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Pervasiveness of non-infectious and non-pest-related disorders accompanying with honey bees colony and control of downfalls

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Abstract

The purpose of this publication is to include information to identify abnormalities of the honey bee and to acquaint beekeepers to diagnose and control disorders. All brood and adult stages of queens, workers and drones may exhibit symptoms (neglected brood, chilled brood, starved brood, overheating, plant poisoning, pesticide poisoning, and queen bee problems) similar to those caused by disease pathogens or pests, but these are due to other causes. Non-infectious and non-pest-related disorders can result from neglect, overheating, chilling, poisoning from plants or pesticides, or from queen failure with effects ranging from minor stress to the death of the colony. Best management practices relating to above disorders are deciding of ways to improve overall colony health and productivity, identifying factors leading to decline in honey bee health such as nutrition, stress and pests, and focusing on new or current major issues (mites, genetic disorders). The priorities may include such as development and implement of measures for the surveillance to detect any incursions to enable to be destroyed before these become established, early detection of targeted disorders, and inspections of peoples, mail parcels, baggage, ships, animals, plants and cargo containers to prevent the entry of foreign bees and disorders they carry.

Keywords: Non-infectious disease, Honey bee pest, Honey bee disorder, Honey bee parasite, Poisoning.

1. Introduction

There are many species of honey bees of the genus *Apis* commonly existing and recognized at global level. These are the *Apis dorsata* group (commonly called rock bees or giant honey bees), the *Apis florea* group (commonly called dwarf or midget honey bees) and the *Apis cerana* group (commonly called oriental honey bees. This group includes the Indian honey bee, Chinese bee, Japanese bee) in Asia. The introduction of the common or European honey bee (*Apis mellifera)* into Asia has increased the total number of distinct species on the continent. Honey bees are managed for their honey, secondary hive products (beeswax and propolis, the latter being a dark, waxy substance also known as 'bee glue' that is collected from trees by bees), genetic stock, and crop-pollination services. Beekeepers typically sell their honey to manufacturers in bulk or to individuals in smaller quantities. Honey is sold in four forms, extracted (liquid), comb honey, chunk honey (a combination of comb and liquid honey), and crystallized (creamed) honey. Beeswax may be used in candles, or most frequently sold as solid blocks to the cosmetic industry. Pollen, royal jelly and propolis can be found in various health food products. Queens, packaged bees, and nucleus colonies (nucs) are sold to supplement or start honey bee colonies. Strawberries, cucumbers, squash, pumpkins, watermelons, muskmelons, beans, blueberries, peas and peppers all require bee pollination to produce larger, more attractive fruits and vegetables. Successful pollination also results in a higher crop yield, where development is more synchronized; conversely, inadequate pollination leads to smaller yields of inferior fruit over an extended period [1, 2].

Since individual bees have more than frequent contact among themselves, and since trophyllaxis (the sharing and orally passing of food among members of the nest) is one of the most important and frequent aspects of the bees' social behavior -- in that it allows hormones and pheromones to be widely distributed throughout the colony-- whenever a pathogenic organism is present in the colony it will be spread with great ease. The effective defense against disease is one of the most essential achievements of the bee colony. The individual bee's immune system functions in a similar way to that of vertebrate animals, although the most effective defense mechanism that can lead to self-healing of the bee colony is the social behavior of removing as many pathogen agents or parasites as possible from the bee colony. This behavioral defense (entrance reduction or stinging) prevents parasites from penetrating the bee colonies, or their killing or removal. If the dead organism is too large to remove, as with mice, the bees completely cover it with propolis. This prevents release of the pathogens during decomposition of the body. Propolis is also applied inside the brood cells before new brood is reared. Disinfection of the inside of the cell is effected by covering with secretion from the mandible and propolis. The most important defense against disease, however, is the bees' hygiene behavior. The defense against brood diseases comprises identification and removal of affected brood, and to this end the bees inspect every single brood cell. On finding an infected larva in a sealed cell, the cell capping is removed, and any sick brood is removed and finally eliminated from the colony. The beekeeper recognizes defense activities against brood diseases from the scattered brood surface. If adult bees fall ill they are either forced to leave the colony or are lost during the first foraging flight. Self-healing is therefore frequently possible by increasing flight activity. This may be initiated by foraging flights or during hibernation by cleansing flights, although it is only possible if the colony is sufficiently provided with pollen and nectar. Despite these very effective defense mechanisms, diseases, parasites and destructive insects may represent a problem for bee colonies [3, 4].

