Mite Culprits for Causing Mortality and Reduction in Population of Honey Bee Colonies and Measures for Pests Control

Muhammad Sarwar
Department of Entomology, Nuclear Institute for Food & Agriculture (NIFA), Tarnab, Peshawar, Pakistan; E-mail: drmsarwar64@yahoo.com

Abstract

This article highlights the most serious invasion of the honey bee colonies by mite pests resulting in an irregular brood pattern or death and stresses upon tactics of maintaining minimum population level of culprits. Parasitic mites are currently the greatest pest threat to honey bees and their colonies, and infested colonies can probably perish if action is not taken to control pests. Thus, they are a significant threat to beekeeper's income and satisfaction. Mites in genera Varroa, Acarapis and Tropilaelaps are cruel parasites of honey bee brood feeding on bee adults, larvae and pupae causing brood malformation, death of bees and subsequent colony decline or absconding. Worldwide, *Varroa destructor* is an external parasitic mite that attacks honey bees *Apis cerana* and *Apis mellifera*, and disease caused by mites is called varroosis. Tracheal mite (*Acarapis woodi*) parasite of honey bee has also been discovered to spread throughout wholly regions of some states, leaving behind thousands of dead bee colonies. Tracheal mite is suspected of playing a major role in causing excessive statewide colony losses in recent years with much loss. Tropilaelaps mites (*Tropilaelaps clareae* and *T. mercedesae*) are external parasitic mites that feed on haemolymph (blood) of drone and worker bee pupae, as well as reproduce on honey bee brood. These mites can also harm to bees indirectly by serving as transmitters of several viruses that can kill bees. Virtually, all feral or wild honey bee colonies have been wiped out by these mites, and beekeepers are continuing to struggle with infestations in their hives. These secondary infections are facilitated when mites compromise to bee's immune systems with condition known as parasitic mite syndrome, which can kill colonies within months of infection. Therefore, it is vital, to understand parasitic mites and options available for their control. Monitoring hives for mite levels enables beekeepers to determine whether treatment is necessary and to make informed decisions about when to take action. Early detection of low levels of mite infestations is a key to its successful management as they can be spotted during colony inspection if present in high numbers that tends to only identify larger infestations. There are some products available that can kill mites and cause these pests to drop from bees. Treatment strips should be hung in the brood nest area of colony for approximately 4 weeks. This is to be used with sticky paper and a fine-mesh screen on bottom board of a colony to capture any mites that may have been present after removal. However, exclusive and continual use of one chemical product is more likely to result in resistance by pest. So, several different products should be used on a rotating basis and under any circumstances, and never experiment with non-approved chemical treatments. Such practices are illegal and may result in bees death, contamination of honey and wax, and severe harm to beekeepers, so, it is recommended that all beekeepers should receive training and certification. Reliance on a single approach is not a long term solution and Integrated Pest Management (IPM) using a combination of different control methods at different times is imperative in order to keep mite populations lower to cause significant harm to a bee colony.

Keywords: Acarapis, Honey bees, Mites, Syndrome, Tropilaelaps, Varroa

1. Introduction

Beekeepers, crop growers, scientists, official authorities and the general public are all concerned and alarmed with the mysterious die offs of honey bee (*Apis mellifera*) colonies that have occurred during the last three years in many countries around the world. This phenomenon has been named colony collapse disorder and many suspects have been suggested as potential culprits of these losses, but no clear explanation has yet been done attributable to weather and pesticides (Stankus, 2008). It is known for example, that the parasitic mites (Acari) *Varroa destructor* and *Acarapis woodi* are causes of colony mortality, and thus several synthetic miticides have been used successfully in their control (Wilson et al., 1997; Ellis, 2001). However, mites resistance to certain active ingredients in miticides is now prevalent. The results on relative effect of parasite levels on mortality and populations of honey bee colonies estimated that most of the colonies have been infested with varroa mites during the fall (75.7%), but only 6.1% tested positive to tracheal mites. Winter colony mortality reached to 27.2%, and when examined as a fraction of all morbidity factors, fall varroa mite infestations have been the leading cause of colony mortality (associated to > 85% of colony deaths), followed by fall bee populations and food reserves. Varroa-infested colonies, with weak populations and low food reserves in the fall, significantly decreased spring colony populations, whereas varroa infestations in the spring, significantly decreased bee populations by early summer. Overall, results suggest that varroa mites could be the main culprit for the death and reduced populations of overwintered honey bee colonies (Anderson and Trueman, 2000; John, 2000; Guzman-Novoa et al., 2010; Sarwar, 2016).

