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AN ECO-FRIENDLY APPROACHES FOR INSECT PEST MANAGEMENT AND ENVIRONMENTAL

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Abstract
For decades, the control of insect pests has been cost millions to billions in agriculture, with synthetic insecticides being considered the most effective method for pest control. However, their overuse has caused harm to human health, the environment, and beneficial insects, while also fostering pesticide resistance in pests. Developing insect-resistant cultivars through conventional host plant resistance (HPR) is challenging, as it involves complex traits across multiple loci. Despite these difficulties, HPR remains essential for integrated pest management. Significant progress has been made in creating resistant cultivars for various crops, with gene transfer to suitable cultivars for different agro-ecosystems being crucial. Incorporating proteins from wild crop relatives and novel genes, such as those from Bacillus bacteria, can improve HPR. This approach can reduce pest damage, promote beneficial microbes, minimize pesticide use, and delay the development of insecticide resistance.

Keywords: Environmental Preservation, Insect Control, Host Plant Resistance (HPR), Pest Management, Agriculture

1. INTRODUCTION

Pesticide residues in food and food-related products, the return of pest problems, the rise of insect resistance, harmful effects on humans, and environmental contamination all result from the careless use of chemical pesticides [1]. Insects and pathogenic plants reproduce quickly, have fast generation times, possess broad genetic diversity, and can tolerate, break down, and avoid harmful substances [2]. Because of these factors, managing multiple pests with the chemical pesticides available today has become very difficult [3]. As a result, ecologically sound, socially acceptable, and financially feasible pest management techniques are critical. In general, chemical pesticides
(herbicides, fungicides, and insecticides) are quite successful at managing plant and insect diseases [4]. Farmers use pesticides more often and in larger quantities, which ultimately leads to failing control operations and rising environmental contamination [5]. In many countries, the overuse of pesticides has led to failures in pest control, forcing farmers to abandon the production of some crops [6]. Due to crop failures caused by damage by cotton bollworms (*Helicover paarmigera*), some cotton farmers in India have even turned to suicide. The number of insect species that are resistant to pesticides has increased exponentially because of widespread insecticide use [7,8].
A number of plant diseases that cause late blights and downy mildews in different crops have become resistant to the fungicides that are used to control them [9]. As a result, it is critical to prioritize nonchemical and alternative pest management strategies, including resistance to host plants (HPR) [10]. The best way to slow down the evolution of pesticide-resistant crop pest populations is to minimize the negative effects on organisms that are not targets, prevent environmental contamination, and to reduce the levels of pesticide residue in food and food products [11]. When plants were domesticated for use in agriculture, farmers chose plants that could endure the negative effects of the environment, such as sickness and insect pest damage [12]. Only resistant plants made it through the crop harvest, and most pest-susceptible plants were removed. Plants that could resist pest damage were naturally selected as a result of

this process [13]. Numerous crop plant landraces that farmers chose have genes that provide insect resistance. The best examples of this procedure are head bug-resistant guinea sorghums grown in West Africa and shoot fly-resistant sorghums (landrace variation Maldandi) grown in India during the post rainy season [14]. Additionally, landrace pearl millet cultivars that are resistant to rust and downy mildew are grown in Asia and Africa.

There are numerous instances of pest-resistant plants inhabiting wild species of different crops. Therefore, host plant resilience, natural enemies, cultural practices, and the selective use of pesticides should be the cornerstones of future pest management plans [15]. The creation of cultivars with insect resistance has not been as quickly embraced as that of disease resistance, despite the significance of HPR as a component of the Integrated Management of Pests (IPM) [16]. This is partly because using chemical insecticides to control insects is easy. However, interest in developing crop varieties that are resistant to diseases and pests has grown. This is due to the rise of insecticide-resistant insects, the harmful effects of pesticides on beneficial organisms, and the public's greater awareness of environmental pollution [17].

2. Progress in the Development and Deployment of Varieties Resistant to Insect Pests and Diseases

Crop improvement projects must produce crops that are feasible under current farm conditions and can deliver higher yields in upgraded or high-input environments. In poorer nations, cultivating pest-resistant cultivars is particularly beneficial for subsistence farming. An efficient resistancebreeding program requires a thorough understanding of the ecology and population patterns of plant diseases and insect pests, followed by the development and standardization of methods for identifying pest-resistant plants. Screening for insect pest resistance involves greenhouse screening, artificial infestation with laboratory-cultured insects or plant diseases, and delayed planting and use of infester rows of vulnerable cultivars [18].

The identification and application of agricultural germplasm for ICRISAT-mandated crop disease and insect pest resistance have advanced significantly. Numerous resistance locations to common illnesses and insect pests have been identified, and these resistances have been passed on to highyielding crop varieties. In many different crops, cultivars that are resistant to insects and diseases are available for Indian farmers to grow. Agricultural production to be sustainable in the future will require cultivars with multiple pest and disease resistance, necessitating a coordinated effort from scientists working on crop improvement initiatives [19].

