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Review

Scope and Relevance of using Pesticide Mixtures in Crop Protection: A Critical Review

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Abstract

Development of resistance and resurgence has limited the application of single pesticide and has given way out to tank mixture. Pest management strategy is mainly relying on chemical pesticides. Mixture of two or more pesticides is very common among the farmers. Pest population to be controlled should be susceptible or have low level of resistance to each pesticide used in the mixture. Combination products have synthetic pyrethroids as one of the component to which cotton boll worm has high level of resistance. Mixtures if permitted may be used as a matter of routine and there might be development of multiple resistances in insect pests. A mixture may give best control of complex pests with varying susceptibilities to the different components of the mixture. Pests that are resistant to one or more pesticides may be susceptible to a combination of toxicants and synergism may be exhibited by the components. How best these mixtures can be utilized to overcome the problem of resistance and how can such mixtures is screened for crop protection is our concern.

Keywords: Resistance, Resurgence, Combination Product, Mixture, Pest population, Pesticide.

INTRODUCTION

Applying a tank mix of pesticides, or a pesticide and a liquid fertilizer, can save time, labor, energy and equipment costs. Pesticide combinations usually alter plant absorption and translocation as well as metabolism and toxicity at the site of action of one or more of the mixed products. Not all changes are for good. Negative effects can occur such as reduced pest control, increased damage to non-target plants, phyto-toxicity and incompatibility problems between materials (Regupathy and Ramasubramnian, 2004). In the wake of the realization that, due to the use of single pesticide molecule resistance development has already occurred. So if we utilize the existing product then it will be better. But development of newer pesticidal molecules is scanty, so a judicious use of the existing products has assumed significant importance (Rodriguez et al., 2002). Furthermore, the problem of pest resistant has necessiate a rethinking on the manner of their formulation and use. Pesticide mixture is one of the promising options that have come to the force. It has potential to increase the commercial lives of pesticide through their use in combinations, by complementing the bioefficacy of the individual products and simultaneously lowering their use pressure on the one hand and broadening the spectrum of activity and overcoming pest resistance to individual pesticide, on the other (Anonymous, 1989).

Need for Pesticide Mixtures

A pesticide mixture is when two or more pesticides (in this case, insecticides and/or miticides) are combined into a single spray solution. A pesticide mixture entails exposing individuals in an arthropod (insect and/or mite) pest population to each pesticide simultaneously. Pesticide mixtures may be more effective against certain life stages including eggs, larvae, nymphs, and adults of arthropod pests than individual applications although this may vary depending on the rates used and formulation of the pesticides mixed together. Development of newer pesticidal molecules is scanty (Mosinski, 1998). Use of the existing products creates the problems of pest resistance. Pesticide mixtures have promising option that has the potential to increase the commercial lives of pesticides through their use in combinations, lowering their selection pressure, broadening the spectrum of activity, simultaneously control two pest species, overcoming pest resistance to individual pesticide.

Pesticide Mixtures

Mixtures of pesticides (herbicides, fungicides and/or insecticides) usually added together at lower than label recommended rates to produce better overall performance against a variety of problems. Combination products or pre – combination mixes are products constituted by mixing two or more compatible pesticide molecules in the right concentration. Proportion of one component is relatively higher than the other. Figure 1.

Scope for Pesticide Mixtures

Pre combination mixture if permitted may be extended to botanicals and other insect growth regulators, defeating very purpose of developing neem and bio-rational compounds. New combination will guide the pesticide industry for further development of proper ready mixture formulation (Mosinski, 2001). Testing of combination products can be taken for generating data and may be recommended after evaluating the development of resistance

Guideline for Evaluating Pesticide Mixtures

Pest population to be controlled should be susceptible to each pesticide used in mixture. Target pest should exhibit no cross resistance to mixture. Mixture should have significant potential effect to reduce dosage. Mixture should have low mammalian toxicity. Permission may be given for evaluating mixture of pesticides belonging to different categories (Anathakrishnan, 2006).

Tank Mixtures

Tank mixing may be defined as ingredients mixing in the field directly by farmers who have little time before spraying. Mixed components may not be compatible which leads to separation, flocculation, agglomeration and coagulation of the ingredients and results in performance problems. Amount of diluents in tank mixture increases when two formulations are mixed in the field (Ahmad *et al.* 2008). It possesses more bioefficacy and additive action, kills the pest in shorter period, minimizes chemical cost, saves labour cost and saves cost of packaging (Walung and Scott, 2003).

Pre-Packed Mixtures

It is scientifically developed and tested products based on compatibility. Final product is a 'ready to use' material. It combines two or more pesticide ingredients or formulation before marketing exists in a single phase system or as multi-phase system. Two pesticide formulations are present, Indian market, multi pesticide formulation- up to six a.i. in European market. Pre packed mixture classified into two categories like, low risk mixture- for Chewing and Sucking pest. One of the compounds is effective against chewing insect and also interferes with the normal physiology of sucking pests making them more susceptible to the other compound which is specific against sucking pests and high risk mixture- for same type of insect sp.

