BIOGLOBIA Vol. 7 (1): 62 –72, 2020 **ISSN: 2349-5626**

Wetland Plant Resources are Vital to the Development of Bihar-Potentialities Emerging in the Post COVID-19 Era

NEETU AND VIDYANATH JHA*

Department of Botany, Magadh University, Bodh Gaya-824234, India
*Department of Botany, M L S M College, L. N. Mithila University, Darbhanga-846004, India
Corresponding author's e-mail: neetumehta0096@gmail.com
Received: 30.05.2020 **Revised: 05.06.2020** **Accepted: 24.06.2020**

ABSTRACT

Post COVID-19 scenario has turned grim all through the globe. Countries in Europe and America have witnessed the worst casualty. Loss of immunity is being held as one of the strong factors. Low deaths in India are being attributed to the natural immunity levels possibly on account of the use of diverse groups of spices and condiments that are proven immune-boosters. While drugs and vaccines are being explored it is the indigenous plants under the AYUSH system that are being projected for regular use by the people. One of the factors behind the success of the Kerala model of tackling the COVID-19 pandemic is being ascribed to the use of Siddha system of indigenous medicine that incorporates a no. of local plants as ingredients. It is under such a situation that a no. of aquaphytes growing in north Bihar floodplains need to be explored for their immune-modulatory properties. COVID-19 has created an unprecedented situation on the front of loss of employment leading to massive exodus of migrant laborers who need to be rehabilitated at their native places. The ambitious **Jal-Jeevan-Hariyali** mission of the Govt. of Bihar envisages to create opportunities for them to raise the prospects of harnessing the naturally available bio resources. The other aspect is to make people aware with the inherent immunomodulatory properties present in the local plant resources that could raise their nutritional status to enable them to cope with the situation.The paper provides a review of the work done on the local aquaphytes like *Eichhornia crassipes,Euryale ferox, Trapa bispinosa, Nelumbo nucifera, Nymphaea* spp., *Alternanthea* spp., *Chrysopogon zizanioides, Asteracantha longifolia* and some species of *Cyperus, Scirpus,Sesbania* and *Ipomoea* with reference to the potentialities that could help boost the immunity of local people against the emerging diseases. It also refers to the situation that could emerge on the front of employability of the natives by enhancing the productivity of these plants and raising their utility through value addition.

Keywords: *Aquaphytes, North Bihar, Immunomodulation, Shattered economy, COVID-19.*

INTRODUCTION

Plants have been there on the surface of this earth since the evolution of life as an integral component of various life forms. Depending upon their adaptation to the availability of water they are classified as hydrophytes, mesophytes, xerophytes etc. Hydrophytes grow under a situation of abundance of water and live in unison with other life forms including fishes that are consumed by humans and other animals in the food web. These days plants with immune-modulatory properties are being widely searched. Wetlands also constitute a repository of plants of various hues that need to be explored for their inherent secondary metabolites that form the drug components. They have been under folk use as drug plants over millennia (Sculthorpe, 1967 and Boyd, 1968).

MATERIALS AND METHODS

A survey was made in Darbhanga, Supaul and adjoining districts for aquatic plants being utilized by the local people for various livelihood purposes. This was with reference to their utility during peak flood periods and also in other parts of the year. Literature available

was searched regarding variations in their utility pattern in wetlands, more particularly those having significant nutraceutical potentials. Records available on the presence of immunomodulating properties in the aquaphytes available in north Bihar have been incorporated in this paper in order to stress upon the people to modify their dietary prescriptions and encourage the use of locally available cheaper food ingredients to boost up their immunity against diseases like COVID-19. Aquaphytes used for raising the economy shattered by reverse migration of lacs of prople belonging to this area have been taken into account. Results have been presented in the form of one table and 4 plates containing 24 figures.

