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Green Medicine from the Coastal Realm: Antidiabetic Properties of Indian Mangroves Explored

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ABSTRACT

Sundri (Heritiera fomes Buch.-Ham.) is an evergreen mangrove tree species found abundantly in the freshwater zone of Sundarbans, Bangladesh and scattered in moderate or strong saline zones of the forest. H. fomes grows well in top canopy having full sunlight and even in full shade under the canopy. This study presents the plasticity of leaf morphological and anatomical characteristics in H. fomes due to variation of light intensity at different canopy depths and of salinity in different saline zones of Sundarbans. The glory of Sundarban, the World Heritage Site (UNESCO 1987), is associated with the distribution of Sundari tree, Heritiera fomes. High complexity in habitat structure and environmental variability has enriched its floral and faunal biodiversity. This tree is only timber producing plant among 'true mangrove' species and popular as traditional folk medicine. The distribution of this native species is highly threatened by several factors. Though, the other mangrove species have showed the capability to adjust the changing environment for their existences in Sundarbans, why this particular species is on the verge of extinction. Research works on Heritiera fomes indicate several physiological disparities with changing hydrological parameter as major thrust for its survival in its own homeland

Keywords: Sundarban, Heritiera fomes, Threats, Anatomical structure, Hydrological parameter

1. INTRODUCTION

The Sundarban is an important tidal mangrove forest from both ecological and economic viewpoints. The forest stands over Ganges basin and playing an outstanding role in balancing the coastal wetland ecosystems in the Bengal basin [1]. The Sundarban covering 10,000 square kilometers of land and water, is part of the world's largest delta (80,000 sq.km) formed from sediments deposited by three great rivers the Ganges, Brahmaputra and Meghna, which covered on the Bengal Basin. About 62% of the Sundarban lies in the Khulna region of the south western part of Bangladesh, while the remaining 38% is in India (Lacerda 2001). So, the total area of the Bangladesh Sundarban is 6017 km2, of which 4016 km2 is forest land and the balance is covered by water [2].

Heritiera fomes is a prominent less saline habitat species of the Sundarban mangrove forest. It is more widespread in south Asia and grows exclusively in tidal areas with large stands or grove which reflected their own ecological community. The natural vegetation of the Sundarban mangrove forest depends on natural regeneration. Although mangroves inhabit in different level of saline sediments, their growths generally decline with increasing sediment salinity [3]. Extremely high salinity negatively influences the growth of mangroves seedlings [4]. Based on extensive studies on previous findings in different mangrove seedlings showed the variations on adaptation and respond positively to moderate salinity but negatively influenced by excessive salinity [5]. Now a day as a genus Heritiera is in a threatened category. Due to environmentally induced mortality declines Heritiera fome has been recorded in many parts of the forest [6] [7] [8]. Various abiotic stresses reduce their survival rate through both ionic toxicity and osmotic stress. Since a complex range of interacting abiotic and biotic factors control the availability of nutrients to mangrove species [9].

Micronutrients or some heavy metals like Fe, Cu, Zn, Mn, B, Mo and Cl are required in small amount and their content in plant components are influenced the metabolic requirements but presence of insufficient and excessive of such micronutrients poses various stresses on plant growth and metabolism [10] [11] [12], and exhibit nutrient stress or toxicity [13]. Fine textured anoxic mangrove sediments are highly efficient and effective sinks for a variety of heavy (trace) metals in which colloidal particles in the sediment scavenged from the water [14]. These underlying sediments, often creating problems of trace metal contamination of sea water and biota. Through mentioned metals (Cu, Fe, Mn, Ni, and Zn) are essential as micronutrient for plants [15] but their excessive presence indicated a high level of metal pollutions in the many mangrove habitats [16]. Since heavy metal concentrations occasionally exceed the EQS (Environment Quality Standard) limit [17]. While exceeded the EQS, deposition of heavy metal like Pb, Zn, Cu, and Cd can be absorbed by plants and maybe led to massive tree mortality [18]. However, growth of mangrove seedlings showed more sensitivity to these heavy metals (Pb, Cd, Cu, Fe, etc.). On the other hand, excessive absorption of individual ions may toxic to the early stages of plants or may retard the absorption of other essential plant nutrients.

