

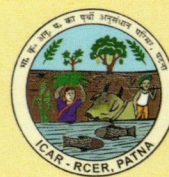
Scientific Cultivation of Water Chestnut (*Trapa natans*)



ICAR-Research Complex for Eastern Region, Patna

Research Centre for Makhana

Darbhangha - 846005, Bihar

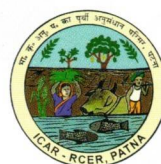


Scientific Cultivation of Water Chestnut (*Trapa natans*)

I.S. Singh, B.R. Jana, Manoj Kumar, Vinod Kumar Padala,
Dhiraj Kumar Singh, Ujjwal Kumar, A.K. Thakur,
Ashok Kumar and Dhiraj Prakash



ICAR-Research Complex for Eastern Region, Patna
Research Centre for Makhana
Darbhanga-846005, Bihar



Contents

Sl No.	Topic	Page No.
1.	Introduction to water chestnut	1
2.	Botanical description of plant	2
3.	Cultivation techniques of water chestnut	6
4.	Pond system of cultivation	6
5.	Field system of cultivation	7
6.	Economic analysis of water chestnut production per hectare	12
7.	Evaluation of different genotypes of water chestnut (<i>Trapa bispinosa</i>)	13
8.	The yield potential of water chestnut	18
9.	Economic importance	20
10.	Medicinal value	23
11.	Conclusion	24
12.	Suggested readings	24



Scientific Cultivation of Water Chestnut (*Trapa natans*)

Water chestnut (*Trapa natans*) is an annual aquatic angiosperm found in tropical and subtropical regions. It belongs to the family Lythraceae and order Myrtales. In India, it is commonly known as water chestnut in English and Singhara or paniphal in Hindi. It is treated as a neglected crop because nowhere in India as well as in whole world the crop is taken under the commercial cultivation. But now a days, it has been proved as a crop of immense industrial and medicine importance. Further, water chestnut has a vast potential pertaining to its nutritional qualities too, which is scientifically proved to be highly beneficial for human health. Moreover, it leaves all their biomasses in the same field where it grows. Hence, it contributes a lot of essential plant nutrients to the soil mass. Keeping in view of its vast importance, a scientific work was conducted at this Research Centre for Makhana, Darbhanga to develop a high yielding variety. The Centre is involved in scientific study of other aquatic crops of high commercial value along with makhana. Earlier, water chestnut was mainly grown in naturally formed ditches, shallow land or ponds in high rainfall areas. Therefore, the poor fishermen could not harvest its full potential to a larger extent.

Introduction to water chestnut

Water chestnut is mainly distributed in temperate and tropical Asia and central and South-East Europe. However, it group well in tropical subtropical and tempertate regions of the war In India, it is extensively grown in the states of Bihar, Madhya Pradesh, Uttar Pradesh, West Bengal, Odisha, chhattisgarh, Jharkhand, Karnataka and Jammu Kasmir. On the basis of morphology of fruits of water chestnut, it is of two types: one is thorny and another one is thorn less. In Bihar, only red colour thorny fruit bearing water chestnut is found. However, in other states like Madhay Pradesh and Uttar Pradesh, both the thorn less and thorn bearing fruit plants are found. For the varietal development programme, the germplasms of water chestnut have been collected from Darbhanga districts of north Bihar and different parts of Madhya Pardesh. Out of 13 collected thorn less germplasms from Madhya Pardesh, 08 were of red colour and 05 of green colour. Some thorn less germplasm were also collected from Odisha, Jharkhand and Uttar Pradesh.

The species is characterised by free floating plants with submerged and floating leaves. Its floating leaves are arranged in a rosette. Individually, the 2-4 cm long upper leaves are slightly rhombic to rhombic-ovate and are sharply dentate along the leaf margins. There are conspicuous veins on the lower surface as well as short, stiff hairs. An air bladder is located at the base of the floating leaves, and the leaf margins are wavy. The submerged lower leaves are alternate and feather-like and can reach up to 15 cm long. The petioles of the floating leaves are 0.6-1.8 m (2-6 ft.) long. The inconspicuous white flowers consist of four 8 mm long, white petals and four green sepals, located in the centre of the rosette. Flowering begins in the in the month of August.

The plant is commercially cultivated for its nutritious nuts. The number of thorn like structure varies from 2-4 per fruit which develops on 2-4 cm wide fruits. Fruits ripen in a

month and can remain viable up to years together. The dried fruit contains about 11.7% 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, vitamin A and phosphorylases, whereas the raw fruit contains 70% water, 23.3% starch (carbohydrate), 4.7% protein, 0.3% fat, 0.6% fibre and 1.1% minerals. It is cholesterol and gluten free. The fruit can be consumed raw, boiled, roasted or dried to make flour. When the fruit has been dried, it is grounded to flour called *singhare ka atta* which is used in many religious rituals and can be consumed as a *Phalahar* (Salt less Fruit diet) during the Hindu fasting days, in Indian traditional festival “*Navratri*” and other religious occasions.

Trapa bispinosa, another species of water chestnut, is an important plant of Indian Ayurvedic system of medicine which is used in the problems of stomach, genito-urinary system, liver, kidney, and spleen. It is bitter, astringent, stomachic, diuretic, febrifuge, and antiseptic. The whole plant is used in gonorrhoea, menorrhagia, and other genital problems. It is useful in diarrhoea, dysentery, ophthalmopathy, ulcers, and wounds. Water chestnut is also beneficial for women. Due to its nutritive, strengthening and cooling properties, it increases fertility and chances of conception. It is rich in proteins, carbohydrates, Vitamin B, C, iron, calcium, magnesium, phosphorus, and iodine and helps to stabilise pregnancy and prevent abortion. These are also used in the validated conditions in pitta, dipsea, dyspepsia, haemorrhage, haemoptysis, diarrhoea, intermittent fever, leprosy, fatigue, inflammation, fractures, pharyngitis, bronchitis and general debility, and also suppress stomach and heart burning.

