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Parasitoid Wasps- a Powerful Weapon Against the Insect Pests

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Abstract:- Phylum Arthropoda includes diverse groups of organisms. Among them one of the most fascinating and the valuable group of insects comes under the suborder Apocrita of order Hymenoptera. This group includes wasps, bees and ants; out of which the wasps play an interesting role in protecting our cultivated and stored crops. The choice of a host to lay their eggs by different types of wasps and thus to provide proper parental care to their young ones are being discussed in this article in brief. There is a group of wasps called Parasitoid wasps. These are the most terrifying and the fascinating creatures which lay their eggs in or on the body of other insects during any of their developmental stages. They have developed brilliant mechanisms to sustain in this planet.

Different organisms employ unique methods of recognising a host and exploit it to sustain their race. In this study we mainly focused on the parasitoid wasps of the super family Ichneumonoidae which includes both Ichneumonids and Braconids families and their unique nature of attacking the host and finally killing it to nurture their young ones. This astonishing and horrifying behaviour of parasitoid wasps can also be made beneficial to humans to protect their agricultural crops. These wasps show mutualism with the polydnavirus and the fungi to eliminate their hosts which are mainly noxious insects like cockroaches and insect pests of crops. Thus these wasps are used as biological control agents. They are host specific and attack the target causing less damage to the non-target species. This is one example for nature's own way to eliminate harmful creatures with no damage to the environment.

Keywords:- *Parasitoid wasp, Polydnavirus, Ovipositor, Hymenoptera, Ichneumonids, Braconids, Apocrita.*

I. INTRODUCTION

Wasps are a diverse group of organisms of the class Insecta under the phylum Arthropoda. They belong to the sub order Apocrita of the order Hymenoptera. The word Apocrita means a narrow waist, thus in this order such insects with characteristic shapes like bees and ants along with the wasps are included. Thousands of described wasp species are found in the world and many are yet to be studied. Wasps are distributed all over the world except in the polar region. They vary in the size depending on their characteristic habitat and behaviour. Wasps are one of the most ancient insect groups living on earth whose fossil record first appeared during Jurassic period.

II. SOLITARY Vs SOCIAL WASPS

Wasps can lead either solitary or social life. The vast majority of them come under solitary wasps. Most of the solitary wasps are Parasitoids. Adult solitary wasps spend most of their time in the construction of nests and supplying food (host insect) to their larvae. They show diverse nesting habits; some may even make burrows in the ground. The solitary female wasp builds its own house without the help of worker wasps. These wasps do not form colonies with queens, instead many females make individual nests to raise their offspring in the same area.

Solitary wasps differ according to their nest making patterns. They are Pollen wasps, mud daubers, potter wasps, predatory waspsetc. Pollen wasps collect nectar from flowers and use it to seal the nests, mud daubers and potter wasps construct the nests using mud, twigs of trees or against a wall. Predatory wasps paralyse the prey by stinging it and lay the eggs inside the host and leave it in that location. Sometimes they drag the prey to the nest and lay eggs inside and seal the nest after depositing with small insects as food to the larvae.

Solitary wasps sting only if directly handled and male wasps are usually sting less. The largest solitary wasp belongs to a group of species known as *Tarantula hawks* (spider wasp, that attack many tarantulas belonging to the genera Pepsis and Hemipepsis) along with the Giant scoliid *Megascolia procer* in Indonesia. The smallest known insect and the smallest flying insect known is a solitary Chalcid wasp.

Most of the social wasps belong to the family Vespidae. They have powerful stings and have conspicuous warning colouration. Social wasps have a colony with a queen and many worker wasps. After every season new queens and workers are produced from each colony. Males die immediately after mating. Each spring the new colony starts when the old queen and the workers die. These worker wasps are sterile females which cannot lay eggs. Social wasps are very aggressive and sting the intruder of its territory as worker wasps are protecting the queen.

Their nest building pattern is unique. They construct nest using mud, plant secretions and their own secretions to construct multiple fibrous brood cells which look like a honeycomb. Some prefer to make nests in the ground; others make nests with multiple combs or spaces under homes or wall cavities. These are the models for mimicry. They mimic distasteful insects like bees and ants to misguide the predator. The largest social wasp is Asian Giant hornet (*Vespa mandarinia*) which is about 5 centimetres.