The critical stages of the mangrove species are seed germination and survival which completely depends on its physical nature and environmental characteristics [19]. During seed germination and early growth, seedlings depend upon minerals stored in the seed for development, and upon depletion of this source plants become dependent on soil minerals. So, Nutrient availability is one of the major factors influencing mangrove forest structure and productivity. Mangroves usually found to cope with low nutrient availability [20]. Because they usually thrive in saline environment and copped various mechanisms such as selective ion transport that may affect in uptake, distribution, loading and excretion of micronutrients within the plant parts [21] [22].

Along with salinity heavy metals also affect on early growth or regeneration of mangroves [23] - [28]. Older mangrove seedlings appeared to be more metal-tolerant than the younger seedlings due to their more efficient exclusion mechanism. Thus, the effects of metal contamination on young seedlings should be assessed when evaluating the risks posed by heavy metals in an ecosystem [29]. Most of the elements are stored in the soils and dead roots and may serve as a sensitive bio-indicator for metal pollution in these ecosystems [30].

In the Sundarban, the main sources of many heavy metals from industrial discharges as waste particle [31] [32]. On the other hand, the oil and gas mining activities also showed harmful for the mangrove habitats biodiversity and ecosystems. So, such affects may change the hydro edaphic condition of the forest by accelerates to change over the biochemistry of the wetland ecosystem [33] [34]. Therefore, to know the abiotic stresses due to accumulation of micronutrients or essential heavy metals, the present study aims to assess the distribution and toxic content of the such micronutrients or essential heavy metals like Cu Zn and Fe in the different parts of the major mangrove viz. Heritiera fomes.

Every year, medicinal plant-based trade is growing rapidly and India's share in the global market of natural drugs is very low as it contributes only 0.5-1%, whereas demand for these products is increasing at a rapid rate [13, 14]. Developing countries and their traditional people have contributed considerably to the global drugs industry [15].

In India, the epic poems such as Vedas and others illustrated our culture, food, and habitat. The extensive use of TM in the Indian coastal region, composed mainly of plants based derivatives, has been linked to communities' composition and cultural aspects. This is why the WHO and World Bank promotes integrated approaches to documents TK and TM in their healthcare system. In the rural areas of India, 70% of the population is dependent on traditional medicines. Indigenous or traditional knowledge has developed from understanding and documenting the processes in nature. Since ethnobotany is a rapidly expanding science, beginning with the study of plants used by tribals for food, medicine, and shelter, now it includes studies like conservational practices of tribals, ethnopharmacology, ethnopharmacognosy, ethnomusicology, ethnogynaecology, etc. Ethnobotanical studies in relation to traditional communities like the tribal groups have been studied by several researchers in India including the island's ecosystem.

India is rich in its diverse natural resources and one of the seventeen biggest natural biodiversity countries of the world. It has rich vegetation of more than 45,000 plant species, out of which 15,000 to 20,000 plants are estimated to have medicinal values. Out of these, only 7,000 to 7,500 plants are used for the medicinal purpose by established communities [16, 17].

The marine biodiversity is an extremely rich resource for the development of a wide array of goods and services in the food web, pharmaceuticals, cosmetics, coastal protection, etc., but it has been extensively utilized for curing various ailments for many tribal and native communities inhabiting the coastal lines in different parts of the world. As a result of the close and respectful interaction with the marine ecosystem, the indigenous coastal communities possess marine life based rich traditional knowledge that also aids in the sustainable development of the community as well as the marine ecosystem. The valuable traditional knowledge (TK) has so far remained confined within their community and generally passed orally from one generation to another [18]. Various forms of TK, including TM knowledge, have been silently developing over the 19th centuries, with the coastal tribes in nations across the world. Unfortunately, marine TK and TM have been underestimated both commercially and legally. It has still not gained its due importance at the international platform for sustainable use and development of new drugs [18, 19].

2. MATERIALS & METHODS

Major mangrove tree species of the Sundarban forest viz. Heritiera fomes Buch, was selected for the present investigation. The Field study was conducted in three different saline zones which are―Chandpai, Jungra and Munshiganj as Oligohaline (4 - 8 dS−1·m), Mesohaline (8 - 15 dS−1·m) and Polihaline (>15 dS−1·m) zones respectively were selected as an experiment site. The Chandpai and Jungra zones are in Chandpai range and Munshiganj zone in Satkhira range of the Sundarban forest. Nine sample plots (9 × 10 m2) have been laid out in these three different saline zones for sample collection. After seed dropping naturally regenerated Heritiera fomes seedlings (6, 9 and 30 months ages) were randomly collected as plant sample from these plots. After washed they excised as root and shoot and then oven dried at 80˚C until constant weight. The plant samples were ground and processed according to the standard procedure [35] for determining the total copper (Cu), Zinc (Zn) andiron (Fe) by Atomic Absorption Spectrometer (Model: Varian AA240 Atomic Absorption Spectrometer Australia).

