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Review on biochemical counter defense of plant insect interaction

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ABSTRACT

Although plant insect interactions can be classified into constitutive and inducible defenses, the pesticides or proteins involved are often similar. The induced defense has aspects unique to all plants, whereas constitutive defense deposition is species-specific. Herbivores activate induced defense locally and systemically through signaling pathways involving systemic, jasmonic acid, oligo galacturonic acid, alkaloids, peroxy terpenoids, cyanogenic glycosides, phenols, hydrogen, etc. become Herbivorous insects have adapted to resist plant defenses, and such adaptations can be constitutive or inducible. Insects with a specific plant host range tend to exhibit constitutive adaptations to the pesticide compounds they encounter, whereas insects that feed on a variety of plant host species can overcome induced adaptations to plant defenses. It often happens. Herbivorous insects can overcome the adverse effects of plant secondary defense metabolites by employing different strategies such as detoxification, sequestration, and secretion. The arms race between plants and insects is the driving force behind the coevolution of the two organisms and the complex relationship between them.

Keywords: Jasmonic acid, Oligo galacturonic acid, Alkaloids, Peroxy terpenoids, Cyanogenic glycosides

INTRODUCTION

Among animals, insects are the most common and diverse group of insects. It is also the most evolutionarily successful animal on Earth. According to MLA, insects have been around for 480 million years, and as plants evolved so did insects to consume plants (Abdul R, et al., 2012).

The interaction between plants and herbivores is one of the largest and most complex interactions between organisms in evolution. Herbivorous insects feed on plant tissue (26%) and make up almost half of the known species on Earth. Fossil records of plant damage, coprolith dispersal, modified mouthparts, and orthopteran gut contents provide evidence for antagonistic interactions between plants and arthropods (Afroz M, et al., 2021). During the late Paleozoic to early Mesozoic 250 Myr, important groups of herbivorous insects such as Coleoptera and Lepidoptera emerged (Agrawal AA, et al., 2009). About 100 million years later, angiosperms emerged and spread worldwide. These important patterns thus contribute to the idea that the diversification of plants and herbivores (particularly insects) is actually the result of biological interactions between plants and animals. Plants can interact with various types of insects. B. Antagonistic interactions with herbivores and mutual interactions with carnivorous and pollinating insects (Arimura GI, et al., 2009).

To combat herbivore attacks, plants produce specialized secondary metabolites and proteins that have toxic, repellent, and/or nutritional effects on herbivores. Plants compete directly with herbivores by influencing host plant preferences or survival and reproductive success. Such defense mechanisms are mediated by plant traits that affect herbivore biology through the production of toxic chemicals such as terpenoids, alkaloids, anthocyanins, phenols, and proteinases that either kill the herbivore or slow its development increase. This is a direct defense mechanism against viruses (Barbehenn RV, et al., 2009). The study of plant herbivore interactions is one of the most important and interdisciplinary efforts in plant biology, describing the chemical and ecological processes that influence the outcome of plant herbivore interactions. doing. It spans various domains. Our understanding of how plants communicate with terrestrial and subterranean environments, commensals, and herbivores is still in its early stages. This is an ecological question and has great potential for use in crop protection (Barbehenn RV, et al., 2011). Great for development. This eliminates the need to use harmful pesticides to get rid of pests. However, plant herbivore interactions continue, and herbivores may co-evolve depending on the genotype of the tolerant plant. Optimizing the production of new crops requires knowledge of the complex chemical interactions between plants and insects. Therefore, the aim of this review is to identify mechanisms of biochemical defense against plant–insect interactions (Becerra JX, et al., 2009).

LITERATURE REVIEW

Biochemical Counter Defense of Plant-Insect Interaction

Living things never exist alone. They interact with other organisms present in their environment, such as predators, parasites, hosts, and reciprocal organisms (Bernays EA, 1981). As a result, they are subject to natural selection pressures carried by other organisms that drive evolution. When the evolution of one species leads to the evolution of the corresponding species and vice versa, they most likely engage in a co-evolutionary process called an arms race (Bernays EA, et al., 2000).

