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CHAPTERS

A substitute to synthetic pesticides: Plant - Biopesticides

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Abstract:- As of now, we are aware of the negative consequences of chemical pesticides, such as insect - resistance to synthetic pesticides, effects on unintended non-target- species, environmental contamination, and pesticide residues found in vegetables. Researchers are now turning to plant-based biopesticides to lessen the burden of the effects of synthetic pesticides because they have a benign impact on the environment, are easily biodegradable, are less expensive, and are accepted by society.

Keywords:- *Vitex negundo,* Insect Growth Regulators, Agriculture.

BACKGROUND

The concept of using plant parts in order to protect economically important crops is not new at all. Agriculture is being practiced for many centuries. When there was no advancement in technology in ancient times, people managed to protect their crops from pest infestation by traditional methods such as the mechanical uprooting of weeds and primitive pesticides such as salt, ash, or soap[1]. For example, - The Parsa (*Cleistanthus collins*) leaf is used in rice fields to combat pests such as Gandhi, case worms, and gall flies. The leaves of the Sindwar (*Vitex negundo*) plant were also employed to reduce infestation damage in stored rice and wheat grains [2]. It has been reported that dried leaves of *Vitex negundo* were burnt to repel mosquitoes by the Birhore tribes of Jharkhand[3]. This approach of protecting crops and human health from pests by using plant parts is now very popular among researchers.

OBSTACLES TO GROWING CROPS

Reduction in crop production is affected by various biotic and abiotic factors. Due to these factors, crops are being affected during plantation in the field. Abiotic factors such as extreme temperatures, lack or excess of water in the growing season, nutrient supply, and high or low irradiance. Animal pests, plant pathogens, and weeds collectively called pests are the biotic cause of crop damage. Biotic factors may be controlled or prevented by applying physical, biological, and chemical measures but abiotic factors can be controlled only within narrow limits[4]. This chapter focuses on the scope of damage due to insect pests.

Example 1: The tobacco caterpillar, *Spodoptera litura* feeds voraciously on the veins of leaves, and stems of small and tender seedlings, particularly during night [5].

Example 2: *Leucinodes orbonalis*, a monophagous pest of Brinjal. It damages tender shoots and fruits, especially during their fruiting stage[6].

Example 3: Potato tuber moth (*Phthorimaea operculella*), an important pest in the field and storage[7].

Example 4: *Helicoverpa armigera* feed extensively on nitrogen-rich plant parts such as leaves, flowers, and pods[8].

Sometimes situation worsened and the intensity of pest attacks increases, when a pest is moved into a new geographical area, and its natural enemies are normally left behind that keep it in check in its aboriginal home.

Table 1 : Indian vegetable crop yield reductions brought on by significant insect infestations [11,12]

Pests	Crops	Yield losses (in percentage)
H.armigera (Fruit borer)	Tomato	24 - 73 %
Polyphagotarsonemus latus (Mites)	Chilli	34%
S.dorsalis (Thrips)		12 - 90 %
L.orbonalis (Fruit and shoot borer)	Brinjal	11 - 93 %
P.brassicae (Cabbage caterpillar)	Cabbage	69%
P.xylostella (Diamondback moth)		17 - 99 %
H.undalis (Cabbage borer)		30 - 58 %
Crocidolomia binotalis (Zeller) (Cabbage leaf Webber)		28 - 51 %
S.litura (Tobacco caterpillar)	Potato	4 - 8 %
Myzus persicae (Sulzer) (Aphid)		3 - 6 %
P.latus (Mite)		4 - 27 %
Phthorimaea operculella (Zeller) (Potato tuber moth)		6 - 9 %
B.cucurbitae (Fruit fly)	Cucurbits	20 - 100 %
B.tabaci (Whitefly)	Okra	54%
E.vitella (Shoot and fruit borer)		23 - 54 %
A.biguttula (Leafhopper)		54 - 66 %
H.armigera (Fruit borer)		22%

For example, Stem Borer (*Chilo partellus* Swinhoe) is one such example, introduced into Africa coming from Asia, now responsible for significant damage to maize and sorghum in many parts of Eastern and Southern Africa[9].

Another example - A soil-borne pathogen *Fusarium oxysporum* f. sp. cubense (Foc.) causes a destructive plant disease called *Fusarium* wilt of banana. The banana weevil, *Cosmopolites sordidus* found widespread in banana plantations, and viable spores of *Fusarium oxysporum* were found on the exoskeletons of 10% of the weevils, which infers that they may be a vector[10].

AN ERA OF SYNTHETIC PESTICIDES

India's move toward self-sufficiency in food production was facilitated by the introduction of the Green Revolution in the late 1960s, which saw an increase in crops with high yields, fertilizers, and chemical pesticides[13]. The potential of insecticides to boost the sustainability of rice cultivation has been more widely known because of the Asian Revolution[14]. Since the beginning of the green revolution, the application of synthetic chemicals has multiplied by more than 100 times. Pest control and agricultural productivity greatly benefited from the introduction of various synthetic insecticides, such as herbicides and fungicides in the 1970s and 1980s, as well as carbamates, pyrethroids, and organophosphate insecticides in the 1960s, 1970s, and 1980s respectively[15]. The crop that people utilize the most is cotton (36%) followed by rice (20%). The state that uses the highest number of pesticides is Andhra Pradesh (23%) followed by Punjab and Maharashtra. Almost 150 pesticides are currently registered and approved for use in India[16]. After the United States, Japan, and China, India is the fourth - largest provider of agrochemicals worldwide. The pesticide industry in India is the largest in Asia and ranks 12th globally[17].