Vanishing trend

The rate of mangrove forest destruction was much faster than that of inland forest and coral reefs worldwide with maximum (35% loss) magnitude from 1980 to 2000 worldwide (Millenium Ecosystem Assessment 2005) which might have fastened with the rate of population declination of Heritiera fomes (GRB EMP 2012). The vegetation pattern arranged by Prain (1903) indicates the dominancy of this species in the central part of Sundarbans in early 20th century (Mandal et al. 1989). But the scenario has changed to stunted growth and scattered distribution in Indian part of Sundarbans during late 20th century (Chaudhuri and Chaudhury 1994). In Bangladesh part of Sundarbans where Heritiera fomes was evenly distributed, is also shifting eastwards (low saline zone) with almost entire retreatment from central and western part of Bangladesh (Dasgupta et al. 2016). Within a period of 38 years (1977-

2015), distribution of Heritiera fomes and Excoecaria agallocha has decreased by 9.9% in Bangladesh part of Sundarbans (Ghosh et al. 2016). There is a prediction that in future Heritiera fomes along with some other mangrove species (adapted at low salinity) will be potentiality replaced by Ceriops decandra (Goran) from Sundarbans (Dasgupta et al. 2016). There is a prediction that within 2010 approximately 40% of H. fomes population will be vanished compared to data recorded in 1950 (FORESTAL 1960).

Increasing salinity as a major threat

Moribund status of many tributaries of River Ganga is creating a serious shortage of fresh water supply to Sundarban mangrove forest especially during post-monsoon time. In anticipation this is intensifying the problem of salinity intrusion and is gradually increasing the salinity level of water and soil substratum (Islam and Gnauck 2008, Banerjee 2013). Construction of Farakka Barrage has aggravated the adverse condition (Aziz and Paul 2015). H. fomes is considered as bio-indicator of climate change due to its strong preference extremely low saline condition in estuarine mangrove regions (Chaudhuri and Choudhury 1994, Mitra et al. 2004). Heritiera fomes is very sensitive to a change of 1.0‰ salinity (Ahmed et al. 2011). Annual growth rate of Sundari tree is reduced with increasing salinity (Aziz and Paul 2015). Above the optimal pH (> pH 6.5) phosphate absorption got reduced in Heritiera fomes and showed various pathological symptoms like top dying, invasion of bacterial and saprophytic diseases (Chaffey et al. 1985). In previous studies, the enhanced salinity was thought to be the main causal factor of top dying disease in H. fomes but recent hypothesis justified the interaction of other edaphic factors to induce top dying in Sundri (Awal 2014). 45.2 million Sundari trees have been affected by top dying disease in Bangladesh of which at least 20 million trees have been seriously affected (Chaffey et al. 1985). Photosynthesis of most mangrove species sharply declines when the air temperatures exceeds 35ºC (Moore et al. 1973). Heritiera fomes (Sundri) is the pre-dominant mangrove tree species due to its great support (65%) to the total merchantable timber from mangrove forest (Chaffey et al. 1985, Siddiqui 2001). Illegal cutting of trees has caused a significant change in spite of government banning on timber extraction (Akhter 2006).

3. RESULTS & DISCUSSION

To combat the problem of salinization many mangrove plant species are well adapted with structural complexity such as salt exclusion mechanism at root level, foliar salt secretion adaptability and reduction capacity of osmotic potential (Drennan and Pammenter 1982, Sivasankaramurthy 2012). Morpho-anatomy play important role in adaptation in mangroves Rodriguez et al. (2012). Rooting pattern of H. fomes may be 815 another reason for exposed salinity stress as their roots spread on the soil surface rather than deep penetration (Kathiresan et al. 2010). Maximum part of the root surface cannot absorb water and nutrients because of substrate salinity (Medina 1999). The function of salt accumulating system normally induces photosynthesis for pumping ions into the specialized tissues along with the benefit of structural development (Medina 1999). Large aerenchymal lacunae in the root cortex which are efficient for conservation of internal oxygen are found in most of the mangrove species except Heritiera fomes (Pi et al. 2009). At higher salinity level, the H. fomes trees might be perhaps forced to face the stress by the functional changes of antioxidant enzymes, modification of leaf and chloroplast structure, alteration in rate of transpiration, photosynthesis and stomatal conductance (GRB EMP 2012). An increased accumulation of salts was observed in the plants body with increasing salinity level (Karim and Karim 1999).

