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EDIBLE INSECTS AND THEIR FOOD PLANTS IN NAGALAND-FUTURE PROSPECTS

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ABSTRACT

Globally, edible insects are a delicacy and popularly consumed, however, despite their nutritional and economic potential, little is known about their developmental stages, feeding behaviour and host plants. The current advocacy of edible insects to combat future food security could lead to indiscriminate collection of insect resources. Due to lack of data on their host plants and related habitat associations, many edible insects are at risks of exploitation and ecological damage. the present study is an effort to collect data on the habitat and host plant preference as well as the lifecycle and feeding behaviour of edible insects that occur in Nagaland. Besides, being naturally available in the wild, insects are reported to also feed on cultivated plants. Knowledge on the ecology of insect and host plants as well as proper management, cultivation, semi-domestication and conservation strategies are discussed. These could possibly lead to large-scale production, sustainable utilization of insects as well as the longevity of the plants they are associated with.

Key words: Edible insects, ecology, entomophagy, environment, food plants, health, mass-rearing of insects, Nagaland, sustainability, traditional knowledge

While plants may be a food/energy resource or nest location for insects, insects may also act as protection, dispersers or fertilizers for plants (Calatayud et al., 2018). To meet the world's future food security and sustainability needs, food production must grow substantially and at the same time agriculture's environmental footprint must shrink dramatically (Dunkel and Payne, 2016). While, entomophagy is advocated worldwide to combat future food insecurity, indiscriminate collection of insects involves serious risks such as overharvesting, ecological damage and consumption of insects that are contaminated by pesticides, environmental contaminants or other disease-causing agents which may exist in the environment (Gahukar, 2016). In this regard knowledge on the food plants of insect species may bring sustainable insect farming which is an ideal solution to address many of our health and environmental concerns (Dunkel and Payne, 2016). As insects have been consumed as food for generations in Nagaland, the present study focuses on certain commonly available edible insect species as well as their food plants for large-scale production possibilities.

MATERIALS AND METHODS

Located at 93°20'-95°15'E and 25°6'-27°4'N, Nagaland shares an international border with Myanmar and falls under the biodiversity hotspot region of the world. The region enjoys a varied altitudinal range from 199-3841 masl, and a unique geographical location constituting 85.43% (14,164 km^2) forest cover, 5,137 km^2 dense forest and 9,027 km^2 open forests (Changkija, 2014). The state's climate is humid subtropical to warm temperate with a mean annual rainfall of 2600 mm. Edible insects feed on agricultural crops, cultivated trees or wild plants and therefore extensive surveys were conducted during the period across eight districts viz., Dimapur, Kohima, Mokokchung, Mon, Noklak, Phek, Wokha and Zunheboto. Prior to the survey, preliminary investigations were conducted for documentation on the seasonal availability of the insect species, their preferred habitat and host plants. We mainly focussed on the commonly available edible insect species and observed their association with its host plants, their habitat and feeding habits. Photographs were taken for further identification. Host plants were identified using published books and literature (Reddy et al., 1985; Changkija, 2014; Pradheep and Soyimchiten, 2016) and authenticated from the Department of Botany, Nagaland University, Lumami.

RESULTS AND DISCUSSION

Among the 106 edible insects reported from Nagaland (Mozhui et al., 2020), food plants of only a few insect species are known. Table 1 gives a detailed description of the edible insect, stage of consumption, food plants, habitat and mode of feeding. Insects are abundant seasonally and feed on host plants to complete

Table 1. List of commonly available important edible insect species and their food plants