RESULTS AND DISCUSSION

The vast wetlands in the area witness the sprawling growth of a large number of micro and macrophytes. A number of aquatic paddy varieties as well as weeds are utilized as staple and subsidiary food and fodder items. Aquatic plants grown in the area are intimately associated with regional culture including dietary habits, customs and rituals (Jha and Jha, 1993; Jha and Goel, 2002 and Jha *et al.,* 1994 & 1996). *Eichhornia crassipes* that infests these wetlands at an abnormally high speed, yields a high phytomass with high potentials of use as an alternative to fossil fuels Fishing community now uses it as a device in capture fishery (Fig.1). People in flood affected areas feed it to the animals (Fig.2). It is fast emerging into a renewable energy source. Its dried biomass can be fabricated as briquettes that are suitable as co-firing agent in coal power plants. The compacted biomass residues in the form of briquettes may decrease the dependence of coal to provide more energy. *E. crassipes* also serves as a co-compost material that could be used to make sandy soil amenable to growing crops. This plant can improve the hydro-physical and chemical parameters of soil and can supply several nutrients to the growing crops. This multifaceted floating aquaphyte is now widely recognized for its phytoremediation ability capable of removing pollutants from domestic and industrial waste water effluents. About a century back, this hyacinth was introduced as an ornamental crop in India. Today it has infested the tropical water bodies in several countries and has achieved the status of an invasive species. Fishing community now uses it as a device in capture fishery (Jha *et al.,* 2012).It provides raw material for manufacturing paper(Goswami and Saikia, 1994) Ashok Paper Mill was established in Darbhanga district in between Thalwara and Hayaghat railway stations by the erstwhile Darbhanga Raj. Today it is languishing for want of management up keep. It is a sad commentary on the part of proper harnessing of the natural resources of the region. It is high time the Government regions took up earnest steps for its revival. Ample of raw materials in the wetlands, if harnessed properly, could provide a basis of sustenance to the COVID-19 affected populace. The region has a strong potential of providing sufficient phytomass for manufacturing paper (Jha *et al.,* 2014). B. S. S. College, Supaul under the B. N. Mandal University has started production of a number of bamboo species through tissue culture method. This is meant for raising green cover and the rural economy. Wetlands in the region are used for cultivating water chestnut that is a good source of nutraceuticals (Jha, 1999, Fig. 3, 4). A wild crop like *Schoenoplectiella articulata* (syn. *Scripus articulatus)* has the potentials to be exploited on a still large scale (Shalini and Jha, 2015) (Fig. 5, 6). Of the wetland plants growing in the region, *E. ferox* is the foremost with reference to economic potentials. The plant is cultivated as Makhana crop in 8 to 10 districts of Darbhanga, Kosi and Purea divisions of north Bihar. It is also cultivated in the adjoining Maldah district of

West Bengal. In Darbhanga division, it is cultivated in ponds and ditches while in the districts of Kosi and Purnea divisions it is generally cultivated in arable fields as a rotational crop. This is because of the facility of high water table in this region. Bamboo boring is utilized to extract ground water in this Kosi belt. Almost 80% of Makhana is produced in the stagnant water bodies of north Bihar. The rest is obtained from the 'beels' of lower Assam and Maldah district. Wild populations of *E. ferox* are found in the Himalayan tracts from the north western lakes of Kashmir to the north eastern lakes of Manipur. It is found in the 'beels' of Bangladesh and the water bodies of lower Nepal lying between Kosi and Baghmati rivers. APEDA (Agricultural and Processed Food Products Export Development Authority) has recently included Makhana in its list of exportable "nutri-cereals" (Ref. APEDA-STR-2020-21-00007 dated the 28th May 2020). The noted Makhana entrepreneur, Mr. Satyajit Kumar Singh (M/s Shakti Sudha Agroventures Pvt. Ltd), has been made a member of this Nutri-cereals Export Promotion Forum. Voice has been raised to restore the old national status of the ICAR-RCER Research Centre of Makhana at Darbhanga. The Centre has developed the first ever '**Swarna Vaidehi**' variety of Makhana. Another variety '**Sabour Makhana 1**' has been developed by the Bihar Agricultural Univ.. Sabour, Bhagalpur. The B. P. S. Agricultural College. Purnea has emerged a major centre for Makhana research is eastern Bihar. A very recent study by Huang *et al.,* (2020) at the Nanjing University of Chinese Medicine refers to achieving an increase in the seed size of *E. ferox* through treatment with the auxin (IAA). They have succeeded in generating a new hybrid line of the plant by crossing the South Gordon Euryale with the North Gordon Euryale. The hybrid showed significant heterosis including the development of a non-prickly thin coated large seed. Another recent study by Kumar *et al.,* (2014) refers to *E. ferox* seeds being made to germinate at will, thereby increasing the possibility of raising its two crops in a year. These efforts could help achieve the goal of raising the productivity of the crop that has the potentials of being introduced to new waterlogged areas of other states. Kumar *et al.,* (2020) have recently succeeded in raising *E. ferox* plants through embryo culture. This research has the potential of making available fresh Makhana plants for introduction to the new areas in other states. Govt. of Bihar has recently resolved to get Makhana branded as a product of the State. This is in light of the recent endevours to harness its resources to produce items worthy of export. Makhana fills this vacuum as a much sought after product that is almost fatless and recently it has been found to have anti-diabetic potentials. *E. ferox* is intimately associated with ethnic practices in the region under study as well as in other parts of India (Kumari and Jha, 2017a)