Diseases may be spread by migration and sale of colonies, equipment or bees. With increasing globalization, bee colonies are transported over great distances and even between continents, in this way foreign species and their diseases are spread. However, new pathogen agents such as *Acarapis woodi* have been imported into Asia with the introduction of the European bee. On the other hand, parasites like *Varroa destructor* or *Tropilaelaps spp.* have managed to transit from their original hosts to the new bee species. This has completely changed the scenario of bee diseases for *Apis* in Asia and throughout the rest of the world. Viruses have been spread by *Apis mellifera* beekeepers migrating or shipping bees to new areas and infecting and sometimes decimating *Apis cerana* colonies. In view of the fact that all bee species in Asia often occupy the same areas the problem of disease has become especially urgent. A number of serious outbreaks of native diseases have already been caused in new areas resulting in immeasurable economic costs to small and large beekeepers alike [5].

2. Non-Infectious and Non-Pest-Related Disorders

There are several different non-infectious and non-pest-related disorders in honey bee colonies. An infectious disease is one that is caused by an organism and that can be transferred from one individual to another. The transfer may be direct, where the disease-causing organisms, such as viruses or bacteria, pass directly from bee to bee, or it may be carried out by an intermediary (called a vector), such as a blood-sucking pests. Non-infectious diseases are diseases that are not due to disease-causing organisms. They include genetic diseases or other causes such as dietary deficiencies that can result from neglect, overheating, chilling, poisoning from plants or pesticides, or from queen failure. Like all other insects, honey bees are susceptible to non-infectious and non-pest-related disorders, the majority of which are specific to honey bees. These disorders can impact the health of a honey bee colony with effects ranging from minor stress to the death of the colony. Some of these disorders are quite common while others are rarely encountered. It is important for beekeepers to be aware of these disorders, learn to identify them and effectively manage disorders to maintain healthy colonies. This is particularly important because the health of one beekeeper’s colony can impact another beekeeper’s colony in the surrounding area. Given the great values placed on honeybees and the services they perform, it is thought that it would be informative to examine the impact of non-infectious and non-pest-related disorders on honeybee colonies and beekeeping operations, and introducing the methods and techniques to use by beekeepers to resolve these problems [6].

2.1. Queenlessness and laying workers

If the queen is not present, having been either accidentally killed or lost during a hive inspection or during transport, or superseded, with the young supersedure queen failing to return from the mating flight, then the hive is termed ‘queenless’. In a queenless hive: there may be present older stages of brood but not young stages; pollen stores build up in the brood nest area; the hive bees emit a loud buzzing sound when the hive is opened. Brood, particularly drone brood, may be neglected and die and have the appearance of European foulbrood disease. After a few weeks a small number of laying worker bees can be present that are worker bees whose ovaries have developed slightly and are able to lay small numbers of unfertilized eggs in worker cells in the brood area. Signs of laying workers are, many eggs per cell; eggs laid around the side walls of the cell and not squarely in the bottom of the cell, and these eggs develop into small, fully functional drones. Queenlessness can occur in many ways, but once a colony becomes queenless the reaction of the colony is predictable. The colony can become agitated and most of the activities of the hive are disrupted. When the beekeeper opens the hive, many bees will fan, much like when they see scenting bees (secretion of Nasonov pheromone and its dispersion by wing fanning). There may also be a loud roar from the bees. Usually within a few hours of being queenless, the bees can begin to construct emergency queen cells from existing cells containing worker larvae less than four days old. Nurse bees can supply to the cell with large amounts of royal jelly to divert the development of the worker larva into a queen. Usually the queen cell is constructed in time to permit requeening, and if not, the colony becomes hopelessly queenless and can eventually die unless if a new queen is added to rejuvenate the colony [7, 8, 9].

