Importance of Pesticide dose in Pest management

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In our daily life, whenever we get ill and visit medical doctors, they recommend some medicine in some amounts, which we call a dose. If we follow the proper dose with precautionary measures, we recover soon. Likewise, there is also an importance of recommended dose for pest management in plant protection, which has often been overlooked by farmers in their agricultural fields. Most of the time, farmers apply insecticides higher than the recommended dose to get quick results. Though it brings temporarily immediate effects, it results in the resistant pest population, pesticide residue, and environmental pollution in the long run. It can be well understood from the ever known example of heavy use of DDT in the last century. It's immoral and wrong use negatively impacted the environment with many drawbacks. Among these, environmental pollution, residue, and resistance are significant. The famous book Silent Spring, during1960-70s, was given an alert for its negative impact on the environment. In India 2017 there was Yavatmal poisoning in Maharashtra, leading to severe health issues due to food poisoning. After investigation, it has found an active ingredient diafenthiuron. Presently, there are around 20 topmost resistant species of Arthropods all over the globe. Two-spotted spider mites, diamondback moth and green peach aphid, are on top of the list. They have been found resistant against 94, 92 and 76 active ingredients of pesticides, respectively. In India, three insects have found resistance against different active ingredients of insecticides in 2021 (Table 1). Ultimately, it has created a loophole in the food web, which is not acceptable for upcoming generations on this planet.

In the last few decades, careless use of pesticides without adhering to the safety norms and recommended practices posed severe health risks to humans, other living organisms, and the environment. The release of chemicals into the soil, water and air has led to pollution almost in the whole biosphere. Nowadays, consumers are more concerned about their health and safety, for which they are purchasing commodities that are free from pesticides residue. Food agencies are also prioritising those food products with minimum pesticides residues or switching over to organic food.

The Dose

The dose can be well understood by the famous line of Paracelsus known as Father of toxicology that "What is there that is not poison? All things are poison, and nothing is without poison. Solely the dose determines that a thing is not a poison". It shows how a slight change in a particular thing may bring no effect or may bring harmful effects to your body. Only the exact amount (Dose) can keep you in the perfect stage. The same thing can also apply in pest management as recommended dose. Some authentic authority has generally given it for specific pest management under various environmental conditions. In toxicology, a median lethal dose confers the suppression or killing of 50 per cent of the pest population in the field. In calculations, we generally compute up to Lethal concentration 99 (LC99) to check its maximum limit for 100 per cent population. Practically, we aim to suppress the pest population but not eliminate them from the environment. Therefore, most pesticide products use labels and booklets to provide instructions for proper application, including places and environmental conditions in which the product should not be applied. Suppose a farmer follows the same as above. In that case, it results in proper control with no adverse effect on crop and no residue and pollutant in harvested products and environment, respectively. Surprisingly, Rao *et al.* (2009) survey from India and Nepal reported a considerable gap in actual applied and recommended doses. The majority of the farmers initiate plant protection based on the first appearance of the pest, irrespective of their population, crop stage, and damage relationships. Hence, considerations must be given over the above mentioned parameters

for effective pest management without altering the ecosystem health.

To standardize the dose, there is an insecticides bioassay. It determines the relationship between the amounts (dose) of insecticides administered and the magnitude of response in a living organism. If toxic effects, i.e. death, result from insecticides, there must be a positive correlation. This relationship is known as the dose-response relationship. There is DDPQS (Directorate of Plant Protection, Quarantine and Storage) for this dose fixation and monitoring in Faridabad, Haryana. It has six divisions in which Central Insecticide Board (CIB) play a crucial role in fixing the recommended dose in any crop against pest in India. They are also used to check the susceptible and resistant pest population by diagnostic and discriminating doses. Diagnostic doses are used to determine the baseline susceptibility of pest against insecticides, while discriminating doses are used to differentiate the susceptible and resistant population of insects against insecticides.

Impact of inaccurate dose

The inaccurate dose is anything above or below the recommended dosages, i.e. overdose and sub-lethal dose, respectively. There are so many harmful effects of inaccurate doses in crop fields, but here we have described the most important effects under the following headings (Figure 1).

1. Resistance in pest population

In the current scenario, resistance to synthetic insecticides is critical problem farmers face in several parts of the world. It is a measurement of an insect's ability to tolerate the toxic effects of a particular insecticide, resulting in the repeated failure of the product to achieve an effective level of control when used according to the label recommendations (Luckmann and Metcalf, 1982). It is the first time Melander (1914) reported in San Jose scale against lime sulphur. Most of the sucking pests have developed biotypes in India against different insecticides.

It is a selection pressure of insecticides on insect pests of agricultural crops to evolve resistance. In selection, pressure dose can influence the mechanism of evolved resistance to the pesticide. Higher doses favour target site resistance, while sub-lethal doses favour other mechanisms, *e.g.* pest resurgence due to hormoligosis. In general, the insect population of crop fields has a cluster of genetic traits that result in susceptibility or competitive advantages in the natural world. When selective pressure is placed on a population against insecticide, individuals predisposed to it effectively mitigate the toxic effects, survive and pass it to their genetic material. The offspring of those resistant individuals then can have the same genes resulting in resistance. Continued exposure of subsequent generations to the same types of insecticides results in a continual increase in the number of individuals with the genetic advantage of resistance to that insecticide. To manage resistant populations, one could use the different chemicals with different modes of action in alternative ways with their accurate dose. Before chemical control, one should check target pest species' economic threshold and status and opt for some IPM based techniques. It makes your food and environment free from pesticides residue and its pollutant.