Botanical Description of plant

Water Chestnut is an annual hydrophilic aquatic angiosperm found in tropical and subtropical regions of the world. It is a floating leaved rooted plant. The species is characterised by free floating plants with submerged and floating leaves. Water chestnut rarely grows where the substrate is low in organic matter. The swiftly flowing water and sharp fluctuations in water level can be detrimental to its survival. The parent plant is killed by frost in autumn and decomposes quickly. It grows in water about 60 cm deep. It roots in mud with finely divided, alternate, feather like submerged leaves which can reach up to 15 cm long. The stems of water chestnut are stoloniferous and branched with long internodes, the latter being longer towards the base of the plant. The floating leaves are simple, petiolate, and stipulate, form rosette, rhomboidal in shape with saw tooth margins. The upper surfaces are dark green and the lower surface light green or reddish purple. The leaves connect to swollen, air filled petioles that

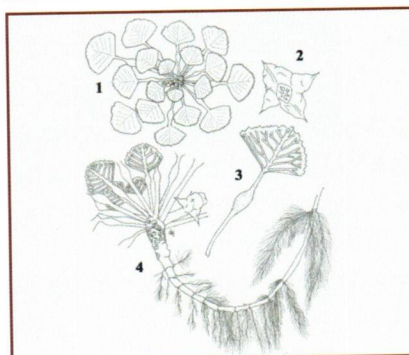


Fig 1: The distinguishing rosette (1), nut (2), leaflet showing buoyancy bladder (3) and root stalk with filiform rootlets (4) of *T. natans*.

keep the upper part of the plant afloat. Leaves at the seedling stage are strap-shaped with a serrated margin; the normal, adult leaves develop later. The nuts are 20 per cent heavier than water upon maturity, and sink rapidly to the bottom where they overwinter in the sediment. Seeds are capable of remaining dormant in bottom sediments for years together; however, seeds quickly lose viability if allowed to dry out.

Vernacular names of water chestnut

English: Water chestnut, Caltrop, Singhara nut

Hindi: *Singhara*, *Singhada*

Malyalam: *Karimphola*

Sanskrit: *Shringataka*

Tamil: *Cimkhara*

Telgu: *Kubjakamu*

Taxonomy

The genus *Trapa* is currently placed in the Lythraceae although previously segregated as the Trapaceae or Hydrocaryaceae. Shiskin and Borov (1974) listed 25 species for the U.S.S.R alone. Botanists have recognized species, of *T. bispinosa* comprising of two varieties: *T. natans* var. *natans* L. and *Trapa bispinosa* Roxb. *Trapa natans*, are now widely distributed in Eurasia, Africa and North Eastern United States. Two stout curved horns (thorns) bearing fruit of water chestnut are popular in Eurasia, Africa & North Eastern United States. Some species of *Trapa natans* are thornless and found abundantly in Asiatic countries.

Scientific classification of water chestnut

Kingdom: Plantae (Unranked) : Angiosperms (Unranked) : Eudicots (Unranked) :
Resides

Order: Myrtales

Family: Lythraceae

Sub-family: Trapoideae

Genus: *Trapa*

Species : *natans*, *bicornis*, *rossica*, *bispinosa*

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 0.6 m deep but is most abundant in sheltered bodies of water about 1.5 m deep with soft, muddy bottoms. It prefers sweet water for better growth as it fails to germinate in acidic and highly saline water. The plant is also intolerant to $\text{Ca}(\text{HCO}_3)_2$ and $\text{Mg}(\text{HCO}_3)_2$. 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 2: One whorl of leaves of water chestnut plant



Fig. 3: Water chestnut growing in aquatic habitat

Floral biology

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. The flowers are generally pollinated by insects.



Fig. 4: White coloured Water chestnut flower

Self-pollination possibly occurs before the flower opens. After pollination the flower stalks droop downward beneath the water surface to facilitate fruit formation.

Propagation

Propagation of the plant is done through both seed (nut) and plantlets. Each nut can produce 10-15 plants and each of these plants may produce up to 20 seeds. However, the commercial propagation is done mainly through seeds only. The fully mature nuts are placed in plastic net bags dipped under water or container with little water to germinate the seeds. The sprouted seeds are stored out and same is broadcasted in nursery fields. At the beginning of the monsoon i.e. in the month of second week of June or First week of July, the seedlings/plantlets are collected from the nursery blocks and planted in the main fields at a spacing of 1-3 meters.

Storage

Harvested kernels can be stored in the cool chambers where temperature is maintained at 8 to 10°C in sealed plastic bags or containers to prevent from drying out. Some kernels get rot after some times of packing, therefore the same need to be sorted out to prevent the rotting of other safe kernels. Rotting of kernels generally takes place in those kernels which have been damaged during harvesting and latter handling. In this way, the kernels can be stored for one year under viable condition for further cultivation.



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 45-60 cm deep shallow agricultural fields.

Ponds system of cultivation

Traditionally, it is grown in naturally formed high organic matter rich ponds/ditches where seed sowing is not required, since leftover seeds of previous crop serve as planting materials of 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 maintained at 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 pond is done with the help of wooden boat.

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

Chemical properties of pond water: It grows well in full sun, low energy, nutrient rich fresh water. It is commonly found in water with alkalinity ranging from 12-128 mg/L of calcium carbonate. It dislikes calcium rich water. Its germination can occur in water with PH ranging from 4.2 to 8.3. It was recorded that the chemical reaction (pH) of water ranged between 6.6 and 7.8. The alkalinity varied from 60 to 78 mg/L; 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 CO₂ 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 (O₂) was observed to 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 fishes too.

Chemical properties of pond soil: The soils of the water chestnut-cum fish pond have exhibited the soil properties such as pH 7.25, EC 0.30 dS m⁻¹, organic carbon 0.52%, available Nitrogen 265 kg ha⁻¹, available Phosphorus 33 kg ha⁻¹ and available Potash 340 kg ha⁻¹. In addition to that an 51 mg/kg available Iron (Fe) content, 25 mg/kg available Manganese (Mn), 2.35 mg/kg, average Copper (Cu) and 0.48 mg/kg available Zinc (Zn) were also recorded in the pond soil. 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 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).