E. ferox has the potential of emerging as a customized or designer food that could help it emerge as therapeutic food formulation for diabetic patients. Biswas *et al.,* (2020) have recently succeeded in developing enzyme mediated resistant starch production from its edible seeds through amylopullulanase treatment. Khadatkar *et al.,* (2019) have recently reviewed the processes related with agronomic management of this high valued food crop. As of now, its cultivation involves a lot of drudgery as all the operations like sowing interculture, harvesting and processing are done manually. In view of high carbohydrate and protein content and also on account of being almost fatless, Makhana is fastly emerging as a choice edible item in the European Union (Anjali Patel, Ahmedabad, Personal communication). Due to its unique biological, physiological and agronomic traits, Makhana is able to exploit small as well as marginal pond owners to be included in low-input cropping systems, representing an alternative viable aquatic food crop for sustainable agriculture in rural India. Nevertheless, this great potential and the considerable increase in new generation consumer demand for

Makhana as ready to eat food, the future of the crop is still uncertain. Indeed, the main obstacles to Makhana production are: (1) the limited areas of cultivation where it is traditionally grown, (2) lack of quality breeder seeds, (3) lack of knowledge on management practices and limited resources, and (4) very high price. Puri *et al* (2000) have reported immunoral properties in this land. There is a need to utilize the young *E. ferox* plantlets (Fig-7) as supplementary food item (on the pattern of Loktak lake in the northeastern state of Manipur) as the same are simply thrown away for making space for a fewer number of plants for full growth. Basically *E. ferox* plants grow in stagnant water. But the farmers plant it in the dry rivulets where they make the little harvest of seeds before the water regains its flow during monsoon (Fig. 8). Fish farmers are now allowing spaces in the middle of the Makhana ponds to enable both capture& culture fisheries (Jha *et al.*, 2006, Fig. 9). The state is all set to do away with its dependence on fishes from other states. As such it is taking up all possible ventures to raise fish production. Integrating both capture and culture fisheries with the Makhana cultivation is one of the options that fish farmers in the state have taken up (Jha *et al.*, 2006).

Makhana cultivation and processing are done with the use of traditional appliances. Rural technologies used in its harvest and processing need to be improved (Jha *et al.*, 1998, 2000, 2003, 2013 and Mandal *et al.*, 2010). All efforts are being made to raise the productivity of Makhana through the introduction of sequential double cropping as well as through removal of drudgeries associated with the crop (Kumar *et al.*, 2011; Kumar *et al.*, 2014; Kumar *et al.*, 2014 & Khadatkar *et al.*, 2015). Seeds are harvested from the pond bottom (Fig.10). Its pops are held sacred and are sold all over India, more particularly as 'Prasad' at religious shrines (Fig.11). Recently seed coats (Fig.12) also have been found to have potential medicinal properties. The region has good potentials to explore the naturally growing *Typha* sp. (Fig. 13,14,15, locally called as **pater**) and vetiver (locally called as **katarajhar** or **khus** (Fig. 16) for procuring thatchings materials and also for carving mats. Vetiver forms a major basis of regional culture and provides raw materials for 'Sikki art'. There is immense scope of popularizing its cultivation as an aromatic crop and also for amelioration of both sandy and flooded soils. The grass is formally worshipped as a sequel to ancient practice of land conservation that is also associated with "sun worship" (Jha, 2004; Jha and Goel, 2006; Jha and Saha, 2006; Jha *et al.*, 2015, 2016 & Kumari and Jha, 2017 b,c). *Ipomoea carnea* (Fig.17), locally known as **behaya** or **patit** as it propagates vegetatively and engulfs almost all the wet abandoned places) yields abundant biomass and has the potential for being used as a raw material in paper industry (Bhalerao & Teli, 2016).Floodplains in north Bihar witness a lush growth of deep **chichorh** (*Cyperus esculentus)* (Fig. 18). Its tubers need to be explored for their nutritional potentials Water bodies in the region witness the growth of *Nymphaea* spp. locally called as **bhent** (Fig. 19) and **kumudini** (Fig. 21). Fig-20 shows the seeds of **bhent** that are popped and used as a delicacy. Fig. 22 shows the flowers of lotus growing in the wetlands of the area. Fig. 23 shows the white flowers of *Ottelia alismoides* emerging from its fronds. Fig. 24 shows *Scirpus grossus* that is a source of Ayurvedic drug in the name of **kasheruk**. Its fronds also are used for carving mats. Species of *Sesbania* under the local names of **dhaincha** and **manager** meet the requirements of fuel in rural areas. Their seeds are made available to the farmers under Government scheme. They are encouraged to adopt organic farming and lessen the use of chemical fertilizers through this practice (Jha *et al.*, 2011; Jha, 2015). *Asteracantha longifilia* is used as drug in the indigenous systems of Ayurved and Unani in the names of *Kokilaaksha* and *Tali makhana*

