AgriCos e-Newsletter
ISSN: 2582-7049
AgriCos e-Newsletter
Open Access Multidisciplinary Monthly Online Magazine
Volume: 04 Issue: 12 December 2023 Article No: 37

Induced Defense System against Insect Pests in Cotton

Suman Natua[1], Archana Anokhe [2] and Priyanshu Pawar[3]
[1]Division of Plant Pathology, ICAR- Indian Agricultural Research Institute, Jharkhand
[2]Scientist, Division of Entomology, ICAR- Indian Agricultural Research Institute, New Delhi
[3]Ph.D Scholar, Jawahar lal Nehru Krishi Vishwavidyalaya Jabalpur, Madhya Pradesh

SUMMARY

Enhancing cotton pest management using plant defences has been described as a promising way to improve the management of crop pests. Using examples from cotton crops, it is shown how mechanical injury like topping, pruning, training etc. can be brought to a state of enhanced defence in plants that causes faster and more robust activation of their defence responses. It revisits the agricultural benefits associated with this technique in cotton crops, with a focus on its potential as a supplementary tool for integrated pest management (IPM). In particular, its role in mediating plant interactions with conspecific neighbouring plants, pests and associated natural enemies. Experimental evidence from various studies shows that artificial injury in cotton plants is a promising technique, particularly for smallholders, which can be used as part of an IPM program to significantly reduce insecticide use and improve productivity in cotton farming.

INTRODUCTION

Over 350 million years of co-evolution, plants have developed various defence mechanisms against herbivory. These defences can be categorized into permanent, constitutive defences that are always present, and temporary, inducible defences that activate in response to herbivore attacks. Cotton cultivation serves as a relevant model for managing pests while minimizing harm to ecosystems and human health. Cotton crops face worldwide threats from pests like Lepidoptera larvae and sap-feeding hemipterans (mirids, whiteflies, and aphids). Growers often rely on synthetic insecticides, necessitating research into eco-friendly approaches to pest control. Leveraging a plant's natural defenses, such as induced defense mechanisms, is a promising avenue. Defence priming, a process where plants prepare to swiftly activate their defence responses, is key to plant immunity and is being explored. Plant defence induction has been observed in various plant species and is seen as an effective strategy to combat both abiotic and biotic stressors. Different triggers, including beneficial microbes, chemical cues, pathogens, and arthropods, can enhance plant defenses. Notably, some agricultural practices involving mechanical damage to plants remain unexplored as potential stimuli for enhancing plant defenses.

Area and Production:

Leading state	Maharashtra	Gujarat	Telangana	All India
Area (lakh ha)	39.41	22.51	18.78	119.66
Production (lakh bales)	71.18	74.82	60.67	341.91

Way of enhancing the induced resistance:

There are several ways of production of resistance in in plant. Induced resistance can be triggered in plants by the infection of pathogens, in response to insect herbivory, or upon root colonization by certain rhizosphere mutualistic microbes. Restricted mechanical injury like topping, pruning and training can induce resistance in plant. While training practices have been widely used in China to enhance cotton yield and quality, little attention has generally been paid to their pest control properties. Nevertheless, the effect of topping on cotton pests has been reported by several researchers in different parts of the world. Vayssieres and Mimeur recommended cotton topping in Africa to control lepidopteran and homopteran pests. Field experiments conducted over a 6-year period in Mali showed that the densities of *Helicoverpa armigera* (Hubner), *Earias spp.* and *Diparopsis watersi* (Rothschild) were significantly lower in topped compared with non-topped cotton plots. In Egypt, topping significantly reduced the incidence of bollworm species such as *Earias insulana* (Boisduval) and *Spodoptera littoralis* (Boisd). In India, topped *Bacillus thuringiensis* (Bt) cotton plants showed significantly lower populations of aphids, jassids and thrips compared with non-topped plants. Lower infestations of the bollworm *H. armigera* (eggs and larvae) were also observed in topped fields in India and China.