This is due to an evolutionary adaptation to specific phytochemicals, and mechanisms have evolved to detoxify, sequester, excrete, or selectively couple plant defenses (Bhonwong A, et al., 2009).

Behavioral studies in the papilio polytene show that the insect adapted to feed on toxin-laden host plants through diversification of cytochrome P450 monooxygenases involved in the detoxification of furanocoumarins. The evolutionary theory was also confirmed by another study showing positive evolutionary trends associated with the progressive diversity and complexity of chemicals (Bones AM, et al., 1996). Because plants can produce an almost inexhaustible number of metabolites, they possess a vast storehouse of potentially protective compounds, many of which have been described in the c ontext of interactions between plants and other organisms (Table 1) (Bruinsma M, et al., 2009). These compounds belong to different chemical groups such as B. isoprene-derived terpenoids including monoterpenoids, sesquiterpenoids, diterpenoids, triterpenoids, and steroids.

Table 1: Plants' specialized compounds.

Compounds	Example	Typical plant source	Approximate number of compounds known
Terpenoids	(E)-B-Farnesene	Ubiquitous	>30,000
Steroids	Phytoecdyson	Ranunculaceae	~200
Cardenolides	Digoxigenin	Plantaginaceae	~200
Alkaloids	Nicotine	Solanaceae	>12,000
Fatty acid derivatives	(3Z)-Hexenylacetate	Ubiquitous	n.d.
Glucosinolates	Sinigrin	Capparales	~150
Cyanogenic glucosides	Dhurrin	Rosaceae, fabaceae	~60
Phenolics	Lignin, tannin	Ubiquitous	>9,000
Polypeptides	Trypsin inhibitor	Ubiquitous	n.d.
Nonprotein amino acids	y-Aminobutyric acid	Fabaceae	>200
Silica	SiO_2	Poaceae	1
Latex	Undefined emulsion	Euphorbiaceae	V.C.

Note: n.d.: TBD; VC: Various Configurations

Sources: Axel Mithofer and Wilhelm Boland 2012 plant defense against herbivores: Chemical aspect. The proposal from Axel Mith and Wilhelm Boland 2012 plant defense against herbivores: Chemical aspect.

Interestingly, inorganic compounds can also have protective functions. This is evidenced by improved protection of high accumulator plants from herbivores.

Silica, SiO_2, is another example of a defense mechanism based on inorganic compounds. When incorporated into plant cell walls or present as siliceous bodies, it influences food intake, especially in small insects, by promoting mandibular wear and promoting the digestion of plant tissues (Burow M, et al., 2017).

Secondary metabolites are compounds that do not interfere with normal plant growth and development, but which reduce the palatability of the plant tissue from which they are made (Campos F, et al., 1988). Phytoanticipins, previously secondary compounds, are primarily activated by β-glucosidases during herbivory and subsequently mediate the release of various biocidal aglycone metabolites. A major advantage of insect induced insecticides is their direct antifeedant effect on herbivores (Chakraborti D, et al., 2009).

As cited in M Afroz et al., several mechanisms have been identified that enable plants to recognize and evolve defense mechanisms against insect attack. Saliva secreted by insects when feeding and egg-laying fluid secreted during spawning to prevent attack by other insects or to adhere eggs to plant surfaces initiate the production of protective chemicals. It is recognized by plants (Chamarthi SK, et al., 2011).

Delayed synthesis of new compounds is a major drawback of inducible defense systems. Conversely, plant constitutive defenses enable the initial production of antibodies in vulnerable tissues (Chen H, et al., 2005). This also has some drawbacks, such as the loss of metabolic energy required to produce the compound in the absence of an insect threat, and the toxicity of the active form of certain compounds not only to insects but also to the plant itself. To avoid this, compounds are stored in a non-toxic form that is readily activated and activated upon insect invasion. An example of this strategy is the separate storage of the protective substance glucosinolate and its activating enzyme myrosinase in specialized cells or specific myrosin cells. Degradation of plant tissue during herbivory results in the mixing of the components of the two cell types and cleavage of glucosinolates by myrosinase to produce labile aglycones (Chen Y, et al., 2009).