WHY THERE IS A NEED OF SHIFTING TOWARDS PLANT-BASED PLANT-BIOPESTICIDES?

Today we are standing in such an era where we are approaching to minimize the effect or usage of chemicals. The approach is not limited to agrochemical industries, many cosmetic and pharmaceutical sectors are also moving towards the green side. Let us understand why there is a need for shifting with the help of examples.

Example 1: Populations of *Spodoptera litura* Fabricius in several parts of Andhra Pradesh become somewhat resistant to pyrethroids, endosulfan, certain organophosphates, and carbamates. For the first time, *Spodoptera litura* in India has been found to be resistant to synthetic pyrethroid insecticides[18].

Example 2: When exposed to pesticides, production employees, formulators, sprayers, mixers, loaders and agricultural farm workers are at a greater risk. Because the procedures involved are not risk-free throughout manufacture and formulation, the likelihood of risks may be higher. Because they handle dangerous substances including pesticides, raw materials, toxic solvents, and inert carriers, workers in industries are at a greater risk[15]. Pesticides are also reported to be involved in Parkinson's, Alzheimer's, and Cancer as well as disorders of the respiratory and reproductive tracts[19]. They performed 12-month survey on the population of S.E. England using prepared food and milk samples to determine the typical daily intake of organochlorine pesticides[20]. Dieldrin and the DDT family of insecticides are constantly found in the diet, according to the results. Additionally, the average daily intake of Dieldrin and DDT is 0.02 mg and 0.07 mg per person per day respectively.

Example 3: In India, 51 percent of food products are affected by pesticide residues, and 20 percent of those products have pesticide residues that are above the global maximum residue levels[21]. Recently, the Punjab government has opted to outlaw up to 10 different insecticides. Following allegations that many samples of fragrant, basmati rice with long grains had pesticide residual levels above the Maximum Residual Level (MRL), which would limit its export[22].

Action Taken: The Indian government is urgently urged by the Pesticide Action Network (PAN) India and Asia Pacific to implement its initial proposal to completely prohibit 27 harmful pesticides and to put the welfare of the public and the environment above the interests of the chemical industry. In Maharashtra, two of those pesticides (monocrotophos and acephate) have previously been outlawed due to their connection to the widespread poisoning of cotton-growing communities. Due to their negative consequences, the Punjab state government decided not to renew the licenses for 5 out of 27 pesticides (benfuracarb, 2,4-D, monocrotophos, methomyl, and dicofol). Since 2011, Kerala has prohibited the use of certain of these pesticides (monocrotophos, carbofuran, and atrazine) due to concerns about public health[23].

PLANT-BASED BIO PESTICIDES

Punjab bans use of 10 insecticides for basmati crop

Chandigarh News

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Punjab government has issued directions to stop sale, stock and distribution of insecticides -- Acephate, Buprofezin, Chloropyriphos, Methamidophos, Propiconazole, Thiamethoxam, Profenofos, Isoprothiolane, Carbendazim, Tricyclazole, said agriculture minister kuldeep Singh Dhaliwal in a statement

These insecticides were being potential constraint in the export and consumption of rice, especially basmati rice, Punjab agriculture minister Kuldeep Singh Dhaliwal in a statement. (HT File)

Figure 1 : Recent highlights.[22]

Figure 2 : Picture showing how workers are spraying high pesticides without PPE kit, concerns human health.[23]

As sessile organisms, higher plants are challenged throughout their entire life cycle by many different stresses i.e., biotic and abiotic. Plants have no other ways of escaping attacks from their enemy organisms. So they must employ other strategies to defend themselves[24]. In addition to primary metabolites (e.g. Carbohydrates, lipids, and amino acids) higher plants are also able to synthesize a wide range of low molecular weight compounds called secondary metabolites. These compounds have no direct role in the maintenance of life processes in plants but rather have an important role in the interaction of plant with their environment[25].

Plants and insects have coexisted for at least 350 million years, plant has developed successful defensive traits[26] due to numerous diversities within plant chemistry, e.g., the ability to synthesize more than 200,000 estimated compounds referred to as specialized metabolites that have evolved in response to particular ecological challenges [27]. Thus, plants have evolved a large assortment of chemical defenses that cause an effective and drastic reduction in insect feeding[28].