Elevated assimilation rate coupled with increased chlorophyll content, more mesophyll and stomatal conductance and higher specific leaf area are quite common in H. fomes at minimal soil salinity (Rodriguez et al. 2012, Ball and Farquhar 1984, Burchett et al. 1984). In Indian Sundarbans the available irradiance (µmol m-2 s-1 PHOTONS PAR) is very high than the maximum requirement for photosynthesis in H. fomes (Nandy and Ghose 2001). Avoidance at high light intensities is controlled by the correlation of photosynthesis and stomatal size and frequency which was recorded with lowest value in H. fomes (Nandy et al. 2005). Rate of transpiration in H. fomes is reduced due to deeply sunken stomata which are covered by peculiar type of trichomes (Mandal and Ghosh 1989, Rodriguez et al. 2012). The low palisade-spongy ratio in leaves of this species is due to poor development of palisade cells traversed by large intercellular spaces (Rodriguez et al. 2012, Das et al. 1995). It was also documented that in H. fomes the salt glands are absent and leaf pubescences were not found developing inability for the survival of the species in stressed environment (Reef and Lovelock 2015). At higher salinity the seedlings are forced to face increased sodium concentration with reducing potassium and carbon concentration (Hossain et al. 2014). Difficulty in germination

There are some gaps in research works of about 50 years (from 1903-1960) when we see there is no concretized data available regarding the distribution and status of Heritiera fomes in Sundarban mangroves. Due to this consequence it is also not clearly known when this mangrove species started the vanishing event especially from Indian part of Sundarbans. Being a representative with a long life span (40 years) (Kathiresan et al. 2010) it is a K-selected species with low resilience property. Even in absence of anthropogenic pressure the k- selected species usually takes long time to set back to previous state after any catastrophic disaster. Thus vivipary which is a modified pattern of epigeal germination are lacking in Heritiera fomes but has evolved in many other mangrove species (Das and Ghose 2003). Since the seeds of H. fomes are matured at the onset of pre-monsoon season (usually in March) (Upadhyay and Mishra 2010) then the salinity of surface soil is comparatively higher due to evaporation and those may possibly make trouble for germination or propagation of saplings. The seeds of H. fomes showed lower germination and less viability at higher salinity levels compared to other species (Hossain et al. 2014). The situation might be unfavorable with occasional cyclonic storm surge resulting in salt water intrusion far upland of high tide line.

Micronutrient or essential heavy metals like, Cu, Zn and Fe content were analyzed in the Heritiera fomes seedlings. Among them Cu and Zn content showed remarkably higher than Fe. Whereas comparatively higher Cu was found in the root (2.26 mg/g) but higher Zn was found in the root and the shoot (0.788 mg/g and 0.804 mg/g) of 6 months age Heritiera fomes seedlings grown at the Chandpai (oligohaline) zone (Figure 1, Figure 2). However at the 9 months comparatively higher content of Cu was found in the root of the seedlings (1.43 mg/g) grown at the Jungra (mesohaline) zone but in the shoot of the 9 months age H. fomes showed comparatively higher Cu content (3.18 mg/g) at the Munshiganj (polyhaline) zone. These elements are toxic to organisms at high concentration. But they do not inhabit germination but cause strong barrier of seedling growth at relatively low concentration [36]. On the other hand, harmless level of these elements were also found in China mangrove forest [37]. These metals act as micronutrients and need small amount to contribute to plants metabolic necessities.