Sorghum (Sorghum bicolor) accumulates cyanide glucosides in the cytoplasm, but its activating enzyme Suriname (endogenous β-glucosidase) remains in the chloroplast (Figures 1 and 2).

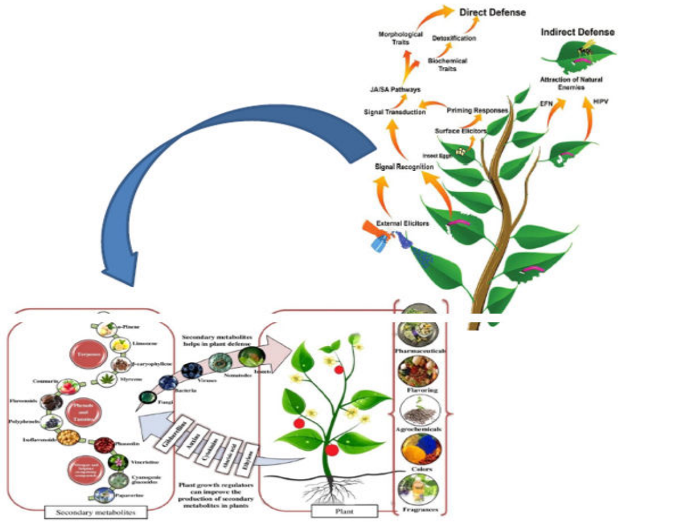

Figure 1: As reported by M Afroz et al., thematic maps represent plant defense mechanisms against pests.

Note: (EPF=Extrafloral nectar; HIPV=Herbivore-Induced Volatiles; JA=Jasmonic Acid; SA=Salicylic Acid).

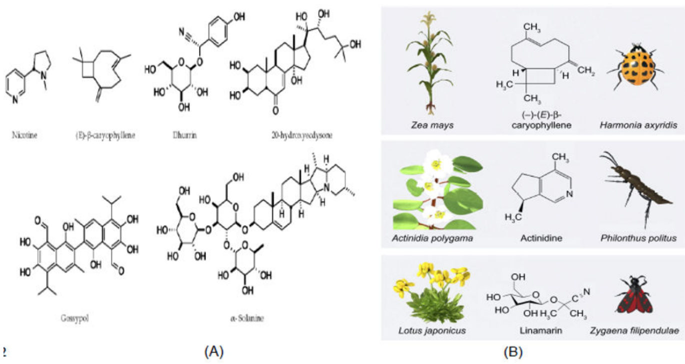

Figure 2: Examples from M Afroz et al., representative chemical structures of plant defense compounds (B).

The maize HPR of the maize earwig *Helicoverpa zea* (Boddie) has been reported to be primarily due to the presence of the secondary metabolite C-glycosyl flavone Maysin the phenylpropanoid product chlorogenic acid. Compounds, 4-Dimethylcyclooctene was found to be responsible for the resistance of the *sorghum* bicolor to the bud fly *A. soccata*. The roles of some secondary metabolites in plant defense are briefly discussed below.

Plant' Phenol

Plant phenols are among the most common and widespread protecting groups for secondary metabolites that play a key role in HPR for herbivores, including insects. Lignin, a phenolic heteropolymer, plays a central role in plant defense against insects. Decreases leaf nutrients (Chow JK, et al., 2005).