2. Economic Impact of Mites

The honey bee is a suitable habitat for diverse mites, including nonparasitic, omnivorous, and pollen-feeding species and parasites. Examination of dead or weakened colonies yielded the presence of mites in most cases, which are directly or indirectly responsible for colony deaths. Many beekeepers have been become discouraged because of excessive colony losses and are no longer keeping bees. Bee management costs have been increased for most beekeepers due to having to replace dead colonies and purchase pesticides for parasitic mites control. These increased costs will have to be passed on to fruit and vegetable growers who rent hives for crop pollination. Increased management costs and rental fees, reduced honey production and pollination, and discouragement experienced by many beekeepers have resulted in a negative economic impact caused by parasitic mites (Sammataro et al., 2010). Thus, the biology and damage of the three main mite pest species *Acarapis woodi*, *Varroa destructor*, and *Tropilaelaps clareae* is outlined in this article along with detection and control methods.

2.1. Varroa Mites

Varroa mites *Varroa destructor* are external, obligate parasites of worker and drone honey bees of *Apis cerana*. Varroa mites are external honeybee parasites that attack both the adults and the brood with a distinct preference for drone brood. They suck the blood from the adults and the developing brood, resulting weakening and shortening the life span of the ones on which they feed. Emerging brood may be deformed with missing legs or wings. Untreated infestations of varroa mites that are allowed to increase will kill honeybee colonies. Losses due to these parasitic mites are often confused with causes such as winter mortality and queen lessness if the colonies are not examined for mites. Varroa mites are visible to the naked eye and look somewhat like a tick. The adult female mites are reddish-brown in color, flattened, oval and measure about 1 to 1.5 mm across. They have eight legs, and are large enough to be seen with the unaided eye most commonly on the thorax and on the bee's abdomen. Their flattened shape allows them to hide between the bee's abdominal segments. This mite is often confused with the bee louse, but the bee louse has only six legs, is more circular in shape and is slightly larger. Mites develop on the bee brood; female mite enters the brood cell about one day before capping and be sealed in with the larva. Eggs are laid and mites feed and develop on the maturing bee larva. By the time the adult bee emerges from the cell, several of the mites will have reached adulthood, mated and are ready to begin searching for other bees or larvae to parasitize, but. there is a preference for drone brood. Inspection of the drone brood in their capped cells will often indicate whether or not a colony is infested. The dark mites are easily seen on the white pupae when the comb is broken or the pupae are pulled from their cells (Boecking and Genersch, 2008; Carreck et al., 2010).

2.1.1. Biology of Varroa Mites

The varroa mite is an external parasite that attacks both adult bees and the developing honey bee larvae. The mated female mite enters the cell of a developing bee larva and lays as many as six eggs. The developing mites feed on the bee pupae, and depending on the number of mites, may kill it and cause it to be deformed, or have no visible effect. While the male mite dies in the cell, the adult daughter mites climb onto an adult worker bee and feed on its hemolymph (a fluid known as bee blood). The female mite can then repeat the cycle by entering cells of other developing larvae. Mites prefer drone larvae over worker larvae, but they will infest worker larvae and eventually kill the colony if preventive measures are not taken. The mites can also harm the bees secondarily as transmitters of several viruses that can kill bees. These secondary infections are facilitated when the mites compromise the bees’ immune systems. They can cause a condition known as parasitic mite syndrome, which can kill colonies within months of infection. Mites spread from colony to colony by drifting workers and drones within an apiary. Honey bees can also acquire these mites when robbing smaller colonies. It is best to isolate captured swarms, package bees, and other new colonies from other colonies and examine them for mites before placing them in an apiary. The first egg laid by mite will be unfertilized and develop into a male. The subsequent eggs will be fertilized and develop into females. Varroa mites are transported from colony to colony by drifting or robbing bees. Visible symptoms of Varroa mite damage can be evident on newly-emerged bees which are due to the mite feeding on the immatures within the cell. The newly-emerged bees may be smaller than normal, have crumpled or disjointed wings, and shortened abdomens. The lifespan of the newly emerged bee is also reduced. Severe infestations of varroa mites within the cell (5 or more foundresses) cause death to the pupa. The end result of unchecked mite populations is an eroding adult bee population and eventual colony death (Sammataro et al., 2000; Helen et al., 2002).

