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Commercial meliponiculture- beekeeping with stingless bee, *Tetragonula iridipennis* Smith (Hymenoptera: Apidae: Meliponini)

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Tetragonula iridipennis, belonging to the family Apidae under subfamily Apinae, is known as stingless bees as they do not have sting apparatus (Devanesan & Raakhee 1999). They are also called dammar bees as they construct numerous elliptical cells for storing pollen and honey by using a special material called "cerumen" consisting of wax and resin (Raakhee and Devanesan 2000).

Stingless bees are ancient eusocial bees which populated the earth 65 million years ago, quite earlier to *Apis* species and are limited to tropics and subtropics because of their inability to maintain the hive temperature. Honey bees and the stingless bees are honey producers coming under the order Hymenoptera, family Apidae and subfamily Meliponinae. They lack sting hence the name "stingless bee" and defend by biting with mandibles. Unlike honey bees stingless bees do not use pure wax for nest building and water for nest cooling. Brood production is similar to solitary bees and they follow mass provisioning to rear their larvae. Both groups make honey in perennial nests founded by a swarm of sterile workers and a queen and colonies occasionally produce male bees**.**

The ICAR All India Co-ordinated Research Project (AICRP) on Honey bees and Pollinators, Vellayani Centre of Kerala Agricultural University, pioneered the research on Meliponiculture in India (Devanesan & Raakhee 1999).

We happened to notice the presence of dammar bees in different districts of Kerala in basements of buildings and compound walls during Thai sac Brood virus (TSBV) disease survey (1992-93) . The photographs were shown to Dr. O.P. Dubey, the then Assistant Director General (PP), who advised us to conduct detailed studies about the bee species. The ICAR sanctioned a project entitled "Bio-ecology, domestication and management of stingless bees in Kerala" (9-7-1999 to 8-1-2003 for INR. 13 lakhs).

We succeeded in standardizing technologies for commercial meliponiculture by a team of scientists (Raghee M, Shailaja K.K, Premila K.S. and Nisha, M. M) under the leadership of Dr. Stephen Devanesan. We developed technologies for hiving, domestication and management of stingless bees with a view to enhance the number of

colonies and this centre has a prime role in popularization of Meliponiculture in the State. As instructed by ICAR, the final report was printed out as "STATUS PAPER ON STINGLESS BEE *TRIGONA IRIDIPENNIS* SMITH" authored by S. Devanesan, K.K. Shailaja and K.S. Premila. The same was released in the Annual Group Meeting held at Rajendra Agricultural University, Pusa, Samasthipur, Bihar in February 2009 by then Assistant Director General (PP), Dr.T.P. Rajendran. It was resolved in the group meeting that the research on stingless bees has to be promoted in all AICRP Centres and Vellayani centre as nodal centre for stingless bee research (Fig. 1).

Out of more than 500 species described worldwide, about 50 species occur in Asia. They have a wide distribution in India with reports of the following nine species. *Lepidotrigona arcifera* (Cockerell, 1929), *Lisotrigona cacciae* (Nurse, 1907), *Lisotrigona mohandasi* Jobiraj & Narendran, 2004, *Tetragonula ruficornis* (Smith, 1870), *Tetragonula bengalensis* (Cameron, 1897), *Tetragonula iridipennis* (Smith, 1854), *Tetragonula praeterita* (Walker, 1860), *Tetragonula aff. laeviceps* (Smith, 1857), *Tetragonula gressitti* (Sakagami, 1978). Asiatic stingless bee *Tetragonula (Trigona) iridipennis* Smith is the common stingless bees found in Kerala which was identified by Dr. David W Roubik, Smithsonian Tropical Research Institute, USA.

