CONNECTING the BEE DOTS

PROFESSOR DATO' DR. MAKHDZIR MARDAN

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PhD (Guelph), MSc., BSc. (LSU), Dip. Agriculture (UPM)

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ABSTRACT

In his autobiographical account that traces and chronicles three defining dots of bee-related events, Makhdzir recognizes and acknowledges what spawned and shaped his interest and enthusiasm on bees over the last 50 years. His passion with bees evolved from his childhood days and over time those telling dots of bee encounters eventually turned out to be the catalyst for his career and profession. The three defining encounters with bees were: i) the behaviour of temperature regulation of a Giant honeybee *(Apis dorsata)* colony, at age five; ii) the gallery-nesting behaviour of carpenter bees *(Platynopoda latipes)* on wooden beams of a house, at age ten; and, iii) the harvesting of honey from Giant honeybee colonies, at age five.

His observations of the contracting and expanding size of Giant honeybee colonies on hot and rainy days haunted him again in later years and he followed up on his curiosity by making it the subject for his *Ph. D.* thesis research. Through experimental manipulation, temperature monitoring of the body parts (head, thorax and abdomen) of the bees that enveloped the open-nesting, broodright colonies of *A. dorsata* to form a protective curtain showed that there were significant body temperature differences (less than 2 ^{0}C) between curtain bees with fluid content in their honeycrops and those without. The fluid (water) in their honeycrops, afforded the curtain bees the opportunity for evaporative cooling by extruding and re-imbibing the fluid content on their mouthparts, in what was termed as gobbetting. The gobetting behaviour was experimentally shown to be stimulated by directing air currents onto the curtain bees that sought incidental evaporative cooling from any passing breeze. Under excess heat stress, during high ambient humidity and temperature, the colony resorted to performing colony *en masse* airborne defecations (CEMA) by the curtain bees to dissipate heat load. Usually more than 50% of the bees in the colony take flight to defecate *en masse* whereby the subsequent advantage is reduced body weight through loss of bee feces, and hence reduced heat load for cooling. The

monitoring of CEMAs from morning till dusk serendipitously led to the discovery of the clockwork regularity of drone mating flights that occurs everyday at sunset where the incidence of loss of brightness was experimentally shown to modulate the onset of drones flying out to drone congregation areas in the direction of sunset in the horizon

The second bee dot event of childhood days was playing kites with captured, gallery-nesting, carpenter bees, which also connected 25 years later to trigger the idea to develop a carpenter bee hive design that leverages on the concept of bee space (gap size of the nesting gallery). Efforts to address the nagging questions about a carpenter bee infested log close to the laboratory led to curiosity about the nature of nesting galleries of carpenter bees inside which subsequently led to the development of a multiple-frame, carpenter bee hive. Founding gynes (reproductive females) were enticed to settle in a new adjacent gallery, and prevented from returning to their old nesting gallery by deception, using wooden, dummy entrances. An observation carpenter bee frame hive was developed using plexiglass and restricting gallery construction within the frame width of slightly bigger than the thorax of the carpenter bee (bee space of 2.2 cm). Hive boxes of carpenter bee nests were introduced and propogated to provide pollination services in passion fruit orchards.

The third bee dot event of observing honey hunters harvesting honey from *A. dorsata* colonies for the first time, led to further forays into the rainforests to observe and learn about the traditional art of honey-gathering from the hundreds of *A. dorsata* colonies that nest on emergent bee trees in the rainforests of Malaysia and the Asean countries. From research expeditions throughout the Asean region, it was realised that there were observable intricate faunistic associations between the Giant honeybees and its natural enemies of several species of birds, bear, bats, etc. Bee eaters and honey buzzards display adaptive morphological features in overcoming its prey *(A. dorsata)* displaying a special ability to remove bee stings and adaptive behaviour of subterfuge by using decoy strategy to confuse the colony. In response, the *A. dorsata* adopts a variety of evasive behaviour for colony defense, such as, colony enlargement by the curtain bees. Both the behavioral responses of the *A. dorsata* against attacks by its natural enemies and the subterfuge by by several species of birds, ranging from bee eaters (spp.), honey buzzards *(Pernis Apovirus)* and falcons *(Micrographis fangillarius)* and bats that depend on the Giant honeybees for food around the bee trees, display an interplay of defensive behaviour.

All three incidents of encounters with Giant honeybees, carpenter bees and honey hunters provided him inspiration for the development model for beekeeping in Malaysia taking into account the resource-needs, or specificity between plants and the type of bees. Different species of plant flowers may have obligate relationship with specific bees.

Most important of all, pursuit of an interest with enthusiasm is the key driving force to foster and sustain interest in any endeavour.

CONNECTING THE BEE DOTS

> *"Great spirits have always encountered violent opposition from mediocre minds" – Albert Einstein*

Many a time, in our lives, we have encountered events or people that were seemingly trivial but eventually turned out to be the defining moments by which we chart the dots of our life. When we connect them, chronologically, with other dots of past incidents into a sequence of events, they become the tell-tale indicators of the milestones in our lifes. In Steve Job's words *"You can't connect the dots looking forward; you can only connect them looking backwards. So you have to trust that the dots will somehow connect in your future"*. Looking back, I see that I have had a fair share of such connecting dots relating to my interest and career in bees and so I would like to hereby chronicle them for posterity ***– Connecting the bee dots.***

I would like to share three happenstances of childhood encounters with bees which I consider the defining dots connected to founding my interest and passion in working with bees. This includes three eventful encounters with honeyhunting, Giant honeybee *(Apis dorsata)* and Carpenter bees *(Platynopoda latipes).* These events, which were transcendental experiences, spawned my interest and fascination with bees. I had my first encounter with both the Giant honeybees and the honeyhunting event, at five, and the Carpenter bees at ten. I am taking this opportunity to communicate my anecdotes, sagacity, eureka-feeling and serendipity in research and invention in an autobiographical style, a style which would not be acceptable in the pages of any journal publication.

1ST BEE DOT : EARLY ENCOUNTER WITH THE GIANT HONEYBEE KIND

I had an early seeding of the concept of thermoregulation of honeybees at the age of five. I watched with awe and wonder, the behaviour of a Giant honeybee colony nesting on the branch of a durian tree overlooking a window of my house. Over many rainy and sunny days of several months, I observed how the colony contracted and expanded in size. I assumed that they were affected by the rain and the sun rays shining on the colony. Childhood inquisitiveness prompted many a question about the colony but I received no satisfactory answers. Little did I realize that those questions would spring up again 25 years later and become the subject of my *Ph. D.* thesis research (Mardan 1989). About twelve years later, I was to recall my observations of the Giant honeybee colony, when I heard over the radio the *Qur'anic* translation of the verses 68 & 69, *Sura An-Nahl.*

> *" And your Lord taught the bee to make its (beehive) cells in the hills, on the trees, and in the houses; Then to eat from all the produce (of the earth), and with skill find the wide ways of its Lord: From their bodies comes a drink (honey) of varying colours, wherein is healing for men: surely this is a Sign for those who think "*

These two incidents stand out as the two defining bee dots that called for connection when I decided to pursue my graduate studies on the hoarding behaviour of honeybees (Mardan1979; Mardan & Rinderer 1980), at the USDA Bee breeding laboratory in USA. Incidentally, the laboratory is located close to the Louisiana State University which is where I pursued my undergraduate studies on plant protection & entomology. The rest as they would say, was inevitable.

Bee Curtain – Enveloping the Nest

The amazing thing about the Giant honeybee colony is its protective curtain. A large, single open-nesting honeycomb of brood and honey is enveloped by thousands of very well-aligned bees forming a beautiful protective wall covering over the colony. The 'bee curtain' is made up of one or more outer layers of young worker bees which dangle entwined and stretched together. The surrounding bees are intertwined by all their three pairs of legs (Morse & Laigo 1969). Seemingly the 'do-nothing' bees that form the majority of the bees in the colony function to protect the brood and their honey. What a boring thing it must be to be a bee curtain, dangling not able to move or run about like a five-year-old kid, I mused. You simply could not agree with the idiom *"As busy as a bee",* on the contrary, it should be "As boring as the curtain bees"!. Certainly, there is more than meets the eye. The Giant honeybees enveloping the nest with several layers of connected bee curtains protect the brood from natural enemies like wasps and birds, and is also protection from the vagaries of the non-biotic environment like rain, sunrays, etc. (Morse & Laigo 1969; Mardan 1989). The protective curtains can be regulated as a single or multi-layered curtain of intertwined bees (Morse & Laigo 1963) which will regulate the temperature of the broodcomb which is homiothermic in terms of temperature regulation, just like a mammal (Southwick & Mugaas 1971; Southwick 1983).