2.1.2. Controlling of Varroa Mites

Delaying treatment can be accomplished if you monitor the level of Varroa infestation in your colonies. Treatment is justified only when the economic threshold is achieved. Economic thresholds are defined as the pest level that justifies treatment in order to prevent the pest from reaching damaging levels. Traditional methods for varroa mite control have been to hang plastic strips impregnated with chemical pesticides between the wax combs of beehives. Unfortunately, the mites are rapidly developing resistance to many of the common treatments, which has prompted researchers to develop alternative methods to prevent and treat varroa mite infestations. These methods range from structurally or mechanically modifying beehives, to obtaining new stocks that are more tolerant of mites and using new biopesticides that are valuable alternatives to the standard synthetic treatments (Peter et al., 1990; Zhang, 2000; Natalia et al., 2009).

2.2. Tracheal Mites *Acarapis woodi*

Tracheal mites (*Acarapis woodi*) have caused the loss of tens of thousands of colonies and millions of dollars. Tracheal mites infest the tracheal system of the adult honey bee, and infestation levels are highest during the winter and spring. Mites prefer adult bees less than four days old. Once they are on the bee, mites are attracted to carbon dioxide emissions and enter the spiracles located on the thorax which lead to the tracheal system. They puncture the wall of the trachea and suck the hemolymph of the bee. Tracheal mites live, breed and lay eggs in the tracheal system. The adults and eggs plug the tubes of the trachea which impairs oxygen exchange. They also spread secondary diseases and pathogens since they puncture the trachea in order to feed. Individual bees die due to the disruption to respiration, damage to the tracheae, microorganisms entering the hemolymph, and from the loss of hemolymph. Honey production may be reduced when over 30 percent of the population is infested with tracheal mites. Also, the likelihood of winter survival decreases with increasing infestation of the mite. Mites are transmitted from bee to bee within a colony and to other colonies by robbing or drifting bees. Infested bees can be seen leaving the colony and crawling on the grass just outside the hive. They will crawl up the blades of grass or the hive, fall back down and try again. The wings may be disjointed and the bees become unable to fly. The abdomens may be swollen and in late stages of infestation, bees will abscond from the hive. If beekeepers are unsure and have tracheal mites, send a sample of bees in alcohol to their local county researchers for verification (Raloff, 1998; Sarwar, 2015).

2.2.1. Biology of *Acarapis woodi*

Tracheal mites are microscopic in size (as long as 1.5 times the diameter of a human hair) and spend their entire life cycle within the tracheae (breathing tubes) of adult honey bees. Female mites lay single eggs in the bees respiratory tract where the developmental cycle occurs. Each female mite lays five to seven eggs 3 or 4 days after entering the tracheae and the eggs require three to four days to hatch. Adult mites (5-9 days old) emerge from their host tracheae in search of a new host. Within 24 hours after the worker bees emerge from their cells, female mites are collected within their tracheae. Studies have found that highest numbers of mites are found in 11-12 day old adult bees, and mite levels decline over 21 days old. Adult mites penetrate the tracheal wall with their piercing mouthparts and feed on bee blood. Normal thoracic tracheae are clear, colorless or pale amber in color. Severely infested tracheae are darkened with crust-like lesions and may appear black. Numerous mites in varying stages of development and mite debris inside the tracheae are thought to reduce capacity for airflow. Bee scientists have discovered a connection between tracheal mite infested bees and flight muscle damage. Flight muscles of mite infested crawler bees are degenerated which affects the ability to fly. Also, blood tests from mite infested bees show a higher than normal bacterial count. Drifting bees between hives and swarms produced from infested colonies are ways the mites are naturally spread within an apiary and between apiaries. Mites are spread within a colony by bee contact and mature female mites exit the bee trachea and climb to the tip of a body hair. Upon contact with a newly emerged bee, the mite transfers to the hairs of the new host and enters the trachea where it will complete its life cycle. If the mite fails to locate a new host within 24 hours, it will die. The tracheal mite population may vary seasonally and during the period of maximum bee population, the number of bees with mites is reduced (Collison, 1990; Skinner, 1991).