Their small size (2-16 mm) allows them to access varied flowers whose openings are too narrow for nectar and pollen from which the *Apis* bees cannot forage (Devanesan, *et al*., 2002). They also collect nectar and pollen from low lying herbs and weeds having comparatively smaller flowers, which are not commonly visited by *Apis* spp. including medicinal plants (Premila, *et al*., 2007). The stingless bees make less honey compared to *Apis* honey bees and are widely distributed in diverse tropical regions of India (Vijayakumar *et al.,* 2013). Although it produces far less honey the honey is unique having great medicinal value fetching high price. It is used in folk medicine, Ayurveda, Sidha, Unani etc for curing many diseases. Stingless bees are excellent pollinators of both rest/agricultural/horticultural flora and crop plants, and exhibit great flower constancy which increases the ecological importance of these bees for conservation of biodiversity and yield enhancement through crop pollination.

Meliponiculture is the art and science of rearing stingless bees on a commercial scale for honey production or pollination. It is reared as backyard beekeeping practice mainly for honey production. It is being popularized in the rural homesteads for additional income generation. In Kerala, the stingless bee colonies are reared in logs, earthen and clay pots, bamboo bits, wooden boxes and coconut shells. Creating awareness about the scientific meliponiculture will be helpful to the farmers for rearing them in homesteads so as to benefit

for the pollination of vegetables and other fruit crops available in and around promoting commercial meliponiculture (Fig. 2). Handling of stingless bees is easier, even children and women can rear stingless bees. Hence it is recommended that "each homestead to have one stingless bee colony". The production of stingless honey does not match the demand. As it is recommended for the cure of different diseases including cancer, the demand has increased in the market due to its medicinal properties.

Natural domicile and nest architecture

Stingless bees prefer darkness and the natural domicile is the crevices in the basements of old buildings, compound walls, tree trunks, hollow blocks etc. The colonies found in natural conditions are called 'feral' colonies. They remain in the same location if there is no disturbance. The nest of stingless bee essentially consists of hive entrance, brood cells, storage pots of honey and pollen, resin dumps, pillars of wax, waste dumps etc.

Openings to the nest are through resin tubes of varying shapes, lengths and sizes, normally built of wax and mud, sometimes sticky in nature. The structure of hive entrance of *T. iridipennis* colonies in wooden boxes, bamboo bits and earthen pots varies in their shape and size (long or short tubular, round or cryptic, half oval in shape etc). Major part of entrance tube material is made up of resin. Some dust materials like soft barks, mud and cobweb like silky material is also found over the tubes (Fig. 3). The texture is not brittle and the nest consist of five parts; an entrance, brood comb, involucrum, store pots and batumen. In the construction of brood comb, storage pot and involucrum they use cerumen (Raaghee and Devanesan, 2020) (Fig.4).

The arrangement of brood cluster is loose in *T. iridipennis.* They build multi-layered combs one over the other and each expanding concentrically and horizontally. Cell construction starts from the bottom of the pillars and proceeds in an upward direction. At a time, a batch of cells is constructed through successive and intermittent contributions of several workers. Brood cells are dark brown in colour in the early stages and as the pupae mature, the cerumen from walls of the brood cells are removed and became creamy in colour so that the cocoons get exposed.

Most of the removed cerumen is used again to build another brood cell, storage pot or other nest structures. The queen cells of *T. iridipennis* are larger (4.00 mm) than that of worker cells (0.22 mm). Queen cells could be seen in stingless bee colonies from November to March. They are intermixed with worker cells or seen at the periphery of the brood cluster. The food chambers are normally oval in shape and larger than the brood cells. The pollen pots are located near the entrance and seen intermixed whereas the honey pots are seen either near the entrance or far from the entrance. The honey pots are also seen intermixed with pollen pots.