Phenol oxidation, catalyzed by Polyphenol Oxidase (PPO) and Peroxidase (POD), is a potential defense mechanism in plants against herbivorous insects. In addition, quinones are directly toxic to insects. Amino acid alkylation reduces the nutritional value of insect plant proteins and adversely affects insect growth and development. A simple phenol (salicylic acid) in willow leaves acts as a scavenger for carnivores such as *Operophtella vulmata* (L.), and there is a negative correlation between salicylic acid levels and retarded larval development (Cooke J, et al., 2010).

Flavonoids

Flavonoids play a central role in many aspects of plants, particularly in plant-environment interactions. They protect plants from various biological stresses, including pathogens and pests. Both flavonoids and isoflavonoids protect plants from pests by affecting insect behavior, growth and development.

Flavonoids are classified into different classes. Most flavonoids have been found as inhibitors against *Spodoptera excepta* (Walk.) and *Spodoptera litoralis* bios. Overexpression of transcription factors that control flavonoid production in *Arabidopsis thaliana* has been described by *Spodoptera frugiperda* (J.E. Smith). Isoflavonoids isolated from wild relatives of chickpeas (judaicin, judaicin-7-O-glucoside, 2-methoxyjudaicin, and marquean) are effective as feed for *Helicoverpa armigera* at 100 ppm (Hubner). It has also been shown that Judaicin and Macchiain inhibit S. *littoralis* and S. *frugiperda*, respectively. Cyanopropenyl glycosides and alilinosides potently inhibit foraging by Indian butterflies, whereas the flavone glycoside isovitexin-6″-D-β-glucopyranoside acts as a direct late-stage food defense.

Tannins

Tannins have a strong negative effect on plant eating insects, affecting insect growth and development by binding to proteins, reducing the efficiency of nutrient absorption, and causing lesions in the midgut. Tannins are astringent (tightening in the mouth) bitter polyphenols that act as a feeding deterrent to many insect pests. When ingested, tannins reduce the digestibility of proteins, thereby reducing the nutritional value of some plant and herbivore plant parts.

Condensed tannins act as a deterrent to some insects such as *Lymantria dispar* (L.), *Euproctis chrysorrhoea* (L.), and *O. brumata*. Concentrated tannins such as (+)-catechin, (+)-gallocatechin, and vanillin in *Quercus serrata* leaves inhibited winter moth larvae *O. brumata*. Procyanin ginseng polymers have been used as deterrents against peanut aphids (Koch).

In addition, tannin induction is also stimulated by light stress and UV exposure in hybrid poplars. However, some polyphagous insect species have the ability to tolerate gallotannins. *B. Shistocerca gregaria* (Forsk.) restricts the passage of tannins by adsorbing them too thick peri trophoblasts and inhibiting the formation of tannin-protein complexes by surfactants in the midgut, thus limiting tannin transit. Tolerates tannins by rapidly hydrolyzing them to avoid the effects.

Plant' Defense Proteins

Changes in gene expression under stress, including insect infestation, cause qualitative and quantitative changes in proteins that play important roles in signal transduction and oxidative defense (Table 2). Changes in the amino acid content of proteins affect their function. The anti-insect activity of proteolytically sensitive toxic proteins can be enhanced by the administration of protease inhibitors that exert protective functions. Recent advances in microarray and proteomic approaches have revealed that a wide range of His-PRPs is involved in plant defense against herbivores. Several signaling pathways, including Jasmonic Acid (JA), SA, and/or Ethylene (ET), regulate arthropod induced proteins due to the different feeding habits of arthropods (Table 2).

Table 2: A plant defense proteins against pests.