2.2.2. Symptoms of Infestation and Diagnosis

No one symptom characterizes a tracheal mite infested colony. Tracheal mites are believed to shorten the life span of adult bees, affect flight activity and result in a large number of crawling bees that are unable to fly. The wings of mite infested bees are often disjointed with the hind wing projecting 90^{o} from axis of the body. However, absence of these symptoms does not necessarily indicate freedom of mites. Infected colonies may not develop normally and may exhibit symptoms of dysentery and an excessive swarming tendency. Often, however, severely infested colonies typically appear normal until their death during the winter. Colonies are most affected during winter confinement and early spring like a stress disease. Mite infestations are at a maximum in the spring when the population is comprised of primarily older bees. The susceptibility of worker honey bees to tracheal mites diminishes rapidly with age and bees over nine days old rarely become infested. Studies have shown that adult female mites transfer preferentially to young bees less than 4 days old, and newly emerged bees, less than 24 hours old, are especially attractive. Positive diagnosis can be made only by microscopic examination of honey bee tracheae. In sampling for this mite, one should try to collect either bees that may be crawling near the hive entrance or bees at the entrance as they are leaving or returning to the hive (50 bees per colony sampled). These bees should be placed in 70% ethyl or methyl alcohol as soon as they are collected. Do not collect bees that have been dead for an unknown period because they are less than ideal for diagnosis. For dissection, each bee should be grasped between the thumb and forefinger, remove front pair of legs and head by pushing them off with a scalpel or razor blade in a downward and forward motion, cut thin transverse section of the prothorax containing the major tracheal trunks with a sharp razor blade, soak disc section overnight with 8% solution of Potassium Hydroxide in water to dissolve muscle tissue, and examine disc sections with a microscope (minimum 40 X). Infested tracheae have various stages of mites and are usually discolored and darkened (Shimanuki and Knox, 1991).

2.2.3. Treatment of *Acarapis woodi*

One method for controlling of tracheal mites is the use of menthol, available from most bee supply companies. The temperature must be above 60 ^{o}F in order for the menthol to work. The bees breath in the vapor which, it is believed, desiccates the mites. Menthol must be removed during a nectar flow in order to not contaminate honey. Another less caustic treatment for tracheal mites is an oil extender patty. It consists of two parts sugar to one part vegetable shortening. Make a small patty about four inches in diameter and sandwich it between wax paper. Cut the wax paper around the edges so the bees have access to the patty. Center the oil patty on top of the frames within the hive body. The bees will be attracted to the sugar and obtain oil on their bodies. The oil acts as a chemical cloak and the tracheal mites are unable to identify suitable bee hosts. The oil patties are acceptable for prolonged treatment since the oil will not contaminate honey supplies (Hall et al., 2009).

2.3. Tropilaelaps Mites

Tropilaelaps mites parasitize the brood of the Giant honey bees *Apis dorsata*, and two species of Tropilaelaps mites (*Tropilaelaps clareae* and *T. mercedesae*) are also able to parasitize European honey bees (*Apis mellifera*). Tropilaelaps mites are external parasitic mites that feed on the haemolymph (blood) of drone and worker bee pupae as well as reproduce on honey bee brood. Tropilaelaps mite infestation causes severe damage to honey bee colonies such as deformed pupae and adults (stunting, damaged wings/ legs/ abdomens), parasitic mite syndrome and colony decline. The colony may also swarm or abscond, for further spreading of the mite to new locations. Tropilaelaps mites can also spread viruses which further affect the colony's health and disease susceptibility. If Tropilaelaps mites are to become established in in locality, they would cause significant losses to managed and wild honey bee colonies, crop pollination and yields of honey products. The life cycle of Tropilaelaps mites is very similar to that of varroa mites in many ways, as both species of mites are external feeders which parasitize the brood stages of the honey bee. However, Tropilaelaps mites have a much shorter life cycle, and because of this, have a much greater reproductive rate than varroa mites. Because of this greater reproductive rate, research has shown that in some hives there can be around 25 Tropilaelaps mites to every varroa mite in a honey bee colony. However, unlike varroa mites which can survive on adult bees for quite a few months, Tropilaelaps mites can only live for around 3 days on an adult worker bee as the adult Tropilaelaps mite mouthpiece cannot pierce the adult wall membrane, and therefore, cannot feed on adult worker bees. For this reason, Tropilaelaps mites spend the majority of their life in the brood and will continue to breed and survive in a honey bee colony as long as there is brood present (Wilde, 2000).