3. Host Plant Resistance (HPR) in Integrated Pest Management

In insect and disease species, substantial plant resistance is useful for achieving the best possible management of target pests [20]. However, HPR in pest management does not require extremely high resistance levels. When used in conjunction with other pest management techniques, varieties that are resistant to pest damage or that have low to moderate resistance can be used. The goal of developing resistance to pest cultivars should be to reduce the need for pesticides and conserve natural enemies. The effectiveness of synthetic pesticides and other pest management techniques is also increased by the use of pest-resistant cultivars. One way to manage pests is through host plant resistant [21].

3.1.Host Plant Resistance (HPR) as a principal pest control method

Integrated Pest Management, plant resistance to diseases, and insect pests have more potential as a pest control strategy than any other form of pest suppression. Generally speaking, despite chemical and biological management, the use of pest-resistant genotypes is not influenced by natural phenomena [22]. The utilizing of pest-resistant cultivars has greatly aided the production of sustainable crops. One important factor in reducing losses from insect pests in pigeonpea, chickpea, and sorghum has been hosting plant tolerance well as sorghum infections [23].

The main successes in creating crop cultivars resistant to insect pests and illnesses have been the creation and introduction of downy mildew-resistant pearl millet, wilt-resistant chickpea, pigeon pea, and midge-resistant sorghum cultivars. Cultivars that are somewhat resistant to *Helicover pea* are found in pea and pigeon pea, shoots fly in sorghum, and diseases of the leaves in groundnut have been observed. The benefits of HPR depend on how serious the infestation is. For example, many insects, like aphids, whiteflies, and mites, as well as diseases, including foliar diseases, downy mildews, and wilts, infiltrate crops in small numbers and then increase in abundance over a few generations prior to achieving the threshold of financial levels. Even low degrees of resistance can help these pests postpone the time required for their levels to become harmful [24].

4. Compatibility of Host Plant Resistance (HPR) 4.1.Biological control

Biocontrol agents and plant tolerance to insects and diseases are complementary. The best varieties for pest management in conjunction with biocontrol chemicals are those exhibit moderate resistance. Within their host area, natural enemies lower the general frequencies of other insect pests and pathogens, facilitating the management of target pests. Due to a good balance between population numbers for both the pest of interest and the natural enemies, pest-resistant cultivars also increased the efficacy of the natural enemies. Insects that exhibit restless activity on resistant types are also more susceptible to natural adversaries. A long time spent in the immature stage makes the target pest more vulnerable to predators. It may also cause the insect's development phases to match the peak activity of its natural enemies [25].

The population dynamics of the bollworm, pod borer, Helicoverpa armigera are significantly affected by natural enemies in conjunction with moderate degrees of plant resistance in cotton, tomato, pigeon pea, and chickpea. By combining unrelated mortality factors, HPR and biological management can lessen the genetic response of the pest population to selection stress resulting from plant resistance or natural enemies. Together, they produce density-dependent mortality during periods of pest abundance and density-independent mortality during periods of low pest density. The selection pressure from natural enemies may increase the effect of resistant plants on insect density. This also includes both the direct and indirect effects of planting resistant varieties on insect pests [26,27] (Figure 1).

Figure -1: Plant Leaf Infected with Insect Pests

4.2 Cultural Control

Agronomic techniques that reduce pest damage and pest-resistant varieties, including those that can avoid insect harm, are very useful in pest control. This will affect the population dynamics of pest species just like the combined effects of insecticides and resistant crops would. For example, planting sorghum variety M 35-1 later in the post rainy (Rabi) season can greatly lower shoot fly damage. On the other hand, downy mildew, ergot, and rust infections are more common in diamond millet and sorghum when cultivars are planted later in the rainy season. By interacting with plant resilience, cultural control might help reduce losses, although it might not be sufficient to reduce pest numbers down to levels below the economic threshold. When combined with cultural control, plant resistance can significantly reduce the requirement for pesticide use [28].

To reduce the number of pests that affect the target crop, crop traps can be used to attract insects or other pets. Two ways to reduce pest damage are either keeping the pests from attacking the crop being studied or by isolating them in a specific area of the field so that they can readily eliminated. Crops that are particularly trapped under subsistence farming including some plants (e.g., sunflower in cotton, chick peas tomato, etc., to prevent *Helicoverpa* pod damage; and mustard in cauliflower and broccoli to reduce diamondback moths, *Plutella xylostella* harm). Sesame row strips, which cover 5% of the total area, can serve as a trap crop in cotton to lure Helicoverpa away from the main cotton plants. The presence of nutrients also influences how insect resistance develops. As more nitrogenous fertilizers are applied, the incidence of sorghum shoot flies declines, whereas the incidence of several foliar diseases rises. To reduce insect damage and maximize crop yield, care should be taken when applying the appropriate amounts of nutrients. Regarding plant infectious agents, trap crops can be used to detect their presence or to predict when a certain disease outbreak is likely to occur so that preventive measures can be taken [29]. Table 1 provides an overview of key strategies for enhancing host plant resistance (HPR) in pest management, highlighting different control methods and their applications.