Putative defense protein	Plant species	Insect species
PIs	*Sorghum bicolor*	*Schizaphis graminum*
	Tomato	*Manduca sexta*
	Gossypium hirsutum	*Helicoverpa armigera*
	Solanum nigrum	*Manduca sexta*
	Nicotiana attenuata	*Spodoptera littoralis*
	Transgenic arabidopsis/oil seed rape	*Spodoptera exigua*
	Transgenic arabidopsis/tobacco	*Spodoptera exigua*
		Plutella xylostella
		Mamesrra brassicae

		Spodoptera littoralis
LOXs	*Cucumis sativus*	*Spodoptera littoralis*
	Nicotiana attenuata	*Bemisia tabaci*
	Alnus glutinosa	*Agelastica alni*
	Wheat	*Sitobion avenae*
	Tomato	*Macrosiphium euphorbiae*
	Nicotiana attenuate	*Myzus persicae*
		Myzus nicotianae
Peroxidases	*Alnus glutinosa*	*Agelastica alni*
	Arabidopsis	*Bemisia tabaci (whitefly)*
	Buffalograss	*Blissus oxiduus*
	Poplar	*Lymantria dispar*
	Medicago sativa	*Aphis medicaginis*
	Corn	*Spodoptera littoralis*
	Rice	*Spodoptera frugiperda*
PPOs	Tomato	*Manduca sexta*
	Buffalograss	*Blissus oxiduus*
	Tomato	*Spodoptera frugiperda*
		Helicoverpa armigera
Chitinases	*Sorghum bicolor*	*Schizaphis graminum*
Hevein-like protein	Arabidopsis	*Bemisia tabaci*
Catalase	*Bufallograssses*	*Blissus oxiduus*
SOD	*Medicago sativa*	*Aphis medicaginis*

Plant' Lectin'

Lectins are carbohydrate binding (sugar) proteins that are ubiquitous in nature and have protective functions against various pests. The insecticidal activity of various plant lectins has been exploited as natural insecticides against insect pests (Table 2). One of the most important properties of lectins is their survival in the digestive system of herbivores and their potent insecticidal activity. By binding to glycosyl groups on the membranes lining the gastrointestinal tract, they act as antinutritive and/or toxic agents, causing many undesirable systemic reactions.

Lectins have shown promise against Homoptera, Lepidoptera, and Coleoptera insects. Insecticidal properties of *Galanthus nivalis* L. Agglutinin (GNA) were the first plant lectin shown to be active against *Hemiptera*. Mannose binding lectins have been reported to be effective against fluke insects by interacting with specific carbohydrate residues in the cell membrane. have been reported by Yuan Z. involving snowdrop lectin expressing tobacco. Sun X et al., 2002, wheat. Plant lectins are induced by elicitors as an inductive response to various stressors (Table 3).

Table 3: Plant defensive lectins and lectin like proteins and target insect pests.

Lectin	**Plant**	**Insect**
Allium *sativum* leaf lectin	Tobacco	Aphids

	Chickpea	*Aphis craccivora*
Jacalin-like lectins	Wheat	*Mayetiola destructor*
Bauhinia monandra leaf lectin	Tobacco	*Anagasta kuehniella* *Zabrotes subfasciatus* *Callosobruchus maculates*
Snowdrop lectin	Rice	Aphids
	Wheat	*Nilaparvata lugens*
	Arabidopsis	Aphids
		Pieris rapae, Spodoptera littoralis
Nictaba-related lectins NICTABA, PP2	Tobacco	*Spodoptera littoralis, Manduca sexta,*
		Acyrthosiphon pisum
Arum maculatum lectin		*Lipaphis erysimi, Aphis craccivora*

DISCUSSION

Enzymes

Enzymes that interfere with nutrient uptake by insects through the formation of electrophiles include Peroxidase (POD), Polyphenol Oxidase (PPO), ascorbate peroxidase, and other peroxidases by oxidizing mono-or dihydroxyphenols, resulting in reactions that lead to the formation of sex o-quinone. The electrophilicity of proteins leads to the formation of polymeric or covalent adducts with nucleophilic groups of proteins. The induction of antioxidant enzymes in herbivorous plants has received considerable attention in recent years.