During the time between queenlessness and complete colony collapse, workers may begin to lay eggs inside the cells. At first glance one would think there is a queen in the colony, but with a closer look, it is obviously laying workers. Workers have the ability to lay unfertilized eggs when their ovaries are stimulated. Worker’s ovary development is normally suppressed by the queen's presence, but if the queen is killed or if it is old and not producing adequate amounts of pheromone then the workers begin to produce queen cells or lay eggs. Differences between worker and queen eggs are undetectable to the naked eye. Laying workers are usually revealed by the manner in which they deposit their eggs. A queen can lay a single egg cemented to the base of the cell in a cohesive pattern of deposition. A worker may lay numerous eggs in all areas of the cell and the pattern can be spotty in a disorderly manner, with one or more eggs per cell, sometimes persisting to the point of two larvae per cell, with many cells skipped altogether. This is the result of multiple competing laying workers, each vying for reproductive dominance and attempting to lay its eggs on top of a rival's. Re-queening a laying worker colony can be difficult because laying workers rarely accept a new queen. Vigilance by the beekeeper and prompt queen replacement are the solutions to this problem [10, 11].

When during hive inspection or transport, the queen has failed then it has a reduced capacity to lay sufficient numbers of fertilized eggs as a result of a disease infection or because of its age or from poor mating. The brood area reduces in size and has a scattered appearance, with brood of mixed ages in the same area. Excess pollen may be present in the brood area. Bee population numbers decrease and large numbers of drones may be reared in worker cells. Drone brood in drone and worker cells may not be fed sufficiently and may die, displaying symptoms similar to European foulbrood disease infection. A small number of supersedure queen cells may be present, usually positioned on the upper third of combs in the brood nest area. The supersedure cells may hatch, resulting in one or more virgin queens present in the hive with the original queen. Generally, one supersedure queen will survive, mate successfully, and replace the original queen. The colony will then build up in strength. Treatment: Find and remove the original queen, queen cells and any emerged virgin queens. Requeen the colony with a mated queen or queen cell, or unite the colony over a strong colony using a sheet of newspaper between the two joined colonies to prevent fighting between adult bees and to assist the uniting process. Treatment: A colony containing laying workers should be united above a strong, healthy colony using the 'newspaper' method. It is difficult to requeen a colony which contains laying workers, as the new queen is often rejected [12, 13, 14].

2.2. Starvation

Starvation is one of the leading causes of colony collapse over winter; however, starvation can occur at any time. Colonies can perish from starvation if they go into the winter period with inadequate honey supplies or if the cluster becomes separated from the honey. Symptoms of starvation are numerous dead bees between the combs and on the floor, and many positioned head first in a cell. It is important to periodically check the colonies to ensure they have proper supplies of honey. Lifting of colonies from the rear is a quick method for determining quantities of honey stores. If the colony is light, mix a heavy 2:1 (sugar: water) syrup and feed them with internal division board feeders, and inverted plastic pails on top of the cluster or hive-top feeders. Recommendations for food needs can vary by region, but for many regions, a single hive colony might need at least one medium super of honey that can be equal to a minimum of 60 pounds of honey or syrup. Colony survival over winter is more likely if proper fall management strategies are followed. These include a strong viable queen, adequate supply of honey and pollen, colonies maintained in a disease-free condition, and well-constructed hives protected from extreme climatic conditions [15, 16].

2.3. Starved brood

Under dearth conditions for nectar and pollen, larvae and pupae are often removed or eaten by adult worker bees. There is little or no brood, honey or pollen present and dead adult bees may be present inside the hive, often facing headfirst into cells. Freshly dead adult bodies break apart easily and when a sudden shortage of adult bees occurs and there are insufficient adult bees to feed the brood, then the brood is starved. Larval stages crawl out of their cells or move to abnormal positions in their cells or no brood food is present in the cells with the larvae. Larvae lose their fat layer and become dull grey, individual body segments are easily seen and internal cotton-like threads of the trachea become visible. In some situations, newly emerging adult bees may become starved and die when are partially out of the cell; often their tongues may be extended. Fr treatment, feed sugar syrup and protein supplement as required and add frames containing mature brood, young bees, and disease-free honey and pollen [17].