Table: Strategies for Enhancing Host Plant Resistance (HPR) in Pest Management

Control Method	**Key Aspects**	**Examples**

Biological Control	Enhances pest resistant cultivars through biocontrol agents; natural enemies help regulate pests.	*Helicoverpa armigera* control in cotton, tomato, pigeon pea and chickpea.
Cultural Control	Agronomic techniques and resistant cultivars help minimize pest impact.	Late planting of sorghum type M 351 reduces shoot fly damage.
Trap Cropping	Uses specific crops to attract pests away from main crops.	Sunflower in cotton, mustard in cauliflower and broccoli.
Nutrient Management	Affects insect resistance through balanced fertilizer application.	Nitrogenous fertilizers reduce sorghum shoot fly incidence.
Integrated Approach	Combining HPR with cultural and biological control methods for sustainable pest management.	Reduction of pesticide use through resistant cultivars and biological agents.

5. Synthetic pesticides

Chemical pesticides are the most efficient way to get rid of pests immediately [30]. However, their wide-ranging mode of action also kills beneficial insects, which has a negative impact on the environment. In addition, they produce harmful contaminants in food and other food items due to their persistence and systemic nature. Using cultivars that are pests-resistant and applying pesticides sparingly are the two most popular integrated pest control methods. When combined with pesticides, even a moderately resistant cultivar can significantly reduce the number of pests. Additionally, plant resistance may increase the efficacy of pesticides by improving the spraying of plant components through the canopy, such as frego-bract in cotton and loose panicles in sorghum. Toxic compounds that negatively impact Insect growth and development or an unbalanced diet may make pets more vulnerable to chemicals. such as antimicrobial antibiotic resistance Helicoverpa in cotton, chickpeas, and pigeon peas. The open plant canopy makes it easier for parasites and predators to enter [31].

In conjunction with pesticides, a number of rice, cotton, sorghum, peanut, soybean, and vegetable cultivars have been used in integrated pest management [32]. Compared with susceptible cultivars that are resistant to insects, pigeon pea, chickpea, and maize cultivars use less insecticide. When combined with HPR, pesticides and resistant cultivars are more successful in reducing shoot fly harm in maize and bean borer damage in pigeon pea. Similarly, applying moderate amounts of fungicides to resistant or tolerant cultivars efficiently reduces plant diseases, extending their useful commercial life and safeguarding the environment [33].

5. Advantages of HPR over Environmental Conservation

HPR is a crucial control tactic for increasing crop productivity and preserving the environment.

Plant resistance is essential in pest management because of its specificity, cumulative impact on insect population density, persistence, compatibility with other pest control strategies, and environmental safety [34]. HPR targets only the intended pest or group of pests. It does not harm non-target organisms. The persistence of HPR is due to the majority of pest-resistant cultivars showing moderate to high sensitivity to the target pests, requiring repeated insecticide applications. HPR is also compatible with other pest control strategies and has no negative effects on people, the environment, or non-target animals [14]. Adoption is simple and doesn't require farmers to be familiar with the application methods. Table 2 summarizes the different types of resistance mechanisms in plants, highlighting their mode of action and examples.

Table 2: Types of Host Plant Resistance (HPR) Mechanisms and Their Examples

Resistance Type	Mechanism	Examples

Antibiosis	Affects pest development and reproduction	Bacillus thuringiensis (Bt) cotton, wheat resistant to Hessian fly
Antixenosis	Deters pest feeding and egg-laying	Hairy-leaved tomato varieties, sorghum resistant to shoot fly
Tolerance	Enables plants to withstand pest damage	Certain rice varieties resistant to brown planthopper

7. Limitations of HPR

Plant resistance is a method of pest management that can tackle insect problems. However, highperformance resistance (HPR) has limitations, such as time constraints and genetic restrictions. HPR is not suitable for immediate or localized pest issues, and it may not be effective if there is not enough susceptibility in the relevant germ plasma. Genetic transformation and interspecific hybridization can help address these limitations. The occurrence of different pest biotypes can restrict the use of certain varieties in specific situations. In such cases, it is important to continually search for new genes and introduce them into high-yielding cultivars. Conflicting resistance traits can also strengthen a plant's defenses against one pest while making it more vulnerable to others.

For instance, cotton hairiness makes the plant resistant to jassids, but bollworms prefer it for laying eggs. Soybeans with pubescence resist leaf hoppers, but capsule borers are attracted to them. Highresistance sorghum midge varieties are susceptible to stem borers, shoot flies, and head bugs.

6. CONCLUSION

Techniques for screening for insect resistance under artificial and natural infestations have significantly advanced. In order to screen and breed various crops for bug resistance, insect rearing facilities need to be set up. We need to find stable and varied sources of resistance or confirm the existence of new insect biotypes. multi locational screening of reported sources and material for breeding must be improved. Farmers should prioritize pest resistance as much as production when choosing new hybrids and varieties to cultivate. Insect-resistant cultivars have a continuous and cumulative impact on insect populations across time and place, do not harm the environment, lessen the need for pesticides, don't cost farmers extra, and do not require inputs or application expertise. In the future, insect-resistant plants will serve as the foundation of pest management initiatives for environmentally friendly crop production.

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