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Wasps play different roles in the environment: they act as pollinators, parasitoids, parasites, predators, model for mimics and it can be also act as a prey to a large predator. They are beneficial to the humans as they act as biological pest control agents and protect our crops from various insect pests. Though wasps are beneficial to the ecosystem, humans are disinclined to them because of their sting. Wasp diet varies with the species. Generally, adult wasps feed on nectar, fruits, honey, small insects, and some plants. Majority of the wasp larvae are omnivorous and are parasitic, they feed on insects. The adult wasp finds a specific host to laying their eggs on as it is the complete food supply for its larvae.

III. PARASITOID WASPS

By definition a parasitoid is an organism that spends a significant portion of its life history attached to or within a single host organism. Parasitoid wasps belong to hymenopteran groups are very well known for their unique nature of laying eggs either outside or inside the body of the arthropods sooner or later causing the death of the host. The order Hymenoptera contains many parasitoid and non parasitoid wasps. The parasitoid wasp is included under very large groups– the Chalcidoidea (5 lakh species), the Ichneumonidae (1 lakh species) and the Braconidae (50 thousand species).

Parasitoid wasps are classified based on their egg laying and feeding habits. They can be either ectoparasitoids or endoparasitoids and can be either idiobiont (paralyze or prevent the growth of the host) or koinobiont (which allows the host to continue its development despite the wasp feeding on it). Selection of the host is the most important criteria for the wasp because the host is the entire food supply till it emerges out as the adult. Parasitoid wasps have the capacity to influence the behaviour of the host by releasing certain chemicals. This brilliant activity of waspis made advantageous to humans.

Scientists have come up with the idea of using this as a biological pest control agent.One important aspect of the using parasitoid wasp as biological control agents is that most of them are host specific; hence they can be deployed by humans with greater specificity.They areable to infect explicitly harmful pest insects and pose a low risk to non-target species ensuring the protection of native species.

One of the important groups of parasitoid wasps employed for the purpose of controlling the pest populations of crop damaging beetle, moths, caterpillars, butterflies and other hymenopterans belong to the superfamily Ichneumonoidae(Greek word which means tracer or foot print)**.** This super family is characterised by the fusion of the coastal and radial veins of the forewing and contain more than 11 antennal segments. The ovipositor consisting of three pairs of appendages is used for depositing the eggs into the host body. The size and shape of the ovipositor varies from species to species. In many parasitic wasps it acts as a piercing organ as well.

Ichneumonoidae are one of the most effective biological control agents that provide both economic and environmental benefits to the society. They are cosmopolitan in distribution showing morphological similarities with the other organisms of same order including ants and bees.The Ichneumonoidaesuper family includes two families: Ichneumonidae and Braconidae.

- *Ichneumonidae*

Ichneumonids are found in all the parts of the world wherever the suitable invertebrate hosts is available except Antarctica. Five species of parasitic wasps associated with hesperiids from peninsular India were documented. A total of about 28 genera and 40 species of Ichneumonid wasps were shortlisted especially in the southern part of India. Few of them are *Adelognathus chelonus* (Kasparyan,1990), *Casinaria ischnogaster* (Thomson, 1887), *Doryctes nigricornis* (Kriechbaumer, 1894) etc.,

Ichneumons the solitary insects of the largest family of any of the animals Ichneumonidae, are slender wasps of varying size and colour varies from yellow to uniform black. Ichneumonids are wasps with a very narrow wasp waist between the middle (mesosoma) and hind body parts (metasoma) and contain powerful chewing mandibles, two pairs of usually transparent membranous wings with complex venation. It has a long antenna with 18 or more segments.

Ichneumonsare host specific and choose holometabolous insect larvae as host. They attack closely related host species and its parasitic larva feeds on the insect host until the host dies. They comprise more than 60,000 (possibly up to 100,000) species worldwide. Their larvae are internal parasites of the larvae of the families comprising beetles, spiders, moths, butterflies, ants, bees, wasps and flies. These are the important parasitoid of even other wasps including the social wasp *Vespula acadica***.**

The parasitoid wasps show mutualism (the type of interaction between two organisms in which both are benefitted) with polydnavirus. These are unique group of insect viruses that replicate in the oviducts of adult female parasitoid wasps. They weaken the host immune system and by altering the host cells make them beneficial to the parasite. These viruses have been incorporated in the wasp genome and inherited.

