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Water Chestnut (*Trapa natans*) a Crop of High Nutritional and Economical Importance-Recent Guidelines on Farming Practices

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The global food problem could 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 thornless Water chestnuts alone or along with fish 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 major carp fish could be successfully incorporated in the Water chestnut growing ponds. The water chestnut prefers to be grown in organic matter rich ponds or shallow lands. It has been found that *T. natans* is very efficient in absorbing nutrients, particularly N, P, K, Cu and Zn. The fruit of the Water chestnut has considerable nutritional and economical 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.

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1. INTRODUCTION

Water chestnut (*Trapa natans*) is an annual aquatic angiosperm [1] found in tropical and subtropical regions of the world such as India, China, and Italy. However, it is considered to be native to temperate and tropical Eurasia and Africa [2]. China has emerged as the largest exporter of water chestnut in the world and accounts for about 42% (1.35 lakh crores ≈38657 million $) of total global export market value i.e. Rs 3.22 lakh crores (1620 crores $). In India, it is extensively and commercially grown in states like Bihar, Uttar Pradesh, Madhya Pradesh, Odisha, Jharkhand, Karnataka, Rajasthan and Jammu Kashmir [3] 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 (24 to 30 lakh $) annually. According to an estimate, the total area under cultivation of water chestnut in Uttar Pradesh has been recorded to be 918 hectares. 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 [4]. In 2022, India exported 185 tonnes of raw water chestnut fruit and earned Rs 1.45 crores (1.74 lakh $). 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. Simultaneously, it has also been found that the aquatic crop can be used for the bioremediation of aquatic bodies which have become massively polluted with heavy metals [5,6]. Recently, it has drawn the attention of the wider populations 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. Cultivation of water chestnut in cropping system mode with makhana and fish is a good option, especially for resource-poor farmers of north Bihar [7,8,9,10,11]. “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” [12,13,14,15]. The possibility of water chestnut cultivation in agricultural fields having a 0.45-0.60 m 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 production 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 to meet out the ever increasing demand worldwide. The growth and production potential of most aquatic plants differ on the depth of water and type of soil, water, and climate.

2. 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” [4] “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” [16].

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.

Fig. 1. One whorl of leaves of water chestnut plant

Fig. 2. Water chestnut growing in aquatic habitat

The bisexual flowers are few, white in colour with four petals and four green sepals.

Fig. 3. White coloured Water chestnut flower

3. CULTIVATION TECHNIQUES OF WATER CHESTNUT

"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" [1]. However, its cultivation in new water bodies (ponds) requires an addition of FYM (N 0.75%, P_2O_5 0.20% and K_2O 0.5%) at the rate of 15 t/ha followed by two to three wet ploughings of the field after that the fields must be filled with 0.45 m 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 [17]. In ponds, where transplanting of rootlets is not possible. Seeds should be broadcast at the rate of 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.

4. 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 [Rohu (*Labeo rohita*), Catla (*Catla catla*), Mrigal *(Cirrhinus mrigala*) and common carp (*Cyprinus carpio*)] and its introduction with water chestnut an aquatic crop of high economic importance.

5. 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 [18]. 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 (4 dS m^{-1}). The organic carbon value ranged in the sufficiency level i.e., above the critical concentration (0.3%). 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" [18,10].

6. FIELD SYSTEM OF WATER CHESTNUT CULTIVATION

The possibility of water chestnut cultivation in agriculture fields consisting of 0.30-0.45 m 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.

7. NUTRIENT CONTRIBUTION TO THE SOIL BY WATER CHESTNUT (*Trapa natans*)

The contribution of nutrients on decomposition of harvest residues to the soil system was not appreciable. It contributed 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 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.

Fig. 4. Water chestnut growing under field conditions in a water depth of 0.45 m

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

Sl. No.	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

Source: Singh, [1].

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 distributed to the farmers for earning high income. The variety has been developed at the National Research Centre for Makhana, Darbhanga [19]. 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 (pH 6.8 to 7.4)

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 deep ploughing two to three times, however, before ploughing, for the proper nourishment of seedlings, fertilizers at the rate of 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 (*Azadirachta indica*)/mahua (*Madhuca longifolia*) /karanj (*Pongamia pinnata*) at the rate of 0.8-1.0 t/ha. These cakes help in keeping soil-borne diseases way from the rhizosphere of plants. It would be more beneficial if the mixtures of these cakes (in equal proportions) are applied in the soil. The field is filled with water up to the 0.45 m 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 broadcast in a nursery area of 182 m^2.