Consideration for Proper Use of Insecticide Mixture

Pest population to be controlled should be susceptible or have low levels of resistance to each insecticide used in mixture. It should not have cross-resistance to population of resistant pest concerned (Attique *et al.,* 2006). The insecticide mixture should delay the development of resistance. Mixture selected should have significant synergism to reduce the selection pressure of pesticide to pest.

Compatibility of Pesticide Mixtures

Compatibility of all components is a pre-requisite for developing ready to use mixtures. Physical compatibility includes; formation of agglomerates or crystals, phase separation of emulsions or suspensions, thickening of spray liquid, appearance of any type of extraneous matter in the combination products, melting and boiling points, volatility and solubility influence the overall physicochemical properties and performance of the mixtures. On the other hand chemical compatibility includes photochemical, thermal stability of ingredients of mixture, hydrolytic stability of ingredients of mixture etc (Blumel and Gross, 2001). Bio compatibility includes nature of joint action (synergistic / antagonistic) of the formulation. Phyto compatibility includes non-phytotoxic action on the plants to be spread and mixture should not adversely influence phytocompatability of individual component. Toxicological compatibility includes indexed by lack of undesirable effects on the useful non-target organisms, mammals and environment, environment.

Action of Pesticide Mixtures

Pesticide mixture act in four ways. First, similar action; two components in a mixture act independently but produce similar effects whether they are applied as a mixture or alone, e.g. quick acting property + residual toxicity. Additive effect in which combined effect of two chemicals is equal to the sum of the effect of each component given alone (1 + 3 = 4). Second,

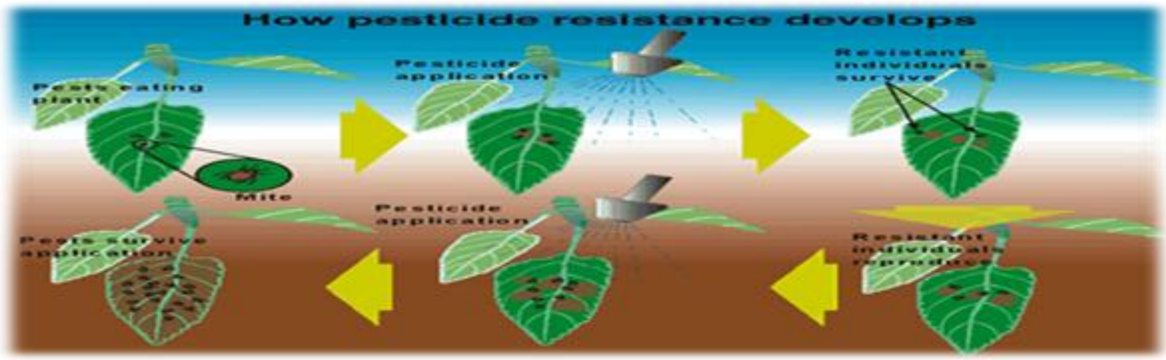

Figure 1. Development of pesticide resistance in system

independent action; two components are different and independent in action *i.e.* no synergistic effect, behave independently with one another. E.g. Herbicide co-occurs with an insecticide. Methyl parathion and 1% Sesamex – against housefly. Third, synergistic action; toxicity of the mixture is greater than that of the sum of the individual components, combined effect of two chemicals much greater than the sum of effects of each component given alone (1 + 3 >>> 4). Referred to as synergism or activation. Eg. 1% Sesamex + Phosphate containing amino groups. E.g. Piperonyl butoxides as synergist for pyrethroids. Fourth, antagonistic action; One component in a mixture reduces the activity of the other in the mixture.Two chemicals administered together interfere with each other's actions or one interfere with the action of the other (2 + 3 < 5). Eg. Thionophosphate compound + Sesamex. Eg. Aldrin and parathion (Lash, 2007; Parmar and Tomar, 2004). Table 1-3.

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Advantages of Pesticide Mixture

Mixtures delay the resistance development. Mixtures of Fenvalerate and Sumithion, for 14 generation, delay resistance development of *Myzus persicae.* After 14 generations of selection the level of resistance fenvalerate developed 52.6- fold, sumithion 11.1-fold, mixture developed only a 3.5-fold resistance. Figure 2.

Pesticide mixture has broad spectrum of activity, control more than one pest or pest species, synergistic joint action, economic pest control, lower quantity as well as cost, reduced application cost, saving time, less number of spray, safe to farmer’s health and environment.

Mixtures Delay Resistance Development and Increase Efficacy

Mixtures of two or three insecticides, for 20 generations. Mixtures of cyhalothrin, phoxrin and parathion-methyl development resistance very slowly. Figure 3.

In contrast, development resistance rapidly in *Helicoverpa* exposed with only one insecticide. Single insecticides, the control efficacy - 6-15%. Two-insecticide mixtures control efficacy - 41-65%.

Proper Mixture Effective Controlling Mite

Mixtures of OP’s + pyrethroid better for two spotted spider mites *(Tetranychus urticae)* than Banks grass mites *(Oligonychus pratensis).* Mixture of dimethoate and bifenthrin with amitraz or piperonyl butoxide. Caused 52.7 to 94.7-fold increases in toxicity against the two spotted spider mite (Raymond, 2011).