Stingless bees also lead a colonial social life and each colony consists of a single queen few drones more and workers as in the case of *Apis* bees. Usually one queen is present in a colony and the queen lays egg and controls and co-ordinates all the activities in it. The queen is much larger than workers and drones, lacking corbiculae and wax glands. It has longer scape, shorter tongue, smaller mandibles, wings partially covering the swollen abdomen and less distinct glabrous streaks on mesonontum, abdomen is dark brown in colour with white stripes. Queen lays 80-120 eggs per day. The developmental period of a queen (egg to adult) is 65-70 days. The newly emerged queen is called 'gyne' or virgin queen. The new queen makes her nuptial flight, where she is mated with a single male. The virgin queen will mate only once. The sperm is stored in a special sac 'spermatheca' in her body for her entire life. The queen's ovaries initiate egg development, enlarging the abdomen, so that she cannot fly anymore. Egg laying commences within 10 days after mating. She can choose whether or not to fertilize each egg with the sperm. The queen and workers develop from the fertilized eggs, and drones/ males develop from the unfertilized eggs. The life span of queen is up to five years, though her stamina for egg laying will be reduced over time. The life span of queen is reported to be up to five years (Raaghee 2000) (Fig.5).

The drones or male bees are developed from unfertilized eggs and are few in a colony and function is mating. Number of drones increase in the colonies during the brood rearing season. The drones can be identified by straightly arranged ocilli, laterally arranged compound eyes, smallest scape, longest antennae, smallest mandibles, less distict glabros streaks on mesonotum, rudimentary corbicula, and wings projecting slightly beyond the blunt abdomen and genitalia (Fig. 6).

Worker bees are females developed from fertilized eggs. Most of the works in a colony are performed by the worker bees. The worker bees are smaller in size than the queen with small abdomen and entire body is black to blackish-brown. Males and workers are very similar and difficult to differentiate. The developmental period of a worker (egg to adult) is found to be 44.5 days. The young workers after emergence perform different jobs, preparation and repairs of the brood chamber, construction of the involucrum and provisioning of cells. Some will become nurse bees, producing royal jelly to feed the larvae, young adults and queen. As age advances, perform duty as guards and foragers and with a life span of 80 days - (Fig. 7).

Honey and pollen are the food of stingless bees as *Apis* bees. Stingless bees do not go far distance for foraging as other boney bees. They visit plants within an area of 1 km around the hive. They forage from medicinal plants, agricultural and horticultural crops, spices, vegetables, cash crops, ornamental plants and number of weed plants around the

locality. They start foraging activity in the early morning.

Studies conducted to document the plants visited by the stingless bee revealed that there are 142 plant species, which provide either nectar or pollen or both to stingless bees in the State (AICRP, 2014). Out of the 142 plants, 70 provided nectar alone, 25 provided pollen only and 47 provided both nectar and pollen. These include medicinal plants, plantation crops, condiments and spices, vegetables, field crops, ornamental plants, wild plants and weeds.

The AICRP on Honey bees and Pollinators, Vellayani centre has standardized technologies for hiving, domestication, management such as division of colonies, honey extraction, hygienic honey processing and dearth season management. These techniques helped meliponiculturists to adopt commercial meliponiculture. The centre disseminated to the public by imparting trainers training in different districts of Kerala in which 2074 women and 8322 men were trained. It is estimated that more than 50,000 stingless bee colonies are domesticated in the state for pollination service, ensuring sustainable agriculture and the conservation of biological diversity resulting in food security.

Hiving of feral colonies to artificial hives (earthen pot/wooden hive) will damage the buildings/ walls and the public hesitate to demolish the structures. However, feral colonies can be easily transferred to hives. For this, the mouth of an earthen pot is to be placed in front of the entrance of a feral colony and its rim is to be firmly attached to the wall using mud. Adequate support to the pot should be provided wherever required. An opening is to be given at the opposite side of the pot as bee entrance and surrounded with wax of stingless bee. The worker bees pass through the hole in the pot using it as new entrance. Gradually the bees realize that there is sufficient space inside the pot to store the brood and food reserves and hence they newly construct pollen and honey pots inside the earthen pot. Eventually they build the brood cells and start brood rearing inside it. The colony and pot should be left undisturbed for at least six months for the feral colony to settle inside the mud pot (Fig. 8). Later the pot with brood, pollen, honey, worker bees and a queen can be detached and shifted to a suitable site to establish as a new colony. Similarly wooden hives can also be used for hiving feral colonies (AICRP, 2011) (Fig. 8).