respectively. In West Bengal its green foliage is used as a green and is sold in vegetable markets as handfuls (*muthia*) under the name of *kulekhara*. Its seeds are known to have acrid, bitter, aphrodisiac, tonic and sedative properties. The plant is known to possess antitumor, hypoglycemic, aphrodisiac, antibacterial, free radical scavenging, hepatoprotective and haematopoietic activities (Chauhan and Dixit, 2010). There is a need to make the populace aware of its nutraceutical potentials. The region has ample scope of producing different hues of honey. Beekeepers in this region keep on moving although the year to Jharkhand, Chhattisgarh and even up to Madhya Pradesh along with their beehives (Jha and Choudhary, 2007). Raising the green cover in this state under the Jal-Jeevan-Hariyali mission is likely to provide a boost to this venture (Jha *et al.*, 2020).

Table 1

Aquaphytes Growing in North Bihar Wetlands with Pronounced Nutraceutical and Immuno-modulatory Properties

Plant & Family	Local Name	Part	References
Euryale ferox (Euryalaceae / Nymphaeaceae)	Makhana	Seed	Jha *et al* (1991a, b, 2018); Puri *et al* (2000); Song *et al* (2011); Kumar *et al (*2016); Huang *et al* (2018); Biswas *et al* (2020)
Trapa natans var. *bispinosa* (Trapaceae)	Singhara	Fruit kernel	Jha *et al* (1999); Patel *et al* (2010); Singh *et al* (2020)
Nelumbo nucifera (Nelumbonaceae / Nymphaeaceae)	Kamal	Seed kernel	Mukherjee *et al* (2010); Sivagurunathan *et al* (2012); Dhanarasu & Hazimi (2013); Sheikh (2014)
Nymphaea spp. (Nymphaeaceae)	Bhent	Rhizome/Seed	Cheng *et al* (2012); Pareek and Kumar (2016)
Cyperus rotundus (Cyperaceae)	Mothi	Rhizome	*Kajaria et al* (2013); Gunasekara & Chandana (2014)
Cyperus esculentus (Cyperaceae)	Chichorh	Rhizome	Salem *et al* (2005)
Alternanthera spp. (Amaranthaceae)	Sarhanchi	Green leaves	Zhang *et al* (1988); Sivakumar and Sunmathi (2016); Kanagarasu *et al* (2017)
Chrysopogon zizanioides (syn. *Vetiveria zizanioides*) Poaceae)	Katarajhar/Khus	Roots	Sunitha *et al* (2015)
Ipomoea aquatica (Convolvulaceae)	Karmi saag	Green leaves	Prasad *et al* (2005); Manvar & Desai (2013)
Centella asiatica (Apiaceae)	Brahmi	Entire plant	Jayatirtha & Mishra (2004)
Asteracantha longifolia (Acanthaceae)	Talmakhana	Green leaves	Chauhan & Dixit (2010)
Schoenoplectiella articulata (Cyperaceae)	Khubahi	Seed pops	Bhardwaj *et al* (2014)

Epilogue: North Bihar is known for its vast number of wetlands of both lentic and lotic types. The region has the history of being a water surplus area, obviously on account of high annual rainfall of an average 1200mm and also due to supply of flood water by the snow fed rivers emanating from the Nepal Himalayas. These factors earlier led to the formation of perennial water bodies that constituted a repository to a diverse group of water plants that provided a basis of sustenance to the people in this area. Gradual decrease in precipitation for over a decade led to extreme crisis of drinking water in the summer of 2019. The situation is likely to ease out on account of the ambitious scheme of Jal-Jeevan Hariyali, basically meant for recharging of ground water in the region. There is a need to encourage the use of *E. crassipes* for meeting the requirements of biomass energy as well as paper manufacturing. *E. ferox* (Makhana) is fast emerging as a potential brand of the region that could lead to development of designer food. Other species mentioned above could be harnessed for their immune-modulatory role that is a much sought after concern to fight the menace of COVID-19.

Fig. 1. A fish shelter belt (locally called **Jhang**) made of *E. crassipes* raised in a stagnant water body.

Fig. 2. A farmer making small pieces of hyacinth for use as fodder.

Fig. 3. *Trapa* fruits sold on the outskirts of Darbhanga town.

Fig. 4. Fresh kernel of *Trapa* fruits after peeling out of fruit

Fig. 5. Lush growth of schoeno-plectiella articulate (Khubahi) after water receded.

Fig. 6. "Khubahi Laai" prepared from the *S.articulata* seed pops sold at Hazipur near Ganga bridge.

Plate- 1

Fig. 7. Young plantlets of Makhana that are simply discarded to facilitate open spaces for full growth of required no of plants.