Field system of water chestnut cultivation

The possibility of water chestnut cultivation in agriculture fields consisting 45-60 cm depth of water has been standardized by the Research Centre for Makhana, Darbhanga. This system is very easy to operate and provides opportunities to cultivate makhana and fodder crops in the same piece of land in same year. It raises the crop intensity by 200-300%. The prerequisite for this system is to raise a nursery.



Fig. 5: Water chestnut growing under field condition in a water depth of 45 cm

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

Research showed that the quantum of contribution of nutrients on its decomposition of biomass to the soil system was not appreciable. It is 7.54 kg/ha/year Nitrogen, 14.40 kg/ha/year Phosphorus, 16.20 kg/ha/year Potassium, 3.66 kg/ha/year Iron and 0.85 kg/ha/year manganese. The total uptake of nutrients made by water chestnut 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 an on yearly basis.

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/year
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 into consideration for producing healthy plants of water chestnut.

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 quality strains (JR-2) of red thornless fruit bearing water chestnut plant is being distributed to the farmers for earning high income. The strain has been developed at ICAR-RCER, Research Centre for Makhana, Darbhanga and the same strain is in the pipeline to be developed as first ever variety of water chestnut. The strain has potential yield of 16 to 20 t/ha while local variety yielded 10 to 12 t/ha. The strain has been developed by pure line selection. The strain is mildly resistant to singhara beetle.

2. *Soil and water properties*

The most suitable soil for its cultivation is clayey or silty clay soil type as such soil retains water for longer time. The soil should also be rich in nutrients like nitrogen, phosphorus, potassium, iron, manganese, zinc and organic matter. The water chestnut plant is primarily highly responsive to organic matter as well as the nitrogen content. It has also been noticed that the plants growing in nutrient rich soil are very less affected by any kind of diseases. The irrigation water should not be too salty and acidic and the pH of irrigation water should vary around neutrality.

Table 2: Classification of soil and water properties for cultivation of water chestnut

Sl. No.	Parameters	Unproductive	Less productive	Highly productive
	Water			
01.	pH	< 6.0	6.0 – 6.5	6.5 – 7.8
02.	Total alkalinity (ppm)	< 30	30 - 90	> 90
03.	Inorganic nitrogen (ppm)	< 0.1	0.1 – 0.5	0.5 – 1.5
04.	Orthophosphate (ppm)	< 0.05	0.05 – 0.2	0.2 – 1.0
05.	Dissolved oxygen (ppm)	< 2.0	2.0 – 6.0	6.0 – 9.0
	Soil			
01.	pH	< 6.0	6.0 – 7.0	7.0 – 8.0
02.	EC (d S/m)	< 2.0	2.0 – 3.0	3.0 – 4.0
03.	Organic carbon (%)	< 0.3	0.3 – 0.5	> 0.5

Sl. No.	Parameters	Unproductive	Less productive	Highly productive
04.	Available N (kg/ha)	< 250	250 - 300	>300
05.	Available P (kg/ha)	< 10	10 - 20	>20
06.	Available K (kg/ha)	< 100	100 - 250	>250
07.	Available Fe (ug g-1 d.w.)	< 10	10 -20	> 20
08.	Available Mn (ug g-1 d.w.)	< 4	4 - 6	> 6
09.	Available Cu (ug g-1 d.w.)	< 0.5	0.5 – 0.7	> 0.7
10.	Available Zn (ug g-1 d.w.)	<0.2	0.2 – 0.5	> 0.5

3. Improved cultural practices

3.1 Nursery raising:

It is well known that nursery raised plants have higher yield potential than the directly sown crop. 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 / ha, respectively, of N, P and K in combination of 15-20 t/ha compost is applied. Prior to puddling, the soil should also be treated with cakes of neem/mahua /karanj @ 0.8-1.0 t/ha. These cakes help in keeping the soil-borne diseases at bay 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 agricultural field is filled with water up to the 45 cm height of bund and the plant rootlets are sown in the month of June or July. For transplanting in one-hectare area, an area of 182 m² is enough for raising the nursery. **For transplanting in one hectare land area 3.0 kg seeds is broadcasted in nursery area of 182 sq m.** The 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 July and transplanted at a distance of 3 m x 3 m. i.e. plant to plant and now to row. Same doses of nutrients are also applied in the main field where transplanting is to be done.

3.2 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 Research Centre for Makhana, Darbhanga has studied the requirements of these nutrients for the water chestnut crop. The doses of NPK for the crop is @120:60:60 kg/ha. The one third of N is applied at the time of puddling and the rest of the fertilizer quantity 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.

3.3 Irrigation

The requirement of irrigation water is very high like any other aquatic plant. As it is transplanted during the monsoon season i.e. in the month of July when precipitation starts to take place. In the absence of good precipitation, five to three irrigation is essential for the better development of the crop. The bund of the field is raised up to a height of 2.0 ft and irrigation water is field up to a height of 45 cm.

3.4 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*, *Sagittaria guianensis*, *Ipomoea aquatica* and *Ceratophyllum demersum*. and hydrilla verticillata. The emergence of these weed plants is primarily suppressed by two to three deep puddling with the addition of neem cake @ 0.8 to 1.0 t /ha, and chloropyriphos weedicide @ 3.0 ml/L solution. Further, the post emergence weedicide such as glyphosate @ 5.0 ml/L can be applied to kill these weeds.

