The use of Mee tree (Madhuca longifolia) in paddy cultivation by ancient Sri Lankans

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Abstract

Agriculture has long been regarded as the backbone of Sri Lanka, contributing to its' economy for over thousands of years. However, with recent technological advancements many of the indigenous practices with regard to cultivation have been neglected or forgotten. The use of toxic chemicals in agricultural practices has led to a host of deleterious effects on humans as well as the environment. This paper looks into how ancient Sri Lankans utilized a native tree, Madhuca longifolia (Mee), in paddy cultivation for various purposes including the prevention of soil erosion, water conservation, soil enrichment and pest control measures. Although our ancestors lacked the scientific knowledge to justify their practice, the basis for these are now understood in the scientific community. Therefore, a return to these practices may be worthwhile in terms of their beneficial influence on agriculture, environment and human health and wellbeing. Keywords: Agriculture; Pest control; Soil erosion; Conservation of natural resources

Introduction

Sri Lanka has a prestigious history of hydraulic-based civilization running back to 5th century BC. Rice cultivation began around 900 BC and has developed in an organized way since 300 BC (Cook, 1950; Vandermeersch and Deraniyagala, 1988; Senanayake, 2006). Until the Green Revolution in the mid-1960s introduced modern farming techniques, inorganic fertilizers and other agro-chemicals (Farmer, 1986; Wilson, 2000), the cultivation of paddy in Sri Lanka was entirely based on indigenous techniques. These were developed based on the extensive experience and knowledge of the local community and tested over two thousand years of implementation (Vandermeersch and Deraniyagala, 1988). The indigenous knowledge of local farmers about rice farming techniques includes land preparation and soil fertility management, seed selection and pre-planting, water management, method of rice planting, weed control and pest and disease control techniques (Senanayake, 2006). The indigenous knowledge system of local farmers is a broad area to discuss. Mee tree (*Madhuca longifolia*) considered as the fertiliser tree of the nation in ancient Sri Lankan aera. According to the ancient literature available in Sri Lanka there were rules imposed of prohibiting of cutting *Madhuca longifolia* tree by of King Mihindu IV. The nectar in the flowers and the fruits of the *Madhuca longifolia* attracts the fruit bats. Bat guano is a very rich fertilizer, due to its high content of carbon and the three vital primary macronutrients: nitrogen, phosphorus and potassium (N-P-K) as well as important secondary minerals such as calcium and magnesium that help control soil pH(Buliga, 2010; Shetty, Sreepada, and Bhat, 2013). When bats visit the *Madhuca longifolia* trees during flowing and fruit seasons it automatically provide guano in return to the ground. The ancient Sri Lankans used these natural combinations to provide fertiliser to their paddy fields. This article focuses on how ancient Sri Lankan farmers used the Mee tree (*Madhuca longifolia*) and its products in paddy cultivation.

The impact of current agricultural practices on the produce: chemical analysis of rice and reservoir water in Sri Lanka

Paddy rice (*Oryza sativa L* .) is the principal food of Sri Lankans. Rice provides 30% of the dietary energy and 20% of the dietary protein intake of Asians (World Health Organization FSD, 2002). It is a well-known fact that rice is contaminated with toxic chemicals and trace elements due to the unrestrained use of agrochemicals in cultivation and the use of contaminated water to irrigate paddy fields. Heavy metals that have been found to be present in high levels include Cadmium (Cd), Arsenic (As), Lead (Pb), Nickel (Ni), Zinc (Zn), Copper (Cu) and Mercury (Hg).

Cadmium is a well-known carcinogenic heavy metal. It also contributes to anaemia, hypertension and renal, pulmonary and skeletal disorders (Khaniki and Zazoli, 2005). The current tolerable exposure level of Cd is 25 µg/kg body weight per month (Satarug, Vesey and Gobe, 2017). The main sources of Cd in rice are phosphate fertilizer and contaminated water.

The dietary intake of Cd in Sri Lanka is chronically high (Bandara, 2008). The study conducted by Bandara et al. (2008) in the Anuradhapura district shows that the Provisional Tolerable Weekly Intake [*an estimated amount of the chemical with no intended function that can be ingested weekly over a lifetime without appreciable health risk*] of Cd is 8.702–15.927 µg/kg body weight for 5–50 years. Further in the study, it has shown that dissolved Cd in reservoir water ranged from 0.03 to 0.06 mg/l, which is a 19-fold increment over the maximum contaminant level set by the WHO (0.003 mg/l). Cd content in lotus rhizomes was 253.82 mg/kg which is a common curry in Sri Lankan meals (Bandara, 2008).