Fig. 8. *E. ferox* plants grown in the dead river channels (early June)

Fig. 9. Farmers allowing open spaces in the middle to facilitate culture fishery along with the traditional capture fishery of air breathing fishes.

Fig. 10. Guri (raw Makhana seeds) being cleaned of unwanted debris after harvest.

Fig. 11. Makhana pops as an ingredient in the "Prasad" at religious shrines.

Fig. 12. Medium quality pops of Makhana with black seeds coats still attached with some pops.

Plate -2

Fig. 13. Lush growth of *Typha* sp., east of the Kosi bridge in Supaul district after the harvest of leaves for mat making.

Fig. 14. Cottony inflorescence of *Typha* sp., on full maturity.

Fig.15. Mats of Pater loaded over a vehicle for transportation and marketing (Bhaptiahi village near Kosi bridge in Supaul district.

Fig. 16. A rural woman harvesting the above ground parts of *Chrysopogon zizanioides.*

Fig.17.Lush growth of *Ipomoea carnea* (Patit/Behaya)

Fig.18. Lush growth of *Cyperus esculentus* (Chichorh)

Plate - 3

Fig. 19. Field view of a water body with *Nymphaea* sp. (Bhent/ Phool Koka)

Fig. 20. Raw seeds of *Nymphaea* sp. (Bhent)

Fig.21 Field view of a water body with *Nymphaea* sp. (Kumudini)

Fig.22. Flowers of *Nelumbo nucifera* (Kamal)

Fig. 23. Field view of a water body with *Ottelia alismoides* (Kaua thuthi)

Fig. 24. Field view of the wild growth of *Scirpus grossus* (Kasheruk)

Plate - 4

REFERENCE

1. Bhalerao, S. A and Teli, N. C. 2016. Significanee of *Ipomoea carnea* Jacq.: A comprehensive review. *Asian J. Sci. Technol,* 7 (8): 3371-3374.
2. Bhardwaj, A., Shakil, N. A., Jha, V. and Gupta, R. K. 2014. Screening of nutritional, phytochemical, antioxidant and antibacterial activity of underutilized seeds of *Scirpus articulatus*: the basis of Khubahi Ramdana industry. *J. Pharmacog. Phytochem.*, 3(4):11-20.
3. Biswas, P., Das, M., Boral, S., Mukherjee, G., Chaudhary, K. and Banerjee, R. 2020. Enzyme mediated resistant starch production from Indian fox nut (*Euryale ferox*) and studies on digestibility and functional properties. *Carbohydrate Polymers* ,Vol. 237(116158 (https://doi.org//10.1016)116158
4. Boyd, C. E. 1968. Fresh water plants: a potential source of protein. *Economic Botany* 23:123–127.
5. Chauhan, N. S and Dixit, V. K. 2010. *Asteracantha longif*olia (L) Nees, Acanthaceae : chemistry, traditional medicinal uses and its pharmacological activities- a review. *Revista Brasileira de Farmacognosia* 20(5): Corpus ID: 53606278 Zheng 2016.
6. Dhanarasu, S. and Al Hazimi, A. 2013. Phytochemistry, pharmacological and therapeutic applications of *Nelumbo nucifera*. *Asian J. Phytomedicine Clinical Res,* 1(2) : 123-136.
7. Goswami, T. and Saikia, C. N. 1994. Water hyacinth: a potential source of raw material for greaseproof paper. *Bioresource Technology*, 50(3): 235-238.
8. Gunasekara, T. D. K. S. C and Chandana, E. P. S. 2014. Cytokine mediated immunomodulatory properties of selected Sri Lankan medicinal plants. *European Int. J. Sci. Technol*, 3(2): 29.
9. Huang, Z., Huang, X., Wang, Q., Jiang, R., Sun, R. G., Xu, Y. and Wu, Q. 2018. Extract of *Euryale ferox* Salisb. exerts antidepressant effects and activated protein kinase- UNC-51 like Kinase 1 pathway. *IUBMB LIFE* 70 (4) :300-309.
10. Jayatirtha, M. G. and Mishra, S. H. 2004. Preliminary immunomodulatory activities of methanol extracts of *Eclipta alba* and *Centella asiatica. Phytomedicine*, 11: 361-365.
11. Jha, V., Barat, G. K. and Jha, U. N., 1991a. Nutritional evaluation of *Euryale ferox* Salisb (makhana). *J. Food Sci. Technol*, 8 (5): 326–328.
12. Jha, V., Kargupta, A. N., Dutta, R. N., Jha, U. N., Mishra, R. K. and Saraswati, K. C. 1991b. Ultilization and conservation of *Euryale ferox* Salisbury in Mithila (North Bihar) India. *Aquatic Botany*, 39: 259–314.
13. Jha, V., Shashi, S. B. and Alam, M. M. 2020. Jal-Jeevan- Hariyali : an ambitious scheme in Bihar envisages to meet the current environmental challenges. Abstract, 6th International Conference in Ecology and Environment held at the Dept. of Botany, Univ. of Allahabad, Prayagraj., 24th Feb. to 26th Feb. 2020
14. Jha, V., Verma, A. M. and Jha, A. K.2003. Indigenous contrivances utilized in Makhana cultivation in north and northeastern India. In: R.K. Mishra, V. Jha and P. V. Dehadrai (eds.) MAKHANA, DIPA, Indian Council of Agricultural Research, New Delhi, *p*. 241-248.
15. Jha, V., Verma, A. B., Kumar, R. and Jha, M. 2014. Ethnic and economic aspects of some emergent aquaphytes in Mithila region of north Bihar. *Ethnobotany*, 26:10-15.
16. Jha, A. and Jha, V. 1993 Plants utilized as supplementary vegetables in Darbhanga district of north Bihar. *J. Applied Biol*, 3(1-2):13-15.
17. Jha, V., Singh, T. T., Verma, A. B. and Kumar, R. 2012. *Eichhornia crassipes* (Mart.) Solms - a shelterbelt for capture fishery in floodplains of north Bihar, India. *Life Sci. Bull*, 9 (1): 135 – 138.
18. Jha, V. 2004. Vetiver and "Sikki Art" in the folk life of rural India in the Mithila region, Bihar. *Vetiverim,* 30:2.
19. Jha, V. 2015. Indigenous methods of livelihood management in a flood prone region-A case study of Kusheshwarsthan area in Darbhanga district of north Bihar. *Bioglobia*, 2(1):32-41.