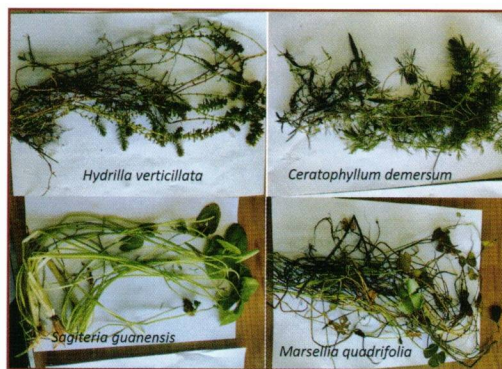


Fig. 6: Different types of weed found in water chestnut field

3.5 Insect-pest control

The most damaging insect of water chestnut is singhara beetle (*G. birmanica* Jacoby) (Chrysomelidae: Coleoptera) which generally infests the plant during the grand growth and fruiting stage of the plant. Both adult and grubs scrap the upper surface of green leaves causing severe defoliation. Singhara beetle, *G. birmanica* has life-cycle of 33-46 days under laboratory conditions. The beetle is mainly controlled by

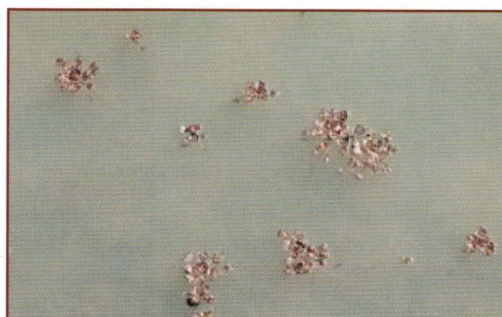


Fig. 7: Aphid infested leaves of water chestnut

application of weedicide imidacloprid @ 0.5 ml/L twice at an interval of 15 days. The other insect which affects the plant at juvenile growth stage in the nursery block is aphid which is controlled by 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

Egg

Gravid females lay eggs on upper surface of the leaves in small batches of 5-13 eggs. In whole life, one female lays eggs up to 110-115 in number. Egg viability ranged from 53-64 per cent. The freshly laid eggs 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.

Grub

The neonate grubs are light brown in colour and gradually turned 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 started biting on the upper epidermis of the leaf. Larvae has three instars to become pupa. Duration of the total larval period ranged from 12 to 14 days. Full grown larvae stops its feeding and became sedentary by settling itself on leaf surface through a gummy secretion from its anus.

Pupa

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.

Management

To control this pest, farmers are using many synthetic insecticides which may lead to resistance to insecticides, resurgence of target pest, residues in food, contamination of groundwater, adverse effect on human health and mortality of non-target organisms. The first insecticide resistance in India reported in Singhara beetle against DDT and BHC by Pradhan and his co-workers in 1963. So, bio control agents such as *Metarhizium anisopliae* IIVR strain (1×10^{10} cfu/ g) + Neem oil 1% or *Beauveria bassiana* IIVR strain (1×10^{10} cfu/ g) found effective for controlling of Singhara beetle.



Fig. 8: Adults of Singhara Beetle



Fig. 9: Eggs of Singhara Beetle

4. Cultivation in cropping system mode

The disease incidence in water chestnut crop may be decreased up to a certain level by doing its cultivation in cropping system mode. The Research Centre for Makhana, Darbhanga has developed some popular water chestnut based cropping systems such as makhana-water chestnut, and Water chestnut - Berseem. The makhana - water chestnut - berseem has been found most economical and sustainable cropping system in terms of maintaining the soil fertility too.

Harvesting and yield of Water chestnut

The plants start flowering after two months of transplanting. After 10 days of flowering in plants, fruiting starts. The fruiting continues up to the next three months i.e. up to the month of December. The harvesting of fruit starts in the month of October and continued up to the month of January. Generally, harvesting of fruit is done at an interval of ten 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 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 get accumulated at the soil surface which subsequently go inside up to a depth of 5.0 cm below the mud. The viability of the seeds which have been settled in the mud is up to years together. The productivity potential of the high yielding strain under field condition is 16 to 20 t/ha whereas under pond condition productivity goes up to 10 to 12 t/ha only. The productivity potential of local cultivar under field condition varies up to 13 to 15 t/ha.



Fig. 10: Harvesting of Singhara fruit from field condition

Economic analysis of water chestnut production per hectare

The cultivation of water chestnut was analysed economically in terms of costs and benefits. It was observed that cost of cultivation per ha for water chest nut comes around Rs 1.15 lakhs. The yield of water chestnut fruit is generally 15 t/ha if crop is healthy at field. Keeping in mind the average price of water chestnut fruits in Indian market @ Rs 20 per kg, the gross return is Rs 3.0 lakhs per ha. After deducting the cost of cultivation, the net return from water Chestnut cultivation comes around 1.7 lakhs per ha which is a very good return. Many cash crop cannot provide this returns in such a short span of time.

Table 3: Component wise cost 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

Name of parameters	Per unit input rate (Rs.)	Total Expenditure (Rs.)
Insect-pest control	1,500	3,000
Irrigation (06 times)	6,000	6,000
Harvesting of fruit (6 times) 15 tonne	3,000 per unit time	45,000
Transportation of raw seed (15 tonnes)	6,000	45,00
Miscellaneous	5,000	5,000
Total cost		1,14,700.00

Evaluation of different genotypes of water chestnut (*Trapa bispinosa*)

Several germplasm of water chestnut were collected and evaluated at Research Centre on Makhana, Darbhanga. In case of Jabalpur Red 1 to Jabalpur Red 8 (JR-1 to JR-8), numbers of days required for first flowering varied from 56 to 62 days. In case of green colour germplasm of water chestnut, numbers of days required for first flowering varied from 60 to 65 in JG1 (**Jabalpur Green 1**) to JG5 (Jabalpur Green 5). Similarly, it was observed that DR1 (**Darbhangha Red 1**) and DR2 (Darbhanga Red 2) took 60 days for flowering. Again, fruit set started within 63 to 70 days in JR after planting and it was 69 to 73 in JG. Similarly maturity of fruit started between 95 and 104 days after planting in case of JR, JG and DR. There was marked variation in root length per plant. It was maximum in case of JR2 (255 cm) followed by JR1. Among the JG germplasm, JG4 recorded the maximum root length (233 cm). Similarly, the highest length of fruit bearing branches was found in JR2 (65 cm) and JG4 (48.55 cm). No marked differences were observed in leaf size of all the collected germplasm.