Gobbetting Curtain Bees

I wondered how the thousands of bees that aligned themselves to form the layers of bee curtains can be so organized and disciplined to withstand the 'do-nothingness' through countless days and nights. When honeybees remain close together in the hot and humid tropics, the corporately generated heat of the brood must be dissipated to keep the hive's temperature below 37^{o} Celsius, the thermal limit for larval and brood life (Free & Spencer-Booth 1962; Heinrich 1979; Heinrich 1980a, 1980b; Mardan & Kevan 1989). On closer scrutiny, the curtain bees are found to serve many critical functions, such as, thermoregulating the colony (Figure 1) apart from the obvious function of shielding the colony from intruders. I discovered that curtain bees all over the colony perform evaporative cooling (Mardan 1989; Kevan & Mardan 1990).

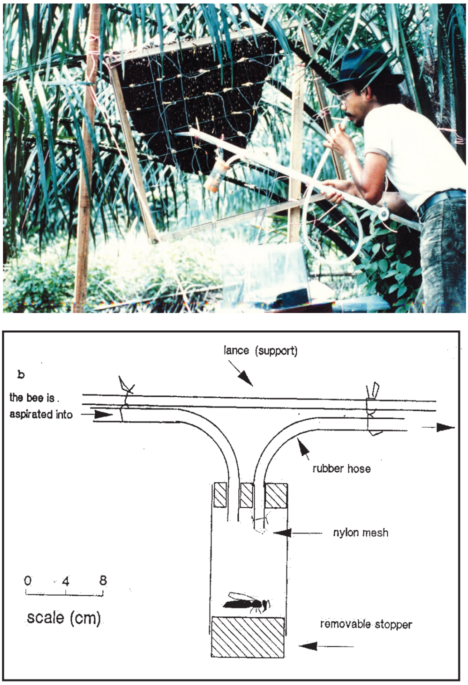


Figure 1 Curtain bees are captured for head, thorax and abdomen temperatures using an aspirator

Bees on the curtain, where there is fluid content in the honeycrop, maintain lower overall body temperatures as compared to those on the curtains where there is no fluid content in the honeycrops (Mardan, 1989) (Figure 2a-b). On hot and humid days, the fluid containing honeycrops of curtain bees were observed to intermittently extrude and re-imbibe water droplets, regulated like a gob on the mouthparts of the curtain bees, which is termed as gobbetting (Mardan, M.

1987; Mardan, 1989). Subsequent investigations on the gobbetting behaviour of the curtain bees showed that their gobbetting rates, i.e. evaporative cooling, increased when subjected to a flowing breeze manipulated by a battery operated fan.

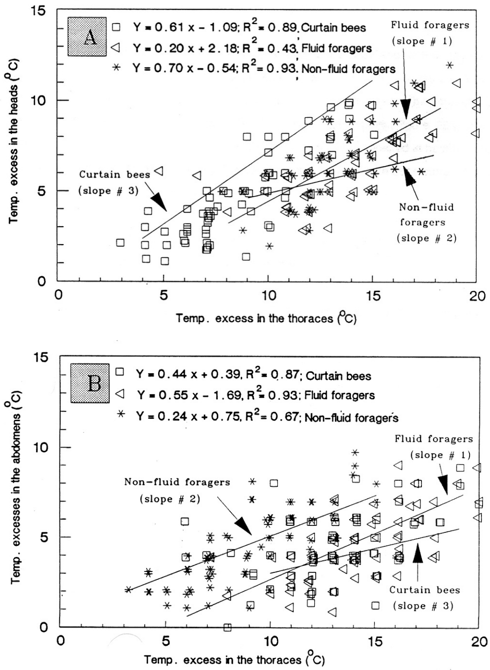


Figure 2a-b The heat transfer rates of thorax-head (a), thorax-abdomen (b), of active fluid foragers, non-fluid foragers, and curtain bees of *A. dorsata*).

On hot and humid days, most broodright colonies generate heat and the colony needs to regulate the brood temperature within the permissible upper lethal and lower critical temperature (Figure 3). By regulating the number of layers of bee curtain and other cooling or heat trapping behaviours the *A. dorsata* colony is able to keep the brood alive. It is even more difficult to conduct evaporative

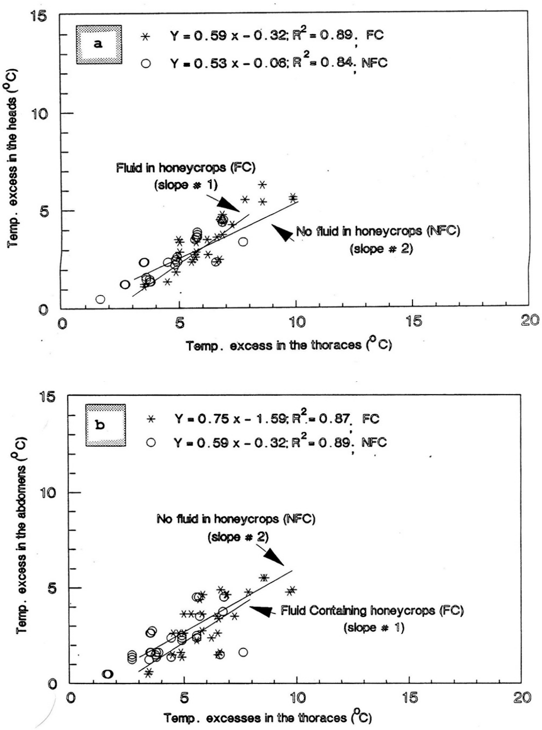


Figure 3a-b The heat transfer rates of the thorax-head (a), and thorax-abdomen (b) in gobetting and non-gobetting curtain bees of *A. dorsata*

cooling on hot and humid days. When the ambient humidity is high, almost all bees that envelop the colony form shining gobbets of water and depend on the occasional intermittent breeze for evaporative cooling to regulate the colony temperature, apart from regulating the number of layers of bee curtain to trap and release the generated heat produced by the broodright colony. The colony temperature regulation reaches inflexion point when the ambient temperature is about 26 °C (Figure 4). At that ambient temperature the curtain bees body heat would have reached thermal compensation, determined at 4.4 °C , which is when the thoracic temperature is about 30.4 °C. At this thoracic temperature, the curtain bees are thereotically at a level where the curtain bees need not do anything to trap heat or cool the hive. A drop in the ambient temperature will stimulate the curtain bees to crowd into several layers of bee curtain. An increase in the ambient temperature will stimulate the curtain bees to forage for water for evaporative cooling via gobbetting behaviour.

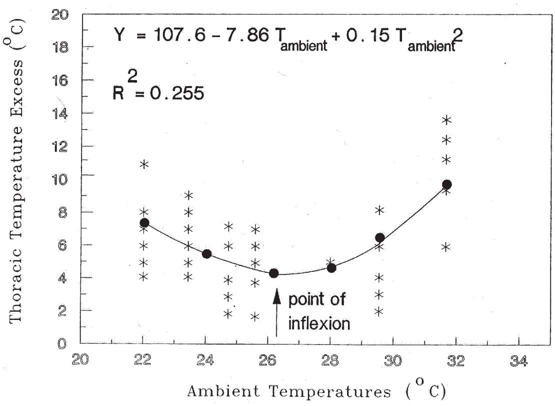


Figure 4 Equilibrium model for colony thermoregulation of *A. dorsata*

Hence, the explanation for the sequence of colony thermoregulation by the curtain bees from evaporative cooling via gobbetting behaviour is as shown in Figure 5.