20. Jha, V., Verma, A. B., Kumar, R. and Jha, M. S. 2015. Vetiver based integrated farming-a case study of Madhubani district in Mithila region of Bihar. In: Asha Gupta and V. Saxena (eds.) Integrated Farm Management, Aavishkar Publ., Jaipur, *p.*187- 203.

21. Jha, V. and Choudhary, S. N. 2007. Migratory beekeeping in north Bihar-a phytogeographical perspective. *Geographical Perspective*, 8: 90-93.

22. Jha, V. and Goel, A. K. 2002. Utilization of aquatic biota: a reference to the folk customs and rituals in Mithila region (north Bihar), India. In: P.C Trivedi (ed.) Ethnobotany, Aavishkar Publications, Jaipur, *p.* 370-382.

23. Jha, V. and Goel, A. K. 2006. Vetiver worship (Katarapuja) in Mithila region (north Bihar): an ancient practice of land conservation in India. *Ethnobotany*, 18:166.

24. Jha, V. and Saha, P. K. 2006. Less known uses of *Vetiveria zizanioides* (L.) Nash-a case study of Mithila (Bihar), India. In: Jha, P.K. *et al*.(eds.) Environment and Plants: Glimpses of Research in South Asia, Ecological Society, Kathmandu, *p.* 187-193.

25. Jha, V., Verma, A. M. and Choudhary, N. J. 1997. Baits and bait-aids utilized in angling method of fishing in north Bihar. *Ethnobotany*, 9 (1-2):85-89.

26. Jha, V., Kargupta, A. N., Saraswati, K. C. and Mishra, S.1994.Plants in cultural life of Mithila (North Bihar.) In: K. C. Sahni (ed.) *Advances in Plant Sci. Res*, 2:92-119.

27. Jha, V., Mishra, R. K., Verma, A. M. and Mishra, I. N. 2000. Forestry products utilized in exploitation of aquatic resources in north Bihar. Proceedings of International Workshop on Agroforestry and Forest Products. North Eastern Hill University, Aizawl, *p.* 337-344.

28. Jha, V., Mishra, S., Kargupta, A. N. and Jha, A. 1996.Leaves and flowers as supplementary vegetables in Darbhanga (north Bihar) and their ethnobotanical significance. *J. Eco.Taxonomic Botany Addl. Series*, 12:395-402

29. Jha, V., Singh, T. T., Prasad, D. and Shashi, S. B. 2006. Management strategies in Makhana-based integrated aquaculture. *Fishing Chimes*, 26 (3): 16 – 19.

30. Jha, V., Verma, A. B. and Kumar, R. 2011. Livelihood options in north Bihar floodplains-a case study of *Sesbania rostrata* Bremek and Oberm. *Ethnobotany*, 23: 143 – 146.