2.4. Overheated bees

Bees may become overheated if they are confined in the hive during hot weather and have no access to water. It is especially a problem when hives are being moved in hot weather for pollination or to follow honey flows. Overheated bees crawl rapidly and flutter their wings and when released from their confinement they may disperse by crawling in a disorderly manner. When bees have died from overheating they are sometimes wet which is due to the bee regurgitating fluids in vain attempts to cool them. Temperatures exceeding 100 degrees F (38 degrees C) are usually the starting point for overheating. Overheating can be avoided by not confining bees during hot days for long periods. The best time to move bees is in the evening when it is comparatively cool. As long as bees are unencumbered by unnatural and temporary things like confinement, they are completely capable of regulating their nest temperature. Overheating of brood occurs when there is loss of control of the temperature and humidity within the brood nest area. This occurs when there is a sudden loss of adult bees, for example due to a loss of nectar-foraging and water-foraging bees from pesticide poisoning. Overheating also occurs when adult bees and brood have been confined to their hives during hot weather or during transport without suitable ventilation or access to water. Larvae are found hanging out of the top of their cells. Larvae dying from overheating are brown to black in color with a watery consistency. Pupae have a black, greasy appearance and newly emerged adult bees may be wingless. Capping on brood cells may appear melted and adult bees become sticky or greasy, dark colored, and run about noisily fanning their wings. Dead adults may be found on the hive floor and between the frames. For treatment, provide shade and ventilation, ensure that colonies have access to water, and badly affected colonies may require feeding internally with water or a dilute sugar plus water syrup. Remove excess supers and dead adult bees and add frames of mature brood and young bees [18].

2.5. Chilled Brood

As ambient temperature begins to drop, worker bees within the hive start to form a winter cluster around the brood area. Their bodies act as both insulators and generators of heat. However, if the population of worker bees is not large enough to encompass the entire region of brood, the brood may die from hypothermia. Chilled brood can also occur during spring build up. Sometimes the worker bees population has dropped over winter and the queen lays more eggs than the worker bees can cover. Chilled brood is usually found at the edges or lower peripheries of the cluster. Instead of pearly white larvae, chilled larvae and pupae are yellow, tinged with black on their margins, or they are dull white with black or brown patches. The remains are pasty or watery. In extreme cases where sealed brood has been affected, brood cells may be punctured or uncapped. Usually, affected brood is at the outer edges of the nest area, with healthy brood remaining in the center. Sometimes the capping of sealed brood that has died can be perforated. Chilled brood may resemble symptoms of European foulbrood, but does not exhibit the characteristic ropy test. Chilled brood is often observed in early spring once the queen has commenced expanding the brood area to a size where the number of adult bees present is not able to cover it adequately. Unexpectedly cold 'false spring' weather results in the adult bees contracting to cover and warm the central core of brood, leaving the outer edges of the brood unprotected and becoming chilled. The management practice of spreading brood frames and introducing empty frames into the brood area in early spring in order to stimulate brood nest expansion may contribute to the outer frames of brood becoming chilled if the temperature cools, because there may be insufficient bees to cover the outer brood combs. Chilled brood may result following brood inspections in cold weather when frames are left exposed outside the hive for extended periods of time during inspection. Also, for treatment remove excess supers and feed sugar syrup if required [19, 20].

2.6. Spotty brood

Spotty brood can be a symptom of diseases like European and American foulbroods or it can be a sign of a failing queen, queenlessnes, varroa mites, or inbreeding. A good queen can lays eggs in a solid pattern so that brood of similar age nay be contiguous and the resulting 'comb solid' with brood. A failing queen may lay eggs in a haphazard manner so that cells of varying stages can be interspersed together. A failing queen may also lay drone brood (upright cells) interspersed with worker brood. The solution for spotty brood is to check for disease or other disorders and requeen as needed [21].