Another survey conducted by Meharg et al. (2013) using rice samples from 12 countries reported a mean Cd concentration of 8µg/kg in Sri Lankan rice which was second only to Bangladesh (mean=99µg/kg). A study published in 2020 shows that the average concentration of Cd in rice was 0.080 $\pm$ 0.130 mg/kg. Although almost 97% of the samples were below the Codex limit for polished rice (0.4 mg/kg), five samples had Cd concentrations of 0.488 to 0.727 mg/kg, exceeding the Codex maximum permissible level by 1.25 to 1.75 times, respectively (Liu et al., 2020).

Arsenic levels in the groundwater and surface water of the country are negligible (Chandrajith et al., 2011). But a study conducted by Jayasumana et al., (2013) shows an elevated level of As (20.6-540.4 µg/kg) in agrochemical-dependent cultivations compared to cultivations done without using agrochemicals (11.6-64.2 µg/kg). Another study published in 2020 shows an average concentration of As of 0.077 $\pm$ 0.040 mg/kg which was considerably lower than the maximum Codex standard level (0.200 mg/kg). But two samples from the Northern Province contained As at 1.1 times that of the Codex maximum permissible level (Liu et al., 2020).

The average concentration of Pb in Sri Lankan rice was 0.031 $\pm$ 0.052 mg/kg. The Pb concentration in three samples from Central, Northern and Western provinces exceeded the Codex threshold (0.400 mg/kg) by 1.5 to 2 times

In summary, the available literature and scientific data attest to the fact that the rice in the local Sri Lankan market contains heavy metals, probably due to the uncontrolled use of agrochemicals for paddy cultivation and irrigation using contaminated water. This is an alarming finding given the health consequences following long-term exposure to these chemicals, even at low concentrations. One of the main concerns in Sri Lanka currently is chronic kidney disease of unknown aetiology (CKDu), the incidence of which is rising among the agricultural communities especially in the North Central province. Although the cause of this disease is yet unidentified, heavy metals have been implicated in the pathogenesis as high levels of these have been found in affected individuals (Kulathunga et al., 2019). Therefore, timely action is required from authorities to regulate agricultural activities in order to minimize their harmful effects on human health. In the Sri Lankan context, this would not prove difficult as the country has a long history of ecological agricultural practices which are safe for both humans and the environment.

The use of Mee tree in indigenous agricultural practices

Mee tree (*Madhuca longifolia*)

Mee is a native (a plant or animal that lives and reproduces in an area without any human intervention) deciduous tree, which grows to a height of 16-20m. Leaves are seen in whorls crowded at the terminal ends and are oblong in shape with a tapered base and apex. The flowers are fleshy, pale yellow in colour and are borne solitary but appear in groups. The fruit is a yellow ovoid-shaped berry. The crown is rounded with multiple branches. The bark is grey, vertically cracked and wrinkled, exfoliating in thin scales. It has a large spreading root system, of which some are superficial.

The importance of the Mee tree for local agriculture had been recognized by the rulers of ancient Sri Lanka. This is evidenced by the presence of a number of stone inscriptions which document rules and regulations pertaining to the protection of these trees. A pillar inscription installed by King Sena II (853-887AD) in Mihinthale prohibits the cutting of palm, coconut, Mee and tamarind trees at the top of the Mihinthale rock and asserts that violators would be fined (Ranawella, 2001) (Figure 1A). King Udaya III (935-938AD) banned the cutting down of coconut and banyan trees as stated in his inscription at Athakada (Ranawella, 2004). Cutting down of Mee and tamarind trees had been banned in the Buddannehela stone inscription belonging to King Sena III (938-946AD) (Ranawella, 2004). The Mihinthale slab inscription of King Mihindu IV forbade the cutting of trees including Mee and palm and decreed that offenders would be fined or put to work in irrigation work (Amarawansa, 1969) (Figure 1B). He further declared in the Abhayagiri slab inscription that lay people should not cut trees or plants (Ranawella, 2004) (Figure 2). The Puliyankulama slab inscription of Udamahaya states that palm and Mee trees should not be cut down (Wickremasinghe, 1912). The Kiribathwehera slab inscription installed by King Kashyapa IV (898-914AD) denotes a Mee tree as one of the borders of an area of land (Wickremasinghe, 1912). This could be due to the fact that Mee trees have a long lifespan owing to the fact that cutting down these trees are prohibited. The Mee tree and palm tree are also mentioned in the Aluthwewa pillar inscription commissioned by the same king (Ranawella, 2001).

