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Insecticide resistance in agricultural pests: Current scenario

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Insecticide resistance

Resistance is defined as the development of an ability in a strain of an organism to tolerate doses of a toxicant which would prove lethal to the majority of individuals in a normal (susceptible) population of the species (WHO, 1957). As per IRAC, insecticide resistance is defined as, 'a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species. Inheritance is one of the key characteristics of resistance and it generally involves alterations, mutations or other such aberrations in the genetic makeup of insects normally involving one or more genes.

Historical overview

Melander (1914) first documented resistance to insecticides in San José scale insects (*Quadrispidiotus pernicious*), which were found alive, under a "crust of dried spray" of sulphur-lime. Between 1914 and 1946, another 11 cases of resistance to inorganic pesticides were reported. In 1947, within a decade of the discovery of insecticidal properties of DDT, resistance in houseflies was reported. With the advent of time, the insecticidal activity of a very large number of molecules were discovered and were utilised against insect pests indiscriminately, ultimately leading to development of resistance to those pesticides in the insect populations within 2-20 years of their use. Wood and Bishop (1981) further highlighted the importance of resistance by quoting, 'It will probably never again be possible to achieve chemical control of insects on the scale achieved between 1945-1965'.

In India, singhara beetle (*Galerucellabirmanica*) was reported to be the first agricultural pest to be resistant to BHC and DDT (Pradhan *et al.*, 1963). Later on, the red

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flour beetle (*Triboliumcastaneum*) became the first stored grain pest to be resistant to DDT and Malathion (Bhatia, 1971).

Development of insecticide resistance

Overexploitation of plant protection agrochemicals has led to significant changes in the susceptibility status of insects. This problem is much more evident in the agricultural ecosystems where the insect pest populations are put under the pressure of pesticides much more frequently than other ecosystems. There are several mechanisms that lead to development of resistance to crop protection products in insects:

- **Metabolic resistance-** Resistant insects may naturally detoxify or destroy the toxin faster than susceptible insects, or quickly rid their bodies of the toxic molecules. The main drivers of metabolic resistance are esterase, glutathione S-transferase (GST) and mixed function oxidase (MFO) enzymes.
- **Altered target-site resistance-** The site where the toxin usually binds in the insect system may be genetically modified to reduce the product's effects. Due to this, the insecticide is not able to bind properly to the receptors and unable to produce the desired effects in the target insects. For example, modified acetylcholinesterase (mAChE)in *T.urticae*is major factor for resistance to carbamate and organophosphate insecticides.
- **Penetration resistance-** Resistant insects may absorb the toxin slower than susceptible insects. For example, the decreased penetration of DDT, dieldrin and permethrin in resistant *Musca domestica* populations was due to a gene termed *pen* (penetration) located on chromosome III.
- **Behavioural resistance-** Resistant insects may detect or recognize a danger and avoid the treated area. The insects may stop feeding on coming across some insecticides or leave the treated area. This type of resistance is reported in many classes of insecticides *viz.*, organochlorines, organophosphates, carbamates, synthetic pyrethroids, neem-based pesticides etc.

Resistance problem in agricultural pests

Agricultural pests are under constant pressure of crop protection chemicals, that is why the resistance build up in them is much more prominent. Earlier, the two spotted spider mites

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(*Tetranychusurticae*) were considered the most resistant arthropod but now the diamond-back moth (*Plutellaxylostella*) is the most resistant agricultural pest to insecticides with 980 reported cases of resistance against as much as 101 active ingredients (Table 1). Among the homopterans, *Bemesiatabaci*, *Myzuspersicae*, *Nilaparvatalugens*, *Aphis gossypyii*and *Phenacoccussolenopsis* are the most resistant pests of agricultural importance.

Resistance of agricultural pests to major groups of insecticides in use

The pesticide resistance problem has now been reported from almost all groups of insecticides. The most commonly used groups of insecticides *viz.*, organophosphates, carbamates, synthetic pyrethroids and neonicotinoids have exhibited the resistance development in a large number of insect species (Table 2).

Strategies for mitigation of insecticide resistance (Mohan *et al*., 2016)

- Integration of resistant management programme (RMP) with IPM
- Implement resistance prevention and management programmes with the introduction of new pesticides
- Consider alternative (non-chemical) pest management measures
- Use more than one class of pesticides preferably with different modes of action
- Apply only recommended pesticide and application rates
- Involve stakeholders
- Evaluate and refine the RMP as and when needed
- Use an integrated approach
- Protect beneficial organisms (predators, parasitoids and pollinators)
- Augment the spray schedule with unrelated compounds
- Use pesticide mixtures with caution
- Monitor problematic pests
- Developing and evaluating resistance breaking products

References:

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S. No.	Species	Order: Family	No. of cases	No. of Active ingredients

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1.	Diamond-back moth, *Plutellaxylostella*	Lepidoptera: Plutellidae	980	101
2.	American bollworm, *Helicoverpaarmigera*	Lepidoptera: Noctuidae	879	52
3.	Mediterranean climbing cutworm, *Spodoptera litura*	Lepidoptera: Noctuidae	690	42
4.	Sweetpotato whitefly, *Bemisiatabaci*	Homoptera: Aleyrodidae	673	65
5.	Beet army worm, *Spodoptera exigua*	Lepidoptera: Noctuidae	641	43
6.	Two spotted spider mite, *Tetranychusurticae*	Acari: Tetranychidae	551	96
7.	Pollen beetle, *Meligethes aeneus*	Coleoptera: Nitidulidae	518	27
8.	Green peach aphid, *Myzuspersicae*	Homoptera: Aphididae	477	81
9.	Brown planthopper, *Nilaparvatalugens*	Homoptera: Delphacidae	445	33
10.	Colorado potato beetle, *Leptinotarsa decemlineata*	Coleoptera: Chrysomelidae	300	56
11.	Melon and cotton aphid, *Aphis gossypii*	Homoptera: Aphididae	283	50
12.	White-backed planthopper, *Sogatellafurcifera*	Homoptera: Delphacidae	216	15
13.	European red mite, *Panonychusulmi*	Acari: Tetranychidae	203	48
14.	Cotton mealybug, *Phenacoccussolenopsis*	Homoptera: Pseudococcidae	199	26
15.	Western flower thrips, *Frankliniella occidentalis*	Thysanoptera: Thripidae	175	30

Table 1. Top 15 insecticide resistant agricultural pests

Source: Mota-Sanchez and Wise (2021)

Table 2. Resistance status of agricultural pests to major groups of insecticides

S. No.	**Insecticide Group**	**IRAC MoAClassfication**	**No. of species reported to be resistant**	**Some important pests**
1.	Carbamates	1A	81	*H. armigera, S. litura, M. persicae, F. occidentalis, N. lugens*
2.	Organophosphates	1B	196	*M. persicae, H. armigera, S. litura, L. decemlineata, P. xylostella, T. urticae*
3.	Pyrethroids, Pyrethrins	3A	175	*B. tabaci, Cydiapomonella, Eariasvitella, F. occidentalis, H. armigera, P. xylostella, S. litura, S. exigua*
4.	Neonicotinoids	4A	30	*A. gossypyii, B. tabaci, M. persicae, N. lugens, Diaphorinacitri*

Source: Mota-Sanchez and Wise (2021)