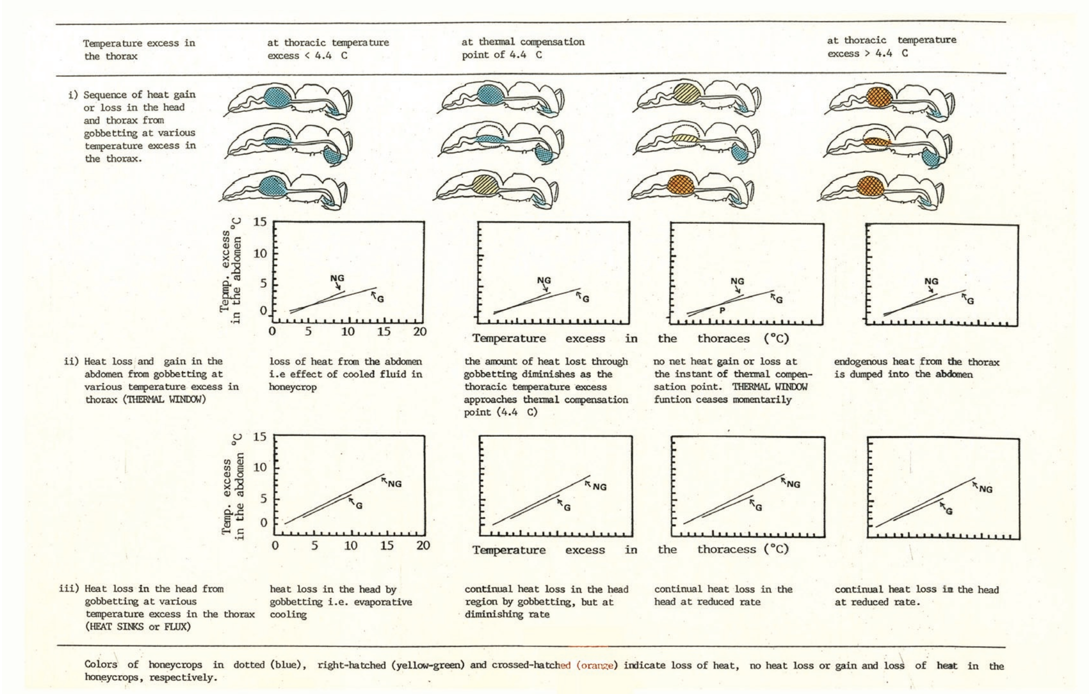


Figure 5 Diagram showing the facultative roles of the abdomen as heat stabilizer and of the head as a heat sink or flux. These changes in functions are pivotal at 4.4 ^{0}C

Dissipates Heat Load: Colony *En Masse* Airborne (CEMA)

Curtain bees, comprising mostly of young bees, contribute to reducing the colony heat load for evaporative cooling by reducing body mass via colony *en masse* defecations (CEMA) whilst airborne near the colony. During this remarkable behaviour of CEMA, almost all the bees in the colony become airborne, flying in gentle arcs about 20 – 30 meters from the colony, for 5-6 minutes and subsequently returning to the colony, (Figure 6a-b).

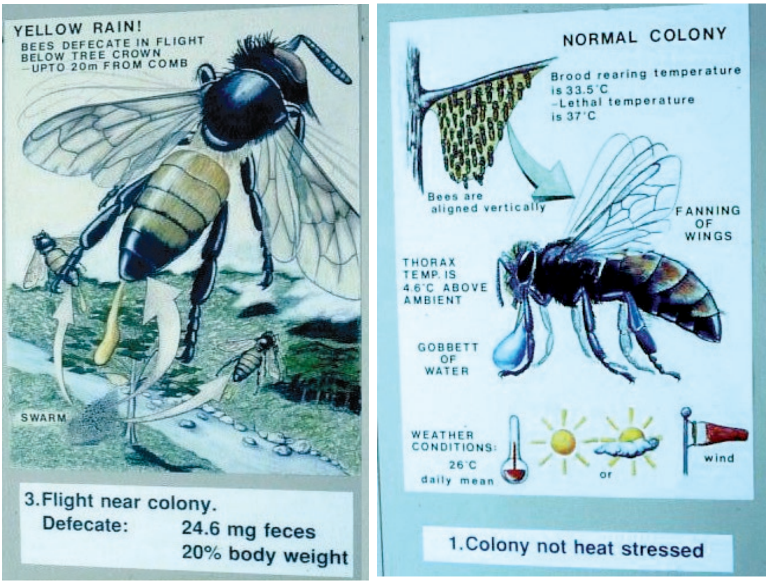


Figure 6a-b Illustration on the Colony *en masse* Airborne (CEMA)

The study which monitored more than 19 CEMA cases indicated that most bees lost about 20% of their body weight, while defecating at a rate of about 18.3 +/- 3.2 millilitres or 24.6 +/- 2.8 mg per bee. At a rate of 1.85 cal per g Celsius of mass specific heat of faeces a typical colony would dump around1.850 calories during CEMA at ambient temperatures of between 28-31 Celsius (Mardan & Kevan 1989, Kevan & Mardan 1990). This clearly points out that apart from physical loss of heat in mass flight, reduction of a bee's body mass greatly increases thermoregulatory efficiency. Given a heat coefficient of 0.83 cal per gram Celsius for animal tissue, the amount of energy needed to be disposed off to reduce the external temperature by 5.11 +/- 1.1 Celsius, before mass flights to 3.4+/- 1.0 degree Celsius afterwards would be 0.22 calories for a bee which has not defecated (mean weight of 123 mg), but only 0.14 cal for one which has (mean weight 98 mg) (Figure 7). That is an energy saving of 36% per participating bee and at least 15% for the colony.

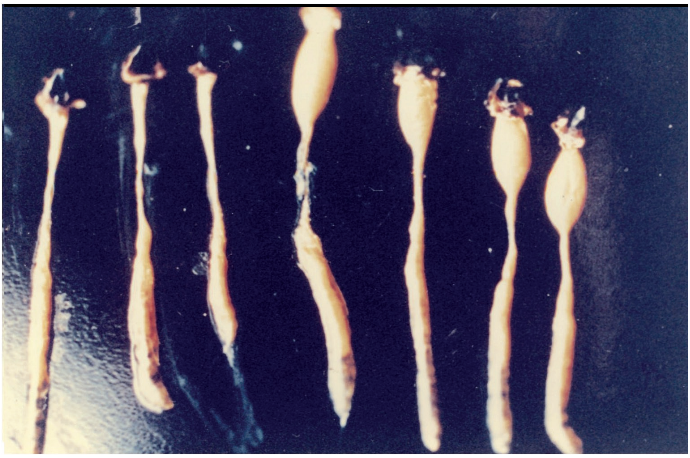


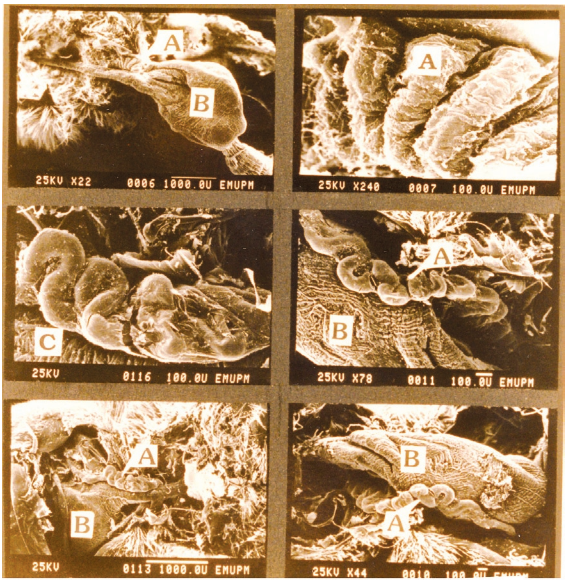
Figure 7 Hind guts of captured callows without feces at the end of CEMA with feces at the initiation of CEMA

Overall there is a significant reduction in heat capacity for evaporative cooling of the abdomen of the curtain bees after the mass defecation flights, with almost 45% energy saving for cooling. It was approximated that *en masse* defecating by one *A. dorsata* colony alone heat dumped about 1 800 calories. Therefore an atypical bee tree with between 50 to 100 colonies would heat dump 90 000 – 180 000 calories from the tree everyday, which is equivalent to bringing 1

250 to 2 500 liters of water into instant boiling point at ambient conditions of 28° Celsius! Subsequent evaporative cooling advantages from passing breeze and cooling activities will enable the colony to achieve faster cooling rates with reduced heat load dissipated. Scanning photographs from electron scanning observations on honeycrops with fluid content and without fluid contents showed that the curley-coil of the aorta (similar to a telephone wire coil) was stretched and spread onto the honeycrops (fluid-filled), but retracted to coil tightly within the constriction of the petiole when the honeycrop is empty (Figure 8a-f). It is interpreted that conductive cooling of the hemolymph in the aorta can be achieved through the stretching of the aurley-coil onto the honeyrop filled with fluids such as water or nectar. Conversely, heat can be shunted within the thorax preventing it from descending into the abdomen when the honeycrop is empty. Hence, en masse colony defecation at dusk is adaptive for colony temperature regulation where the cool night does not require the open-nesting *A. dorsata* to gain evaporative cooling but instead traps brood heat by forming multi-layers of bee curtains. The curtain bees are actually not doing nothing after all.

