Whiteflies

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Whiteflies are a group of universally occurring phloem sap sucking insects that has secured a status of most devastating pests for causing both direct and indirect damages to crops. A few of them serve as vectors of plant viruses that are detrimental to the crop in question and cause an actual loss in productivity. A lot of attention is focused on pest control measures under the umbrella of IPM (Integrated pest management).

whiteflies RNA interference target genes anti-whitefly proteins genetic engineering nanotechnology genome editing next-generation strategies viral disease IPM Transgenic crop

1. Introduction

Adoption of *Bacillus thuringiensis* (*Bt)* crops not only transformed the cultivation profile but also altered the pest status as there has been a decline in the prominence of lepidopteran pests and an upsurge of sap feeders such as whiteflies [1]. Some other reasons and factors have also influenced the rise in sap-sucking pests such as declining use of broad-spectrum chemical insecticides [2], either due to environmental concerns or due to redundancies caused by *Bt*-technology; changes in global temperature and humidity patterns that have become more favorable for whiteflies and other sap-sucking pests to thrive [3]. Moreover, chemical insecticides were collaterally able to keep the level of these pests under the economic threshold by virtue of their broad-spectrum nature, and minimization of their usage concomitantly allowed an increase in these sap-sucking pests [1]. Among phloem sap feeders, whiteflies have arisen as a global pest of agriculture, horticulture, and ornamental crops in the last two decades. The presence of whiteflies has been recorded from all continents except Antarctica. It is believed that the most economically important whitefly viz; *Bemisia tabaci* (also referred to as Cotton, Tobacco, Sweetpotato, or Silverleaf whitefly) has made its geographical spread via international transport of infested plant products. Once adopted, it quickly spreads and now it is included among 100 of the “World’s Worst” invaders as per the Global Invasive Species Database (http://www.iucngisd.org/gisd/100_worst.php, accessed on 8 October 2020).

Whiteflies cause up to 100% yield losses due to their direct feeding action, other pathogens that their feeding behavior attracts, and due to the fact that they vector several plant viruses that in turn cause great loss in yields or otherwise severely damage the crops [4]. That these are recognized to be a serious pest can be judged from the extensive economic losses for several crops worldwide, and financial estimates have worked out these losses to be in billions of currency units. It is noteworthy that reliable estimates of the economic impact on global agriculture have not been available in recent years. It might be because it has affected almost all known crops as well as ornamental plants in widespread areas. The concerns deepen when one considers the increasing costs for controlling this pest, which, at the same time, also depreciates the quality of agricultural produces, thereby severely encroaching upon the profitability of the crop production worldwide.

Knowledge about the biological and ecological factors governing pest endurance is a prerequisite for proficient control. Being a multiple-crop pest, whiteflies have numerous hosts and a high reproductive rate which deliver optimal conditions for their expansion. Hence, the development of sustainable management strategies needs a mechanistic acquaintance of factors that affect the growth of the pest population on the montage of host crops and others. Numerous control strategies under the umbrella of IPM, including physical barriers/cultural control measures, biotic agents, pesticides, and host–plant resistance, have been used to combat hemipteran pests in general and whiteflies in particular [5][6]. The IPM strategies mainly focus on keeping the number of adults on plants below an economic threshold level largely by the application of non-eco-friendly chemical pesticides [7]. Insecticide application can manage the whitefly population a bit but causes serious environmental damages in many ways. A dose of chemicals beyond the saturation level might also pose harm to birds and even aquatic organisms. Induced resistance in field crop pests including whiteflies under pesticide stress is now considered a universal problem; thus, banking on insecticide-based management is questioned.