Edible insect			Food plants	Habitat	Mode of feeding
Common name	Scientific name	Edible stages			
Stink bug	*Coridius janus* F., *Cyclopelta siccifolia* Westwood	Adult	*Cucurbita moschata* Dutch, *Lagenaria vulgaris* L., *Phaseolus vulgaris* L., *Vigna unguiculata* L. and *Psophocarpus tetragonolobus* DC.	Home garden	Sucking
Dinidorid bug	*Coridius* sp.	Adult	*Prunus cerasoides* D.Don	Home garden/ wild	Sucking
Litchi stink bug	*Tessaratoma javanica* Thunberg	Adult	*Litchi chinensis* Sonn.	Home garden	Sucking
Wood borers	*Batocera rubus* L. *Batocera parryi* Hope *Batocera rufomaculata* De Geer	Larva, pupa	*Aguilaria agallocha* Roxb. *Moringa oliefera* Lam. *Phyllantus emblica* L *Artocarpus heterophyllus* Lam. *Mangifera indica* L.	Home garden/ wild	Chewing
Palm weevil	*Rhynchophorus ferrugineus* Olivier	Larva	*Caryota obtusa* Griff. *Caryota urens* L.	Home garden/ wild	Chewing
Bamboo borer	*Omphisa fuscidentalis* Hampson	Larva, pupa	*Bambusa* sp. *Dendrocalamus* sp.	Wild	Chewing
Poinciana looper	*Pericyma cruegeri* Butler	Larva	*Delonix regia* (Boj. Ex.Hook) Raf.	Home garden/ wild	Chewing
Banana skipper	*Erionata torus* Evans	Larva	*Musa* sp.	Home garden	Chewing
Carpenter worm	*Cossus* sp.	Larva, pupa	*Alnus nepalensis* D. Don, *Quercus griffithii* (Hook. f. and Thomas ex. Miq.), *Qercus serrata* (Murray)	Wild	Chewing

their lifecycle. Some common edible insects along with their host plants are described below:

The stink bugs (*Coridius janus* F. and *Cyclopelta siccifolia* Westwood) depend on host/food plants to complete their developmental stages. The red pumpkin stink bug *C. janus* generally colonizes on the stems of *Cucurbita moschata* (Dutch) (Fig. 1a), bottle gourd *Lagenaria siceraria* (Molina) Standl., string bean *Phaseolus vulgaris* L., cowpea *Vigna unguiculata* L. and Goa bean *Psophocarpus tetragonolobus* DC. The stink bug feeds by sucking on the sap on soft parts of the plant and damages the plant. The dinidorid bug *Coridius* sp. colonizes on wild Himalayan cherry *Prunus cerasoides* D. Don.

Cucurbita moschata Duchesne: Climbing or trailing herbs, annual, densely hairy. Leaves simple, broadly ovate (12-25 x 20-30cm), shallowly 5-lobed, apex acute, base cordate, margin denticulate, rough on both surfaces; petiole 10-20cm. Male and female flowers solitary, axillary. Fruit globose or ovoid. The plant has a uniform distribution in Nagaland.

Lagenaria siceraria (Molina) Standl.: Annual scandent herb, pubescent. Leaves broadly ovate or suborbicular, base cordate, apex acute or acuminate, shallowly lobed, petiole 5-10 (-30) cm. Male flowers on longer pedicels, female flowers on shorter pedicels; flowers are white. Fruit, globose or cylindrical; seeds obovate, compressed, with distinct margin. The plant is found in the warmer regions of Nagaland.

Phaseolus vulgaris L.: Annual herbs, twining. Leaves pinnately 3-foliate, leaflets simple, lateral ones oblique, margin entire, base rounded or cuneate, apex acuminate; stipules lanceolate. Inflorescence axillary raceme, shorter than leaves, flowers borne on swollen nodes in clusters. Flowers white or purplish. Legumes linear-oblong (10-15cm long), slightly curved, glabrous and beaked. Seeds (5-10), oblong or kidney shaped, white, purple brown to black or variously mottled. The plant has a uniform distribution in Nagaland.

Prunus cerasoides Buch.-Ham. ex D.Don: Deciduous trees, 8-15m. Leaves ovate or oblong-elliptic, base rounded or cuneate, apex long acuminate, margin serrate, 8-14 x 4-6cm, glabrous, petiole 1-2 cm, 3-5 raised glands at apex of petiole. Flowers in fascicles of 1-3, at axils of fallen leaves, pink. Fruit a drupe, ellipsoid. In Nagaland, the plant is distributed mostly in the colder region, also cultivated as avenue trees.

Psophocarpus tetragonolobus (L.) DC.: Annual or perennial climbing herb. Stems glabrous, stipules lanceolate. Leaves 3-foliolate, leaflets ovate-deltoid (4-10x3.5-8cm), base rounded or truncate, apex acute or acuminate, margins entire. Inflorescence axillary raceme, 2-12 flowered. Legumes tetragonal, 10-25(-40) cm long, wings 0.3-1cm wide, margins wavy, serrated. Seeds subglobose, brown, black. The plant is cultivated in the warmer regions of Nagaland.