Yellow Rain: The Unlikely Chemical Warfare which was Bee Faeces

In the early 1980s, the yellow spots on forest leaves, from the mass defecations by Giant honeybee colonies in the forest of Laos and Cambodia, were misidentified as toxic residue from aerial spraying of chemical agents (Seeley & Seeley 1982; Seeley 1985a). The Reagan administration accused the Soviet backed forces in Vietnam of violating a treaty banning the use of such weapons but this residue was later found to be bee faeces (Seeley 1985a) though the extraordinary behaviour of mass defecation by the Giant honeybee colonies was not explained then. Following that, in 1985, I coincidentally, came up with the explanation of the bees' thermoregulation behaviour to dissipate heat load and the resultant yellow spots on leaves of surrounding vegetation within a 20 meter radius of the colony (Seeley & Seeley 1982; Mardan 1989).



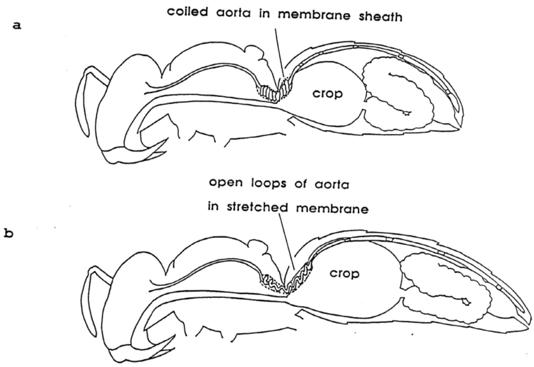


Figure 8a-f Figure 30a-f Scanning Electron Microscopy (SEM) photographs showing the position of the curley-coil (labeled A) and the honeycrop (labeled B) of A. dorsata worker bee) (Figure 35a,b Diagram showing the position and the sinuosity of the aorta in the petiole near the crop in relation to the state of the distention of the abdominal segments during high temperature(a) and retraction of the abdominal segments during cool temperature(b)).

Drone Congregation Area

There is another facet of the colony *en masse* defecations that is entwined with another phenomenon called the drone congregation flight of *A. dorsata* at dusk. During monitoring of mass defecations by the colonies on bee trees, it eventually became clear to me that the daily *en masse* defecation flights at sunset occurred simultaneously with the mass drone congregation flights with clockwork regularity (Mardan 1987; Tan & Mardan 1996; Tan *et. al.* 1997).

This serendipitous discovery of the association between an *en masse* airborne colony and drone flights began to emerge while I was catching *A. dorsata* drones for another experiment with Professor Niklaus Koeniger of *Institut fur Bienekunde,* Frankfurt, Germany, back in 1993 (Koeniger *et. al.* 1991; Koeniger *et. al.* 1990a; Koeniger *et. al.* 1990b; Koeniger *et. al.* 1993). After days of monitoring at sunset and chasing drones near a mosque in Serdang during the fasting month of *Ramadhan* , I began to realize that every time I started taking food to break my fast upon the call for *Azan* prayer from a nearby mosque the drones from the colony being observed started to fly out in the direction of the setting sun. Before my food settled, and while still munching, I had to run with an insect net in one hand and my food on the other to catch the flying drones,. For several days I had been inconvenienced by repeated episodes of breaking fast on the run, while chasing after drones flying out to the drone congregation area, and later, having to rush for prayers. In jest, I told Professor Nikolaus Koeniger that the bees were Muslims and that they flew out with joy to celebrate the breaking of the fast and to answer the call to prayer. Jokes aside and on further thought, it dawned on me that the common denominator between the time for breaking of the fast, the call for *Maghrib* prayer, and the occurrence of drone flights was sunset. The possible explanation for this is the sudden drop in light intensity (scotophase) being a stimulus to initiate drone flight. The same is also the cue for the breaking of the Ramadhan fast, and the call of the *Azan* for the *Maghrib* prayer. To verify that the sudden drop of light intensity at sunset was the causal factor for drone flight, I decided to put up a daylight fluorescent light on one side of the single-comb Giant honeybee colony before sunset, and let the other side receive normal darkness at sunset. None of the drones on the illuminated side of the single-comb of the Giant honeybee colony took flight, and only drones on the non-illuminated (dark) side took flight to head for the drone congregation area. I also figured out that the drone flight time would be a few minutes earlier or later in other locations in the country due to earlier (east side) or later (west side) sunset times. That could be easily predicted by referring to the prayer times published in the local daily newspaper. Subsequent observations and monitoring of drone flight times in Pedu Lake, Kedah were conducted on colonies on a bee tree and it turned out that they occured as expected with a few minutes variation attributed to cloud cover on the horizon. Colonies that were located on the lower branches experienced darkness earlier at sunset compared to bee colonies on the upper branches, and hence the drone flight times started earlier. Further studies on the flight times of drones from the *A. dorsata* colonies in different areas (Koeniger & Vorwohl 1979; Koeniger *et. al.* 1994) were predicted, with corrections for clouds on the horizon, date, latitude and time of year. Further scrutiny of secondary data of drone flight times of other sympatric Asian honeybees *(A. andreniformis, A. florae, A. cerana)* drone flight times in Sri Lanka (Koeniger & Vorwohl 1979), Cantaburi, Thailand (Wongsiri *et. al.* 1990) and Tenom, Sabah (Tingek *et. al.*1988; Koeniger *et. al.*1988; Tan & Mardan 1996) indicate that the drone flight times occur during the expected times at azimuth times of 90 degrees(noon), 45 degrees (mid afternoon) and 0 degree at sunset (Figure 9). Coincidentally, this is how the prayer times for Muslims is determined.

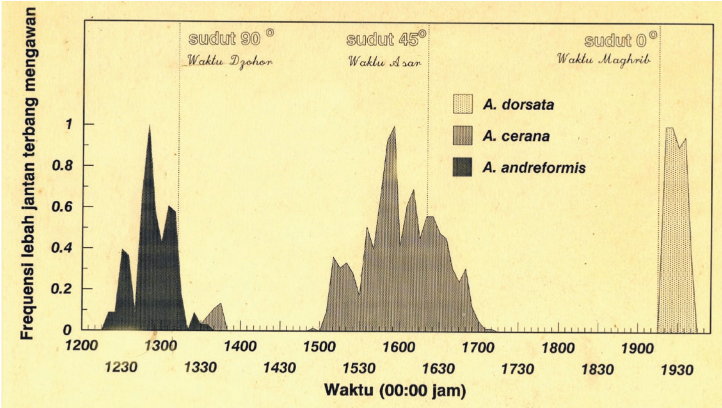


Figure 9 Different times occurrence of drone flight of the sympatric species of *A. andreniformis, A. cerana* and *A. dorsata*

2ND BEE DOT: CLOSE ENCOUNTERS OF THE CARPENTER BEE KIND

Secondly, another 'dot' incident that connects significantly with my career path is the nesting behaviour of the Carpenter bees *(Platynopoda latipes).* I was repeatedly queried by foreign visitors about the larger Carpenter bees *(Platynopoda latipes)* nesting inside a wooden log outside the bee laboratory in UPM. This reminded me of similar questions that I had asked when I was 9 years old. Back then, I had lots of experiences of capturing Carpenter bees in jars and knocking them out of their nesting galleries in the wooden beams of old houses into bottles, and later tethering them with a string and flying them like kites with friends. How I wished I could see what they were doing inside the galleries. Do these bees bump into each other inside the galleries? How do they bypass each other in the narrow galleries which were only about their body width in size (bee space) inside the gallery? Do they push at each other? Who gives way, or do they push each other's heads like my goats do? How do they cut such deep holes in the wood?