2.3.1. Biology of Tropilaelaps Mites

A female Tropilaelaps mite will enter worker and drone brood cells that are in the process of being capped and lay 1-4 eggs (though typically 3 or 4). The development from egg to adult takes approximately one week and the adult mites (usually about 2-3) will emerge from the brood cell along with the emerging young adult bee. While in the capped cell, the larva/ nymph stage of the mite is white in color and feeds on the developing brood. Adult Tropilaelaps mites are active, red-brown mites around 1 mm in length and typically 0.5 mm wide, about one third the size of a Varroa mite. Considering that Tropilaelaps mites cannot survive for very long on adult bees, the vast majority of adult mites (> 95 percent) will typically mate and re-enter a brood cell to lay more eggs within 2 days of the adult bee emerging from the capped brood cell. The mites in the genus Tropilaelaps are particularly parasites of honey bee brood, feeding on bee larvae and pupae causing brood malformation, death of bees and subsequent colony decline or absconding. An infestation by Tropilaelaps can be recognized either visually on bees or by examining hive debris. Irregular brood pattern, dead or malformed immatures, bees with malformed wings that crawl at the hive's entrance, and especially the presence of fast-running, large, red brown, elongated mites on the combs, are diagnostic for the presence of *T. clareae*. An early diagnosis can be made after opening brood cells and finding immature and adult mites therein (Anderson and Morgan, 2007).

2.3.2. Treatment of Tropilaelaps Mites

The beehive (colony) may be treated with various chemicals that cause the mites to drop off combs and bees. Sticky boards on the bottom of the colony can be used to examine hive debris and mites In countries with infestations of Tropilaelaps spp., fluvalinate in slow-release formulations controls Tropilaelaps, as do monthly dustings with sulphur and treatments with formic acid. The inability of this mite to feed on adult bees or to survive outside sealed brood for more than a few days, such as caging the queen for a few weeks, is being used as a non-chemical control method. Many of the same acaricides used for Varroa can also kill Tropilaelaps and strips of plastic-impregnated fluvalinate will kill mites. Alternatively, tobacco smoke in the smoker will cause mites to drop off bees. Strips of filter paper, available in some countries are prepared by soaking in an aqueous solution of 15% potassium nitrate to which two drops of amitraz (usually 12.5%) are added. After the paper dries, the strip is ignited and inserted into the hive. The smoke causes many mites to drop off. Another method is to use plates or pads soaked with 20 ml of 65% formic acid (very caustic and will burn hands and face) and the pads are placed in the colonies, near the top (Buchler, 2010).

3. Mites Detection Methods

It is difficult to simply inspect a colony and determine if it has a high level of mites. It is important, therefore, to sample beehives to estimate the degree of infestation (Fries et al., 1991; Ostiguy and Sammataro, 2000; Koeniger et al., 2002).

3.1. Sugar Shake Method

This method estimates the mite prevalence within the colony (the percentage of adult bees with mites). Obtain a clear pint jar or other container with a lid made from 8-inch hardware cloth or similar meshes material. If a researcher cannot find a jar with a mesh lid, make a mesh lid for any available container. Brush or shake approximately sufficient adult bees from a frame with an emerging brood into the jar. Close the mesh lid on the jar and add to 3 tablespoons of 6× powdered sugar through the lid. Set the jar aside for several minutes to allow the bees (and mites) to be covered in sugar. Shake the sugar (and dislodged mites) out of the jar onto a clean, flat surface (preferably white). The bees although covered in sugar are not killed and can be returned to the colony. If few or more mites are found per bee, take appropriate measures to control the mite population (a magnifying glass may be necessary to see the mites).

3.2. Sticky Board Method

This method estimates the total mite load of the colony (the total number of mites in the hive). Purchase a commercial sticky board from a beekeeping supply company. A sticky board has a pre-applied adhesive and sampling grid drawn on the surface. Alternatively, a sticky board can be constructed with a stiff sheet of white paper. Spray the upper surface of the paper (facing the bees) with an aerosol cooking spray, or apply a thin layer of petroleum jelly to the upper surface of the paper to create a homemade sticky board. Place the board or paper between two 8-mesh wire covers (with one cover on the top and one on the bottom) so that the bees do not adhere to the sticky surface. Place the sticky board on the bottom floor of the hive. A portion of the mites will fall off the bees, fall through the mesh screen and stick to the white board. Remove the board 4 hours later and count the total number of mites on it. If the number of mites is between 60 and 90 (depending on the size of the colony) then appropriate control measures should be taken.