Vigna unguiculata (L.) Walp.: Annual or perennial herbs, erect or twining. Stems subglabrous, stipules lanceolate. Leaves pinnately 3-foliate, leaflets entire or lobed, lateral ones oblique, leaflets ovate-rhomboid (5-11x4-6cm), base acute to rounded, apex acute. Inflorescence axillary raceme, clustered at top of the rachis. Legumes terete, up to 70cm long. Seeds many, dark red or black, mottled, oblong or reniform. The plant is cultivated all over Nagaland.

Among the larger stink bugs (e.g., *Eurostus grossipes* Dallas and *Tessaratoma javanica* Thunberg), the litchi stink bug *T. javanica*is commonly appreciated as a food source and is recorded to feed on two commonly available host plants (the litchi tree *Litchi chinensis* (Sonn.) and host plant belonging to Sapindaceae family) where they complete their developmental stages (Fig. 1b). Members of tessaratomidae are phytophagous and they spend most of their lives on the leaves and stem of the host plants and exhibit maternal care of eggs and offspring. As stink bugs are reported to feed on fruit and vegetable plants, farmers intend to spray pesticides which can have adverse effects on health as well as the environment. However, hand collection for consumption happens to play an important role as an alternative biological control method.

Litchi chinensis Sonn.: Medium sized tree up to 15m tall, bark grey, crown dense, branching nearly from the base. Leaves 10-25cm with petiole, leaflets 2-4 pairs, 5-15 x 2-5cm, ovate-lanceolate, base cuneate, apex acuminate, margin entire, coriaceous, glabrous and shining above. Inflorescence terminal, paniculate, much branched, 15-30cm long. Flowers are pale green, small, 0.3-0.5 cm across. Fruit globose, dark red when matured. Seeds are oblong-ovoid, brownish-black, covered by a fleshy aril. The plant is cultivated in the lower altitude of the state.

Of all edible insects, larvae of long horn beetles such as *Batocera rubus* L., *Batocera parryi* Hope and *Batocera rufomaculata* De Geer, are important edible insects harvested from the wild. These infest various tree species such as agarwood *Aguilaria agallocha* Roxb., drum stick tree *Moringa oliefera* Lam., Indian gooseberry tree *Phyllantus emblica* L, jackfruit *Artocarpus heterophyllus* Lam., mango tree *Mangifera indica* L., tamarind tree *Tamarindus indica* L., etc (Fig. 1c). Using its strong jaws, the larva bores through and feeds on its host plant. Because of their wood-boring habits, long horn beetles are considered as pests; however, they are also known to have immense economic and ecological importance (Kariyanna et al., 2017). As wild harvesting may lead to the destruction of biodiversity, therefore formulation of artificial feed as per their food plants can help maintain the biodiversity as well as combat food insecurity.

Aquilaria agallocha Roxb.: Large evergreen tree of 15-25m high, straight trunk with an elongated crown, bark greyish white, minutely warty. Leaves alternate, elliptic-lanceolate or oblanceolate, apex caudate acuminate, base rounded or cuneate, glabrous. Inflorescence terminal, umbellate cymes. Flowers are white, silky. Fruit capsular, obovoid. Found in the warmer regions of Nagaland. The wood is used as incense, perfume. The population of this plant is getting depleted due to illegal felling for the priced agar.

Moringa oleifera Lam.: Medium sized deciduous trees, bark grayish smooth to wrinkled. Leaves 3 pinnate, 30-60cm, leaflets variable in size, ovate, obovate-oblong, 1-2.5 x 0.5-2cm, pubescent when young but glabrous at maturity, oblique at base, apex rounded or emarginate, glaucous beneath. Inflorescence a panicle up to 30cm. Flowers are white, fragrant. Fruit a capsule, linear oblong, up to 50cm. Seeds subglobose, winged along the angles. The plant grows in the warmer regions of Nagaland, planted as live hedge. The leaves, flowers and fruits are used as vegetables, bark and roots are used medicinally.

Phyllanthus emblica L.: Small or medium sized trees, 3-15m high, bark grayish, lenticellate. Leaves distichous, numerous, linear-oblong, apex subacute, base slightly oblique. Inflorescence a fascicle. Flowers are minute, creamish or yellowish. Fruit a drupe, globose, compressed. Seeds reddish. The plant has a uniform distribution in Nagaland. The fruit is used medicinally.