Designing Carpenter Bee Hive: Bee Space & Movable Frame Hive

Forward twenty-five years later, in the eighties, there was this dried wooden stump heavily infested with Carpenter bees nests located near the doorstep of the bee laboratory. For many months, this log, fully infested with galleries of Carpenter bees (Figure 10), caught the attention of most visitors, especially foreigners. Their persistent enquiries bothered me because I did not have the answers and their questions were similar to those that I had asked during my childhood days. How deep are the galleries? Are the galleries connected?

Figure 10 Male & female carpenter bees *(Platynopoda latipes)*

Finally, through a series of experimentations with my assistants, we built an observation Carpenter bee hive with movable frames attached with transparent plexiglass that enabled us to observe the behaviour of the Carpenter bees inside the nest (Mardan *et. al.* 1990) (Figure 11). Subsequently, we built a movable frame Carpenter bee hive placed in a wooden box. The design of the Carpenter bee hive enabled additional expansion of frame substrates to cope with increasing colony population similar to that adopted in the invention of the honeybee movable frame hive design. The key to the construction of the Carpenter bee hive is leveraging on the concept of ‘bee space’, which is the opposite of the architecture of the honeybee hive design. Bee space is defined as the space width of the gallery gap which is wide enough to allow a bee to pass through (Mardan *et. al.* 1992) (Figure12).

Figure 11 Natural and improvised nest of carpenter bees

Figure 12 Dummy entrance of a carpenter bee nest

Enticing Founding Gynes

Initially the challenge to build the movable frame substrate stemmed from the curiosity to know whether carpenter bees built joint galleries that connected to each other. To discover this we dissected existing galleries of Carpenter bees in wooden logs and amazingly we discovered that they do not build galleries which were linked to each other but were instead built as close as possible to each other. Next we enticed founding gynes to build new gallery entrances on new wooden frames by introducing dummy entrances at specific sites on a narrow wood plank of less than 21% moisture (Said 1996). This is to ensure that the bee bread of pollen grains and nectar do not ferment. Other studies on gallery construction of Carpenter bees in Israel using X-ray photographs did not show any indication of gallery adjointment by Carpenter bees (Gerling *et. al.* 1989). Most galleries were constructed in directions that would avoid each other. However, we do not know what would happen if we limit the construction space within a bee space gap like that on a frame. Would that affect the direction of gallery construction? We therefore needed to entice the Carpenter bees to construct galleries with specific sites for nest entrances leading to a thinner wooden substrate of up to exactly the bee space, or gallery size of 2.1 cm (Mardan *et. al.* 1990; Mardan *et. al.*1992, Said 1996) (Figure13) which was walled on one side with a transparent plexiglass. The progress of the gallery construction could then be slowly monitored and appraised as to the precise gallery size (bee space) from the other side of the plexiglass wall which also enabled us to open and close the transparent wall with a paper cover on the outside to keep out the light source. We occasionally lifted up the paper to observe the progress of the gallery construction or bread provisioning at the end of the gallery. With constructions of this type we enabled developmental studies monitoring and observing the various stages of the life cycle of the Carpenter bees; starting from pollen provisioning, egg laying(3 days), hatching (3 days), larval feeding (6 days) and post-larval growth (6 days) until emergence of the adult (18 days for male and 22 days for females). Following this we studied the pre-social behaviour of weaning of young adult Carpenter bees which involved nectar feeding at the gallery entrance and the provisioning of bee bread by expectant female Carpenter bees. This study had not been possible before the invention of the Carpenter bee movable frames observation frame hive (Said 1996). These movable frame Carpenter bee hives were then deployed in the passion fruit orchard for pollination services (Mardan 1992; Mardan *et. al.* 1992; Mardan 1995; Mardan *et. al.* 1990).

Figure 13 Observation frame of multi-frame, movable carpenter bee hive

3RD BEE DOT: FAUNISTIC ECOWEB OF BEE-BATS-BIRDS-BEARS

The third childhood incident that connected the dots of my academic career is the experience of watching honey hunting on a moonless night behind my house. Until today I still remember seeing only the glowing embers falling to the ground in pitch darkness and hearing the voices of the honey hunters harvesting honey from a Giant honeybee colony on a durian tree.

Since prehistoric times, human's fascination with honey bees has been varied, excruciating, wide-ranging and enduring. Throughout the world, human's interest in bees permeates all ages, professions, gender and ethnic groups and that is why it is one of the most studied insects in the world! That interest has also been depicted in cave paintings (Mathal 1984)(Crane 1978) (India, Spain and Africa), emblems (Pharaoh), and also manifested in rituals, ceremonies, observance of taboos, natural healings and the handicraft *(batik)* of a few ethnic groups in the continents of Africa and Asia, where native bees are found. The great books of religion *(Qur'an, Bible* and *RigVeda)* contain verses that prescribe honey for health. In the native area of honeybees, tropical Asia, the Giant honeybees, or *Apis dorsata,* aptly epitomizes that ethno-bee association best. The Giant honey bees have culturally and ecologically been associated with native people and the rainforest through honey hunting (Emby 1997; Hamid 1997; Mardan *et. al.* 1988; Mardan *et. al.* 1989a; Mardan *et. al.* 1989b; Roy, P.1997). The triad relationship of Giant honeybee-man-rainforest has been in existence for more than 6000 years as seen from historical records and it encapsulates the dream of co-existence and sustainable living in the rainforest ecosystem. Honey hunters are considered the most adaptive natural enemy of the Giant honeybees, who can inflict destruction on Giant honeybee colonies with his skills and knowledge. Honey hunters with varying skills and experience operate singly or cooperatively, either in pairs or in groups, when harvesting honey from colonies that are nesting low, singly, in small numbers or in aggregate like those on bee trees (Mardan *et. al.* 1989a; Mardan *et. al.* 1989b; Mardan 1989c). Those honey hunters who operate in groups seek honey from colonies on bee trees deep in the jungle and harvest several hundred colonies per honey season. Honey hunting has evolved into a subculture steeped in the observance of taboos and rituals that has made the profession or art sustainable (Mardan 1989b; Mardan *et. al.* 1989c).

Human Benefits from Honeybees

In the broad strokes and bandwidth of social behaviour, humans have benefitted tremendously, in terms of community living, from his association with this social insect, the honeybee. This social insect, the Giant honeybees in the rainforest have inspired man to draw inspiration of diverse social aspects as follows: refrain from direct aggression and use aggression as a last resort; preference to adopt indirect competition by outdoing the competitor by finding foraging niches or the Blue Ocean Strategy (foraging competition with smaller species); practice of cooperative and communal living involving sharing of resources and job tasks that are economical for sustainable living; frugality and parsimony in utilizing resources; the engineering feat of constructing hexagonal cells; living up to the corporate culture of hard-work; job specialization based on genetic capabilities such as being an undertaker, water forager, nurse/house bees, etc.; choice of selecting a new queen based on majority rule; warfare strategy of mass stinging attacks to inflict fear in its enemy and persistence in pursuit of the enemy; superb mass communication system through the bee dance communication behaviour using the sun as a compass; practicing democracy in food searching decisions but autocracy in matters of nest defense and security; practicing hijrah during emergency situations or when it is a matter of survival; and many other untold socially-derived benefits is to be learned from these Giant honeybees.

Man and the Malayan Honey Bear

Humans and bears have a common interest in the honey and brood comb of the Giant honeybees. The Malayan honey bears *(Helarctus malayanus)* have thick fur to fend off stinging attacks by bees, and have strong legs and claws to enable them to climb trees to plunder the brood and honeycombs of the bee colonies. They may seem to compete with man for honey but in reality they have never been found to engage in aggression against each other, but quite to the contrary, they can be considered as communalism in terms of their association with man.

I found that most honey hunters in the rainforests in the region related amusing encounters and humourous anecdotes about the Malayan honey bears, but none ever mentioned any aggressive encounters. Honey bears have often been reported to be around the bee trees during honey harvesting or scavenging for food at the honey hunters' camp while they were asleep. Traditional honey hunting groups are usually more amenable to sharing the brood and honey bounty with the bears. In a sense that is part of the ritual, to share half of the first harvest of the honeycomb with the unseen owner, which refers to the bears or other beings (Mardan 1989a). One honey hunter related an unexpected encounter with a Malayan honey bear high up on the branches of a bee tree. Both of them were so equally surprised and startled that both of them screamed and shrieked with trepidation and simultaneously slid down the trunk of the bee tree. None of the honey hunters in the region had ever been attacked, but only have fond memories of the innocuous Malayan honey bear.