(Insert Figure 1 Here)

(Insert Figure 2 Here)

These artefacts bear evidence to the degree of concern that ancient Sri Lankan rulers had for the protection of the natural environment. The reason for their explicit interest in conserving the Mee tree could be that the ancestors were aware of the value of the tree in preventing soil erosion, conserving water, cooling the environment, providing food and medicinal substances and ensuring the survival of various animal species. Owing to its' importance in the livelihood of the people, the Mee tree was sometimes chosen as the site for religious and spiritual rituals in villages (Figure 3).

(Insert Figure 3 Here)

The role of Mee tree in paddy cultivation

Local farmers planted 3-4 Mee trees per acre of paddy field. These trees were planted in the water inlet areas as well as the water outlet areas since they have a deep as well as a superficial root system that prevents soil erosion at the water entry and exit points. Ancient farmers were also aware of the fact that by planting Mee trees at water exit points, nutrition-rich liquid fertiliser would be carried away to downstream paddy fields.

The irrigation system of the Nuwara Kalawiya region had been designed in such a way that water from one lake flows into another. The water from one paddy field joins the canal carrying waste water and thence to the adjacent lake or paddy field. Since this stream of water flows across a plantation of Mee trees, nutrient components mix with the water and are carried to the adjacent field. This is evidence that the ancestors had efficiently combined the irrigation and agricultural systems with elements of the natural environment and is a testament to their indigenous knowledge as well as their altruistic attitudes.

Farmers knew the chemical properties of the various parts of the Mee tree and took advantage of having these trees at the water inlet points of paddy fields. Chopped roots of the Mee tree exposed to water helped to control insect larvae and pupae in the paddy field (Irangani and Shiratake, 2013). Ancient farmers would also select a Mee tree in a specific location of the field, remove a certain number of rings from the bark and place them in the water inlet or mix them with sand and spray to the field in order to get rid of rats. The seeds of the tree were chopped and sprayed to the field to get rid of paddy bugs (Jayatissa, Dissanayake and Perera, 2019). The oil extract from the seeds was used as a natural pesticide against Kola hakulana dalambuwa (leaf roller – *Cnaphalocrocis medinalis*) (Irangani and Shiratake, 2013). The oil was also used to light oil lamps in the paddy field to prevent insects such as paddy bugs from destroying the produce (Jayatissa, Dissanayake and Perera, 2019). By such methods, the farmers managed to control pests without the use of harmful agrochemicals.

The flowering season of the Mee tree attracts insects and birds to it (for the nectar of the flowers and for the fruits) and creates a natural food chain around the tree. This natural food chain attracts various predator birds towards the paddy field which naturally reduce the pest infestations. Also farmers placed the petiole of coconut leaves at different locations around the paddy field as resting places for birds. This allow the predator birds to rest on the paddy field further reduce the pests. These petiole of coconut leaves functioned as a resting site for owls at night who hunt rats who damage paddy in its final growth phase as well. By this method, the farmers were able to attract birds across the field and encourage natural pest control. The insects themselves attract insectivorous bats who feed on them and eventually help control the pests.

The fruit of the Mee tree is one of the favourite meals of the fruit bat (Old World fruit bats, Pteropus flying fox). Swarms of bats arrive and consume the fruits once they are ripe enough and leave bite marks on the remaining fruits (Figure 4). By the dusk of the second or third day, these fruits too ripen and the villagers believe that these bats have the remarkable ability of flying back in search of the fruits that they marked. Occasionally, the bats would carry a few ripe fruits back to their roosting sites. The fruits that fall from their grip along the journey gets planted in the vicinity and is a reason for the abundance of Mee trees around the roosting sites of bats. The excrement produced by bats (guano) after consuming the fruits of the Mee tree is a source of organic fertilizer for paddy fields. These stools contain organic matter, carbon, nitrogen, phosphorus etc. Bat guano is an organic fertilizer that can improve plant growth and soil structure. Mee trees were therefore grown in paddy fields to attract bats in order to collect their guano for fertilizer. Traditional farmers also used the leaves of the tree as fertilizer (Jayatissa, Dissanayake and Perera, 2019).

(Insert Figure 4 Here)

Scientific evidence for the benefits of using Mee tree in cultivations

The chemical composition and properties of the essential oil extract of the Mee tree were studied and it was found to have high levels of Farnesol and its' analog, Farnesene. Farnesol is considered to act as a pheromone for several insects and as a pesticide for mites. It also has antimicrobial action against certain bacteria and fungi (Suryawanshi and Mokat, 2019) .

