Innovative Farming
-An International Journal of Agriculture

ROLE OF SECONDARY METABOLITES IN PLANT DEFENSE

Mini Review Article

D. Dey
Department of Entomology, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar- 751003, India.
**Corresponding author's E-mail: dipankard799@gmail.com*

KEY WORDS
Metabolites, Terpenes, Phenol, Flavonoid

ARTICLE INFO
Received on:
03.09.2016
Revised on:
04.10.2016
Accepted on:
06.10.2016

ABSTRACT

Secondary metabolites, which are a characteristic feature of plants, are important and can, protect plants against various microorganisms (Virus, Bacteria, Fungi) and herbivores (Arthropods, Vertebrates). So, host plant resistance to insects, particularly, induced resistance, can also be manipulated with the use of chemical elicitors of secondary metabolites, which confer resistance to insects. Induced resistance could be exploited as an important tool for the pest management to minimize the amounts of insecticides used for pest control.

Introduction

Secondary metabolites are small organic compounds (molecular masses generally less than 3000 Da), which, as opposed to primary metabolites have no function in the life cycle of cells. The production of specific secondary metabolites varies between species or genera and is thus, apart from appearance and size *etc*., an aspect of characterization of a species. Plants and insects have been living together for more than 350 million years. In co- evolution, both have evolved strategies to avoid each other's defense systems. This evolutionary arms race between plants and insects has resulted in the development of an elegant defense system in plants that has the ability to recognize the nonself molecules or signals from damaged cells, much like the animals, and activates the plant immune response against the herbivores. To counter the herbivore attack, plants produce specialized morphological structures or secondary metabolites and proteins that have toxic, repellent and antinutitional effects on the herbivores. Plants confront the herbivores both directly by affecting host plant preference or survival and reproductive success (direct defense), and indirectly through other species such as natural enemies of the insect pests (indirect defense). Direct defenses are mediated by plant characteristics that affect the herbivore's biology such as mechanical protection on the surface of the plants (e.g., hairs, trichomes, thorns, spines, and thicker leaves) or production of toxic chemicals such as terpenoids, alkaloids, anthocyanins, phenols, and quinones) that either kill or retard the development of the herbivores. Indirect defenses against insects are mediated by the release of a blend of volatiles that specifically attract natural enemies of the herbivores and/or by providing food (e.g., extra floral nectar) and housing to enhance the effectiveness of the natural enemies.

Secondary metabolites

Plants produce a large, diverse array of organic compounds that appear to have no direct function in growth and development. These substances are known as secondary metabolites, secondary products, or natural products. Secondary metabolites have no generally recognized, direct roles in the processes of

photosynthesis, respiration, solute transport, translocation, protein synthesis, nutrient assimilation, differentiation, or the formation of carbohydrates, proteins, and lipids. Secondary metabolites also differ from primary metabolites (amino acids, nucleotides, sugars) in having a restricted distribution in the plant kingdom. That is, particular secondary metabolites are often found in only one plant species or related group of species, whereas primary metabolites are found throughout the plant kingdom. High concentrations of secondary metabolites might result in a more resistant plant. Their production is thought to be costly and reduces plant growth and reproduction (Harvell and Tollrian, 1999; Siemens *et al*., 2002).

Function of Secondary metabolites in plant defense

In natural habitats, plants are surrounded by an enormous number of potential enemies. Nearly all ecosystems contain a wide variety of bacteria, viruses, fungi, nematodes, mites, insects, mammals, and other herbivorous animals. By their nature, plants cannot avoid these herbivores and pathogens simply by moving away; they must protect themselves in other ways. A group of plant compounds known as secondary metabolites defend plants against a variety of herbivores and pathogenic microbes. Plants produce a high diversity of natural products or secondary metabolites with a prominent function in the protection against predators and microbial pathogens on the basis of their toxic nature and repellence to herbivores and microbes and some of which also involved in defense against abiotic stress (e.g. UV-B exposure) and also important for the communication of the plants with other organisms (Schafer *et al*., 2009), and are insignificant for growth and developmental processes (Rosenthal *et al*., 1991).

Principal groups of Secondary metabolites

Plant secondary metabolites can be divided into three chemically distinct groups viz: Terpenes, Phenolic compounds and Nitrogen-containing compounds.