2. Pesticides residue

When a crop is treated with pesticides, a minimal amount of the pesticides and their metabolites can remain until after they are harvested, called pesticide residue. It will have many harmful effects on all living organisms. At present, among agriculture commodities, fruit and vegetables are recognized as the top categories that contain the highest pesticide residue compared to others due to consuming them in a raw form. Hence, food control is necessary to monitor pesticide residues in food commodities before introducing them into the market and official directions established by authorities to regulate it. In most cases, when pesticides are applied in the crop fields, a tiny portion of the pesticide has reached the target. For example, Pimentel and Berguss (2012) stated that only 50 per cent of applied pesticides are estimated to reach their target pests. However, the remaining pesticide content accumulates in the different environment components and leads to a residue.

3. Environmental pollution

Environmental pollution is the result of using the overdose of pesticides and from multiple activities of humans during pesticides application itself. After pesticide usage, the empty containers are usually buried inside the soil by the practitioner, but chemical remnants ultimately spoil the ground. All modes of application, either as an aerial spray or from foliage to directly soil

applied, large amounts of pesticide eventually reach the soil, which degrades both biotic (beneficial microbes) and abiotic properties of soil. The improper timing, direction of spray, wind speed, type of spray *etc.*, during pesticide applications contributes to environmental pollution. Applications during the afternoon time usually promote volatilization. Volatilization evokes toxic content into the atmosphere. Against the wind direction and high wind speed, usually more than 8 km promotes off-target drifts. It affects the micro-biota and population of beneficial insects in the surrounding area. These all activities promote the concentration of toxic contaminants in the environment. These cumulative effects lead to bio-magnification in food chains, for which at now, humans do not have any alternative.

Farmer's role

The most trending popular and sustainable strategy is integrated pest management in the recent past. Farmers have to follow schedule based approaches to control crop pests. From pest monitoring to risk assessment, farmers can employ several tactics like cultural, physical, mechanical and biological methods to control the pest at initial levels. Besides this, biorationals like semiochemicals and insect growth regulators are now in trend for effective pest management. However, their non-availability in the market is limiting for their successful use. Ultimately chemical control can be employed as the last sort of measure in IPM. Farmers can use novel insecticides with very low dose requirements and minimal side effects.

Future prospects

From recent past, most trending popular and sustainable strategy is integrated pest management. Farmers have to follow schedule based strategies to control crop pests. Starting from pest monitoring to risk assessment, farmers can employ several tactics like cultural, physical, mechanical and biological methods to control the pest at initial levels. Besides this biorationals like semio-chemicals and insect growth regulators are now in trend for effective pest management. However, their non availability in market is a limiting factor for their successful use.Ultimately chemical control can be employed as the last sort of measure in IPM. Of which, farmers can use novel insecticides which have very low dose requirement and without much side effects.

Conclusion

In the present era, chemical control is the most adopted strategy among farmers. However, awareness among farmers for protecting themselves and the environment from pesticides hazard is still lacking. Their knowledge of recommended dose is very little. For which, creating awareness on improved formulation, dosage calculations, frequency, and application methods is highly necessary. From the setting of recommended doses by pesticide manufacturers to the implications for the evolution of pesticide resistance and non-target toxicological impact is quite complex. The adverse effects of pesticides are well documented. Nevertheless, to increase the farmers' knowledge about pesticide and their hazards associated with pesticides, one should develop and implement pesticide safety education and certification programs for farmers. They should be trained against pesticides' risks and understand the pesticide regulatory framework.

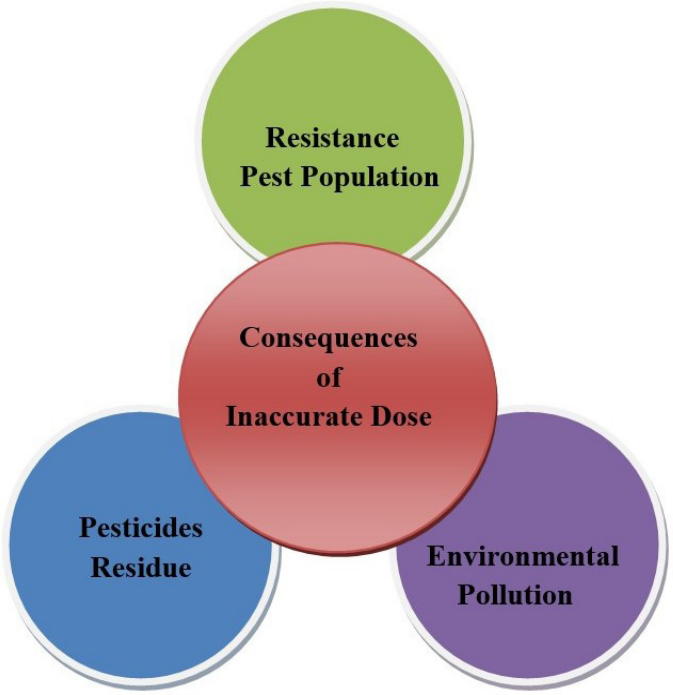

Fig. 1. Harmful effects of inaccurate pesticide dose in crop fields.

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Table 1. Resistant insect in India against different insecticides during 2021 (Source: APRD)

Sl. No.	Insect Name	Family -Order	Cases	Active ingredient	Group
1	*Hyposidra talaca*	Geometridae: Lepidoptera	4	Bifenthrin, Deltamethrin	Agriculture
2	*Plutella xylostella* (Diamond back Moth)	Plutellidae: Lapidoptera	60	Chlorantraniliprole, Cypermthrin, emmamectin benzoate, Fipronil, Flubendimide, Indoxacarb, Novaluron, Spinetoram, Spinosad	Agriculture
3	*Sitopilius oryzae* (Rice weevil)	Lionidae: Coleoptera	1	Deltamethrin	Agriculture

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