(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 at the rate of 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 FYM/compost is added at the rate of 15-20 t/ha.

Fig. 5. Weed control technique

(ii) Irrigation

The requirement of irrigation water is very high for all aquatic plant. As the plants are 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 0.45 m.

(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*, *Sagitaria guanensis*, *Ipomoea aquatica* and *Ceratophylum demersum*. The emergence of these weed plants is primarily suppressed by two-three deep puddling with the addition of neem cake at the rate of 0.8 to 1.0 t/ha.

(iv) Insect-pest control

The most damaging insect is the Singhara beetle (*Galerucella 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 [20]. Singhara beetle, *G. birmanica* has a life cycle of 33-46 days under laboratory conditions. The beetle is mainly controlled by the application of insecticide imidacloprid at the rate of 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 at the rate of 3.0 ml/L or imidacloprid at the rate of 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. One female can lay eggs up to 110-115 eggs in her lifetime. Egg viability ranges from 53-64 percent. The freshly laid eggs are small, round in shape, light yellow in colour and gradually turns to reddish brown in colour before hatching. The incubation period varies 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 ranges from 12 to 14 days. A full-grown larva stop its feeding and becomes 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 ranges from 3-5 days. The adult beetles are bright yellow in colour immediately after emergence and gradually turns 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 to be 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 to be most economical and sustainable cropping system in terms of maintaining soil fertility.

5. Production potential of Water chestnut

The plants start flowering two months after transplanting then after 10 days of flowering, the fruiting starts [21]. The fruiting continues for up to 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 interval of seven (7) days. Thus, a total of eight harvesting is done to get the maximum return [22]. The length of a raw (fresh) fruit varies from 0.05 to 0.075 m and breadth is from 0.12 to 0.145 m. The average mass of one raw fruit is 24 g including peels whereas the average mass 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 0.05 m below the mud. The viability of the seeds that have been settled in the mud for years together. The production potential of the high-yielding strain under field conditions is 16 to 20 t/ha whereas under pond conditions production goes up to 10 to 12 t/ha only.

Fig. 8. The yield potential of Water chestnut

8. 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 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.

9. 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 [23]. 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 [24,25,26,27,28]. 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. The uptake trend of nutrients in *T. natans* was highly efficient in absorbing the nutrients, particularly N, P, K, Cu and Zn which could help in lessening the pollution load of the polluted water bodies (Table 4). This much capacity of absorbing the nutrients from the soil-water system confirms that it has tremendous potential of recycling nutrients and heavy metals in aquatic ecosystems. The finding is in conformity with the findings of [29,30,31].

10. 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 at the rate of 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 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

Source: Jana, [32].

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		

Source: Singh et al. [20], Jana et al. [32].

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%	NA
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

Source: Singh [33] & Singh, et al. [26,34]
NA: Not available

Table 5. Detailed cost economics of Water chestnut cultivation

Name of parameters	Per unit input rate (Rs/ha)	Total Expenditure (Rs.)
Field preparation	3,000 (36.02 $)	3,000 (36.02 $)
Compost (15 tonnes) Bio compost -8 quintal	15,000 (180.08 $) 5,000 (60.03 $)	20,000
Chemical fertilizer	5,000 (60.03 $)	5,000 (60.03 $)
Cost of preparation of nursery in 167.22 m^2 land area	4,000 (48.02 $)	4,000
Plantation of rootlets in main field (10,000 m^2)	4,800 (57.63 $)	4,800
Weed control (03 times)	4,800 (57.63 $) per unit time	14,400
Insect-pest control	1,500 (18.01 $)	3,000
Irrigation (06 times)	6,000 (72.03 $	6,000
Harvesting of fruit (6 times) 20 tonne	3,000 (36.02 $) per unit time	60,000 (720.32 $)
Transportation of raw seed (20 tonnes)	6,000 (72.03 $)	6,000
Miscellaneous	5,000 (60.03 $)	5,000
	Total cost	1,31,200.00 (1575.11 $)

Source: Singh et al. [34]

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. 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.

11. MEDICINAL VALUE

"The medicinal values of the whole herb and fruit have been recognized in folklore medicine as a cure for various diseases" [35]. The whole herb has been reported for hepato-protective activity, antimicrobial activity, antibacterial activity [36], antitumor activity, antioxidant activity and free radical scavenging activity [37,38,4,39]. The fruits have been used as an anti-inflammatory, anti-diarrhoea, intestinal astringent, aphrodisiac antileprotic agent and in urinary discharges, fractures, bronchitis, and anaemia. 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.

12. CONCLUSION

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* (boul-shaped depression) 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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