For transferring feral colonies from electric meter boxes or such structures, tubes/bent tubes are to be used. For this carefully remove the entrance tube of the bee colony. Then fix the detached entrance tube to one end of the plastic tube (1cm diameter). Fix the other end of the tube or bent tube in the original position of the hive entrance. The foragers will pass through the newly fitted plastic entrance hole. After a week time, a new wooden box hive / earthen pot with entrance hole at opposite side is to be attached to the

feral colony. It should be left undisturbed for at least six months.

Kerala Agricultural University (KAU) wooden hive

Among the different types of hives (wooden box, earthen pot, bamboo bit with volume of 1500 cc, 2250 cc, 3000 cc, and 3750 cc) evaluated for domestication, bamboo hive with 1500 cc capacity showed better brood development and maximum storage of pollen and honey followed by earthen pot and wooden hive. Considering the scarcity of bamboo bits, this centre has designed and developed a new 'KAU wooden hive' with two equal halves for the domestication of stingless bees. Volume of the box is 1960 cc and the internal measurements are: length - 35 cm, breadth – 7 cm and height - 4 cm, providing a hole in the centre of two halves on one side of the hive will act as the hive entrance. This hive is suitable for easy hiving, domestication, proper brood development, division of colonies and honey collection (Fig.9).

Seasonal Management of stingless bee colonies

The stingless bees have brood rearing season (October - December) followed by honey flow season (February - May) and a dearth season (June -September). Brood rearing season is best suited for the beginners to start meliponiculture. Acquiring knowledge about scientific meliponiculture through trainings and field practical will help for sustainable meliponiculture. Weekly observations of hives are not required as in *Apis* bees. Open the colonies for honey extraction during April-May and division of colonies during October-November. Protective measures have to be taken to prevent the attack of ants, predatory spiders, mites etc.

Growth period management

During the natural growth period, worker bees construct pillars of wax, which serve as base to the brood cells, over which oval/elliptical brood cell cups are constructed with the help of several workers. Queen bee lays more eggs during growth period. The laying queen bee, inspect the cup cells and few workers fill the cups with food materials for the growth and development of larvae. Then the queen lays an egg over the food stuff in the cup. This is known as 'mass provisioning.' After oviposition worker will close the cup cell with the resin. Once the first set of brood cells are provisioned and oviposit newer cells are constructed above it (Fig.10). When, the population of worker bees increase, new queen cells (royal cells) are produced naturally resulting in swarming of stingless bees colonies. Keeping empty KAU hive in the apiaries with stingless bees, pasted with stingless bee wax in the hive entrance will help to trap the swarm. Management of colonies properly during the growth period will help to increase the number of colonies through division.

Division of the colonies

Healthy and disease-free, active colonies having sufficient mature brood, young brood, pollen, honey and queen cells are to be selected for division. Division of the colonies is to be done during evening hours. Rainy and cloudy days are unsuitable for opening the hive.

While dividing the colonies many worker bees may be lost. To minimize the loss of worker bees, they are to be safely removed from the colony before opening it, as done during honey extraction. After removing the worker bees, locate the queen/queen cells and transfer the queen along with half the quantity of mature brood, one-fourth quantity of young brood and half the volume of pollen and honey pots to a new hive. A good healthy queen cell is retained in the mother colony. If no queen cell is present in the selected colony a queen cell is to be grafted from another colony. The daughter colony with queen is to be shifted to a new site approximately 1000 ft. (300 m) away from the original site. Mother colony with queen cell is to be maintained in the original site.

The colonies maintained in the newly designed wooden hive with two equal halves is easier to divide. Open the hive and equalize the brood, pollen and honey storage in both the halves and provide an empty half box above the bottom piece of the hive. Similarly, provide the other empty half below the other piece to make a full hive. Care should be taken to provide either a queen or queen cell in each of the newly divided colonies (Fig.11).