Even though there is a scarcity of documented evidence for the use of bat guano in Sri Lanka, there is plenty of documented evidence from world history to understand the importance of bat guano use in cultivation by ancient farmers. Andean people from the small islands of Peru have used bat guano as a soil amendment as far as 1500 years ago (Cushman and Guano, 2013). In Tanzania, the Kisarawe caves are said to harbour three million bats producing one ton of guano per day (Juma, 2001). There are reports that over 3000 tons of bat guano were obtained from these caves between 1934 and 1954 for agricultural use, especially for farms near the areas of the cave of Sukumawera in Mbeya, South Tanzania (Nilsen, 1980).

When considering the chemical composition of guano of insectivorous bats, one study has shown that on average, oxygen was the most abundant element (54.94%). This helps to increase the soil bacteria and other helminths which enrich the soil structure. Additionally, macro-nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium and sulphur were also abundant in the guano (Misra, Gautam and Elangovan, 2019). As mentioned above, when a food chain developed around these trees, eventually bat and bird guano dropped to the paddy field. The average composition in the fresh guano of insectivorous bat and birds are around 50% carbon, 10% nitrogen, 2–7 % phosphorus pentoxide (P_2O_5) with sulphur abundances of 10–20%

(Shahack-Gross et al., 2004; Forbes et al., 2007). These key elements nourished the ancient paddy fields and farmers managed to control their cultivation in an eco-friendly manner. The incorporation of bat guano into the soil enhances crop production and studies have thus emphasized the importance of conservation of insectivorous bats and their guano(Sridhar et al., 2006).

Remnants of insects including agricultural pests belonging to the orders Coleoptera, Lepidoptera, Homoptera and Hemiptera were found in the faecal matter of insectivorous bats in a study done in India (Misra, Gautam and Elangovan, 2019) . There is a lack of published data except for the indigenous knowledge of local farmers that bat pest control contributed to the food security in Sri Lanka. However, there are plenty of published data to provide evidence that both bats and birds increased the yield of the crops. Indonesian cacao plantations produced increased yield when the herbivorous insect population reduced with natural pest control(Maas, Clough and Tscharntke, 2013). According to published data, cotton yield worth USD 741,000 was protected annually in the United States by bats feeding on cotton bollworms (Cleveland et al., 2006). It has been shown that an estimated USD 3.7 billion worth of cotton harvest was saved annually across the US by bat populations. A study conducted in Thailand has shown that bats protects rice worth more than USD 1.2 million annually (Wanger et al., 2014). The same study highlighted that the bats also feed on other major rice pests in Asia such as the brown planthopper (*Nilaparvata lugens- - Dumburu Pela Keedawa)* and the White-Backed Planthopper (WBP). The bats not only feed on adult male and winged female White-Backed Planthoppers but also consume pregnant WBPs which prevents future offsprings from hatching(Wanger et al., 2014). The western world has understood the value of these bats and has taken steps to attract bats to their farmlands. For example, in California, USA, farmers have installed resting boxes for bats within their farmlands to help control agricultural pests(Tuttle, Kiser and Kiser, 2005).

Conclusions

The rice we eat is contaminated with various chemicals and heavy metals introduced to farmlands by the use of numerous agrochemicals and contaminated water for irrigation. This could be one of the reasons for the various organ malfunctions and cancers burdening the population of the country. There is an abundance of indigenous knowledge used by local farmers in cultivation. Sri Lankan farmers used eco-friendly methods of cultivation which were developed based on their experiences and the scientific basis of these practices has now been proven by various studies. At present, although most Sri Lankan farmers are dependent on agrochemicals introduced by the western world, the agricultural sectors of those countries are attempting to revert to organic cultivation techniques used by ancestors since time immemorial. This shift should be regarded as a wake-up call by farmers and authorities to adopt sustainable agricultural practices in order to safeguard the environment as well as human health.

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Figure Legends

Figure 1 - A) Mihinthale pillar inscription B) Mihinthale slab inscription

Figure 2 - Abhayagiri slab inscription

Figure 3 - Worshipping Lord Gana (a deity) near a Mee tree in Madawadiwiya, Kidagalegama, Sri Lanka.

Figure 4 - Bats resting in Kumbuk trees along the Malwathu river bank near Jethawana project, Anuradhapura

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