Secondary metabolites and plant defense

Secondary metabolites are the compounds that do not affect the normal growth and development of a plant, but reduce the palatability of the plant tissues in which they are produced. The defensive (secondary) metabolites can be either constitutive stored as inactive forms or induced in response to the insect or microbe attack. The former are known as phytoanticipins and the latter as phytoalexins. The phytoanticipins are mainly activated by ß-glucosidase during herbivory, which in turn mediate the release of various biocidal aglycone metabolites. Phytoalexins include isoflavonoids, terpenoids, alkaloids, etc., that influence the performance and survival of the herbivores. The secondary metabolites not only defend the plants from different stresses, but also increase the fitness of the plants. It has been reported that maize HPR to corn earworm, *Helicoverpa zea* (Boddie) is mainly due to the presence of the secondary metabolites C-glycosyl flavones maysin [2"-O-a-L-rhamnosyl-6-C-(6deoxy-xylo-hexos-4-ulosyl) luteolin] and the phenylpropanoid product, chlorogenic acid. Compound, 4, 4-dimethyl cyclooctene has been found to be responsible for shoot fly *A. soccata* resistance in sorghum *S. bicolor.*

Terpenes

Terpenes constitute the largest class of secondary metabolites and are united by their common biosynthetic origin from acetyl-coA or glycolytic intermediates (Gerhenzon *et al*., 1991; Grayson, 1998). A vast majority of the different terpenes structures produced by plants as secondary metabolites that are presumed to be involved in defense as toxins and feeding deterrents to a large number of plant feeding insects and mammals (Gershenzon and Croteau, 1991). Below, several examples will draw from the 5 major subclasses:

Monoterpenes : Many derivatives are important agents of insect toxicity. For example, the pyrethroids (monoterpenes esters) occur in the leaves and flowers of *Chrysanthemum* species show strong insecticidal responses (neurotoxin) to insects like beetles, wasps, moths, bees, etc. and a popular ingredient in commercial insecticides because of low persistence in the environment and low mammalian toxicity (Turlings *et al*., 1995).

Sesquiterpenes: A number of sesquiterpenes have been till now reported for their role in plant defense such as costunolides are antiherbivore agents of family composite characterized by a five membered lactone ring (a cyclic ester) and have strong feeding repellence

to many herbivorous insects and mammals (Picman, 1986).

Diterpenes: Abietic acid is a diterpene found in pines and leguminous trees. It is present in or along with resins in resin canals of the tree trunk. When these canals are pierced by feeding insects, the outflow of resin may physically block feeding and serve as a chemical deterrent to continued predation (Bardley *et al*., 1992).

Triterpenes: Several steroid alcohols (sterols) are important component of plant cell membranes, especially in the plasma membrane as regulatory channels and maintain permeability to small molecules by decreasing the motion of the fatty acid chains. The milkweeds produce several better tasting glucosides (sterols) that protect them against herbivory by most insects and even cattle (Lewis and Elvin-Lewis, 1977).

Polyterpenes: Several high molecular weight polyterpenes occur in plants. Other one is rubber, a polymer containing 1500-15000 isopentenyl units. Rubber found in long vessels called laticifers, provide protection as a mechanism for wound healing and as a defense against herbivores (Eisner *et al*., 1995; Klein, 1987).

Phenolic compounds

Plants produce a large variety of secondary products that contain a phenol group a hydroxyl functional group on an aromatic ring. These substances are classified as phenolic compounds. Plant phenolics are a chemically heterogeneous group of nearly 10,000 individual compounds: Some are soluble only in organic solvents, some are water-soluble carboxylic acids and glycosides, and others are large, insoluble polymers. In keeping with their chemical diversity, phenolics play a variety of roles in the plant. After giving a brief account of phenolic biosynthesis, we will discuss several principal groups of phenolic compounds and what is known about their roles in the plant. Many serve as defense compounds against herbivores and pathogens. Others function in mechanical support, in attracting pollinators and fruit dispersers, in absorbing harmful ultraviolet radiation, or in reducing the growth of nearby competing plants.

Nitrogen-containing compounds

A large variety of plant secondary metabolites have nitrogen in their structure. Included in this category are such well-known antiherbivore defenses as alkaloids and cyanogenic glycosides, which are of considerable interest because of their toxicity to humans and their medicinal properties. Most nitrogenous secondary metabolites are biosynthesized from common amino acids.