Table 4. Growth parameters of water chestnut plants

Genotype	Flowering	Fruit set	Fruit maturity	No. of leaves per plant	Leaf size LXB cm	Root length cm	Length of fruiting branch cm
JR1	58	66	97	99	6x8	185	55.32
JR2	56	63	95	104	7x8	255	65.00
JR3	60	68	97	89	6x9	160	62.00
JR4	57	66	98	101	6x8	190	57.65
JR5	60	67	100	102	5x7	109	50.35
JR6	59	67	96	103	5x8	140	54.65
JR7	60	67	98	102	6x9	180	60.40
JR8	62	70	98	105	6x8	165	58.20
JG1	60	69	101	101	6x9	211	47.25
JG2	62	71	102	101	6x9	202	46.00
JG3	64	71	104	102	5x7	195	45.00

Genotype	Flowering	Fruit set	Fruit maturity	No. of leaves per plant	Leaf size LXB cm	Root length cm	Length of fruiting branch cm
JG4	63	72	100	100	5x8	233	48.55
JG5	65	73	104	99	6x9	165	10.35
DR1	60	68	102	105	5x7	194	52.60
DR2	60	67	100	111	6x7	210	60.45

All the local collection namely DR group had three spines on the body of the fruit. The colour of mature fruit was red in JR and DR while it was green in JG. The size of whole fruit as length and breadth varied from 5.1x12.6 cm to 7.3x14.3 cm in JR. The maximum fruit size was noticed in JR2. Among the JG germplasm, JG4 again recorded the highest fruit size (6.3x13.5 cm). But, maximum kernel size varied from 4.57x11.45 cm to 7.01x13.65 cm and 4.4x11.74 to 5.35x12.78 cm in JR and JG4, respectively. The variation in weight of kernel was at par in all the collections. Weight of individual fruit as well as kernel was also found to vary in different collections. Fruit weight ranged from 25 g in JR2 to 24.1 g in JR5. Accordingly, in case of JG collections, it varied from 20.9 g in JG4 to 20.4 g in JG1. The variation between fruit weight and kernel was obviously due to content of skin of fruit which has not been worked out separately. Marked variations in number of fruits plant were recorded among the collected germplasm. **The maximum number of fruit per plant was found in JR2 followed by DR2 and JG4. Thus, it can be concluded that JR germplasm is having the highest yield potential as compared to JG and DR collections.**

Table 5. Yield parameters of water chestnut plants

Genotype	Colour of fruit	Fruit size LxB cm	Kernel size LXB cm	Weight per fruit (g)	Weight per kernel (g)	Kernel (%)
JR1	Red	6.1x13.6	5.61x13.2	24.3	12.72	47.65
JR2	Red	7.3x14.3	7.01x13.65	25.0	13.69	45.24
JR3	Red	6.5x13.4	5.75x12.61	24.5	13.42	45.22
JR4	Red	5.1x12.6	4.57x11.45	24.6	12.48	49.26
JR5	Red	5.2x12.2	4.78x11.40	24.1	13.26	44.97
JR6	Red	6.0x13.5	5.24x12.87	24.5	11.42	53.38
JR7	Red	7.0x14.0	6.08x13.36	24.8	12.44	49.83
JR8	Red	7.1x14.1	6.53x13.46	24.6	13.50	45.12
JG1	Green	5.0x12.3	4.4x11.74	20.4	12.46	38.92
JG2	Green	5.1x11.6	4.71x10.26	20.8	12.77	38.60
JG3	Green	5.4x13.2	4.91x12.62	20.5	11.56	43.60

Genotype	Colour of fruit	Fruit size LxB cm	Kernel size LXB cm	Weight per fruit (g)	Weight per kernel (g)	Kernel (%)
JG4	Green	6.3x13.5	5.35x12.78	20.9	12.45	40.43
JG5	Green	6.0x13.0	5.08x11.50	20.5	12.66	38.24
DR1	Red	5.2x9.3	4.66x8.61	22.0	11.56	47.45
DR2	Red	5.7x11.5	4.93x10.68	22.5	11.57	48.57

All the collection had same self-life and storage life at 10°C. Both parameters were slightly lesser in case of local collections. **Number of fruiting branches was found to be maximum in JR2 (7) followed by JG4 (6) and Dr2 (5).** Thus, the marked variation in yield per plant was noticed among the collections.

Table 6. Nutritional properties of water chestnut plants

Genotype	No. of fruiting branches	Wt. of 10 raw fruit (g)	Shelf life (days)	Storage life at 10°C	Total soluble solid (°B)	Juice (%)
JR1	5	243	4.0	8.0	9.0	51.0
JR2	7	250	4.0	8.0	9.2	53.3
JR3	4	245	4.0	8.0	8.4	52.0
JR4	3	246	4.0	8.0	8.4	52.3
JR5	5	241	4.0	8.0	8.2	52.1
JR6	5	245	4.0	8.0	8.4	52.3
JR7	4	248	4.0	8.0	9.1	52.5
JR8	5	246	4.0	8.0	8.6	52.2
JG1	5	204	4.0	8.0	7.3	56.20
JG2	5	208	4.0	8.0	7.5	56.52
JG3	6	205	3.5	8.0	7.2	56.41
JG4	6	209	4.0	8.0	7.5	57.00
JG5	6	205	4.0	8.0	7.2	55.41
DR1	5	220	3.0	6.0	6.4	52.50
DR2	5	225	3.0	6.0	6.6	52.70

Pertaining to fat, fibre, water and mineral contents of fruit, no marked variation was observed among all the collections. However, the values of different quality parameters showed that the JR2 was the superior one among all the collected germplasm as the maximum protein (5.1%), carbohydrate (25%) and minimum acidity (0.242%) was recorded in JR2 only. The nutritional properties of water chestnut is shown in following table.