Faunistic Association of the "Bee Tree"

Unlike other honeybee species, the Giant honeybee displays varied nesting strategies under varied conditions of availability of food sources, nesting support and places for shelter. When nesting in high density in the rainforest, with availability of nectar and pollen resources, they nest in aggregates of more than 100 or even up to 250 colonies on a single huge, 'bee tree' (Reddy, 1963; Crane, 1978; Ruttner 1987) (Figure 14). A bee tree is a tall tree rising above the forest canopy overlooking the forest blooms (Mardan & Kiew 1984; Mardan 1994). An atypical bee tree harbours a large biomass of protein and energy source for man, bear, birds, insects and the many other creatures of the rainforest. Bee trees are usually tall, with huge smooth trunks that make it difficult for any scansorial or climbing primates like bears, monkeys or humans to climb, and hence provides protection for the bee colonies from intruders (Seeley & Seeley 1982; Seeley 1985b). The canopy of the tree usually stands

Figure 14 Bee Tree and honeyhunters

above the forest canopy and a few species like *Koompassia* spp.and *Alstonia* spp. are often chosen by the Giant honeybee colonies to nest in aggregate. With such bountiful, concentrated biomass of food protein from the brood and honey harboured on the bee tree, it is only natural that a faunistic ecoweb develops and converges around the bee tree. A bee tree teeming with a bevy of more than a hundred Giant honeybee colonies is attractive to a wide ranging group of natural enemies in the rainforest fauna, such as, multitudes of birds, bats, flying squirrels, bears, insects, mites, etc (Mardan 1993). Such nesting habits on tall trees with smooth-bark and with girth beyond the full-hug of a man or bear, pose difficulties and deters climbing primates like man, bears and monkeys (Mardan 1989a; Mardan 1994; Seeley 1985b).

Interaction of Predatory Birds

From my experience of working and observing more than 30 bee trees in the region (Malaysia, Thailand, India and Indonesia) several species of birds appear to be the most dominant and have developed an interestingly, highly-evolved association with bees. These birds include several species of bee eaters *(Merops* spp. and *Nyctornis* spp.), honey buzzards (*Pernis* spp.), orange-rumped honeyguides (Cronin & Sherman 1976) and black-thigh falconets (*personal communication,* 1986). Bee eaters have special long beaks and are very dexterous and adept in removing the stings from the abdomen of the bees, as dexterous as the Chinese in using their chopsticks to pick up grains of rice from the rice bowl. Additionally, bee eaters usually work in large flocks of hundreds, unlike the honey buzzard which only act singly or in pairs. It is common to see several hundreds of bee eaters perching on tree branches near bee trees and preying on the fast flying forager bees. Slow flying foragers leaving from any of the scores of the honeybee colonies are easy targets for the fast flying bee eaters from amongst the 5 species of *Merops* spp. and *Nyctornis* spp. Both the *Nyctornis amicta* and *Nyctornis athertoni* are the most primitive of the bee eaters and they are endemic to the rainforest of Peninsular Malaysia (Fry 1984). Heavy predation by these tenacious bee eaters is deemed to be one of the several defining evolutionary, selection pressures on faster flying worker Giant honeybees. The behaviour of nesting in aggregate is adaptive in terms of nest defense strategy in that the Giant honeybee colonies rely on cooperative defense by nesting in aggregate hence sharing predation and colony defense against both bee eaters and honey buzzards. Theoretically, the explanation is that when a single nesting colony of Giant honeybee is detected by a pair of bee eaters that consume a maximum estimated number of forager bees per day, it can share this predation rate if nesting in aggregates (Figure 15).

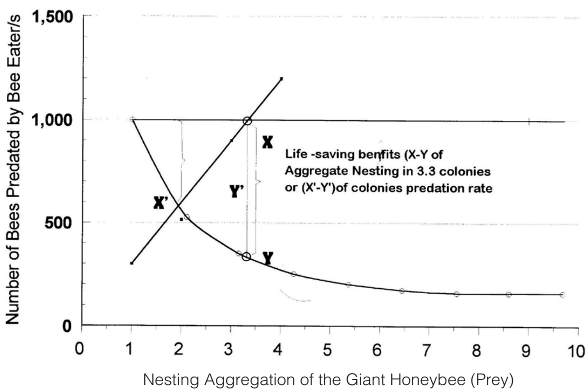


Figure 15 Proposed bee eater-Ginat honeybee predation equilibrium

Apart from sharing the bee eaters' predation rate with other colonies, nesting in aggregate also affords cooperative defense when attacked by honey buzzards. Within this facet of bird interaction, another predatory bird, the Black-thigh falconet, comes into the picture. According to honey hunters the falcon stays on top of the bee tree and is attracted by the presence of so many species of birds, including the hundreds of bee eaters concentrating around the bee tree. The Black-thigh falconet is one of the fastest flying predatory birds that can speed up to 70 miles per hour when attacking its prey during flight. It is equipped with menacing sickle claws and have been observed by honey hunters to attack honey buzzards around a bee tree. Hence the heavy presence of bee eaters and honey buzzards attracts the falcon which preys on them and the Giant honeybees inadvertently gets protection from the falcon perching on the top of the bee tree.

Overall, there is a noticeable interplay of prey-predator interaction between the honeybees, bee eaters, honey buzzards and falcons.

Subterfuge of the Honey Buzzards

Apart from forming a protective covering layer which regulates the brood temperature, the bee curtain also performs wave-like ripples across the comb nest, as a protective screen to fend off intruders like predatory wasps, flies and birds like honey buzzards (*Pernis* spp.), honey guides and bee eaters (*Merops* spp. and *Nyctornis* spp). The Giant honeybee curtain bees also display an amazing feat in mimicking an enlarged colony when attacked by honey buzzards (Mardan 1989a: Mardan 1994). The 3-4 layers of bee curtain enveloping the colony suddenly enlarge into a single layer bee curtain and enlarges 4-5 times the original size of the comb area when approached by honey buzzards (Mardan 1989b) (Figure 16).

Figure 16 Enlarged bee curtain & illustration

The behaviour of enlarging the bee curtain has several adaptive affects. Such enlargement of the bee curtain has an off-centering effect on the brood comb by reducing the probability of the brood being directly targeted by the flying birds during attack on the colony.

Bee curtain enlargement also gives the false appearance of a combless colony (transit swarms with no brood or honey) and sends the attacking bird off target. When any flying object swoops past the colony, the colony emits snake-like hissing sounds whilst simultaneously protectively enlarging the enveloping curtain of bees over the honeycomb from several layers into a single large layer of bee curtain. This happens when a flying honey buzzard approaches the colony. In that single layer of bee curtain are foragers in readiness to take flight and chase the potential intruder, relentlessly. Honey buzzards are 'intelligent' enough to pounce on the broodcomb of the colony by flapping its wings while attacking the colony with its beak with extra long feathers protecting the eyes, whilst both claws (legs) grab onto the brood comb for protein (Figure – plundering illustration of honey buzzard). After plundering the colony brood causing hordes of guard bees to fly off or sting and attack, the honey buzzard takes flight away from the colony and will fly past any other moving object such as human beings, livestocks, etc. This acts as a decoy leading astray the guard bees to attack the innocent victim that passes by. This is indeed what actually happenes when we hear about innocent human beings, cows, buffaloes, cows and chickens being subjected to stinging attacks to death by colonies of Giant honeybees. My co-researchers and I have had several experiences of being suddenly attacked by Giant honeybees, unprovoked. Often times, honey buzzards work in pairs perching at a nearby tree and waiting for any passerby to be in the vicinity to act as a decoy, as a diversion for attack. One of the pair will plunder the colony and take flight away from the colony with hordes of guard bees chasing after it. Once the ferocious guard bees leave the colony to relentlessly chase the intruding honey buzzard, with only young bees left in the colony, the other honey buzzard will return to plunder the brood comb of the colony, while the guard bees are off chasing the innocent decoy.