2. Next-Generation Control Strategies of Whiteflies

Whiteflies pose a very serious challenge to crop productivity due to their (1) polyphagous nature, (2) worldwide occurrence (3) biological diversity, and (4) virus transmission capabilities. The pest can infest almost all crops or vegetables and has developed an inclination to switch to the next available host very quickly when the previous one is harvested. Infestations of whiteflies not only affect the plant per se but also several facets of the economically important end-products. More information is available about whitefly-vectored viral diseases on crops such as tomato, cotton, cucurbits, etc., across the globe. This is perhaps because these are cash crops and their viral diseases have been best studied all over the world. Among indirect damages, the transmission of diseases by some whiteflies is the most important consequence often leading to complete yield loss. The list of countries/territories indicates the preponderance of the pest infestation and disease epidemics to occur in regions where whiteflies are in the greatest abundance, especially the tropical and sub-tropical regions of the world. Various review articles on several whitefly-vectored viral diseases in recent years indicate that these diseases are the foremost threat to crop production. However, based on the fact that these diseases are vectored by whiteflies, it is the whiteflies that must be regarded as the main culprit for loss in crop productivity. Control of whiteflies is very challenging as it reproduces very quickly and develops resistance to insecticides. In the present time, the use of insecticides either alone or under the umbrella of IPM is the only and major approach employed by farmers in most of the countries to manage whitefly populations because of their usefulness and convenience. IPM is, however, not foolproof primarily because strategies are specific to a given cropping season, geographical area, as well as the crop in question, and also because it is not economically feasible at all times for various crops or in all countries.

The measures for controlling whiteflies have been falling short of the required high mortality (95–100%) at low concentration, and the complete elimination of whiteflies indicates their inefficiencies. We have witnessed a paradigm shift with which we have approached whitefly control in the last decade. It is largely turning away from harmful pesticides towards more environment friendly and sustainable strategies, e.g., RNAi and genetic engineering approach. These next-generation strategies have the greatest scope for research and improvement in the future. Various vital genes governing important metabolic pathways have been targeted through RNAi in whitefly. However, a careful and critical exploration of the generic region, unique to whiteflies should be performed using the available transcriptome of whiteflies so as to avoid off-target effects, if any. The selected generic region/genes encoding unique proteins would serve as the target for RNAi. Likewise, evaluation of known insecticidal proteins for possible anti-whitefly function has not shown very exciting results. So, the discovery of new whitefly-specific insecticidal protein(s) and their expression in transgenic crops that provide high resistance is desirable because this technology could be provided to end-users as seeds. However, there is no report of such a transgenic crop to date that provides trustworthy and stable resistance to whiteflies. There is a belief that nature is replete with a plethora of metabolites and macromolecules that have the potential to act as a toxin to one class of organisms even as they are beneficial to yet another class. Acting on this belief, exploration of our huge plant biodiversity for a variety of molecules that can be extracted and tested for their efficacy against the whiteflies should be the future approach. Targeted exploration of proteins specific to whiteflies that are toxic at low ppm level and then incorporation of genetic engineering tools for the development of transgenic plants resistant directly to whiteflies may be one of the best strategies to overcome the pest as well as associated diseases. The introduction of *tma12* into cotton has been a major success in terms of the levels of protection offered[8]. The next generation of whitefly-resistant transgenic plants must be designed in such a way that it achieves maximum expression of anti-whitefly proteins in phloem and also prevents the inception of resistance and hence provides sustainable crop protection. We are of the view that these two approaches, where RNAi against a unique generic region of whiteflies or protein(s) specific to whiteflies are involved, would deliver a comprehensive solution to the problem that will be target-specific and relatively safe to the environment as well.

With the development of science and technology, some new whitefly control strategies based on nanotechnology and genome editing have also been tested. Although these approaches are at the budding stage, preliminary results offer great potential for whitefly control in the future. The promising results obtained in laboratories should be further evaluated and validated for their field applications. However, care should be taken that the modification will not lead to deleterious effects on the beneficial insect population. These outstanding technologies should be employed to design whitefly-specific nanoparticles to confer resistance in crops. Moreover, semiochemicals are also being studied for pest management. The discovery of a true repellent of whitefly that prevents the colonization of the pest should be the future target. Active NPs may also be exploited as a carrier for whitefly-specific siRNAs, new anti-whitefly proteins, or volatile organic compounds via sprays or slow-release dispensers. It is also crucial to make the public aware and willing, especially in developing countries, to accept GM/GE crops. This will encourage researchers to generate the safety data required for the deregulation of these technologies and to take the lab-ready technologies in farmers' fields rather than restricting them to good journals. An open forum discussion among the scientists, policymakers, industrialists, farmers, NGOs, hardliners, etc., should be held to identify a roadmap to overcome all probable issues linked with GM/GE technologies. Countries should also increase their gross domestic product investment in R&D related to whitefly management based on GM/GE crops and/or nanotechnology to promote innovation, in the agriculture sector, where these technologies hold potential for ‘Agriculture Revolution’. These multiple whitefly-centric strategies will ensure a successful campaign towards control of these tiny flies that are in actuality a mighty pest.

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