31. Jha, V., Verma, A. B. and Mishra, A. 2013.Plants in relation to fisheries practices: a survey on biodiversity utilization in north Bihar, India. In: Asha Gupta (ed.) Biodiversity Conservation and Utilization, Pointer Publishers, Jaipur, *p.* 155 – 160.

32. Jha, V., Verma, A. B., Kumar, R. and Jha, M. S. 2016. *Chrysopogon zizanioides* (L). Roberty (Katarajhar) could emerge as a significant tool for rural development in flood plains of Mithila (north Bihar), India. *J. Trad. Folk Prac*, 4(2):106-118.

33. Jha, V., Verma, A. M., Jha, A. K. and Banerjee, L. K. 1998.Rural technology for harvesting Makhana seeds (*Euryale ferox* Salisb.) in Bihar. ENVIS Newsletter (Botanical Survey of India). August 19, No. 5:7-8.

34. Jha, V., R. Shalini, A., Kumari, P. Jha, and N. K. Sah, 2018. Aquacultural, nutritional and therapeutic biology of delicious seeds of *Euryale ferox* Salisb: a mini review. *Curr. Pharma. Biotechnol*, 19:545 – 555.

35. Jha, V. 1999. Nutritional evaluation of *Trapa natans* L. var. *bispinosa Roxb*. (Singhara) and scope of raising the crop potential under integrated aquaculture. *J. Freshwater Biol*, 11 (1-2): 11-17.

36. Kajaria, D., Tripathi, J. S., Tiwari, K. and Pandey, B. L. 2013 Immunomodulatory effect of ethanplic extract shirishadi compound. *Ayu*, 34 (3): 322-326.

37. Kanagarasu, R, Bhawan, P. S., Rajkumar, G., Nathiya, V., Satgurunathan, T. and Manjula, T. 2017. Phytochemical characterization of *Alternanthera sessilis* and assessment of its growth promoting potential on the freshwater prawn *Macrobrachium rosenbergii*. *Int. J. Res. Stu. Zool*, 3(4): 25-38.

38. Khadatkar, A., Mehta, C. R. and Gite, L. P. 2019. Makhana *(Euryale ferox Salisb)*: a high valued aquatic food crop with emphasis on its agronomic management:- a review. Scientia Horticulturae (https//doi.org/10.1016). *J. Scientia*, 2019.108995

39. Khadatkar, A., Gite, L. P. and Gupta, V. K. 2015. Interventions to reduce drudgery of workers in the traditional method of harvesting makhana (*Euryale ferox* Salisb.) seeds from ponds. *Curr. Sci.*,109(7): 1332-1337.

40. Kumar, L., Singh, A. K. and Bhatt, B. P. 2016. Nutritional status of recently developed makhana (gorgon nut) variety - Swarna vaidehi. *J. AgriSearch*, 3 (4): 199–205.

41. Kumar, L., Gupta, V. K., Singh, I. S., Bhatt, B. P. and Kumar, D. 2014. Sequential double cropping system of makhana (*Euryale ferox* Salisb.) cultivation in agricultural fields of north Bihar, India. *Int. J. Agri. Stat. Sci*, 10 (1) : 105–108.

42. Kumar, R., Abdin, M. Z., Jha, V., Singh, I. S. and Kumar, A. 2020 Optimization of *in vitro* conditions for embryo culture of *Euryale ferox* Salisb. (Makhana) using 2,4-D as growth regulator. *Annals of Plant Sci*, 9(3): 3774-3777.

43. Kumar, U., Kumar, A. and Singh, K. M. 2011. Constraints and drudgery in makhana cultivation. *Int. J. Ext. Edu*, 7: 47–51.

44. Kumar, V., Rajak, D., Kumar, R., Kumar, V. and Sharma, P.B.2014. Design and development of low-cost makhana grading and roasting machine. *Int. J. Food Engineer*, 10 (3) :357–366.

45. Kumari, A. and Jha, V. 2017a. Ethnic uses of Makhana (*Euryale ferox* Salisb.) in Mithila(north Bihar) and other parts of India. *J. Traditio. Folk Practi*, 5(I). 60-74.

46. Kumari, K. and Jha, V. 2017b. *Cyperus procerus* Rottb. and other plants used for mat making in flood plains of Mithila (north Bihar), India. *Bioglobia*, 4(1): 26-31.

47. Kumari, K. and Jha, V. 2017c. Mothi (*Cyperus rotundus* Linn.) as a basis of livelihood-A case study of Godhanpur village in Lakhnaur block of Madhubani district of north Bihar. *Bioglobia*, 4 (2):67-71.

48. Mandal, R. N., Saha, G. S. and Sarangi, N. 2010. Harvest and processing of makhana (*Euryale ferox* Salisb.)-an unique assemblage of traditional knowledge. *Ind. J. Trad. Know*, 4: 684–688.

