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Issue Article

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A REVIEW OF THE BIOLOGY AND BIOLOGICAL CONTROL OF THE ENTOMOPATHOGENIC FUNGI-BASED BIOLOGICAL CONTROL OF THE WHITEFLY, BEMISIA TABACI (HEMIPTERA: ALEYRODIDAE)

Abstract*: Bemisia tabaci, a species of whitefly, is a significant pest of ornamental and vegetable crops worldwide, causing billions of dollars in annual losses. Adult Bemisia tabaci are tiny insects that deposit large amounts of their oviposita and feed on leaves. They can transmit plant pathogenic viruses and slow down photosynthesis. Chemical insecticides are the most popular method for controlling Bemisia tabaciinfestations, but overuse has led to issues such as health risks, insect resistance, and non-target species extinction. Researchers are now exploring biological control agents like entomopathogenic fungi. B. tabaci's life cycle consists of six stages: egg, juvenile, adult, and nymphal instars. Temperature, relative humidity, and host plants significantly impact the life cycle of whiteflies. The ideal temperature for Bemisia tabaci production is 28°C.*

Key words*: bemisia tabaci, adult, species, biological control, cotton, okra, potato, tomato.*
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Introduction

Out of all the documented species of whiteflies globally, Bemisia tabacicontinues to be one of the most economically significant pests of ornamental and vegetable crops. Several solanaceous and ornamental crops, such as tobacco, cotton, okra, potato, tomato, and brinjal, are consumed by the insect. Bemisia tabacican cause minor to severe economic harm, with annual losses in several crops reaching billions of dollars globally. Adult Bemisia tabaciare tiny insects, typically measuring 1 to 3 mm in length, that deposit enormous amounts of their oviposita and feed on the undersides of leaves. Bemisia tabaci can transmit a wide range of plant pathogenic viruses, such as begomoviruses, carlaviruses, criniviruses, ipomoviruses, and torradoviruses, and it can also slow down the rate of photosynthesis in plants by excreting honeydew while feeding. The most popular approach for managing an infestation of Bemisia tabaciis the use of chemical insecticides. Conventional methods of controlling Bemisia tabaciinvolve the use of chemical pesticides with comparable mechanisms of action, such as neonicotinoids and insect growth regulators.

Many issues have arisen from the overuse of these pesticides, including the harm to the health of farm produce users and consumers, the emergence of insect resistance, and the extinction of non-target creatures. As an alternative to chemical control methods, researchers have been more interested in adopting biological control agents, such as entomopathogenic fungi, in recent years. In a protected setting, biological control techniques have been effectively applied to manage whiteflies for the past 50 years. Gennadius initially described Bemisia tabaci as a tobacco pest in Greece in 1889, naming it Aleyrodes tabaci. As of right now, it can be found all over the planet, with the exception of Antarctica. On the other hand, a number of European nations, including the United Kingdom, Finland, Sweden, and the Republic of Ireland, have yet to record the discovery of B. tabaci.

The typical life cycle of a whitefly consists of six stages: the egg, four juvenile stages (also known as nymphal instars), and the adult stage. The primary elements that have a significant impact on the life cycle of whitefly species are temperature, relative humidity, and host plants. The temperature has a major impact on the quantity of eggs deposited by Bemisia tabaci, which deposits its eggs on both the upper and lower leaf surfaces of plants. The ideal temperature for Bemisia tabaciproduction is 28 °C. The deposited eggs are pear-shaped, measuring about 0.2 mm in length. They are bright white when first laid, but eventually turn dark. Depending on the host species, temperature, and humidity, the eggs typically take 5 to 9 days to incubate.

After feeding, the whitish-yellow nymphs in the second instar stage develop a yellowish dome shape. However, after feeding, the light yellow, recently molted third instar nymphs gradually turn dark yellow and become more spherical in shape. The fourth instar nymphs are often referred to as "pupal" or "red-eye nymphs" because of their yellowish-white hue and huge eyes that are visible through the integument.

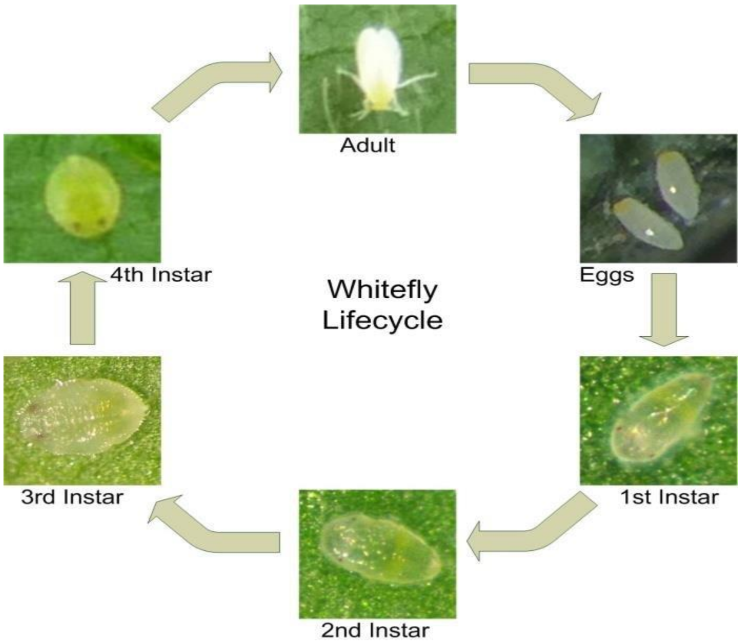

Fig. 1. White fl y lifecycle. (Images of the eggs and fi rst, second and third instars are reproduced with the permission of Dr. Surendra Dara, from University of California Coop- erative Extension).