Induced defense mechanism:

Cotton plants show a wide range of natural resistance strategies against arthropod herbivores that can be divided in two different categories: direct strategies, such as morphological traits and the production of toxic secondary metabolites, and indirect strategies, such as the emissioof volatile organic compounds (VOCs) and extrafloral nectaries (EFNs). Direct strategies have a direct effect on the herbivore through changes in its fitness, including survival, reproduction and developmental time. In contrast, indirect strategies act by preventing the herbivore from feeding and/or enhancing the effectiveness of natural enemies. The nature of the underlying mechanisms and how these strategies impact pests and their antagonists in the cotton–pest–natural enemy system have been reviewed elsewhere. Some of these plant defence strategies are operational at any time (constitutive defiance) while others require activation that usually involves mechanical or herbivore damage (induced defence). In this section, we discuss the resistance strategies of cotton plants that could be induced by training practices. We will therefore concentrate on those strategies that require activation through mechanical damage and will focus on the production of toxic secondary compounds, the production of EFNs and the emission of VOCs by cotton plants and how they can affect the interaction with undamaged neighbouring plants, pests and their natural enemies.

Production of toxic secondary compounds

Cotton plants produce various non-volatile terpenoids, including gossypol and gossypol-like compounds, which are toxic to a wide range of herbivores and pathogens. These terpenoids act as deterrents against leaf-chewing insects and inhibit the growth of several pest species. Gossypol, the most extensively studied cotton terpenoid, is found in various plant parts, such as seeds, roots, and leaves. Additionally, toxic terpenoids like hemigossypol and desoxy-hemigossypol are present in the roots, while gossypol-like terpenoids such as hemigossypolone, heliocide H1, H2, H3, and H4 are found in seeds, flowers, buds, and leaves. Flavonoids, another group of secondary metabolites, play a vital role in plant resistance, especially in Asian cotton species like *Gossypium arboreum*, where they hinder the growth of specific lepidopteran species. While these secondary compounds are typically produced in photosynthetically active plant parts, studies have shown that herbivore or mechanical injury can induce their production. In *Gossypium hirsutum* cotton plants, higher terpenoid levels in young leaves result from both the expansion of existing glands and the formation of new glands for terpenoid storage, particularly following herbivore and mechanical damage to mature leaves, as observed by Opitz et al.

Production of EFNs

Cotton plants produce floral and extrafloral nectar. EFNs are known to play an important role in plant defense against herbivores by providing nectar rewards that attract ants and other carnivorous insects. Some studies have reported that cotton plants with EFNs support an important beneficial community of arthropods. These structures are located on the lower surface of the leaves (on the main and sometimes on the secondary veins) and also on the bracts. These nectaries are present in all cotton species except *Gossypium tomentosum* and Gossypium gossypioides. Interestingly, EFN production is constitutive but leaf EFN production can also be induced by herbivore damage. Constitutive production of bracteal nectar exceeds the production of leaf nectar but it is not induced by herbivory. Wackers et al. showed that foliar nectar production increased by a factor of 12 on the damaged leaf and on the younger leaves adjacent to the damaged leaf following foliar injury by *Spodoptera littoralis*. In addition, cotton foliage nectar production can also be induced by below-ground herbivore injury. The authors showed that foliar nectar production increased in the whole plant in response to both damage by the root-feeder wireworm *Agriotes lineatus* and mechanical root damage. While it is known that EFNs play an important role in plant indirect defense, more research is needed to determine the impact of EFNs on the community of both antagonist and beneficial arthropods.