Avoid damage of the honey pots during division which may cause invasion of ants and fermentation of honey. Since the brood cells are very soft, care should be taken to minimize the damage of brood cells, otherwise the colony fails to establish. Presence of excess pollen and honey in the colony make them prone to pests and disease incidence and hence, it is desirable to remove excess pollen and honey periodically to maintain healthy colonies. While handling a hive, the direction of hive opening is to be marked so that the hive entrance can be retained in the original direction itself to avoid the confusion of foraging bees to find the entry.

Dearth season management

Feed can be prepared by using previous year's waste honey (collected during honey processing). A plastic tray used in the fridge for keeping the vegetables, with small ventilation (2-3 mm), is used as feeding tray, through which only the stingless bee workers can pass. Place a rectangular glass piece at the bottom of the tray. Put a cotton layer over the glass plate and drip with honey syrup using a wash bottle. 10-20 ml of syrup can be used for a single colony. Close the device with another piece of glass and keep the tray in a stand with proper ant protection devise (Fig.12).

Honey extraction

The honey from stingless bee colonies is extracted once in a year during April -May. The traditional method of honey extraction from stingless bee colonies is by squeezing the honey pots along with the pollen pots and brood cells resulting in unhygienic honey. The honey extracted by this method contained large quantity of pollen and other extraneous matters, which caused contamination. It also resulted in the destruction of bees, brood and ultimately the colony. Care should be taken to use sterile knife, spoons, vessels and cover head and mouth with mask and use glouse.

While opening the colonies for honey extraction many worker bees will bite the beekeeper and may be lost. To minimize the loss of worker bees, before opening the colony for honey extraction the bees are to be removed and protected in empty water bottles. For this, the mouth of an empty water bottle (dried), with adequate small holes is to be placed at the hive entrance tube. Gently tap on the hive so that the worker bees' start coming out from the hive and will enter into the bottle. Two or more bottles can be used according to the strength of the colony. Cap the bottles, keep them aside and open the hive for extraction (Figs. 13, 14).

The pots alone are collected by using a sterile spoon from the nest and are kept in a clean tray. The tray is to be exposed to sunlight in a slanting position. The wax of the honey pots melt due to the heat of the sun and the honey pouring out is to be filtered and bottled. There is no need for heating stingless bee honey like *Apis* honey. This method is relatively simple and yield clear honey without extraneous matters. After extraction, the bees in the bottles may be released.

Stingless bee honey

The stingless bee honey (SBH) is a natural product produced and marketed worldwide, collected from stingless bees which is only produced in tropical and subtropical regions and features a distinct sweetness, mixed with an acidic taste, fluid texture, high moisture content and minimal crystallization. Stingless bee honey is popular for its unique behavior of collecting nectar from multiple flowers and extra floral nectaries. The nectar then goes through a conversion in the bees' 'honey stomach' to transform into honey and deposited into cerumen pots which are developed from propolis. This gives the honey rich in nutrients and phenolic compounds, mainly flavonoids and phenolic acids, which act as potent antioxidants.

The stingless bee honey (SBH) has high nutritional and therapeutic value due to the diversified plants foraged including medicinal plants and structure of nest, the antimicrobial activity of SBH is little bit stronger than other honeys with unique therapeutic properties with great potential to be developed for modern medical uses. It is used in many medicines in Indian System of

Medicine, the Ayurveda for many diseases, in reducing the heat of the body, inflammation, bleeding in the throat, impurities of the blood, boils and even for cancer. SBH as a therapeutic agent in various health issues such as anti-diabetic wound healing, anticancer, treatment of eye diseases, and also in fertility. Studies have proven that the SBH has excellent potential and portrays beneficial effects as antimicrobial, anticancer agent, improving hypertension, lipid profiles, and with some studies showing better anti-diabetic effects. In order to provide a major comprehensive understanding on the potential uses and benefits of the SBH, more systematic studies need to be carried out. In terms of quality control, methods to authenticate pure SBH need to be developed. A rapid and destructive analysis technique is required to avoid possible adulteration by irresponsible manufacturers. The quality standard can be established by the identification of its bioactive component since SBH is rich in antioxidants and innovative efforts should be taken to fully explore and utilize these benefits. Honey-based products should be diversified, such as making supplement capsules or tablets which contain probiotics isolated from the SBH that can aid in gastrointestinal health. These properties should also be made readily in the form of topical creams or gels for wound healing or other purposes (Fig.15).