3.3. Alcohol Wash Method

Similar to the sugar shake, this method requires that the beekeeper brush or shake adult bees from a frame into a clear container to measure the prevalence of parasitic mites. Pour two inches of rubbing alcohol (isopropyl alcohol) into a clear pint jar or container with a solid lid. Brush or shake approximately some adult bees from a frame with emerging brood into the container. Vigorously shake the container for at least 30 seconds and then examine it for dead mites sinking to the bottom. If there are few or more mites per bee, then beekeepers should treat the colony.

3.4. Drone Brood Inspection

Because of the variation in sampling, this method is not always a reliable indicator of mite levels in a colony. However, it can be used to verify the relative degree of mites infestation. Find any capped drone brood within the hive, which is typically located on the periphery of the brood nest. Uncap the cells and gently remove the pupae. Closely inspect the drone pupae for adult mites. If few percent or more of the drones are infested, then beekeepers should take appropriate measures to reduce the mite population. Current recommendations are to monitor each honey bee colony for mites infestation several times over the course of a season to determine if and when treatment is necessary. Use different sampling techniques for monitoring efforts to make sure that an accurate measure is obtained for each hive.

4. Integrated Pest Management against Mites

One of our most important honey producers and pollinators, the honey bee Apis species, faces serious threats from parasites especially the mites. Therefore, improving pest control is a highly significant way of increasing access to our food. The best way to achieve this is through Integrated Pest Management (IPM). The IPM means using a combination of different control methods at different times of the year in order to keep the mite population to such a level as it causes no significant harm to a bee colony. Chemical treatments have been used for a number of years, based on a combination of thymol based treatments and oxalic acid. These offer a very simple means of controlling mite numbers effectively. As a general rule, mite populations should be monitored three or four times a year. Most infested colonies die within 1 to 2 years if the beekeeper does not take actions against mites. If upon initial examination of colony beekeepers do not see visible mites, use a capping scratcher on drone brood to see if mites are inside cells. Varroa mites prefer drone brood over worker or queen. If mites are detected beekeepers may need to treat in order to save bee colony. At this time there are four treatments available for varroa mite control, coumaphos, fluvalinate, thymol and fenpyroximate. Always follow manufacturer's instructions when using these products. Also, never treat colony during a nectar flow because the chemicals can contaminate the honey and never leave strips in hives after the recommended time because this encourages resistance. In recent years mite resistance to synthetic miticides has become a problem throughout the world. Therefore, rotating chemicals, delaying treatment and using cultural controls are recommended to manage mites in a more sustainable manner. It has been about few years ago that mite resistant stock has been widely available to beekeepers to avoid attacking of the pests from different angles. It is important to have a variety of sources to keep a diverse gene pool of resistant stock (Delaplane, 2001; Delaplane et al., 2005; Ibrahim, 2007).

5. Conclusion

Integrated Pest Management (IPM) is using a combination of different control methods at different times of the year. It is particularly useful to beginners and should be seen as an important part of mite control approach that can be adapted as necessary. It allows the beekeepers to choose the products or methods appropriate to them and encourages careful monitoring so that treatments are used in line with known risk. Mite levels fluctuate within and between seasons, and beekeepers must carefully sample the mites to prevent their populations buildup. Despite of its limitations, field studies like this are valuable because a large number of colonies have been evaluated under natural conditions, which might shed light on the causes of colony losses to manage by beekeepers. If a colony is found to be infested, all colonies at the site should be treated for mites with pesticide strips in the same manner. These strips contain the miticide fluvalinate and are not to be used during honey flow, or when there is surplus honey present in the colony that may be removed for human consumption at a later date. Therefore, late fall, after removal of surplus honey, or early spring, prior to honey flow, are the best times to treat for mites. As precautionary declaration, in order to protect peoples and the environment, pesticides should be used safely and this is everyone’s responsibility especially the user. Read and follow label directions carefully before beekeepers buy, mix, apply, store or dispose of a pesticide. It is a violation of State and Federal Laws to use pesticides in a manner inconsistent with its label.

References

Anderson DL, Morgan MJ. (2007). Genetic and morphological variation of bee-parasitic *Tropilaelaps* mites (Acari: Laelapidae): new and re-defined species. Exp. Appl. Acarol., 43: 1-24.