The majority of them are harmless to humans and are stingless as the ovipositor is mainly used to bore eggs in to the host body or used to reach hosts that are hidden in the crevices. Permanently extruded ovipositor which is often longer than the entire body, is the needle like appendages present on the crown of the abdomen of females are the device for depositing the eggs into or onto a host. The eggs then hatch and develop into ichneumon larvae that slowly eat their host. Eventually, they kill the host by the time they pupate and emerge as mature parasitoid. The young ones hatch out as adults devouring the host. Males do not have the ovipositor hence their abdomen is short and they are mainly involved in search of females for reproduction.

A very important aspect of Ichneumonids' behaviour is their ability to detect the host. They use different mechanism to parasitize the host though it is deep

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inside in the crevices or nests of other animals. One example is the relationship between the species Ichneumon enmerusand its host butterfly *Phengaris rebeli*(Alcon blue butterfly)**.**Though these species are not usually seen in India it is very interesting to know the behaviour of these organisms. The butterfly larva itself is a parasite within the nests of the Myrmica ant nests.

The butterfly larvaereleasea chemical called Allomone**,** which has the ability to affect the behaviour ofMyrmica ants. Allomone makes the ants think that the butterfly larva is one of their own and makes them to protect it. The Ichneumon wasp has the ability to detect and enter ant nests to lay its eggs into this host butterfly larva. It invades the ant's nests releasing certain chemicals which make the ants fight among themselves; meanwhile the wasp starts to lay its eggs into the butterfly larvae. The ants guard the caterpillar considering as their own and few days later the larvae hatch and the adult wasps comes out of it. This adult wasp terrorise the others in the same way that their mothers did.

They have employed a torturous way to end the host's life. The feeding process usually can take up to two to three days. They start the process by injecting a toxin into the host body and paralyzing it instead of killing in order to keep the body fresh to feed their larvae after the eggs hatch. The dying process of the host is very slow and is in the most painful manner. The wasp starts the eating process in a systematic way starting from fat cells, muscles, non-vital organs and leaving the vital organs like heart and central nervous system untouched in order to keep the host alive for a time till the adult wasp comes out of the host.

Finally, the remaining organs are eaten and the victim dies leaving only an empty shell. The host is observed to be writhing in pain as they are slowly consumed from inside by the wasp larvae. At the end the adult wasp comes out breaking the host shell and killing it.

Some Ichneumon wasps lay their eggs in the ground but most of them inject egg into the host with the very long ovipositor. Certain genera of wasps like Giant Ichneumon Wasp *Megarhyssa macrurus* and Pigeon Tremex Horntail(*Tremex Columba),* wander tapping their antennae on the surface of the logs and tree trunks in search for the scent or the vibrations produced by wood-boring larvae of the Horntail wasps which resides in the tree trunk**.** These giant ichneumon wasps have a fearsome appearance. Both the species of Ichneumon wasps drill and lay eggs in the host simultaneously in the same dead or dying tree. Females have a very long thread like egg laying ovipositor on the end of their abdomens.

With the help of antenna, the female detects the vibration produced by the host and then drills a hole at right angles to the tree surface. The lower abdomen membrane twist into a disc and a special fluid is secreted which helps to dissolve the woody material of the tree and the parasite injects the eggs into the host. Eventually the egg hatch and the larva will devour the host and emerges out killing it. The ovipositor is well mechanised for the purpose of drilling the woods. It is observed to contain three tubes, two of which serve as a sheath that contain drilling tubes and helps to guide it and protect it when it is not in use.

The interesting thing to focus is its ability to drill her ovipositor into solid wood. There is no explanation for this yet. Scientists have found the presence of metals like ionised manganese and zinc on the tips of some species' ovipositors. The adult insect after pupation faces the difficulty of extricating itself from the tunnels of its host. They overcome this because of the high metal concentrations on the surface of the mandibles. This hardened mandible with the metals helps to chew itself out of the wood. So the metals are limited not only to the female's ovipositor but also to the adult mandibles.

When these wasps lay eggs a white rot fungus *Daedalea unicolour*develops on them. This fungus grows along with the horntail larvae and it helps in successful development causing infection to the trees. This fungus changes the tree trunk structures by weakening the tree which makes it easy for the pupated larvae to exit through the holes of the tree.

IV. BRACONIDAE

Braconids make up the second largest family after Ichneumonids in the order Hymenoptera. Around 17,000 species are recognised and many are under undescribed. It comprises of about 47 subfamilies and 1000 genera. Braconids are classified as Cyclostomes and Non cyclostomes as in the cyclostome braconids, the labrum and the lower part of the clypeus are concave when compared to upper clypeus and the dorsal side of the mandibles.