Pollination service and playhouses

There is ample potential for utilization of stingless bees in pollination service as they are better pollinators of some crops than honey bees which thrive much better in tropical areas and are polylectic. The smaller body size, shorter foraging distance, less aggressiveness, floral constancy, higher longevity of the colonies, efficient worker recruitment behavior towards food sources, medium colony size, lesser swarming tendency, tolerant to high temperature and less pest and disease incidence are the advantages of stingless bees as pollinators. Studies conducted at Tamil Nadu Agricultural University (Tej *et al*., 2017) revealed that keeping stingless bees in greenhouse cucumber can improve its pollination and thus fruit weight and yield. Stingless bees play an important ecological role as pollinators of many wild plant species and seem good candidates for future alternatives in commercial pollination. Eleven stingless bee species across six genera have been found to forage effectively under enclosed conditions, indicating the potential of stingless bees as pollinators of greenhouse crops- over the past six years the number of crops reported to be effectively pollinated by stingless bees has doubled, putting the total figure on 18 crops. (Judith *et al.*, 2006*).* It is reported in sweet pepper *Capsicum annuum* L. that despite flowers are considered autogamous, this crop benefits from pollination by stingless bee *Melipona subnitida*, producing fruits significantly heavier and wider, containing a greater number of seeds and of better quality (lower percentage of malformed fruits) than self-pollinated sweet pepper. Thus, *M. subnitida* can be considered

an efficient pollinator of greenhouse sweet pepper (Cruz *et al.*,2006). The potential of stingless bees for seed production, pollination and yield enhancement of various crops under protected cultivation to be explored in India has by conducting scientific studies.

Pests / Enemies of stingless bee

Studies conducted at this centre could identify some enemies of stingless bees, either attacking while foraging or encountering the colony. They are dipteran fly *Hermetia illucens* L., Nitidulid beetle *Aethina* sp. reduviid bug *Acanthaspis siva*, Assassin Bug *Sycanus* sp., predatory spiders *viz*., *Thomisus lobosus*, *Thomisus projectus*, *Menemerus bivittas*, *Neoscona nautica*, *Heteropoda venetoria*, ants *Solenopsis geminata*, a species of megachilid bee, a mite *Amblyseius* sp. etc

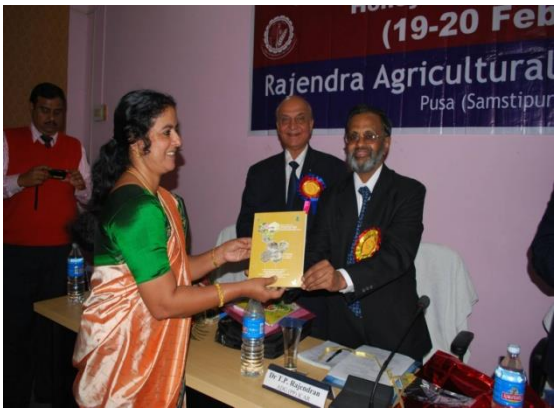

Fig. 1. Dr.T.P. Rajendran, Assistant Director General (PP), released the book "status paper on stingless bee *Trigona iridipennis* smith"