Anderson DL, Trueman JWH. (2000). *Varroa jacobsoni* (Acari: Varroidae) is more than one species. Experimental and Applied Acarology, 24 (3): 165-189.

Boecking O, Genersch E. (2008). Varroosis – the ongoing crisis in bee keeping. Journal fur Verbraucherschutz und Lebensmittelsicherheit, 3: 221-228.

Buchler R, Berg S, Conte YL. (2010). Breeding for resistance to *Varroa destructor* in Europe. Apidologie, 41: 393-408.

Carreck NL; Ball B, Martin SJ. (2010). Honey bee colony collapse and changes in viral prevalence associated with *Varroa destructor*. Journal of Apicultural Research, 49(1): 93-94.

Collison CH. (1990). Tracheal Mites Past- Present- Future. ESA Journal, 17 (3): 5-6.

Delaplane KS, Berry JA, Skinner JA, Parkman JP, Hood WM. (2005). Integrated pest management against *Varroa destructor* reduces colony mite levels and delays treatment threshold. Journal of Apicultural Research, 44 (4): 157-162.

Delaplane KS. (2001). *Varroa destructor*: revolution in the making. Bee World, 82 (4): 157-159.

Ellis MD. (2001) Chemical control of varroa mites, in: Webster T.C., Delaplane K.S. (Eds.), Mites of the honey bee, Dadant and Sons, Hamilton, Illinois, pp. 179-196.

Fries I, Aarhus A, Hansen H, Korpela S. (1991). Comparison of diagnostic methods for detection of low infestation levels of *Varroa jacobsoni* in honey bee (*Apis mellifera*) colonies. Experimental and Applied Acarology, 10: 279-287.

Guzman-Novoa E, Eccles L, Calvete Y, Mcgowan1 J, Kelly PG, Correa-Benitez A. (2010). *Varroa destructor* is the main culprit for the death and reduced populations of overwintered honey bee (*Apis mellifera*) colonies in Ontario, Canada. Apidologie, 41: 443-450.

Hall MJ, Martin S J, Schroeder DC. (2009). Deformed wing virus implicated in overwintering honey bee colony losses. Applied and Environmental Microbiology, 75: 7212-7220.

Helen MT, Michael AB, Richard FB, Medwin HB. (2002). First report of *Varroa destructor* resistance to pyrethroids in the UK. Apidologie, 33 (4): 357-366.

Ibrahim A, Reuter G S, Spivak M. (2007). Field trial of honey bee colonies bred for mechanisms of resistance against *Varroa destructor*. Apidologie, 38: 67-76.

John RH (2000). Heating Adult Honey Bees to Remove *Varroa jacobsoni*. Journal of Apicultural Research, 39 (3-4): 181-183.

Koeniger G, Koeniger N, Anderson DL, Lekprayoon C, Tingek S. (2002). Mites from debris and sealed brood cells of *Apis dorsata* colonies in Sabah, (Borneo) Malaysia, including a new haplotype of *Varroa jacobsoni*. Apidologie, 33: 15-24.

Natalia D, Liesel BG, Pedro B, Jorge AM, Martín JE. (2009). Acaricidal and insecticidal activity of essential oils on *Varroa destructor* (Acari: Varroidae) and *Apis mellifera* (Hymenoptera: Apidae). Parasitology Research, 106 (1): 145-152.

Ostiguy N, Sammataro D. (2000). A simplified technique for counting *Varroa* sticky boards. Apidologie, 31: 707-716.

Peter GK, Terence ML, Harold AD. (1990). Association of *Varroa jacobsoni* with organisms other than honeybees and implications for its dispersal. Bee World, 71 (3): 119-121.

Raloff J. (1998). Russian queens bee-little mites' impact. Science News, 154 (6): 84.

Sammataro D, Gerson U, Needham G. (2000). Parasitic mites of honey bees: life history, implications, and impact. Annu. Rev. Entomol., 5: 519-548.

Sarwar M. (2016). Challenges due to bacterial infections of the honey bees and contributions to manage pest problems. International Journal of Entomology Research, 1 (1): 4-10.

Shimanuki H, Knox D. (1991). Diagnosis of Honey Bee Disease. USDA, Agric. Handbook No. A- 690, 5 p.