Table 7. Nutritional qualities of raw water chestnut plants

Genotype	Acidity (%)	Total sugar (%)	Protein (%)	Fat (%)	Fibre (%)	Water (%)	Carbo Hydrate (%)	Mineral (%)
JR1	0.244	4.63	4.3	0.3	0.4	71	23	1.0
JR2	0.242	4.70	5.1	0.2	0.5	69	25	1.2
JR3	0.244	4.64	4.4	0.2	0.4	70	24	1.0
JR4	0.243	4.65	4.0	0.3	0.5	71	23	1.2
JR5	0.246	4.62	4.2	0.3	0.3	72	22	1.2
JR6	0.248	4.64	3.6	0.2	0.2	72	23	1.0
JR7	0.246	4.67	4.3	0.2	0.5	71	23	1.0
JR8	0.243	4.65	4.5	0.2	0.3	70	24	1.0
JG1	0.265	3.94	4.2	0.3	0.5	72	22	1.0
JG2	0.265	3.96	4.3	0.2	0.5	70	24	1.2
JG3	0.262	3.95	4.2	0.2	0.6	73	21	1.0
JG4	0.260	3.98	5.5	0.1	0.4	70	23	1.0
JG5	0.263	3.94	4.3	0.2	0.5	70	25	1.0
DR1	0.292	3.78	3.0	0.2	0.6	72	23	1.0
DR2	0.290	3.82	3.1	0.3	0.6	72	25	1.0



Fig. 11: Green colour water chestnut plant with thorn less fruit



Fig. 12: Red colour water chestnut plant with thorny fruit



Fig. 13: A green colour thornless fruit bearing water chestnut plant growing in repository

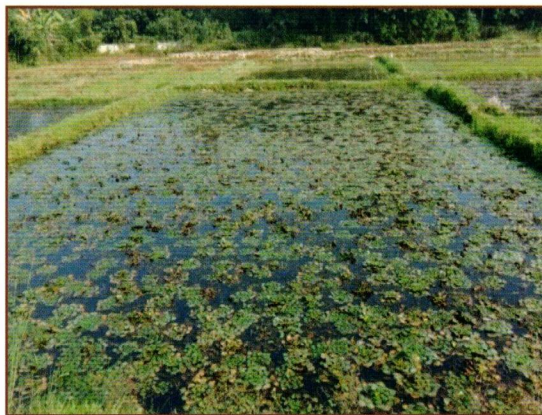


Fig. 14: A red colour thorn less fruit of water chestnut germplasm JR2

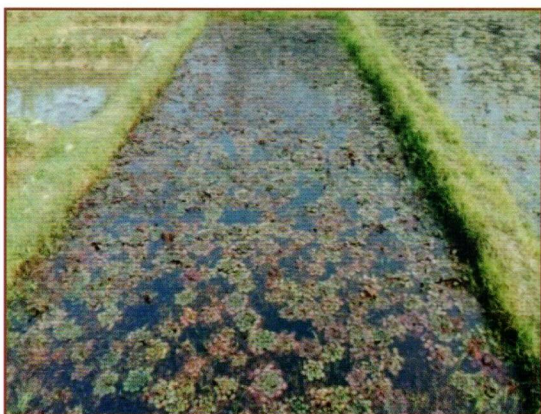


Fig. 15: Local red colour water chestnut plant bearing thorny fruit growing in repository block



Fig. 16: A red colour thorn lessfruit bearing water chestnut plant growing in repository block



Fig. 17: A thornless red colour fruit bearing water chestnut plant



Fig. 18: Thornless red colour water chestnut plant

The yield potential of water chestnut

Fruit Description

The fruit of water chestnut develops under water. It is green to red in colour. The fruit is a single seeded nut, triangular- shaped drupe, the fleshy layer of which soon disappears, leaving the hard endocarp. The endocarp bears upwardly projecting thorns or is thorn less. The seeds are ex-endospermic and ripen under water, and become detached when ripe. The fruiting season starts from September which may last up to first week of December. Fruits ripen in about a month and can remain viable for years together. once it is settled deep in soil 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.



Fig. 19: A view of different varieties of red colour water Chestnut fruits

Nutritional properties of water chestnut

Water Chestnut is a highly nutritious fruit rich in carbohydrate and protein. It also contain several necessary minerals which are vital for human health. The nutritional properties of raw as well as dry fruit of water Chestnut was estimated. It was observed that raw fruit is having 70% of water followed by 23.3% carbohydrate and 4.7% protein. Fat and fibre content were very less. In case of dried fruit, the carbohydrate content was 75.7% followed by protein (7.3%), minerals (3%) and fibre (1.4%).

Table 8: 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

Similarly, nutrient contents in dry fruit of water chestnut was estimated. 100 g of dry fruit gives 339 Kcal of energy. Among vitamins, Vitamin B1 was present in ample quantity. Different minerals viz. Potassium (583 mg/100 gm dry fruit), Phosphorus (205 mg/100 gm dry fruit) and Calcium (205 mg/100 gm dry fruit) were present in good quantity.

Table 9: Nutritional value of dry fruit of water chestnut

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

Nutrient content (w/w) in plant tissues

Micronutrient concentrations in aquatic plants vary considerably according to anatomical and morphological characteristics of the plant tissues of the plant as well as to the chemical characteristics of the elements (Singh, 2017). There is usually very less 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 water chestnut plant has shown higher concentrations of C, P, K and Zn in their 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 uptake of Fe, Mn and Cu. Uptake trend of nutrients in *T. natans* was more 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 10: 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%

Sl. No.	Elements	Leaves	Roots	Fruit
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 water chestnut is a nut of nutritional and medicinal value. It is sold both fresh and boiled in street markets of India. With the introduction of thorn less selection of water chest germplasm, the fishermen on an average are easily earning an additional income (by selling raw fruit only) of Rs. 1, 70,000/- from cultivation of the crop in one hectare area. It has been recorded from Madhaya 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 grounded into flour for bread (chapattis or poories). The dried nuts (kernels) and flour are sold at Rs 150 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.