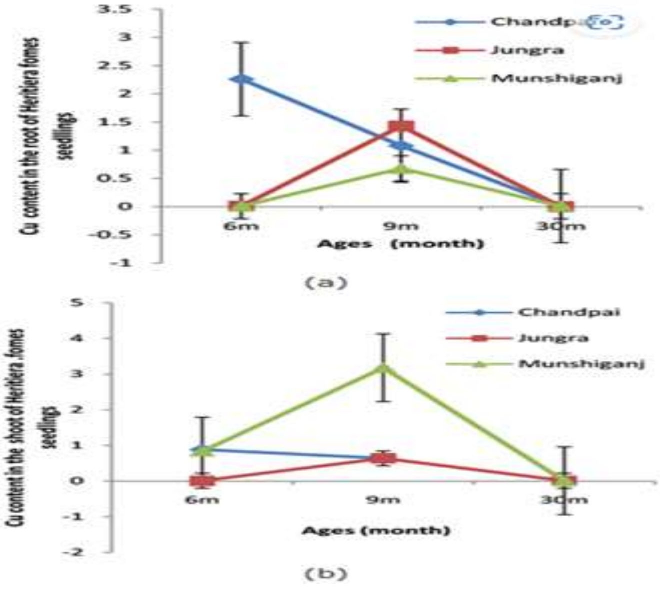

Figure 1. Cu content in the Root (a) and the Shoot (b) of Heritiera fomes seedlings.

Their lack may damage the whole enzymatic system but excess can alter cell membrane permeability and inhabit enzyme activity by interfere the different metabolic processes. However, Cu and Zn were found comparatively lower at the age of 30 months (0.01 mg/g - 0.002 mg/g and 0.01 mg/g - 0.00004 mg/g) (Figure 1, Figure 2). On the other hand, relatively higher Fe content were found in 30 months root and shoot of H. fomes seedlings grown at Chandpai saline (less saline) zone (0.02 mg/g) but lower in 6 months old seedlings (Figure 3). Higher content of Cu and Zn were also noticed by many researchers in the early seedling stages [38]. Present observation also noticed that H. fomes also showed relatively lower content of micronutrients (Cu and Zn) in the older age viz. 30 months due to their more efficient ion exclusion or avoiding mechanism. It was also reported that at the older ages' mangrove seedlings appeared to be more metal-tolerant than the younger ages [30].

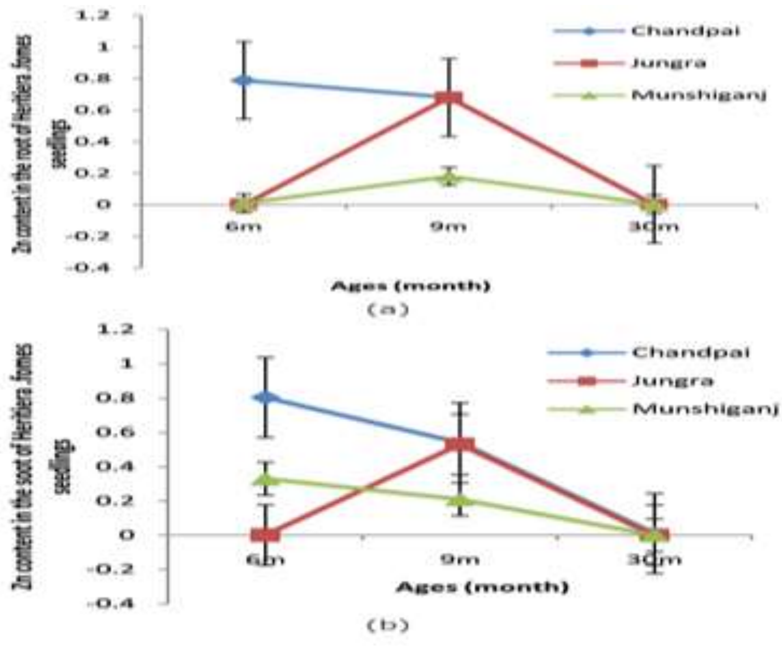

Figure 2. Zn content in the Root (a) and the Shoot (b) of Heritiera fomes seedlings.

4. CONCLUSION

The Heritiera fomes species in early seedling stage are affected with high content of micronutrient or heavy metal and response differently by tolerance of metals in different plant parts and ages. At the older age seedlings appeared to be more metal-tolerant than the younger age seedlings. Thus, the effects of metal contamination on young seedlings should be assessed when evaluating the risks posed by heavy metals in an ecosystem. Finally it can be suggested that the environmental stresses along with anatomical inequity in together are pushing Heritiera fomes to be physiologically inefficient for surviving in habitat with increasing salinity. The time that is not so far away when there will be necessity of using magnifying glasses to find out the Sundari tree, Heritiera fomes from Indian part of Sundarban mangroves. Finally it can be suggested that the environmental stresses along with anatomical inequity in together are pushing Heritiera fomes to be physiologically inefficient for surviving in habitat with increasing salinity. The time that is not so far away when there will be necessity of using magnifying glasses to find out the Sundari tree, Heritiera fomes from Indian part of Sundarban mangroves.

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