Skinner J. (1991). Tracheal Mites in Tennessee. E & PP Info., 952 p.

Wilde J. (2000). How long can *Tropilaelaps clareae* survive on adult honeybee workers? *In:* Proceedings of the Euro-Conference on Molecular Mechanisms of Disease Tolerance in Honeybees (MOMEDITO), held in Kralupy near Prague, Czech Republic, 17-19 October 2000. Bee Research Institute, Dol, Czech Republic, 217-221.

Wilson WT, Pettis JS, Henderson CE, Morse RA. (1997). Tracheal mites, in: Morse R.A. and Flottum K. (Ed.), Honey bee pests, predators, and diseases, Root Publishing, Medina, Ohio, pp. 253-277.

Zhang ZQ. (2000). Notes on *Varroa destructor* (Acari: Varroidae) parasitic on honeybees in New Zealand. Systematic & Applied Acarology Special Publications, 5: 9-14.

- Dr. Muhammad Sarwar, Principal Scientist, is going through 25th years of Service experience in Research orientated Department of Agriculture (16-05-1991 to 31-05-2001, Government of Punjab) and Pakistan Atomic Energy Commission (01-06-2001 to date).
- Have 187 research work publications in National (126) and Foreign Journals (61) with suitable Impact Factor.
- Award of Higher Education Commission of Pakistan "Post-Doctoral Scholarship Phase II, 2006" on the basis of merit for research work at Institute of Plant Protection, Chinese Academy of Agricultural Sciences, Beijing, China.
- Shield award, Letters of Appreciation and Certificates of performance granted from Chinese Academy of Agricultural Sciences, Beijing, China.The Zoological Society of Pakistan in recognition of research contributions presented Prof. Dr. Mirza Azhar Beg Gold Medal-2010 during 30th session of Pakistan Congress of Zoology hosted by University of Agriculture, Faisalabad on March 2, 2010.
- Researched on Integrated Pests Management of Rice, Cotton, Chickpea, Brassica crops, Fruit flies, and Stored grains. Undertaken research work on Predatory Mites, Ladybird Beetle Chrysoperla, Trichogramma and parasitoids of Fruit flies culturing as Bio-control agents, Integrated Management of Fruit Fly and Mosquito, and other arthropod pests control methodology.
- Worked on Vertebrate pests control especially controls of rodents in field crops and storage.
- Opened a new avenue on rearing of Predatory Mites as bio-control agents of insects & mites pests in greenhouse and field crops.
- Explored, hitherto the unexplored 36 new species of stored grain & stored products mites belonging to 8 genera viz., *Forcellinia, Lackerbaueria, Acotyledon, Caloglyphus* and *Troupeauia* of family Acaridae; and *Capronomoia*, *Histiostoma* and *Glyphanoetus* in family Histiostomatidae. Identification keys, taxonomical observations, differentiation remarks, comparison of characters, similarity matrices, Phenograms and Geographical maps of new species along with 48 alien species have been prepared.
- Conducted research work on Integrated Management of Cotton Leaf Curl Virus (CLCV), Pest scouting, Pest monitoring & forecasting, planning, designing and layout of different research trials & data recording for integrated pest management on different crops, vegetables and orchards. Training of the farmers and Field Staff, and provision of advisory services to the farmers regarding plant protection practices. Training of the pesticide's dealers for proper handling, distribution and storing of pesticides, their legal aspects and sampling of pesticides for their quality control.
- Collaborative Research Work with CCRI, PCCI & Ayub Agricultural Research Institute for locating resistance in cotton genotypes.

- Under Coordinated Research Program, collaborated with NIA, NIFA and NIAB to trace resistance sources for rice, gram, rapeseed, mustard plants, and stored cereals and pulses.
- Imparted training to field staff and the progressive farmers regarding plant protection practices in some Districts of Sindh, supervised Post-graduate research wok and acting as External Examiner for Post-graduate studies, Reviewer for Scientific Journals, and joined different working Committees.
- Granted Research Productivity Award-2011, by Pakistan Council for Science and Technology.
- Included in the list of Higher Education Commission **(**HEC) of Pakistan approved Supervisor.
- Completed “Basic Management course” organized by Pakistan Institute of Engineering & Applied Sciences (PIEAS), Islamabad, held from 31 January to 18 February. 2011.
- Acquired different National and International (Beijing, Bangkok, Vienna and Havana) trainings.