Artocarpus heterophyllus Lam.: Evergreen trees, 10-20m tall, bark blackish,brown, branchlets smooth or furrowed, glabrous. Leaves ovate, elliptic, obovate, 7-15 x 3-7cm, lobed on new growth, leathery, base cuneate, apex rounded to acuminate, margin entire, stipules broadly ovate, caduceus, leaving annular

scar. Male inflorescence axillary on branchlet, female inflorescence globose fleshy. Fruit a syncarp, oblong, globose, 30-60cm. The plant is cultivated in the warmer regions of Nagaland.

Mangifera indica L.: Evergreen trees, 10-25cm tall, with a dense crown, bark dark brown or reddish brown, warty. Leaves elliptic or lanceolate, 10-20 x 2-6cm, glabrous, apex acuminate, base cuneate, margin undulate, petioles 1-5cm. Inflorescence terminal, panicles up to 30cm long, purplish. Fruit a drupe, ovoid-oblong with a curved tip, green, yellow or reddish when ripe. Seed compressed. The plant grows in the warmer regions of Nagaland.

Among the edible insects, the palm weevil *Rhynchophorus ferrugineus* (Olivier) is important for its successful indoor breeding. Palm weevil breeding still depends on natural food plants (Hanboonsong et al., 2013). In Nagaland, the palm weevil larvae feed on two commonly available food plants- *Caryota obtusa* Griff. and *C. urens* L. While, they are considered as pests due to the damage caused by them, weevil larvae are appreciated as health foods and are semi-domesticated by members of the Naga tribes for personal consumption (Fig. 1d). In the process of semi-domestication, the palm trunks are cut into different lengths and the adult male and female weevils are released and covered with palm branches. The cut trunks are watered twice a day until

Fig. 1. Commonly available edible insects of Nagaland (a) *Coridius janus* feeding on its host plant (*Cucurbita moschata*); (b) *Tessaratoma javanica* on its host plant Sapindaceae; (c) edible wood boring beetle larvae; (d) edible palm weevil larvae; (e) *Omphisa fuscidentalis* on its host plant *Bambusa* sp.; (e) *Cossus* sp. larvae on its host plant *Quercus* sp.

harvesting. Similar palm weevil rearing and harvesting method is practiced in Thailand (Hanboonsong et al., 2013). The potential of palm weevil breeding for mass production should be considered and initiated given the successful indoor breeding in Thailand.

Caryota urens L.: The trunk of the plant is up to 15m tall, grey, smooth, with annular leaf scars, crown elongate. Leaf sheaths long. Leaves very large, drooping, 2-pinnate, lateral leaflets up to 30 cm, base cuneate, apex oblique, irregularly lobed. Inflorescence developed at the apex and subsequently produces flowers lower on the trunk. Fruit globose, fleshy mesocarp. The plant is distributed in the lower altitude of the state. Seeds and young shoots are eaten, leaves are used as fibres.

Caryota obtusa Griff.: Tall, large palms, up to 40m. Trunk girth about 1m in dia, swollen, greyish. Leaves borne in compact crown at the top of stem; petiole 1-2m, spreading almost horizontally; primary pinnae 19-22/side of rachis, secondary pinnae 20-25/side of secondary rachis; coriaceous, base cuneate, oblique, jagged margin, apex obtuse. Inflorescences borne among leaves, up to 6m. Fruit globose, reddish; 2 seeded. The plant is usually found in montane rain forest in limestone soil areas in the eastern parts of the state.

Lepidopteran bamboo borer *Omphisa fuscidentalis* (Hampson) infestation is found on *Bambusa* sp. and *Dendrocalamus* sp. (Fig. 1e). The infestation does not harm the plant but is reported to make the bamboo stronger than the uninfested ones. The presence of bamboo larvae can be recognised by the length of the internodes i.e., shorter internodes are reported to hold larvae which are collected for consumption.

Bambusa sp.: Arborescent perennials, up to 25m tall. Rhizomes pachymorph, without extended necks. Culms usually glabrous. Culm sheaths with large auricles; deciduous. Branches several, branchlets of lower branches sometimes form weak or tough thorns. Leaves shortly petioled, leaf blade variable in size, upto 25cm. Inflorescence fully bracteate, iterauctant; psuedospikelets clustered on flowering branches. Fruit a caryopsis. The plant is distributed all over the state.