Nesting Strategies

Conceivably, there seems to be a pattern of dichotomous nesting syndrome behaviour among the Giant honeybee colonies which nest high, open and in aggregate on bee tree or on eaves of tall buildings, and nest low, concealed/camouflaged and singly and dispersed. (Mardan 1989b; Reddy 1963). The average person would easily notice or detect colonies of *A. dorsata* from afar, nesting in aggregate on tall trees or buildings, but many do not realize that they also nest on any available low nesting supports in bushes, even close to the ground, and these locations are under shade, not easily noticed, and not accessible by any arboreal primates and are usually behind screens of overhanging vines or branches that afford camouflage and deny detection by birds and bears. Nesting high on lofty tree emergents, cliff faces and tall buildings makes the *A. dorsata* not easily accessible by arboreal and scansorial predators like humans, bears, monkeys, armadillo, etc (Seeley 1985b).

BEE DOTS CONNECTED

Lesson # 1: Centre of Bee Diversity & Beekeeping Development

Honeybees *(Apis* spp*.)*, Carpenter bees (*Xylocopa* spp.), and the whole genera of *Apoidea* family of stinging insects have touched our lives and captured our imagination. It captured my enthusiasm during the first 40 years of my life that has become one of my favourite pastimes, as well as my career. There could not have been a better place in this world to indulge and be passionate about bees than in the Indo-Malaya region, the center of honeybee diversity whereby seven out of the nine honeybee species of the world are sympatric & endemic to the region, viz. *A. dorsata, A. Andreniformis, A. florea, A. cerana, A.*

koschevnikovi, A. nuluensis, A. nigrocinta, except for *A. mellifera*, the European honeybees *(A. mellifera)* and the *A. laboriosa.* The rainforests of Southeast Asia have bountiful bee plants. In evolutionary timescale and geological epoch, the estimated explosion and rise of the *Angiosperms* (flowering plants) in the *Cretacious Period* at about 65 million years ago, is considered propitious for the rise of the honeybee species, which is estimated to have been in existence for not less than 35 million years. Geological and paleontological studies on tectonic plate movements showed that the land strip from Burma to Peninsular Malaysia served as the Noah's Ark of biodiversity of flora-fauna for the landmass Gwondwanaland (Audley-Charles 1990), and it would not be a surprise if it can mean that it is the cradle of the rise of the *Angiosperms*, as it is the centre of biodiversity of bees and honeybees.

Diversity of Bee Niches

The diversity of bees is consonant with the highest flora species diversity in the region. Sabah is indigenous to 5 sympatric honeybee species of both single-comb, open-nesting *(A. dorsata and A. andreniformis)* and multi-comb, cavity nesting *(A. cerana, A. koschevnikovi, A. nuluensis)* honeybees, the highest number of indigenous honeybee species in the world. All these sympatric species established their niche and co-exist in the rainforest to forage for nectar and pollen from the boundless sources of floral diversity, since the rise of the *Angiosperms* during the *Cretacious Period,* 65 million years ago.

Co-evolved with Natural Enemies

Birds and mites have so far been the most insurmountable obstacles in the development of beekeeping with the introduction of the European honey bees in Malaysia. Records on colony introduction of European honeybees since 1941 indicates that none of the over several hundred colonies introduced into Malaysia could survive more than 2 years (Mardan 1984). By that measure, it is only logical that the promotion of beekeeping of these species of honeybees (Mardan & Osman 1982; Mardan 1983) with different niches warrants that we should be species-specific when putting forth recommendations for honey production or crop pollination of agricultural crops. For example, the open-nesting and nocturnal foraging *A. dorsata,* which cannot be hived in a box but can be induced to nest on rafter supports, or the tikung is preferable to be promoted for honey production in the diversity of flora of the rainforest or nocturnal flowering plants like durians, kapok, etc, (Mardan & Zainal 1986). On the other hand, multiple-comb and cavity-nesting honeybees like *A. cerana, A. nuluensis and A. koschevnikovi,* which can be hived in boxes with multiple combs, would preferably be promoted in agricultural crop areas such as orchards like starfruit, coconut, pineapple plantations, etc. On a different note, the gallery-nesting Carpenter bees are to be specifically promoted for rearing to provide pollination services to obligate flora-fauna association of cantharophilous plants, such as, passion fruit *(Passiflora edulis)*, gourds, etc. Specifically, the nectar rewards of passion fruit and other cantharophilous plants are secured by nectar robbers of non-pollinating fauna like honeybees, ants, etc. in the cavity at the base of the passion fruit flowers which require the strong mandible of the Carpenter bees to open up the operculum which secures the nectar rewards, which is hence unavailable to honeybees (Mardan *et. al.* 1992).

Niche Consideration for Developmental Beekeeping

Being at the epicenter of the honeybee biodiversity brings along with it the baggage whereby the endemic natural enemies of the honeybees have also co-evolved a high degree of defense-subterfuge inter-play between the honeybees. Being single-comb and open-nesting would make the colony only covered or protected by bees, vulnerable to both the biotic and abiotic environment. Several species of birds *(Merops* spp., *Nyctornis* spp. *Pernis* spp.) have evolved adaptive strategies and morphological features that show a high degree of interaction and it is a hindrance to the introduction of the European honeybees for beekeeping. The slow-flying European honeybees *(A. mellifera)* cannot cope with (Mardan 1984) predation intensity of several species of bee eaters and wasps *(Vespa affinis).* The brood of European honeybees have longer life cycles (longer larval and pupal development stages) which make it vulnerable to parasitizing of the hemolymph by Varroa mites *(Varroa jacobsoni)*, as compared to the indigenous *Apis cerana* honey bees which are more adapted to the natural enemies of birds and mites with shorter life cycle and are fast flyers. My almost 30 years of working with bees gives me insights into the need to be more defined in efforts to promote beekeeping for both honey and pollination with the Giant honeybees, Carpenter bees, and other bees, according to the specific bee plants that we deal with. The difficulty lies in the existing tendency to generalize the approach without regard to bee-plant specificity and ends up with over generalized recommendations and subsequent failure (Mardan 1991). The diversity of the flowering plants with different physical architecture, temporal reward offerings and stratified heights present different conditions for resource-partitioning for the pollinators and therefore the same is expected in the efforts on developmental beekeeping. The more than 25 indigenous species of Stingless bees *(Trigona* spp.), 6 spp. of Honeybees, 5 spp. of Carpenter bees, and many other species of bees cannot be bundled-up into a single approach as there should be diversity and specificity in seeking solutions for either pollination or honey production.

Under the circumstances, it is highly likely that the introduction of Apis mellifera for beekeeping development would encounter high predation and pestilence pressure from the myriad endemic natural enemies like bee-eaters, wasps, mites, microbial organisms, etc. In this regard, I would only recommend the introduction of *Apis mellifera* for beekeeping, only for initial endeavours, to transfer management skills and technology to be used in beekeeping with the indigenous bees, *Apis cerana*. There is a deep biological adaptation of the indigenous *A. cerana* life cycle and drone capping to cope with the parasitisation of the Varroa mites. Other than that *A. cerana* are faster flyers and would hence fare better with regards to predation by bee eaters and wasps.

Lesson # 2: Bee Dots of My Life

I believe it is our passion and interest which motivates and fuels our enthusiasm to pursue knowledge. We need to retain our childlike inquisitiveness in order to be unencumbered by our knowledge trappings which we take for granted sometimes. Over the years of research & experience in connecting the bee dots in my life, I have discerned certain philosophical aspects of wisdom in life, such as: asking the right questions; fostering inquisitiveness; persistence of purpose; sustaining the urge to seek knowledge which serves as fuel to enthusiasm and keeps us young. I believe that we have to find what we love which can make us willing to go the extra mile to go beyond the call of duty. We cannot love what we do not know. Our love and passion is limited by our knowledge. *Tak kenal. Tak Cinta*. The desire to know is the beginning of the journey of what we are going to love by seeking truth and knowledge.

In life, we have many close encounters which could have been the defining dots that changed the course of our life destiny. That sequence of defining dots could have connected differently to affect other things that form the basis of our love and passion. Any probable change in the connecting dots would have been very much influenced by our perseverance in whatever we undertake in pursuit of our interest. Our perseverance span is a function of the tenacity of our mind, which is also governed by the summation of our enthusiasm, beliefs, values, intuition, curiosity, critical mind and willingness to go the extra mile i.e. hard work. My small headways in establishing the bee dots of my life are founded on smaller reinforcing dots that make a big difference in my interest and working career. I thank UPM for giving me the opportunity in ***connecting the bee dots*** of my life.