Value added products of water chestnut

1. Singhara Burfi

Ingredients: Water chestnut flour, cashew nut powder, milk & sugar

Ratio of water chestnut powder and cashew powder: 55: 45

Methods of preparation:

Water chestnut powder is fried in ghee in a pan until its colour changes to light brown.



In another pan water and milk are boiled together.



Then powder of sugar and cardamom is added.



Further, fried water chestnut powder and cashew powder mixture is added and blended well with continue stirring until it reaches to the perfect consistency.



When blended mixture starts coagulating, plate is greased with ghee and coagulated material is poured into the plate for setting down to give it a form of burfi.



After ten minutes, when coagulated material cooled down and set properly, it is cut into diamond shape.



Fig. 20: Singhara Burfi

2. Singhara pickle

List of ingredients:

- (i) Steamed singhara kernels: 500 g
- (ii) Red capsicum powder: one big spoon
- (iii) Peeled garlic buds: 10-12
- (iv) Mustard /Rai powder: One big spoon
- (v) Saunf/fennel (Coarse powder): One small spoon
- (vi) Turmeric powder: One small spoon
- (vii) Mustard oil: 3-4 big spoon

Method of preparation:

Keep the steamed singhara kernels (unpilled/sabut singhra) in sun light for one hour for drying.



Peeled of the kernel and cut into two equal pieces.

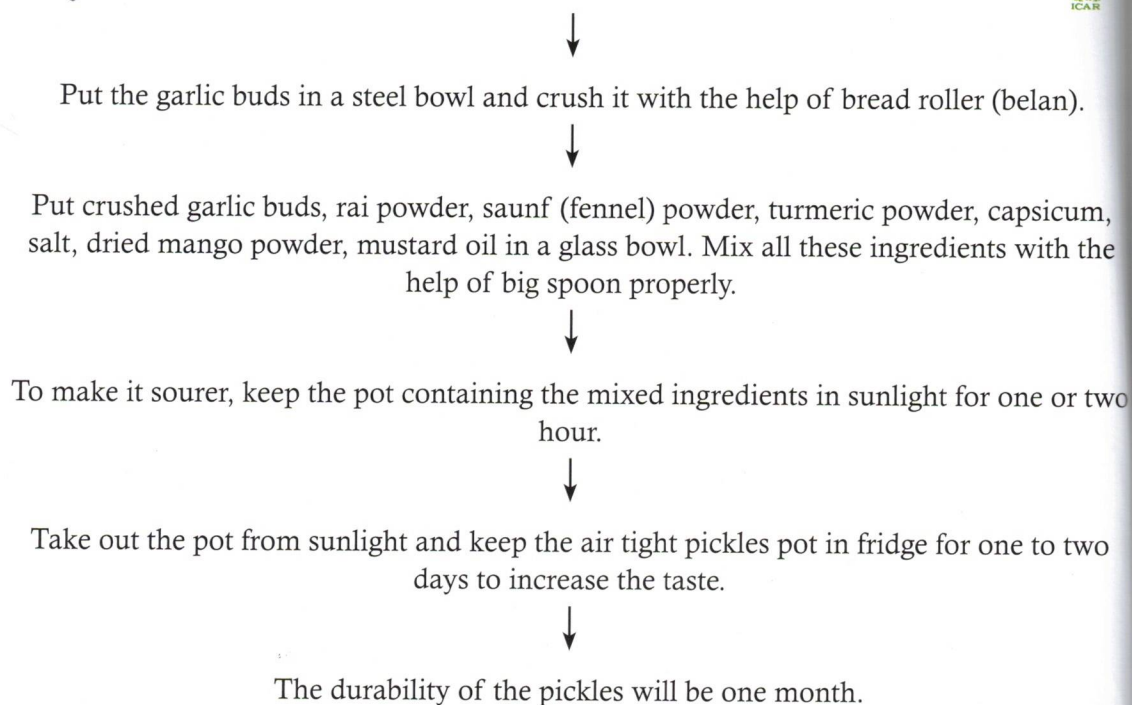


Fig. 21: Singhara Pickle

3. Singhara ka halwa

Ingredients:

- (i) Singhara flour:
- (ii) Sugar
- (iii) Ghee
- (iv) Dry fruits such as almond and cashew nut

Method of preparation:

Heat the ghee in a broad nonstick pan.



Add water chestnut flour and cook on a slow flame for four minutes or till it turns light brown colour while stirring continuously.



Add two cups of warm water and mix well and cook on a slow flame for another four minutes or till all the water has been absorbed while stirring continuously.



Add the sugar and mix well for another four minutes or till all the water has been absorbed while stirring continuously.



Switch off the flame and add the cardamom powder and mix well.



Serve hot garnish with almonds, cashew nut and pistachios.



Fig. 22: Singhara Halwa

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 anti-inflammatory, anti-diarrhoea, intestinal astringent, antileprotic agent and in urinary discharges, fractures,

bronchitis and anaemia. The fruits of *T. bispinosa*. has been identified as the Ayurvedic drug Shurangataka. It is also said to have cancer-preventing properties. Stem juice is used in ophthalmic preparations.

Conclusions

Water Chestnut is currently an underutilized crop. However, it has huge potential for expansion in water abundant areas of Bihar and other states. With the research of varietal development programme of water chestnut, it has been seen that the fishermen have started growing water chestnut crop scientifically in their ponds or unused *chaur* lands in association with fox nut and fishes. Fishermen are happy with the newly identified thorn less germplasm of water chestnut, as it is easy in plucking the fruit from the plants, transportation and post-harvest processing. As a result of this, the fishermen are getting almost two-fold higher income in comparison to their previous activities. If grown scientifically, the crop can give immense benefit to poor households belonging to fisherman community. However, more research is required for development of good quality, high yielding Water Chestnut variety and its package of practices.