The oxidative state of the host plant has been linked to his HPR in insects. POD is an important part of the plant's immediate response to insect damage. Many processes that play direct or indirect roles in plant defense are regulated by POD. This includes lignification, sub-erization, somatic embryogenesis, auxin metabolism, and wound healing. The role of POD in plant resistance to pests has been studied in various plant systems. Generation of phenoxy and other oxidative radicals by POD combined with phenol produces toxins that directly interfere with insect feeding and/or reduce plant digestibility. This leads to malnutrition of insects, which dramatically affects their growth and development. Furthermore, POD has been reported to be directly toxic in the gut of herbivores.

PPOs are important plant enzymes that regulate pest nutrition, growth and development, and play important roles in plant defense against biological stress.

Quinine is more toxic to herbivores than the original phenol. In addition to its role in plant tissue digestibility and palatability, melanogenesis from PPO improves cell wall resistance to insects. Induction of his PPO activity under biotic stress and treatment with compounds related to the octadecanoid pathway make PPO an important tool for plant tolerance to herbivorous stress.

The PPO gene is differentially induced by signaling molecules and injury and insect invasion. PPO *Spodoptera litura* (Fab.), *H. armigera*, *Bemisia tabaci* (Gen.), *Tetranychus cinnabarinus* (Boisd.), *Myzus persicae* (Sulzer), *Empoasca fabae* (Harris), *Aphis medicaginis* (Koch), S and *Agelastica alni* (L.). However, its induced his PPO levels were significantly higher in L. *dispar Orgyia leucostigma* (JE Smith), Barbehenn RV. et al., 2009 and Blissus occiduus Barber. Lipoxygenase (LOX) is involved in the octadecanoid signaling pathway. In addition, the end products of lipid peroxidation also act as insect repellents or anti-investments and are toxic to pests (antibiotics).

Maize transformed with the wheat oxalate oxidase gene showed upregulation of LOX transcripts and a (14-fold) increase in free phenols, and the European corn borer *O. nubilalis*.

Cyanogenic Glycosides

Many constitutively present protective substances are harmful or toxic to plants. Therefore, plants must be able to produce and store these substances without poisoning themselves. It can tolerate large amounts of cyanogenic glycosides. Therefore, it is also necessary for plants to protect themselves during the biosynthesis of these compounds. This is achieved through the formation of a multi-enzyme complex. This metabolite enhances catalytic efficiency by creating a tightly cooperating active center, thereby preventing the release of noxious intermediates.

Glucosinolates'

In addition to cyanogenic glycosides, the best known co-protective agents are glucosinolates. Tropaeola family. Larvae of the lepidoptera generalist trichoplusia avoid *Arabidopsis thaliana* ecotypes that produce isothiocyanates during glucosinolate hydrolysis and instead feed on nitrile-producing ecotypes to enhance the biological activity of isothiocyanates. Was again clearly demonstrated. Interestingly, certain parasites recognize their hosts using glucosinolates released by feeding herbivores.

Terpenoids

Terpenoids are a highly diverse group of carbon-based compounds, all derived from the 5 carbon isoprene moiety and ubiquitous. Isoprene also reduces the attractiveness of the parasitic wasp *Diadegma semiclausum*, thereby weakening the plant's indirect defenses. It is well documented that the predatory tick *Phytoseiulus persimilis* is attracted to (3S)-(E)-nerolidol.

Alkaloids: Nicotine and Others

Alkaloids form a diverse group of nitrogen compounds. Plant families rich in alkaloids are *Solanaceae*, *Poppies*, *Apocynaceae*, and *Ranunculaceae*. Colchicine is produced by *Colchicum autumnale*. It inhibits microtubule polymerization by binding to tubulin, inhibits mitosis and is added to food. Their toxicity and growth inhibitory properties in insects are due to inhibition of midgut sucrase and trehalase of various other tissues, rendering sucrose uptake and trehalose unavailable (Figure 3).

The biosynthetic sequence of nicotine is triggered by herbivores.