Dendrocalamus sp.: Arborescent perennials, up to 30m tall. Rhizomes pachymorph, without extended necks. Culms with dense hairs; culm sheaths with small auricles, deciduous. Branches unequal. Leaves large, up to 50 cm. Inflorescence fully bracteate, iterauctant. Pseudospikelets clustered on soft or spiky globose mass at nodes of leafless flowering branches. Fruit a caryopsis. The plant is distributed all over the state.

Poinciana looper *Pericyma cruegeri* (Butler) larva feed gregariously at first on the foliage of the gulmohar tree *Delonix regia* (Boj. Ex.Hook) Raf. but separate when older. It is considered as a pest causing defoliation; however, the larvae are an important food item of the Nagas.

Delonix regia (Bojer ex Hook.) Raf.: Large deciduous trees, to 20m tall. Bark greyish brown, rough, crown umbrella like. Leaves 20-60cm, pinnae 15-20 pairs, 7-15cm; leaflets 12-25 pairs, oblong, obtuse or subacute, base rounded or oblique. Inflorescence corymbose racemes, terminal or axillary. Flowers bright red. Pods large, laterally compressed, black when ripe. The plant grows in the tropical parts of Nagaland.

The rounded palm-redeye *Erionata torus* (Evans) larva feed on *Musa* sp. making leaf shelters where all its developmental stages occur. They are considered as a serious pest as they cause severe foliar damage and considerable reduction in photosynthetic efficiency resulting in a decreased bunch size and weight (Jayanthi et al., 2015). Hand-picking is a way of physical/ mechanical control, which is highly practical and its collection for human consumption is a control method.

Musa sp.: Perennial herbs, tufted, rhizomatous, stoloniferous. Pseudostems composed of closely packed leaf sheaths, base swollen. Leaves very large, petiole long, base enlarged into a sheath, leaf blade oblong. Inflorescence terminal, erect, pendulous or subpendulous. Bracts green, purple, brown, or yellow. Fruit fleshy. The plant is uniformly distributed in Nagaland.

Among the lepidopterans, the cossid moth, *Cossus* sp. is a popular one and is found mostly in oak trees such as *Quercus griffithii* (Hook. f. & Thomas ex. Miq.), *Quercus serrata* (Murray) and Alder tree *Alnus nepalensis* (D. Don.). The adult lay eggs on the tree trunk, the larva after emergence eat their way into the trees and may take two to three years to mature. Due to its immense dietary benefits, the larva is much sought after (Fig. 1e).

Alnus nepalensis D. Don: Trees up to 20m tall, barkgray, warty, horizontally lenticellate. Leaves broadly elliptic, obovate-oblong, 4-16 x 4-9 cm, base cuneate or rounded, apex acute to acuminate, margin entire or minutely serrate. Male spikes long up to 25cm,

female spikes short to 1 cm. Fruiting spikes oblong, blackish brown when ripe. The plant is distributed from middle to high altitude region of Nagaland.

Quercus griffithii Hook.f. & Thomson ex Miq.: Deciduous trees of 10-25m. Bark gray, fissured, warty. Leaves crowded at branch tips, obovate, elliptic, 10-25x4-10cm, base cuneate or rounded, margins serrulate, apex acute to acuminate, glabrous above, glaucous tomentose beneath. Male spikes drooping, slender, many together, female spikes clustered at tip. Cupule enclosing half of the nut. Acorn ellipsoid to ovoid ellipsoid, 1.2-1.5 cm. The plant is distributed from the middle to high altitude region of Nagaland.

Quercus serrata Murray: Deciduous trees, to 20m. Bark deeply splitting vertically. Leaves lanceolate, or elliptic-lanceolate, 5-15x1.5-6cm, apex acute to acuminate, margin serrate, base rounded, lateral nerves 10-18 pairs. Male spikes 5-10 cm, female spikes 2-4 cm. Fruit solitary or in pairs; cupule hard, woody, enclosing one-third of nut. Acorn globose or subglobose, 1.2-1.7 cm. The plant is distributed from the middle to high altitude region of Nagaland.

Edible insects have been utilized as food by the different ethnic communities all over the world for generations. Today with the increasing demand for meat as well as the search for an alternative source of protein, it is really important to determine the host plants of edible insect which in turn will not only help in easy harvesting but can also help in developing methods through technology intervention for large scale production, sustainable utilization of insects as well as the longevity of the plants they are associated with. Through this study, it can be concluded that knowledge on the food plants of edible insects is extremely important while looking forward to large-scale production of edible insects.

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