An inverted "T"-shaped incision on the dorsal surface of the pupal case is where fully grown adults of Bemisia tabaciemerge. An adult's body is yellow, and its two white wings cover its abdomen and thorax in the shape of an inverted V. The male Bemisia tabacihas a pointed abdomen, whilst the female has a big, spherical belly. From egg to adult, B. tabaci's life cycle spans from 16 to 31 days, while the length of each stage varies depending on the host plant used to raise them. Compared to the B biotype, the Q biotype of Bemisia tabacihas been reported to have a shorter life cycle and a longer adult lifespan.

Through the production of honeydew and the spread of plant viruses, Bemisia tabaci can harm host plants during feeding, resulting in large financial losses for crops. By sticking their mouthparts into the plants while feeding and spreading a lot of viruses that can seriously harm sensitive plant species, Bemisia tabacinymphs and adults both cause harm to the plants.

It has been discovered that Bemisia tabacinymphs have the ability to inject enzymes that alter plant physiology, resulting in uneven fruit ripening and delayed interior pigmentation. The honeydew that Bemisia tabaciexcretes serves as a medium for the development of sooty mold on the leaves and fruits, which lowers photosynthetic activity and may have a detrimental effect on the quality of agricultural products. Furthermore, Bemisia tabacifeeding on leaves can result in yellowing and crumpling, which in turn causes reduced plant growth and malformed fruits.

Bemisia tabacihas the ability to transmit over 200 different plant viruses, most of which are members of the genera Begomovirus, Carlavirus, Crinivirus, Ipomovirus, and Torradovirus. Cassava, cotton, cowpea, cucurbits, crucifers, eggplants, tobacco, tomato, potato, soybean, sweet potato, okra, lettuce, pea, bean, pepper, poinsettia, and chrysanthemum are some of the crops that are most susceptible to these viruses. Begomoviruses are the most common virus spread by Bemisia tabaciand are responsible for yield losses in crops of 20–100%, with losses amounting to millions of dollars.

About half of the nation's cassava plants are afflicted by the devastating viral illnesses cassava mosaic and cassava brown streak, which are spread by Bemisia tabaciand result in yearly production losses exceeding $1 billion USD. The most devastating global disease affecting cotton is cotton leaf curl disease complex, which is caused by several begomovirus species including Cotton leaf curl Burewala virus (CLCuBuV), Cotton leaf curl Multan virus (ClCuMuV), and Cotton leaf curl Kokhran virus (CLCuKoV). This is another example of a virus spread by whiteflies that causes losses amounting to millions of US dollars annually worldwide. Apart from cassava and cotton, begomoviruses spread by whiteflies, especially the Tomato Yellow Leaf Curl Virus species, have also had a significant negative impact on tomato production worldwide.

Control and Management of Whitefly. IPM is a globally accepted method of pest management that aims to lessen the harm that chemical pesticides cause to the environment and human health. Biological control, crop plant resistance, mechanical and physical measures, and the use of selective chemical pesticides when needed are all part of the integrated pest management (IPM) program for B. tabaci. Increased worry over the increased use of synthetic chemical pesticides has led to the successful development of host plant resistance to whiteflies. Bemisia tabaciand numerous other sap-sucking insects have been screened out of cultivars of cotton, tomatoes, and other field crops. However, breeding programs have significant challenges in the selection and development of resistant cultivars against viruses spread by whiteflies because genotypes with resistance genes must be selected by screening and inoculating a large number of plants.

Biological Control of Bemisia tabaciwith Entomopathogenic Fungi. Since they may infect insects directly through the cuticle, EPF, a significant class of biological control agents for whiteflies and other sap-sucking pests as well as pests with chewing mouthparts, are crucial to the natural death of whitefly populations. The groups Laboulbeniales and Pyrenomycetes (phylum Ascomycota), Hyphomycetes (phylum Deuteromycota), and Zygomycetes (phylum Zygomycota) comprise over 700 species of EPF. The majority of the EPF under study are classified as Hyphomycetes in the phylum Deuteromycota and Entomophthorales in the phylum Zygomycota. EPF can be cultivated in artificial conditions after being isolated from soil or insect cadavers, according to research findings from the past. Conidiophores or conidia and hyphae on a granular substrate can be employed in solid-state, liquid-state, or diphasic fermentation processes for the large-scale generation of EPF. The most popular technique for managing Bemisia tabaciis the spray and dip approach, which has many encouraging outcomes. To assess the effectiveness of EPF, several bioassay techniques have been devised; most of these techniques involved either spraying or dipping B. tabaci.

Conclusions.

Worldwide, Bemisia tabaci is regarded as a damaging insect pest of many different crops. Bemisia tabaciaffects crops both directly during feeding and indirectly through viral disease transmission, which can result in severe crop damage and production losses that cost millions of dollars. Despite a number of disadvantages, including pesticide resistance and health risks to farmers and consumers, the management of Bemisia tabaciprimarily depends on pesticides. Because of this, the IPM strategy-which incorporates biological management based only on the efficient use of natural parasites (parasitoids), predators, and entomopathogens is seen to be a safer and more effective way to control B. tabaci. Numerous studies have clearly shown that EPF is an efficient biological control strategy for B. tabaci. Ashersonia spp., B. bassiana, I. fumosoroseus, M. anisopliae, and Verticillium lecanii are the most widely used and popular EPFs for controlling B. tabaci; these have all been the topic of several evaluations. It is possible to maintain high EPF populations and their efficacy against Bemisia tabaciby enhancing the conidia's formulation and substrate. These initiatives might shorten the time needed to kill Bemisia tabaciand improve the stability of EPF propagules. Additionally, certain EPF, like B. bassiana and M. anisopliae, are connected to plants as symbiotic endophytes, which could aid in the creation of insect pest management techniques that are more successful.

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