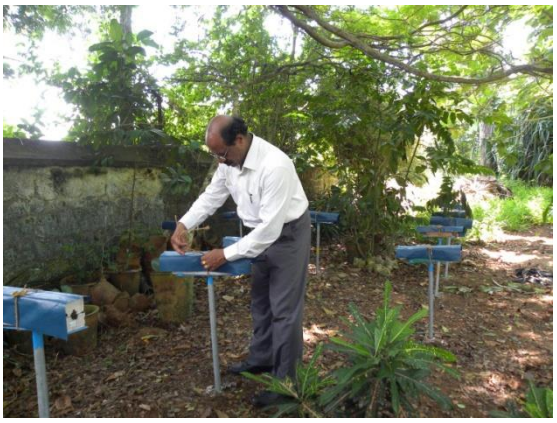

Fig. 2. Commercial meliponiculture

Fig. 3. Hive entrance helps to detect the presence of feral colony

Fig. 4. Nest architecture

Fig. 5. Stingless bee queen

Fig. 6. Stingless drone

Fig. 7. Stingless worker

Fig. 8. Hiving feral colonies without damaging compound wall

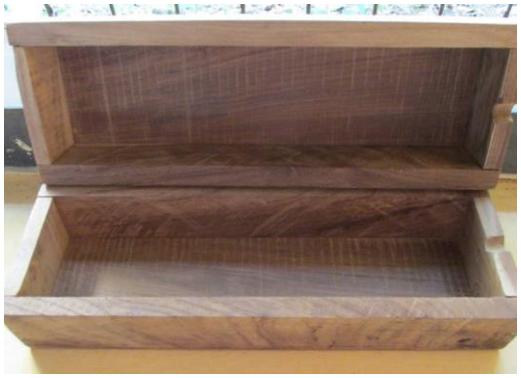

Fig. 9. KAU hive for commercial meliponiculture

Fig. 10. Mass provisioning

Fig. 11. Division of colonies

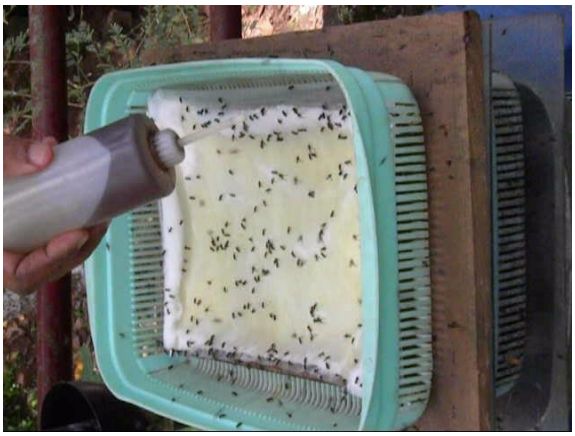

Fig. 12. Dearth season management- Artificial feeding of colonies

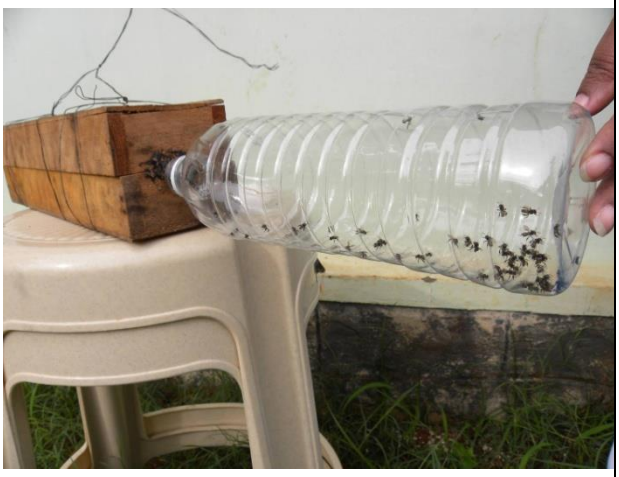

Fig. 13. Worker bees transferred in the empty water bottle.

Fig. 14. Honey extraction without harming the worker bees

Fig. 15. Hygienic pure honey pots

Conclusions

Practicing commercial meliponiculture in the homesteads will provide the service of stingless bees in pollination of various crops particularly vegetables and fruits and their yield enhancement. The services of stingless bees can be utilized for quality seed production too. “If the bee disappears from the surface of the earth, man would have no more than four years to live. No more bees, no more pollination, no more plants, no more animals, no more man." (Albert Einstein)

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