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I thank my graduate supervisors, Profesor Dr. Peter G. Kevan and Thomas E. Rinderer who have guided and supervised me in my *Ph.D.* and Masters degrees at University of Guelph (Canada) and Louisiana State University (LSU), respectively. Professor Nikolaus Koeniger, Dr. Gudrun Koeniger and Professor Gard Otis, with whom I have been significantly associated with in my bee research, have contributed immensely to the development of my scientific thoughts and research ingenuity. Professor G. F. Townsend and Professor Edwards C. Burns have been great mentors, assisting me in making decisions, both in science and career development. I also thank Professor Dr. Abd Rahman Razak for his encouragement and administrative support to the bee research projects.

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Last but not least, my sincere thanks and gratitude to all those who have assisted me throughout my career.

BIOGRAPHY

Makhdzir Mardan was born into the proletariat family of Mardan and Jamilah, on 25th February 1953, in Sungei Sudah, Muar, Johor. Despite being of rural upbringing, both Mardan and Jamilah wanted the best education possible for their eldest son and thus they decided to send him to English medium primary and secondary schools. He was lucky enough to have an American friend from the *peace corps* from whom he learnt to speak English and also had the opportunity to borrow many magazines, periodicals, books and other sources of reading materials from.

It was during those years of working and playing in rubber and oil palm plantations that he got throrougly exposed to and experienced in working in the field and hence gained great familiarity with the field of agriculture. Specifically, he was fascinated with honeybees and carpenter bees. He used to beat and jar the wooden beams of the village houses to force carpenter bees to emerge from their nesting galleries and then trap them in bottles. Later he would tether them with a string and play with them like 'kites' with fellow friends in the village.

With this agricultural setting and upbringing it was only natural that he later chose to enrol in the Diploma in Agriculture program at Kolej Pertanian Malaya, in 1970, upon completion of his secondary school education. After completing the diploma program in 1974, he was awarded a scholarship to pursue his baccalaureate studies at the Louisiana State University in Plant Protection (1976), and Masters in Entomology (1979). He specialised in the field of apiculture (rearing of bees) for his Masters degree and conducted his research at the USDA's (United States Department of Agriculture) Bee Breeding and Laboratory Centre at Baton Rouge, Louisiana, USA. while working towards his Masters thesis on the hoarding behaviour of honeybees.

Upon completion of his masters program he joined Universiti Pertanian Malaysia and worked as a lecturer in the Faculty of Agriculture. His interests in bees was enhanced and promoted further with the varied generous funding support from the International Development Research Centre (IDRC) spanning a decade (1983 – 1993) totalling about RM 3.4 million. With these grants he formed a multi-disciplinary research and development team; the Malaysian Bee Research and Development Team (MBRDT) comprising of about 10 researchers from various agricultural institutions (UPM, MARDI, DOA, RISDA, FELCRA & LPGM) and other local universities (Universiti Malaya & USM). In 1985 he was awarded the IDRC scholarship to embark on a sandwich, *Ph.D.* program (1985 -1987), between University of Guelph and Universiti Pertanian Malaysia, where he took courses in Gueph, Canada and conducted his research in the rainforests of Malaysia, based at Universiti Pertanian Malaysia.

Specialisation: Apiculture and Pollination Biology

Makhdzir's interest in honeybees was formed early when he was just five years old. One day, an *Apis dorsata* colony built its nest under the eave of a branch of a tall durian tree that overlooked the window of his house. He used to wonder why the colony of *A. dorsata* expanded and contracted in size during different times of the day. Never did he realize that these childhood thoughts would sow interest and be the founding dots for his pursuit of this subject matter for his *Ph.D.* thesis, 30 years later. This interest was further imbued and deepened when he studied the Qur'anic verses in the Chapter of Bees (verses 68&69 of *Surah An Nahl*) back in the summer of 1976. While there elements of serendipity in his interest on honeybees emerged in that the largest bee breeding laboratory in the United States was located near the Louisiana State University, the place where he was studying. When he enrolled for his *Ph.D.* program at the Univesity of Guelph, his interest in pollination biology deepened under the tutelage of his supervisor and mentor Professor Dr. Peter G. Kevan. Professor Gard Otis (Univ. of Guelph) and Professor Nikolaus Koeniger (Univ. of Frankfurt) are two bee scientists who influenced him with their discipline and honed his scientific mind in the field of apiculture and pollination biology. The International Development Research

Centre (IDRC), Canadian High Commission and Yayasan Di Raja Sultan Mizan (YDSM) provided him with generous research and development grants which also offered him the opportunity to travel, conduct research of his interest, and conduct extension in beekeeping and honey gathering.

Landmark Endeavour, Awards and Honourable Mentions

Over a career span of more than 25 years he established himself professionally as a bee scientists in several landmark research & development areas and endeavours in: i) thermoregulation of the Giant honeybees; ii) hive-design of carpenter bees; iii) formation of *Apis cerana* beekeeping cooperatives; iv) pollination of tropical orchard trees (durian, belimbing, etc.); v) development of honey hunting as an ecotour item; vi) development of bottle-design for organic gelam (*Melaleuca* spp.) honey in Mercang, Terengganu; He earned himself professional recognition for his work on bees, as exemplified by the following accolades of awards and honourable mention: i) *J.W. Edmund Memorial graduate Award* (1986); ii) *G. F. Townsend Award* for international apiculture (1987); iii) *Humboldt Stiftung Fellowship* stint in Frankfurt, Germany (1993); iv) IDRC Fellowship Award; v) *The Royal Thailand, Excellent Research Award* in beekeeping research via the Asian Apicultural Association (AAA)(1993); vi) *IDRC Fellowship* Award (1985); vii) Listed in *Who's Who* in 1993 & 1994; viii) Awarded *D.I.M.P Dato'ship Award from the Sultan of Terengganu* (His Royal Highness, Sultan Mizan Zainal Abidin) (2006); ix) Research Excellence Award UPM, (1999). He has also extended his influence and service to the board of the *Yayasan Di Raja Sultan Mizan* (YDSM).

Administrative Experience

Over a span of more than 27 years of service at Universiti Putra Malysia, since 1979, he has held key administrative positions as: i) Deputy Vice Chancellor for Development (2000 – 2003); ii) Director, AgroBio Unit, the Chancellory (2003-

2004); iii) Director for Institute of Plantation Studies (2003-2006), iv) Director, Multimedia Centre (1999-2000); v) Director for CyberCreative Laboratory, University Business Center (1997-1999), etc. At the national and international levels he has contributed immensely to conceptualising the *AGROPOLIS Master Plan* (Ministry of Agriculture) and the concept proposal on *Rainforest-derived Knowledge Industry* (RKI) to the government of Malaysia. He has assumed several national appointments (*Biro Pertanian UMNO*, Agribusiness Cluster for MTEN, MIMOS committees for Flagship Applications for multimedia) and been on several international committees (Standing Committee for Biology to the APIMONDIA, Panel of Experts Asian Apicultural Association, etc.) and company boards *(InnoIntegrasi Sdn. Bhd)* (BioNexus status company) and (*MicroGreen Sdn Bhd)*. He was the President of the Ecological Society of Malaysia (2000 – 2002) and currently he is the Vice President of Kelab Pemain Golf UPM (KPGU since 2007).

Interests & Hobby

Makhdzir has wide-ranging interests and hobbies. He is an avid reader who subscribes to more than 15 magazines and journals, ranging from bees, science, economics, business, ICT, technologies, etc. He is also a keen golfer.

LIST OF INAUGURAL LECTURES

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2. Prof. Ir. Abang Abdullah Abang Ali
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3. Prof. Dr. Abdul Rahman Abdul Razak
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7. Prof. Dr. Mohamed Mahyuddin Mohd. Dahan
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8. Prof. Dr. Ruth Kiew
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13. Prof. Dr. Kapt. Mohd. Ibrahim Haji Mohamed
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16. Prof. Dr. Md. Nordin Hj. Lajis
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18. Prof. Dr. Mohamed Shariff Mohamed Din
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19. Prof. Dr. Tengku Azmi Tengku Ibrahim
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