Suggested Readings

1. Adkar, P., Dongare, A., Ambavade, S.K. and Bhaskar, V.H. (2014) *Trapa bispinosa* Roxb: A Review on Nutritional and Pharmacological Aspects. *Advances in Pharmacological Sciences*, 1-13. Article ID: 959830; <http://dx.doi.org/101155 / 2014 / 959830>.
2. Alfasane, M.A., Khondken, M. and Rahman, M.M. (2011) Biochemical composition of the fruits of water chestnut (*Trapa bispinosa* Roxb.). *Dhaka University Journal of Biological Sciences*, 20(1): 95-98.
3. Babu, M., Dwivedi, D.H., Yogita and Ram, R.B. (2011) Studies on physic-chemical traits of local water chestnut (*Trapa natans* var. *Bispinosa* Roxb.) germplasm under central Uttar Pradesh. *Plant Archives*, 11(2): 949-951.
4. Babu, Mukesh and Dwivedi, D.H. (2012). Evaluation of biochemical attributes in water chestnut (*Trapa natans* var. *Bispinosa* Roxb.) collected from Luck now region. *The Asian Journal of Horticulture*, 7(2): 442-444.
5. Chakor, I.S. (1974) Improved practices of nursery raising for water chestnut. *Indian Farming*. Dig. 7: 37-38.
6. Chandana, M., Rupa, M. and Chakraborty, G.S. (2013) A review on potential of plants under *Trapa* species. *International Journal of Research in Pharmacy and chemistry*, 3(2): 502-508.
7. Chowdhury, S.R., Sahoo, N., and Verma, N. (2003) Growth behaviour and yield of five water chestnut varieties under waterlogged condition. *Indian Journal of Plant Physiology*, 8 (4): 369-371.

8. Das, P.K., Bhattacharya, S., Pandey, J.N. and Biswas, M. (2011) Antidiabetic activity of *Trapa natans* fruit peel extract against streptozotocin induced diabetic rats. *Global Journal of Pharmacology*, 5(3): 186-190.
9. Ghosh, Souvik, Chowdhuri, S.R., Mohanti, R.K. and Brahmanand, P.S. (2016) Impact of integrated farming of water chestnut and cat fish on livelihood of farmers in seasonal waterlogged areas of Odisha. *Agricultural Economics Research Review*, 29 (01): 159-165.
10. Hummel, M. and Kiviat, E. (2004). Review of World Literature on Water chestnut with Implications for Management in North America. *Journal of Aquatic Plant Management*, 42: 17-28.
11. Hummel, Meredith and Kiviat, Erik (2004) Review of world literature on water chestnut with implications for management in North America. *Journal of Aquatic Plant Management*, 42: 17-27.
12. Jana, B.R. (2020) Agronomic Management of Water chestnut (*Trapa natans* L.): A Review. *International Journal of Current Microbiology and Applied Sciences*, 9 (8): 2773-2777.
13. Jana, B.R., Bhatt, B.P. and Singh, I.S. and Idris, Md. (2020) A study on commercial cultivation and storage of water chestnut (*Trapa natans* L.). *International Journal of Applied and Natural Science*, 11 (2): 528-533.
14. Majumdar, B.C. and Jana, S. (1977) Physico-chemical analysis of water chestnut (*Trapa bispinosa*) fruits. *Science and Culture*, 43 (8): 361-362.
15. Mazumdar, B.C. (1985). Water chestnut-the aquatic fruit, *Agric. Int. Series.*, 32(2): 42-44.
16. Methe, B.A., Soracco, R.J., Madson, J.D., Boylen, C.W. (1993) Seed production and growth of Water chestnut as influenced by cutting. *Journal of Aquatic Plant Management*, 31: 154-157.
17. Mullin, B.H. (1998) The biology and management of water chestnut (*Lythrum salicaria*) *Weed Technology*, 12: 397-401.
18. Patel, B.P. (2009) Development and evolution of water chestnut products. Unpublished M.Sc. Thesis, Jawaharlal Nehru Krishi Vishwavidyalaya (JNKVV), Jabalpur, 9-19.
19. Rani, Bina, Verma, Deepmala, Bhatt, Itishree, Chharang, Harsukh and Maheshwari, R.K. (2016). Health Benefits of Scrumptious Water chestnut / Water caltrop (*Trapa natans* L.). *International Archive of Applied Sciences and Technology*, 7(3): 32-36.
20. Razvy, M.A., Faruk, M.O. and Hoque, M.A. (2011) Environment friendly antibacterial activity of water chestnut fruits. *Journal of Biodiversity and Environmental Sciences*, 1(1): 26-34.
21. Rodrigues, R.P., Aggarwal, C. and Saha, N.K. (1964) Canning of Water chestnut (*Singhara*) (*Trapa bispinosa* Roxb.). *Journal of Food Science and Technology*, 1: 28-31.

22. Roy, Chowdhury S., Sahoo, N., Mohanti, R.K., Jena, S.K. and Verma, H.N. (2004a) Performance of water chestnut in farmer's field. In coastal areas in Odisha. *Journal of Indian Society of Coastal Agricultural Research*, 22: 267-269.
23. Singh, G.D., Sharma, R., Bawa, A.S. and Saxena, D.C. (2008) Drying and dehydration characteristics of Water chestnut (*Trapa natans*) as a function of drying air temperature. *Journal of Food Engineering*, 87: 213-221.
24. Singh, G.D., Singh, S., Bawa, A.S. and Saxena, D.C. (2009) Physicochemical, pasting, thermal and morphological characteristics of Indian Water chestnut (*Trapa natans*) starch. *Starch Starke*, 61: 35-42.
25. Singh, I.S. (2016). Evaluation of different genotypes of water chestnut (*Trapa bispinosa*). *Annual Report*, ICAR-RCER, Patna, Pp. 32-33.
26. Singh, I.S., Thakur, A.K. and Prakash, Dhiraj (2018) Scientific cultivation of water chestnut crop- a Boon for poor fishermen. *Indian Farming*, 68 (03): 23-27.
27. Singh, S. and David, J. (2017) Development of pudding with different levels of water chestnut (*Trapa bispinosa*) powder. *The Pharma Innovation*, 6(4, Part B): 1-11.



हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch