with 45 cm depth of water. The bundle of three rootlets is planted at one point and another bundle of three rootlets is planted at a distance of 3 m and row to row distance should also be 3 m. In ponds, where transplanting of rootlets is not possible then seeds should be broadcasted @ 69 kg/ha.The transplanting of saplings is done in the month of June-July in agricultural fields. The harvesting of fruit in the pond is done with the help of a wooden boat.

Chemical properties of waters and soils of water chestnut-cum fish pond

Chemical properties of pond water

It was recorded that the chemical reaction (pH) of water ranged between 8.2 and 8.6. The alkalinity varied from 13.5 to 31.0 mg/L. The hardness of water ranged from 7.2 to 26.0 mg/L. The concentration of Ca and Mg was recorded between 1.65 to 7.31 mg/L and 0.52 to 2.25 mg/L, respectively. The free CO_2 content ranged from 3.4 to 16.7 mg/L. The water also showed the chloride content varying from 6.21 to 13.82 mg/L. The dissolved oxygen (O_2) was observed to be found between 2.41 and 9.26 mg/L. The above-mentioned chemical properties of water showed that underground irrigation water is highly suitable for the growth of carp fish and its introduction with water chestnut an aquatic crop of high economic importance.

Chemical properties of pond soil

The soils of the water chestnut-cum fish pond have exhibited soil properties as pH 7.25, EC 0.30 dS m^{-1}, organic carbon 0.52%, available N 265 kg ha^{-1}, available P 33 kg ha^{-1} and available K 440 kg ha^{-1}, available Fe 51 mg/kg, available Mn 25 mg/kg, available Cu 2.35 mg/kg, and available Zn 0.48 mg/kg. The above soil properties revealed the fact that water chestnut-fish integration maintained the soil reaction in neutral range which is caused due to continuous flooding of soil and deposition of organic matter into the soil. The electrical conductivity was also recorded far below the hazardous level. The organic carbon value ranged in the sufficiency level i.e., above the critical concentration. Water chestnut cum fish integration was also found to be highly beneficial in maintaining the available phosphorus and potassium contents in the optimum

level of fertility of the pond soil. Considering even the highest value of critical limits of Fe (6.5 mg/kg), Mn (1.4 mg/kg), Cu (0.22 mg/kg), and Zn (0.4 mg/kg), these pond soils appeared to be sufficiently rich in these micronutrients except available zinc (Zn) and suitable for cultivation of water chestnut and fishes.

Field system of water chestnut cultivation

The possibility of water chestnut cultivation in agriculture fields consisting of 30-45 cm depth of water has been standardized by the National Research Centre for Makhana, Darbhanga. This system is very easy to operate and provides opportunities to cultivate water chestnut and fodder crops in the same piece of land in the same year. It raises the crop intensity by 200-300%. The prerequisite for this system is to raise a nursery.

Fig 4. Water chestnut growing under field conditions in a water depth of 45 cm

Nutrient contribution to the soil by water chestnut (*Trapa natans*)

The quantum of the contribution of nutrients on decomposition of its biomass left out at the last harvesting of fruits to the soil system was not appreciable. It contributes 7.54 kg/ha/yr N, 14.40 kg/ha/yr P, 16.20 kg/ha/yr K, 3.66 kg/ha/yr Fe and 0.85 kg/ha/yr Mn to the soil system (Table 1). The total uptake of nutrients made by the plant was 21.91 kg/ha N, 21.58 kg/ha P, 17.40 kg/ha K, 1.48 kg/ha S, 3.83 kg/ha Fe, 0.878 kg/ha Mn, 0.035kg/ha Cu and 0.601 kg/ha Zn.

Table 1. Nutrient contribution to the soil by the decomposition of biomass of water chestnut plants

Sl. No.	Name of plant nutrients	Contribution to the soil kg/ha/yr
1.	Nitrogen (N)	7.54
2.	Phosphorus (P)	14.40
3.	Potassium (K)	16.25
4.	Sulphur (S)	0.80
5.	Iron (Fe)	3.66
6.	Manganese (Mn)	0.85
7.	Copper (Cu)	0.025
8.	Zinc (Zn)	0.394

The following aspects are taken under consideration for producing healthy plants.

1. Improved plant type
2. Soil and water properties
3. Improved cultural practices
4. Cultivation in cropping system mode
5. Climate (Rainfall)

1. Improved plant type

The first ever developed high-yielding variety *Swarna Lohit* i.e., red thornless fruit-bearing water chestnut plant is being distributed to the farmers for earning high income. The variety has been developed at the National Research Centre for Makhana, Darbhanga. The strain has a potential yield of 16 to 20 t/ha while the local variety yielded 10 to 12 t/ha. The variety has been developed through pure line selection. It is mildly resistant to the singhara beetle.

2. Soil and water properties

The most suitable soil for its cultivation is clayey or silty clay loam soil type as such soils retain water for a longer time. The soil should also be rich in nutrients like nitrogen (N), phosphorus (P), potassium (K), iron (Fe), manganese (Mn), zinc (Zn) and organic matter. The water chestnut plant is basically highly responsive to organic matter as well as nitrogen content. It has also been noticed that the plants growing in nutrient-rich soil are much less affected by any disease. The irrigation water should not be too salty and acidic; the pH of irrigation water should vary around neutrality.

3. Improved cultural practices

Nursery raising:

It is well known that nursery-raised plants have higher yield potential than direct-sown crops. Thus, the nursery raising technology in water chestnut crops was also introduced by the National Research Centre for Makhana, Darbhanga. Under this technology, the field is well prepared by two to three deep ploughing, however, before ploughing, for the proper nourishment of seedlings, fertilizers @ 120:60:60 kg/ha, respectively, of N, P and K in the combination of 15-20 t/ha compost is applied. Before puddling the soil should also be treated with cakes of neem/mahua /karanj @ 0.8-1.0 t/ha. These cakes help in keeping soil-borne diseases way from the rhizospheric region of plants. It would be more fruitful if the mixtures of these cakes (in equal proportion) are applied in the soil. The field is filled with water up to the 45 cm height of the bund and the plant rootlets are sown in the month of June or July. For transplanting in one-hectare area, an area of 182 m^2 is enough for raising the nursery. For transplanting in one hectare land area 30 kg seeds is broadcasted in a nursery area of 182 m^2. A water level of 45 cm height is maintained throughout the growing period of seedlings, i.e., from June to July. The seedlings are transferred from the nursery plot to the already prepared main field in the first week of August and transplanted at a distance of 3 m x 3 m. The same doses of nutrients are also applied in the main field where transplanting is to be done.

(i) Manures and Fertilizers

Being an aquatic plant, its requirement of some essential primary nutrients such as nitrogen (N), phosphorus (P) and potassium (K) is very high. The National Research Centre for Makhana, Darbhanga has studied the requirements of these nutrients for the water chestnut crop. The doses of NPK for the crop are @120:60:60 kg/ha. The one-third of N is applied at the time of puddling and the rest of the fertilizer amount is sprayed on the plant at an interval of 20 days while the whole amount of P and K is added in the soil during puddling. The organic fertilizer like compost is added @ 15-20 t/ha.

(ii) Irrigation

The requirement of irrigation water is very high like another aquatic plant. As it is transplanted during the monsoon season i.e. in the month of July when precipitation starts taking place; in the absence of good precipitation, two to three irrigation is essential for the better development of the crop. The bund of the field is raised to a height of 0.60 m and irrigation water is filled up to a height of 45 cm.

(iii) Weed control

The infestation of aquatic weeds is a major problem in filed cultivation. The weed plants which are commonly found in the water chestnut fields are *Marsilea quadrifolia, Sagitariaguanensis*, *Ipomoea aquatica* and *Ceratophylumdemersum*. The emergence of these weed plants is primarily suppressed by two-three deep puddling with the addition of neem cake @ 0.8 to 1.0 t/ha, chloropyriphos weedicide @ 3.0 ml/L solution. Further, the post-emergency weedicide such as glyphosate @ 5.0 ml/L is sprayed to kill these weeds.

Fig 5. Weed control technique

(iv) Insect-pest control

The most damaging insect is the Singhara beetle (*G. birmanica*Jacoby) (Chrysomelidae: Coleoptera) which generally infests the plant during the grand growth and fruiting stage of the plant. Both adults and grubs scrap the upper surface of green leaves causing severe defoliation. Singhara beetle, *G. birmanica* has a life cycle of 33-46 days under laboratory conditions. The beetle is mainly controlled by the application of weedicide imidacloprid @ 0.5 ml/L twice at an interval of 15 days. The other insect that affects the plant at the juvenile growth stage in the nursery block is aphid which is controlled by the application of neem oil @ 3.0 ml/L or imidacloprid @ 0.5 ml/L twice at an interval of 15 days. Aphids are among the most destructive insect pests on cultivated plants in temperate regions.

Life cycle of Singhara beetle:

Gravid females lay eggs on the upper surface of the leaves in small batches of 5-13 eggs. Whole life one female lays eggs up to 110-115. Egg viability ranged from 53-64 percent. The freshly laid eggs are small, round in shape, light yellow in colour and gradually turned to reddish brown in colour before hatching. The incubation period varied from 3.5 to 5.5 days. The neonate grubs are light brown in colour and gradually turn to dark brown with age. Immediately after hatching, they remain passive for a while and then gradually move to different directions on the leaf and start biting on the upper epidermis of the leaf. Larvae have three instars to become pupa. The duration of the total larval period ranged from 12 to 14 days. Full-grown larvae stop its feeding and became sedentary by settling on the leaf surface through a gummy secretion from its anus. The pupa is exarate, bright orange-yellow in colour. The pupal period ranged from 3-5 days. The adult beetles were bright yellow in colour immediately after emergence and gradually turned to greyish brown. It was also observed that adult beetles were sluggish in nature and fly occasionally.

To control this pest farmers are using many synthetic insecticides which may lead to resistance to insecticides, resurgence of target pests, residues in food, contamination of groundwater, adverse effects on human health and mortality of non-target organisms. The first insecticide resistance in India was reported in the Singhara beetle against DDT and BHC by Pradhan and his co-workers in 1963. So, bio control agents such as *Metarhizium anisopliae* IIVR strain (1 x 1010 cfu/ g) + Neem oil 1% or *Beauveria bassiana* IIVR strain (1 x 1010 cfu/ g) found effective for controlling of Singhara beetle.



Fig 6. Aults and eggs of singhara beetle Fig 7.Aphid-infested leaves

4. Cultivation in cropping system mode

The disease incidence in water chestnut crops may be decreased up to a certain level through its cultivation done in cropping system mode. The National Research Centre for Makhana has developed some popular water chestnut-based cropping systems such as Water chestnut-Makhana, and Water chestnut-Berseem. The Makhana-Water chestnut-Berseem has been found most economical and sustainable cropping system in terms of maintaining soil fertility.

5. Production potential of water chestnut

The plants start flowering after two months of transplanting thereafter 10 days of flowering fruiting starts. The fruiting continues up to the next two months i.e. up to the month of January, 202. The harvesting of fruit starts in the month of October and continues up to the month of January. Generally, harvesting of fruit is done at an interval of seven (07) days. Thus, a total of eight harvesting is done to get the maximum return. The length of a raw (Fresh) fruit varies from 5.0 to 7.5 cm and breadth is from 12 to 14.5 cm. The average weight of one raw fruit is 24 g including peels whereas the average weight of one peeled-off fresh kernel is 12 to 13 g. The density of singhara nut is 20% higher than the water as a result of this after detaching from the plant at the time of ripening the nuts sink in the water and accumulate at the soil surface which subsequently goes inside up to a depth of 5.0 cm below the mud. The viability of the seeds that have been settled in the mud for years together. The productivity potential of the high-yielding strain under field conditions is 16 to 20 t/ha whereas under pond conditions productivity goes up to 10 to 12 t/ha only. The productivity potential of local cultivars under field conditions varies up to 13 to 15 t/ha which fetches substantial earnings.

Fig 8. The yield potential of water chestnut

Fruit Description

The fruit develops under water. It is green to red in colour. The fruit is a one-seeded nut, triangular-shaped drupe, the fleshy layer of which soon disappears, leaving the hard endocarp. The endocarp bears upwardly projecting thorns or is thornless. The seeds are ex-endospermic and ripen under water, and become detached when ripe. The fruiting season starts in September which may

last up to the first week of December. Fruits ripen in about a month and can remain viable for up to about twelve years. Each seed can give rise to ten to fifteen rosettes, and each rosette may produce as many as twenty seeds. The total yield potential of the crop is 16-20 t/ha.

Nutritional properties of water chestnut

Nutritional values of raw and dry fruit of water chestnut are presented in Table 2 and Table 3.

Table 2. Nutritional value of raw fruit of water chestnut

Sl. No.	Parameters	% (g/100 g)	Parameters	% (g/100 g)
	Raw fruit		**Dry fruit**	
1.	Water	70.0	Water	11.7
2.	Carbohydrate	23.3	Carbohydrate	75.7
3.	Protein	4.7	Protein	7.3
4.	Fat	0.3	Fat	0.8
5.	Fibre	0.6	Fibre	1.4
6.	Minerals	1.1	Minerals	3.0

Table 3. Nutritional value of dry fruit of water chestnut

Sl. No.	Parameters	(mg/100 g)	Parameters	(mg/100 g)
1.	Calories (kcalories/100 g)	339	Iron (mg/100 g)	4.4
2.	Vitamin B1 (µg/100 g)	37.4	Manganese (mg/100 g)	5.0
3.	Vitamin B2 (µg/100 g)	1.4	Copper (mg/100 g)	1.5
4.	Phosphorus (mg/100 g)	205	Zinc (mg/100 g)	20.7
5.	Potassium (mg/100 g)	583	Total amylose (%)	16.1
6.	Sodium (mg/100 g)	44		
7.	Calcium (mg/100 g)	205		

Nutrient content (w/w) in plant tissues

Micronutrient concentrations in aquatic plants vary considerably according to the part of the plant as well as to the chemical characteristics of the elements. There is usually very little mobility of Mn from the roots to the leaves. The accumulation pattern of nutrients in the tissues of different parts of the plant varies a lot. The plant has shown higher concentrations of C, P, K and Zn in its leaves compared to its root and fruit parts. However, N was found to be contained in appreciably higher amounts in the tissues of fruits. While root parts of the plant were noted to be more efficient in the uptake of Fe, Mn and Cu. Free-floating macrophyte-like water hyacinth (*Eichhornia crassipes*) was found to be a heavy absorber of nutrients, particularly N and P and heavy metals from contaminated water. The uptake trend of nutrients in *T. natans* was highly efficient in absorbing the nutrients, particularly N, P, K, Cu and Zn which would help in lessening the pollution load of the polluted water bodies (Table 4). Most of the macrophytes have a tremendous capacity for recycling nutrients and heavy metals in aquatic ecosystems. The bio-remediation properties of water chestnuts resemble much with other aquatic macrophytes.

Table 4. Nutrient content of tissues of water chestnut (on dry weight basis/Gravimetric analysis)

Sl. No.	Elements	Leaves	Roots	Fruit
1.	C	32%	23%	--
2.	N	0.42%	0.26%	0.80%
3.	P	0.80%	0.68%	0.41%
4.	K	0.85%	0.70%	0.11%
5.	S	0.03%	0.05%	0.04%
6.	Fe	1989 mg/kg	2080 mg/kg	118 mg/kg
7	Mn	350 mg/kg	550 mg/kg	22 mg/kg
8.	Cu	15 mg/kg	17 mg/kg	10 mg/kg
9.	Zn	280 mg/kg	200 mg/kg	150 mg/kg

Economic Importance

The fruit of the water chestnut is a nut of much economical value. It is sold both fresh and boiled in street markets in India. With the introduction of a thornless selection of water chest germplasm, the growers on an average are easily earning an additional income (by selling raw fruit only) of Rs. 2, 68,800/- from the cultivation of the crop in one hectare area. The raw fruit of water chestnut is sold @ Rs 20/kg. The gross benefit obtained is Rs 4,00,000.00. In this way, the total net profit is 4,00,000.00-1,31,200.00 = 2,68,800.00.Detailed cost economics of water chestnut cultivation is presented in Table 5.