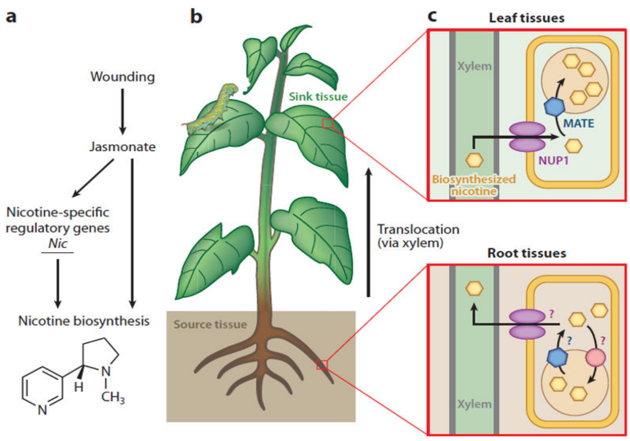

Figure 3: "Model for herbivore/wounding-mediated nicotine accumulation in the leaves of *Nicotiana tabacum*.

- The herbivory-induced phytohormone jasmonate is transported by the phloem to the roots and triggers nicotine biosynthesis along with upregulation of the required transporters.
- Illustration of the transport routes with transporters in tobacco plants.
- The biosynthesized nicotine (yellow hexagons) is loaded *via* a jasmonic acid–induced Multidrug and Toxic compound Extrusion (MATE) transporter into the vacuole. In the leaves a second transporter, Nicotine Uptake Permease (NUP1), translocates the alkaloid from the xylem to the leaf cells".

Source: Axel Mithofer and Wilhelm Boland 2012 plant defense against herbivores: chemical aspect.

Nicotine is a known protective substance (EC50: 0.2%; *A. mellifera*). In early studies using electrophysiology and radioligand-binding techniques, researchers identified insect nAChRs as the most likely sites of nicotine action. Nicotine tolerance has been reported in the aphid Myzus persicae, *M. nicotinate*.

Latex

Latex is the general name for a chemically undefined milky suspension or emulsion of particles, usually held under pressure inside living plant cells called lactic acid producing cells. Latex is found in about 10% of all plant species and can contain a wide variety of specialized metabolites and proteins in much higher concentrations than leaves. This latter effect is the main function of chewing gum to trap insects, discolor and stick to mouthpieces.

When lactating cows are mechanically injured, latex can quickly leak out of the wound and come into contact with herbivores. For example, as shown in the spurge *Hoodia gordonii*, latex added to artificial diets or applied to the leaves of host plants prevented both larval feeding and adult oviposition. Herbivores, in particular, try to avoid contact with latex. Additionally, some practitioners are able to blunt the latex defenses by using a vein-cutting or burrowing action that cuts the lactobacillus and contracts the latex in response to internal pressure. This allows the insects to start eating. After cutting plant tissue.

CONCLUSION

Through the production or secretion of secondary metabolites, plants can alter insect physiology and behavior, resulting in insect virulence or host plant non-selectivity. Insects also act in different ways to meet this challenge. In general, in the context of plant protection, the ability of plants to generate protective secondary metabolism should be enhanced by optimizing the performance of PPPs against insect damage at all plant stages according to their importance.

A future challenge is to exploit plant secondary chemical defense triggers for pest control and to identify the genetic code for proteins that are up-and/or down-regulated during plant responses to herbivores. An herbivore conferred by genetic transformation. However, before the secondary compounds released by plants can be effectively used in agricultural systems, we must understand the chemical changes they inoculate the plants, the effects these compounds have on herbivores, and the changes in plant growth. It is important to check whether there is come. Yield and biological performance. Resistance to one particular herbivore can lead to susceptibility to another herbivore, which can lead to resurgence and may help pests develop biotypic traits, some defense responses involve toxic bioactive natural compounds and proteins that reduce the digestibility of plant material and thus can have negative environmental and non-target effects. Until we develop carnivorous plant tolerant crops and reduce the need for microbial pesticides, the food and manufacturing industries will benefit greatly, both economically and environmentally feasible.

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