Flavonoids

Flavonoids play a central role in various facets of plant life especially in plant-environment interactions (Treutter, 2006). These defend plants against various biotic and abiotic stresses including UV radiations, pathogens and insect pests. Flavonoids are cytotoxic and interact with different enzymes through complexation. Both flavonoids and isoflavonoids protect the plant against insect pests by influencing the behavior, and growth and development of insects (Simmonds, 2003).

Tannins

Tannins have a strong deleterious effect on phytophagous insects and affect the insect growth and development by binding to the proteins, reduce nutrient absorption efficiency, and cause midgut lesions (Sharma *et al*., 2009). Tannins are astringent (mouth puckering) bitter polyphenols and act as feeding deterrents to many insect pests.

Summary

Because they are sessile organisms, plants often use secondary metabolites in much the same way animals use behavior to interact with their environment. Among their many functions, secondary metabolites serve to attract beneficial organisms such as pollinators and seed dispersing animals, to protect against herbivores and pathogens. There are three major groups of secondary metabolites: terpenes, phenolics, and nitrogen-containing compounds. The study of plant secondary metabolites has many practical applications. The breeding of increased levels of secondary metabolites into crop plants has made it possible to reduce the need for certain costly and potentially harmful pesticides.

References

Bradley, D.J., P. Kjellborn and C.J. Lamb. 1992. Elicitor and wound induced oxidative cross linking of a proline rich plant cell protein: A novel rapid defence response. Cell, **70**: 21-30.

Eisner, T. and Meinwald, J. 1995. Chemical ecology: The chemistry of biotic interaction. Eds, National Academy Press, Washington, DC.

Gershenzon, J. and Croteau R, 1991. Terpenoids. In Herbivores their interaction with secondary plant metabolites, Vol I: The chemical participants, 2 ed., G.A. Rosenthal and M.R. Berenbaum, eds, Academic press, San Diego, pp: 165-219.

Grayson, D.H., 1998. Monoterpenoids. Natural Product Reports, **5**: 497-521.

Harvell, C.D. and Tollrian, R.., 1999. Why inducible defenses? In The ecology and evolution of inducible defenses, eds. Tollrian R and Harvell CD, Princeton, New Jersey: Princeton University Press, pp: 3–9.

Klein, R.M. 1987. The green world: An introduction to plants and people. New York: Harper and Row.

Lewis, W.H. and Elvin-Lewis M.P.F. 1977. Medical Botany; plants affecting mans health. Wiley, New York.

Morant, A.V., Jorgensen, K., Jorgensen, C., Paquette, S.M., Sánchez-Pérez, R. and Moller, B.L., 2008. beta-Glucosidases as detonators of plant chemical defense. *Phytochemistry*; **69**:1795-813.

Picman, A.K. 1986. Biological activities of sesquiterpene lactones. *Biochemical systematic and Ecology*, **14**: 255-281.

Sharma, H.C., Sujana, G. and Rao, D.M. 2009. Morphological and chemical components of resistance to pod borer, *Helicoverpa armigera* in wild relatives of pigeonpea. *Arthropod-Plant Interact*, **3**:151-61.

Siemens, D.H., Garner, S.H., Mitchell-Olds, T. and Callaway, R.M., 2002. Cost of defense in the context of plant competition: *Brassica rapa* may grow and defend. *Ecology*, **83**(2): 505–517.

Simmonds, M.S.J., 2003. Flavonoid-insect interactions: recent advances in our knowledge. *Phytochemistry*, **64**: 21-30.

Treutter, D. 2006. Significance of flavonoids in plant resistance: a review. *Environ Chem Lett*, **4**:147-57.

Turlings, T.C.J., Loughrin, J.H., Mccall, P.J., Roese, U.S.R., Lewis, W.J. and Tumlinson, J.H. 1995. How caterpillardamaged plants protect themselves by attracting parasitic wasps. Proceeding of the National Academy of Sciences of the USA, **92**: 4169-4174.

How to cite this article?

D. Dey. 2016. Role of secondary metabolites in plant defense. *Innovative Farming*, 1(4): 115-118.