Table 5. Detailed cost economics of water chestnut cultivation

Name of parameters	Per unit input rate (Rs.)	Total Expenditure (Rs.)
Field preparation	3,000	3,000
Compost (15 tonnes)	15,000	20,000
Bio compost -8 quintal	5,000	
Chemical fertilizer	5,000	5,000
Cost of plantation in 1800 sq ft	4,000	4,000
Plantation	4,800	4,800
Weed control (03 times)	4,800 per unit time	14,400
Insect-pest control	1,500	3,000
Irrigation (06 times)	6,000	6,000
Harvesting of fruit (6 times) 20 tonne	3,000 per unit time	60,000
Transportation of raw seed (20 tonnes)	6,000	6,000
Miscellaneous	5,000	5,000
	Total cost	1,31,200.00

It has been recorded from Madhya Pradesh where it is grown in around 5,000 hectares of land which fetches 20 to 25 crores of rupees annually. The immature pulp of the fruit, called milky water chestnut, is eaten raw or cooked, while the mature pulp is used to prepare dishes after boiling and drying. Fresh and boiled water chestnuts are used not only as vegetables, but also in tea and in preparing curries. The kernels are dried and sold as nuts, and are also ground into flour for bread (chapattis or poories). The dried nuts (kernels) and flour are sold at Rs. 250 and Rs. 300/kg, respectively. The nutritive value of the fruits is similar to that of wheat. Water chestnut is also used for preparing tea in Japan, in the commercial production of wine, and for special food during festivals. A paste prepared by diluting the dough of water chestnut is an excellent diet for some patients.

Medicinal value

The medicinal values of the whole herb and fruit have been recognized in folklore medicine as a cure for various diseases. The whole herb has been reported for hepato-protective activity, antimicrobial activity, antibacterial activity, antitumor activity, antioxidant activity and free radical scavenging activity. The fruits have been used as an anti-inflammatory, anti-diarrhea, intestinal astringent, aphrodisiac antileprotic agent and in urinary discharges, fractures, bronchitis, and anemia. The fruits of *T. bispinosa*. have been identified as the Ayurvedic drug Shurangataka. It is also said to have cancer-preventing properties. Stem juice is used in ophthalmic preparations. The dimension of its starch particles ranges between 15 and 39 µ which is very near to those of potato's starch particles.

Conclusions

With the constant research carried out on the varietal development of water chestnut, it has been seen that the farmers have started growing improved thornless red colour water chestnut crops scientifically in their ponds or unused *chaur* lands. Farmers are happy with the newly identified thorn-less variety of water chestnut, as it is easy in plucking the fruit from the plants, transportation and post-harvest processing. Nutritional studies have also revealed the fact that it is no where inferior as compared to other nutritionally rich aquatic crops. As a result of this, the water chestnut growers are getting almost two-fold higher income in comparison to their local cultivar.

References

1. Hoque A, Davey MR, Arima S. Water chestnut: potential of biotechnology for crop improvement. Journal of New Seeds. 2009 Aug 21;10(3):180-95.
2. Rajkumar P, Rajithasri M. Water chestnut: Growing conditions, nutritional and phytochemical composition, novel extraction methods and health properties. Pharma Innov. Inl. J. 2022;11(7):599.
3. Kachare S, Tiwari S, Tripathi N. Water chest nut: biotechnological and pharmacological advances. Progressive Research-An International Journal. 2016;11:5149-56.
4. Hossain MK, Rahmatullah SM. Potentiality of water chestnut (Trapa natans) in aquaculture of Bangladesh. Soc. Sci. 2020;7(2):77-87.
5. Puste AM, Sarkar PK, Das DK. Balanced nitrogen economy as a flexible strategy on yield stabilizing and quality of aquatic food crops in wetland ecosystem. Science in China Series C: Life Sciences. 2005 Sep;48:980-7.
6. Nandy SK, Jana BB, Lahiri S, Ghosh P, Bhakta JN, Bag SK, Biswas JK, Jana S. CNP Ratio and Dose Regulated Production of Water Chestnut Trapa: Social and Environmental Implications. Russian agricultural sciences. 2018 Jul;44:318-25.
7. Chauhan JS, Singh HJ, Karmakar S. Traditional cultivation practices of water chestnut in Northeast India (Assam): a field survey. InInternational Conference of the Indian Society of Ergonomics 2021 Dec 8 (pp. 369-381). Cham: Springer International Publishing.

8. Akao S, Hosoi Y, Fujiwara T. Utilization of water chestnut for reclamation of water environment and control of cyanobacterial blooms. Environmental science and pollution research. 2014 Feb;21:2249-55.