2.7. Neglected brood

Under normal conditions, nurse bees feed sufficient food to the larvae and maintain the temperature and humidity in the area of the brood nest suitable for brood survival and growth. When this system fails, for example when there is a sudden loss of adult bees, there are fewer adult bees to feed the larvae and maintain temperature and humidity control. These situations often result in larvae and pupae becoming neglected and dying from chilling, starvation or overheating [22].

2.8. Plant poisoning

Some plants produce nectar and pollen which are attractive to bees, but that are toxic to the adult and brood stages. An example is Darling Pea *Swainsonia galegifolia,* when this plant predominates, heavy mortality may occur to bee brood and in some cases it may cause the loss of many colonies. Symptoms of affected larvae are similar to and may be confused with the virus infection called 'sacbrood disease'. Poisonous plants can be a problem under certain conditions in limited areas. If a plant's nectar is poisonous, the symptoms of plant poisoning are limited to the blooming period. If the poison is in the pollen, the symptoms may linger as long as the pollen remains in the combs. There is no clear-cut method for differentiating between plant poisoning and pesticide poisoning. The effects of plant poisoning are usually more gradual and last longer than the effects of pesticide poisoning. Plant poisoning usually occurs in the same geographical area at the same time each year, whereas pesticide poisoning is indiscriminate [23, 24]. Some examples of plant poisoning are listed below:-

2.8.1. Purple brood

Purple brood occurs when adult bees collect and use the pollen and nectar from *Cyrilla racemiflora* (titi, southern leatherwood). This disease is characterized by the blue or purple color of the affected larvae.

2.8.2. Paralysis

The *Aesculus californica* (California buckeye) is probably the best known of the poisonous plants in the few states. Field bees exhibit symptoms similar to those of chronic bee paralysis; specifically, the bees are black and shiny from loss of hair and they tremble. Also, either the eggs do not hatch or the larvae die soon after hatching.

2.8.3. Milkweed pollinia

The pollen of milkweed (*Asclepias* spp.), is produced in pollinia (coherent pollen grains) that are attached in pairs by a slender filament. When removed from a flower, the pollinia resemble a wishbone with pollen masses hanging from the ends. Honey bees become ensnared in the thin pollinia attachment and free themselves by pulling the pollinia from the flower. Honey bees often become seriously encumbered and cannot remove themselves from the flower, or they may have difficulty in flying and crawling back to their hives with the pollinia still attached to their body parts. For the treatment of infected bees, move hives from the area and feed sugar syrup if required.

2.9. Genetic lethality

Bees can also die from genetic faults during all stages of development, usually without exhibiting symptoms of known diseases. However, drone broods from laying workers and drone-laying queens often die with symptoms resembling with European foulbrood, but in the absence of known pathogenic agents. Genetic lethality is the suspected cause of this condition [25].

2.10. Pesticide poisoning

The most apparent indication of serious pesticide poisoning is the sudden loss of adult bees. This loss is characterized by the appearance of many dead and dying adult bees and sometimes pupae at the colony entrances. In many instances, however, the bees are lost in the field before returning to the colony. If the pesticide is brought back to the hive by the foragers, the nurse bees die from feeding on contaminated honey or pollen and the brood exhibits symptoms of neglect or poisoning. The symptoms of poisoned honey bees often depend on the class of pesticide involved [26].

Poisoning of bees generally occurs after a pesticide has been applied to a crop or weeds that contain flowers or secretions attractive to bees. The pesticide may be applied directly onto bees foraging on the crop and bees may fly to the treated plants and collect contaminated nectar or pollen. Bees may collect water near treated crops, or forage on a cover crop associated with a treated crop, for instance, clover in an orchard. Pollen-collecting bees may collect the pesticide or contaminated pollen and return them to the hive. At times, pesticides drift from their point of application onto nearby flowering plants, or across apiaries. Depending on the type of pesticide, foraging bees may die on the return flight to their hive, resulting in a severe reduction in the field population. When bees are able to return to their hives with contaminated nectar before dying, or bring back contaminated pollen, the common feature is large numbers of adult bees dead on the ground in front of the hives [27]. The following field symptoms are a guide for determining pesticide poisoning:-