Having knowledge of defensive phytochemicals, which belong to different classes of secondary metabolites such as alkaloids, saponins, terpenoids, etc. is important in terms of options to manipulate as an alternative to synthetic pesticides. Pesticidal pollution and its impact on soil, water, non-target organisms, human health, etc. is now a global issue of discussion. Due to synthetic insecticides, Integrated Pest Management is now facing challenges globally on the ecological and economic front, as it causes harm to humans and the environment. The sustainability of the agriculture systems collapsed, constant farmers' income, the cost of cultivation rises at a higher rate, and food security and safety were threatened due to the heavy usage of chemical fertilizers and harmful pesticides on crops.

For the identification of novel effective insecticidal components, researchers have paid much attention to the exploitation of plants. An idea or approach of shifting from chemical insecticides to botanical insecticides has emerged as a promising alternative for crop protection and integrated pest management. Bio-pesticides term defines as compounds from microorganisms, living organisms, or their products that are used for agricultural management of pests that are injurious to plants by nontoxic means. These biopesticides have the advantage of being less phytotoxic and more degradable in the environment[29]. Plants are a huge source for the introduction or discovery of new products with medicinal importance, anticancer, antimicrobial, antifeedant properties, etc.

Figure 3 : Biopesticides made from neem available in Amazon, an online shopping portal[30].

TO REDUCE INSECT PEST'S DEVASTATING EFFECTS: AN ANTIFEEDANT APPROACH

You might be thinking what antifeedant is. What do you do when you have hair fall, wrinkles, and aging problems? You, I guess use anti-hair fall, anti-wrinkles, and anti-aging products as many peoples do. Right!

These products reduce hair fall, wrinkles, and aging. Similarly, Antifeedant is a chemical that modifies behavior and prevents insects from feeding by directly affecting their taste organs. Instead of directly killing insects, most plant defensive compounds prevent insect herbivores by inhibiting larval growth, preventing eating and oviposition, or both. The search for antifeedants is our priority from an ecological point of view also.

According to Isman (2002)[31] antifeedants is a chemical that modifies behavior and prevents insects from feeding by directly affecting their peripheral sensilla (also known as taste organs). Instead of directly killing insects, most plant defensive compounds prevent insect herbivory by inhibiting larval growth, preventing eating and oviposition, or both.

The identification of potential deterrent compounds that may be isolated in large enough amounts or synthesized for use as crop protectants is one use of our understanding of plant defense chemistry. Despite the fact that the majority of antifeedants probably work by activating a deterrent receptor, this signal - which reads "do not feed"- is then sent to the feeding centre in the insect's central nervous system while some are hypothesized to block or otherwise obstruct the perception of feeding stimulants or others may generate irregular bursts of electrical impulses in the nervous system, preventing the insect from gathering relevant taste information on which it may base a proper feeding behavior. Studies have demonstrated a favorable correlation between the antifeedant activity of azadirachtin and the degree of neuronal reactivity of particular "deterrent neurons" in the taste sensilla on the mouthparts of lepidopteran larvae[32]. The insect's capacity to recognize plant chemicals will have an impact on how it behaves when it comes across a possible host plant. We still do not fully comprehend which taste receptors, which an insect uses to sense its food, are most crucial for allowing an insect to recognize antifeedants.

INSECT GROWTH REGULATORS: IT IS EFFECT ON INSECT POPULATIONS

IGRs are chemicals categorized as ecdysone disruptor agonists and juvenile hormone mimics. Due to their particular mode of action on insects and lesser toxicity toward vertebrates than standard insecticides, insect growth regulators such as juvenile hormone analogs appear promising in integrated pest management[33].

IGR may interfere in some way with the target pest's growth and development processes without necessarily killing the pests directly. It must occasionally be combined with adulticides to provide an instant knock-down effect because they take longer than conventional insecticides to diminish insect populations. It can be roughly categorized into three groups: (i) juvenile hormone analogues or mimics (ii) chitin synthesis inhibitors and (iii) others also encompass a variety of pharmacological classes with various modes of action[34]. These compounds delay transformation until the larva is completely grown and are produced in the corpora allata, tiny cell clusters found right below the brain in the majority of insect species. When the corpora allata are removed from young larvae, early puberty and the development of dwarfed adults result, whereas the implantation of the same organ into mature larvae delays or suppresses metamorphosis and results in the development of enormous forms[35].

For example 1: Methoprene (IGR) is applied topically to prevent cat flea eggs from hatching quickly, increase larval mortality, and finally cause aberrant pupae and adults to emerge. The residual ovicidal activity is supplemented by a knockdown effect on the adult population when used in combination with pyrethrin.

For example 2: Hydroprene (IGR) is most commonly used to manage cockroaches and pests in stored grain, either alone or in conjunction with permethrin.

CONCLUSION

The backbone of the Indian economy and the source of all food is agriculture. The productivity of agricultural crops is at risk by harmful organisms called pests such as insect pests, pathogens of crops, and weeds. The key foundation of the challenge is to protect agricultural crops from insect pests. Pest control and agricultural productivity greatly benefited from the introduction of various synthetic insecticides with the introduction of the green revolution. We witnessed the harmful side of agrochemicals. To reduce the burden of chemicals, we are moving towards safer and cheaper botanical insecticides. Antifeedants and Insect Growth Regulators are two approaches to controlling insect populations.

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