Emission of volatiles

Plants emit volatile organic compounds (VOCs) to interact with their environment, which can be altered by pest-induced damage. These VOCs can deter herbivores or attract beneficial insects and vary based on factors such as species and environmental conditions. In cotton, both local and systemic VOC emissions increase when leaves are injured. For example, after several days of *Spodoptera exigua* or *Helicoverpa zea* larvae feeding on lower cotton leaves, significant amounts of specific volatile compounds were released by the undamaged upper leaves of the same plant. Similarly, herbivore feeding on cotton flower buds prompts the release of certain cotton volatiles. These VOCs can be classified into two categories: constitutive compounds, which are typically released by healthy plants, including green leaf volatiles (GLVs) such as (Z)-3-hexenal, (Z)-3-hexenol, (Z)-3-hexenyl acetate, and other specific plant constituents, as well as monoterpenes and sesquiterpenes. Cotton plants also store specific volatile compounds in specialized glands and trichomes, releasing them rapidly when leaves are damaged. Inducible compounds are newly synthesized and systemically released in response to herbivore damage. In cotton, herbivore-induced plant volatiles (HIPVs) primarily include acyclic terpenoids like (E)-β-ocimene, linalool, (E)-β-farnesene, (E,E)-α-farnesene, (E)-4,8-dimethyl-1,3,7-nonatriene, and (E,E)-4,8,12-trimethyl-1,3,7,11-tridecatetraene, along with (Z)-3-hexenyl acetate, indole, isomeric hexenyl butyrates, and 2-methylbutyrates.

Effects on herbivores

Induced plant volatiles play a significant role in influencing herbivore behavior. These chemical signals help herbivores locate food efficiently and assess its quality. Herbivores benefit by avoiding plants emitting these volatile organic compounds (VOCs) because they reduce competition, secondary compound consumption, and encounters with natural enemies. For instance, studies revealed that damaged cotton plants became less appealing to Spodoptera spp. larvae, leading to a preference for undamaged plants. Additionally, *S. littoralis* reduced egg-laying on herbivore-damaged cotton plants, likely due to VOC exposure. Interestingly, Thrips tabaci showed an increased attraction to injured cotton seedlings, possibly driven by their predation on the spider mite *Tetranichus urticae*. This suggests that herbivores utilize cues from damaged plants to locate potential prey. Electrophysiological studies demonstrated the sensitivity of certain sensilla in *S. littoralis* to herbivore-induced plant volatiles. Another pest, the boll weevil Anthonomus grandis, also relies on VOCs emitted by conspecific-damaged cotton plants to select suitable host plants.

Effects on neighboring plants

Volatiles emitted from damaged plants can induce defense responses in undamaged neighboring conspecifics, thus triggering defense reactions against herbivore attack in receiving plants. It is now well established that induced plant volatiles function as signals between plants in a wide range of plant species. In cotton, Bruin et al. showed that undamaged cotton plants can gain protection against mite herbivory following exposure to compounds released by mite-injured plants. The oviposition rate of spider mites on leaves previously exposed to volatiles from infested plants was 10% lower compared with untreated controls. Moreover, field and laboratory experiments have shown that *S. littoralis* females reduced their egg-laying on undamaged cotton plants when sprayed with volatiles collected from damaged plants. Interestingly, research conducted in Mali showed that manual topping in cotton greatly reduced bollworm infestations not only on topped plants but also on neighboring plants.

CONCLUSION:

Insect pests, particularly Lepidoptera larvae, are a major obstacle to the intensification of cotton production in many cotton-producing countries, where they can cause losses of up to 80% of the crop. Because of its ecological and agricultural benefits, induced defense should be promoted as an ecologically intensive crop and pest management tool in cotton. Traditional practices, such as plant topping and plant pruning, can be components of these techniques, when used specifically for pest control purposes. Experimental evidence from various studies has shown that making of artificial mechanical injury in cotton is a promising technique, particularly for smallholders, as part of an IPM program, to significantly reduce insecticide use and to improve productivity in cotton farming.

REFERENCES:

FAO, *Growing Greener Cities in Africa. First Status Report on Urban and Peri-urban Horticulture in Africa*, Food and Agriculture Organization of the United Nations, Rome (2012).

Garnett T, Appleby MC, Balmford A, Bateman IJ, Benton TG, Bloomer P *et al.*, Sustainable intensification in agriculture: premises and policies. *Science* **341**:33–34 (2013).

Greenberg SM, Adamczyk JJ and Armstrong JS, Principles and practices of integrated pest management on cotton in the Lower Rio Grande Valley of Texas, in *Integrated Pest Management and Pest Control-current and Future Tactics*, ed. by Larramendy M and Soloneski S. In Tech, Rijeka, pp. 3–34 (2012).

Pretty J and Bharucha ZP, Sustainable intensification in agricultural systems. *Ann Bot* **114**:1571–1596 (2014).