Most or all of the hives in the apiary are affected due to pesticides and adult bees die within a few days of each other. Usually, deaths do not occur over a long period of time although this can occur with certain pesticides. Dead adults typically, but not always, have their wings unhooked, tongues fully extended, and their hind pair of legs outstretched behind them. In severe cases, dead adults can be present inside the hive between the frames and on the hive floor. Laboratory analysis is required to confirm pesticide poisoning and the affected adult bees may move slowly or behave abnormally. Brood may be dead from neglect or from being fed contaminated nectar or pollen, and queen failure or supersedure may occur within 30 days. Some pesticides, for example systemic pesticides, have a less noticeable but debilitating effect, resulting in an overall weakening of the colony. Bee population numbers reduce, and stages of the brood cycle, or complete brood cycles, are missing [28].

3. Treatment and management of affected apiaries

Inspection for bee pests or diseases is an important part of beekeeping. Apiary inspectors and beekeepers must be able to recognize bee diseases and parasites and to differentiate the serious diseases from the less important ones. Generally, move hives away from the sprayed area, remove excess supers and feed colonies inside the hive with a dilute sugar**:** water syrup, since a loss of field bees results in a lack of fresh nectar, water and pollen being brought into the hive. Be prepared to manage the hives for queen failure or supersedure problems and do not requeen until it is considered that the chemical is no longer active in the hive. Frames inside the hive that have been contaminated from pesticide drift or contain contaminated nectar or pollen may need to be replaced, and in extreme cases hive materials, brood boxes are needed to be replaced or cleaned thoroughly before reuse. Colony survival over winter is more likely if proper fall management strategies are followed. These include a strong viable queen, adequate supply of honey and pollen, colonies maintained in a disease-free condition, and well-constructed hives protected from extreme climatic conditions [29, 30].

4. Research, Educational and Regulatory Priorities

Researchers might design best management practices relating to research factors leading to decline in honey bee health, such as nutrition, stress and pests; focus on new or current major issues (mites, genetic disorders). Educating of public on honey bee best management practices and address misconceptions, working to improve viability of beekeeping industry, encouraging and educating new or potential beekeepers, and improving information transfer techniques. Educating of apiarists on changing bee forage, advising of public and local agencies on disease facts, along with appropriate preparations and action plans. Promoting of local and small-scale queen and bee production, as well as local pollination services, provide information on alternative pollinators, and informing to crop growers about beneficial farming practices that protect pollinators (timing and planting nectar bearing plants). Developing and maintaining interstate collaborations, because working groups may find it easier to get new control methods in the pipeline or registered for beekeeper use. Exploring the possibility of reclassifying honey bees as livestock in order to protect beekeepers from economic losses during natural disasters, but only where doing so will not trigger ordinances prohibiting livestock. Reducing in the liability of beekeepers for hive activities, producing lists of certified queen breeders, developing and implementing of regionally valid hive inspections, and training of beekeepers in pesticide safety, and encouraging them to get private applicator licenses are crucial. Exploring of the possibility of reclassifying honey bees as livestock in order to protect beekeepers from economic losses during natural disasters, but only where doing so cannot trigger ordinances prohibiting livestock. Reducing liability of beekeepers for hive activities, producing lists of certified queen breeders, develop and implementing regionally valid hive inspections, training beekeepers in pesticide safety and encouraging them to get private applicator licenses.

5. Conclusion

In contrast to infectious or extrinsic diseases, noninfectious or intrinsic conditions of honey bee are neither contagious nor communicable. They arise from inside the body as a result of hereditary conditions or other causes, such as dietary deficiencies. All brood and adult stages of queens, workers and drones may exhibit symptoms similar to those caused by disease pathogens or pests but these are due to other causes. Non-infectious and non-pest-related disorders can result from neglect, overheating, chilling, poisoning from plants or pesticides, or from queen failure. Presence of pests and diseases, pesticide poisoning, poor hive and seasonal management, ecological problem and lack of queen rearing are potential problems identified by the beekeepers. Vigilance by the beekeepers or check for other disorders and prompt queen replacement are the solutions to these problems.

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