Braconids are long and thin body creatures with long antenna. Few of them contain a long ovipositor usually smaller than the Ichneumonids. They exhibit striking coloration and pattern though few species have black-brown bodies. Unlike Ichneumonids they either possess one or no recurrent veins or show divergent wing venation patterns. About 16 or more antennal segments are present and have hind trochanters with 2 segments.

Long ovipositor of Braconids helps to reach the host caterpillars through the layers of plant tissue and is also used to bypass the caterpillar defence mechanisms (spines, hair) to reach the Coleopteran larvae that are burrowed deep inside the trunks. Braconids parasitize a large number of larval stages of Coleoptera, Diptera, Lepidoptera and hemimetabolous insects such as Aphids, beetles, moth, flies, butterflies, Heteroptera or Embiidina. The most common hosts are: Asian Corn Borer (pest of maize in East Asia), African Sugarcane Borer (a moth commonly found in sub Saharan Africa), the butterfly *Danaus chrysippus*in Ghana, Tomato hornworm in North America.

Braconids usually feed on flower nectar and pollen, flowers with small florets, herbs and carrot family members. Adults lay eggs in or on soft bodied caterpillars including cabbage worms, tomato hornworms and other garden pests. They recognise the caterpillars crawling on the branches by the smell. A female wasp lays about 200 eggs a day in a warm summer climate. These wasps are harmless to humans and they do not sting unless provoked.

The activity of braconid wasp can be explained by one common example: the common tiny braconid wasp *Cotesia congregatus*and the tomato horn worms *Manduca quinquemaculata*, the common pest on the tomato plants. As usual the parasite wasp finds the host caterpillar by the smell and deposits its eggs inside the body using their long ovipositor. The larvae emerge out of the eggs and start feeding on the host larvae from inside. Once outside the future wasps pupate, spinning tiny oval white cocoons that look like insect eggs all over the host body especially on the sides and the back of the host.

The damage to the caterpillar occurs much before the white cocoons spun on its skin. When the adult wasps pupate from the cocoon the weakened host immediately dies. The polydnavirus that resides in the host along with the wasp weakens the immune system of the host without which it is not possible for the eggs to hatch. This way the parasitic wasp kills the host and prevents it from causing the damage to the plant.

There are certain species which are very well known for their distinguishing characteristics. For example, the species *Microplitis croceipes*possess an extremely accurate ability to sense the smell. This wasp can be trained for use in narcotics and explosives detection. Another intelligent wasp *Trichogramma pretiosum*kills numerous undesirable insects efficiently.It uses the smell of the host to determine the suitability of the host. It selects very harmful insects for the environment as its host which include European corn borer, army worm, bag worm, tomato horn worm, cabbage looper, corn earworm and many more.

These wasps are very beneficial to the farmers to eradicate the pests from the fields. This wasp lays a single egg in the eggs of the pest(host) and after consuming the pest eggs a new adult comes out and start its activity of identifying a mate to reproduce and further to lay eggs in the host. It has a very short life span but quick in its activity as it effectively controls the pests.

V. DISCUSSION AND CONCLUSION

Parasitoid wasps act as a more sustainable or preferable means of pest control than alternatives such as spraying insecticides and pesticides or genetically altering crops and are used by most farmers and environmentalists. They control insect pests by eliminating many insects before they reach an adult (reproductive)stage. Most common groups which play the role of biological control agents are Ichneumonid wasps, Braconid wasps, Techinid and Chalcid wasps.

Biological control involves usage of natural enemies to reduce the pest number. Natural enemies are mostly invertebrates. Wasps are recommended to reduce the pest number because of its host specific attack and studies have shown the presence of certain antibiotics in their saliva and venom which quickly detect and remove infected individuals before the disease spreads. Different types of parasitoid wasps are involved in controlling the pests as only few of them are being discussed in the present article. It is very important to know their behaviour before utilising them as the natural biocontrol agents.

Though various parasitoid wasps are considered as the terror organisms because of their psychic way of torturing the host and finally killing the host, it is the evolutionary adaptation employed by the wasp in order to transfer their genes to the next generation and to provide the young ones a sustainable environment for their growth and development. Every creature tries its best to survive and transfer the genes to the next generation. There is no blaming game, as these wasps have employed a unique and horrifying technique.

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