49. Manvar, M. N and Desai, T. R. 2013. Phytochemical and pharmacological profile of *Ipomoea aquatica. Ind. J. Medical Sci*, 67(3): 49-60.

50. Morton, J. E. 1975. Cattails (*Typha* spp.)- weed problem or potential crop? *Economic Botany*, 29:7-29

51. Mukherjee, D., Khatua, T. N., Venkatesh, P., Saha, B. P. and Mukherjee, P. K. 2013.Immunomodulatory potential of rhizome and seed extracts of Nelumbo nucifera Gaertn. *J. Ethnopharmacology*, 128(2): 490-494.

52. Pareek, A. and Kumar, A. 2016. Pharmacognostic studies on *Nymphaea* spp. *World J. Pharmaceutical Res*, 5(6) www.wipr.net. <Doi-10.20959/wjprzo166-6285

53. Patel, S., Banji, D., Banji., O. J. F., Patel, M. M. and Singh, K. K 2010. Scrutinizing the role of aqueous extract of *Trapa bispinosa* as an immunomodulator in experimental animals. *Int. J. Res. Pharmaceutical Sci*, 1 (1): 13-19

54. Prasad K. N., Diwakar, S., Shivamurthy, G. R. and Aradhya, S. M. 2005. Isolation of a free radical scavenging antioxidant from water spinach (*Ipomoea aquatica* Forsk.). Journal of the Science of Food and Agriculture 85 : 1461-1468.

55. Puri, A., Sahai, R. and Singh, K. L. 2000. Immunostimulant activity of dry fruits and plant materials used in Indian traditional medical system for mothers after child birth and invalids. *J. Ethnopharmacology*, 71 (1–2): 89–92.

56. Salem, M. L., Zommara, M. and Maizumi, K. I. 2005. Dietary supplementation with *Cyperus esculentus* (tiger nut) tubers attenuated atherosclerotic lesion in apolipoprotein E knockkannt mouse associated with inhibition of inflammatory cell responses. *American J. Immunology* , 1(5) : 60-67.

57. Sculthorpe, C. D.1967. The Biology of Aquatic Vascular Plants. Edward Arnold, London, 610 *p.*

58. Shalini, R and Jha, V. 2015 *Schoenoplectiella articulata*.(L.) Lye (Khubahi) : a basis of sustainable livelihood in flood plains of north Bihar. *Ethnobotany*, 27:102-107.

59. Sheikh, S. A. 2014. Ethmomedicinal uses and pharmacological activities of lotus (*Nelumbo nucifera*). *J. Medicinal Plants Studies*, 2(6) : 42-46.

60. Singh, S., Kumar, V., Kumar, N., Sharma, P. and Walheed, S. M. 2020. Protective and modulatory effects of *Trapa bispinosa* and *Trigonella foenum graecum* on neuroblastoma cells through neuronal nitric oxide synthase. *Assay and Drug Development Technologies*, 18(1) :(https://doi.org/10-1089/adt.2018.12

61. Sivagurunathan, A., Innocent, B. X. and Lakshmi, S. M.2012. Immunomodulatory effect of dietary *Nelumbo nucifera* (Lotus) in growth and haematology of *Cirrhinus mrigala* challenged with *Pseudomonas aeruginosa*. *J. Applied Pharmaceutical Sci*, 2(7):191-195.

62. Sivakumar, R. and Sunmathi, D. 2016. Phytochemical screening and antimicrobial activity of ethanolic leaf extract of *Alternanthera sessilis* (L) R.Br. Ex DC and *Alternanthera philoxeroides* (Mart) Griseb. *European J. Pharmaceutical Sci*, 3(3): 409-412.

63. Song, C., Wang, S., Zhou, L., Hou, F., Wang, K., Han, Q., Li, N. and Cheng, Y. 2011. Isolation and identification of compounds responsible for antioxidant capacity of *Euryale ferox* seeds. *J. Agricul. Food Chem*,59: 1199–1204.

64. Sumitha, V. S., Sunil, M. A., Radha, E., Krishna, K. and Mathews, J. 2015. Immunomodulatory activity of *Vetiveria zizanioides* extract on peritoneal macrophages of albino mice. *Int. J. Pharmaceutical Res*, 4:1-4.

65. Tanushree, B. and S. Sethi, S. 2018. Water hyacinth: a wonder weed. *Int. J. Home Sci*, 4(1) : 291-294.

66. Zhang, S. M., He, Y. S., Tabba, J. D. and Smith, K. M. 1988. Inhibitor against the human immunodeficiency virus in aqueous extract of *Alternanthera philoxeroides*. *Chinese Med. J*, 101: 861-866.