Proper Mixing Procedures

1. Wettable Powders (WP) then Flowables (F, DF)
2. Agitate then add adjuvants such as anti-foaming compounds, buffers

Table 1. Formulation of Combination Pesticide (Insecticides)

Combination Product	Combination Product
Carbaryl 4% + Gamma BHC 4% Gr.	Deltamethrin 1% + Triazophos 35% EC
Phosalone 24% + Cypermethrin 5% EC	Profenofos 40% + Cypermethrin 4% EC
Cypermethrin 3% + Quinalphos 20% EC	Chlorpyriphos 50% + Cypermethrin 5% EC
Acephate 5% + Imidacloprid 1.1%	Imiprothrin 0.1% + Cyphenothrin 0.15%
Acephate 25% + Fenvalerate 3% EC	Chloropyriphos 16% + Alphacypermethrin 1% EC
Ethion 40% + Cypermethrin 5% EC	Propoxur 0.25% + cyfluthrin 0.025% Aerosols
Cyfluthrin 0.025% + Tranfluthrin 0.04%	Deltamethrin 0.75% +Endosulfan 29.75% EC
Acephate25%+Fenvalerate 3%EC	Methyl bromide 98% + chlorpicrin 2%

Table 2. Formulation of Combination Pesticide (Herbicides)

Herbicide mixture	Trade name	Crop	Weed killed
MSMA + Barban	-	Wheat	Wild oats and green foxtail millet
Atrazine + Metolachlor	-	Maize	Most of the weeds
Dicamba + MCPA	Diamet – D	Wheat	Monocot & dicot weeds
2, 4-D amine + Dicamba	Dialem	Wheat	Effective on weeds, resistant to 2,4-D
Mecoprop + Dicamba	Diaprem	Wheat	Effective on weeds, resistant to 2,4-D

Table 3. Insecticide-Herbicide Interaction

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Carbaryl 4% + Gamma BHC 4% Gr.	Deltamethrin 1% + Triazophos 35% EC
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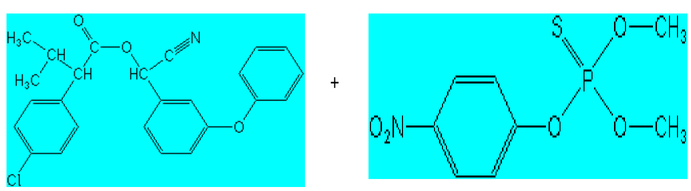

Figure 2. Synergistic interaction of Organo-Phosphorus insecticide

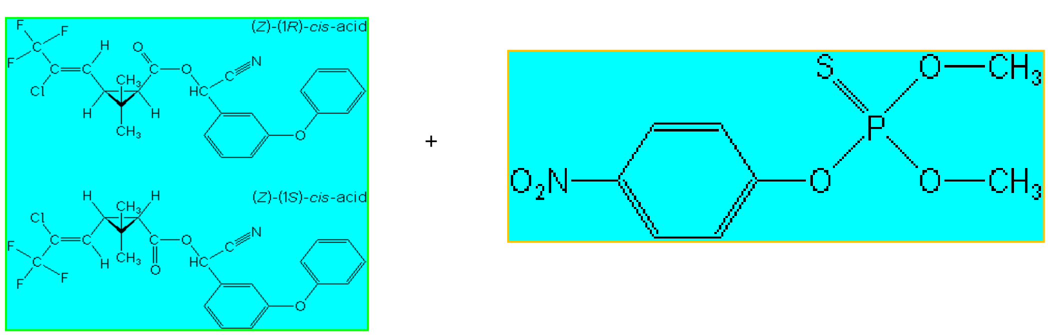

Figure 3. Antagonistic interaction of Synthetic Pyrithroids insecticide

3. Liquid and Soluble products
4. Emulsifiable concentrates (EC)
5. Surfactants

Limitation

Analysis of a.i. in multi pesticide formulations is a difficult task. Some limitation are product, toxicology, undesirable additive effect in mixture, spectrum of mammalian toxicity altered, non availability of antidotes for mixture, accidental intakes become unmanageable.

Relevance of Pesticide Mixture

Pest populations are susceptible or have low levels of resistance. Mixture exhibits no cross-resistance to populations of resistant pest. Significant synergism is needed to reduce the selection pressure of pesticide. One of the tactics for resistance management strategy is it lowers mammalian toxicity of mixtures.

CONCLUSIONS

Pesticide mixtures should be compatible with each individual component. It should have additive or synergistic action. Multi-pesticide formulation need to be developed. It should delay the resistance development. It increase efficacy and should have broad spectrum activity. It should avoid undesirable additive effect and spectrum of mammalian toxicity. Antidotes for pesticide mixtures are required /needed. Pesticide mixtures will continue to be an integral component of pest management programs due to the continual need to deal with a multitude of arthropod pests associated with ornamental cropping systems. The use of pesticide mixtures to mitigate resistance must not divert attention from the implementation of alternative pest management strategies including cultural, sanitation, and biological control that can reduce reliance on pesticide mixtures and mitigate pesticide resistance.

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