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Review on protagonist role of ready-mix insecticides in management of horticultural insect pests

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Abstract
Insect pests can cause significant damage to horticultural crops, leading to reduced yields and economic losses for farmers. Ready-mix insecticides have become a popular solution for controlling these pests, as they offer several benefits over traditional insecticides. Ready-mix insecticides are formulated with active ingredients that target specific pests, making them highly effective in controlling insect populations. They are also available in various formulations, including sprays, dusts, and granules, making them convenient and easy to apply. One of the advantages of using ready-mix insecticides is their ability to control a wide range of insect pests. These pests include aphids, whiteflies, thrips, and mites, among others. In addition, some insecticides have residual activity, meaning that they continue to control pests for a period even after the initial application. The use of ready-mix insecticides in horticultural crops has several benefits, including reducing crop damage and increasing yields. They also save farmers time and money as they do not need to mix different insecticides themselves. However, it is important to use these insecticides with caution to avoid overuse, which may lead to the development of pesticide resistance in pest populations. In conclusion, ready-mix insecticides play a leading role in the control of insect pests in horticultural crops. They offer an effective, convenient, and affordable solution to farmers while also contributing to the sustainable management of pests. As with all pesticides, farmers should follow recommended application rates and practices to maximize the benefits of these insecticides while minimizing potential risks.

Keywords: Insecticide, mixture, ready-mix, residue, toxicity, yield

Introduction

- India is the leading country in the production of horticultural crops and we all are know the importance of horticultural crops and its products.
- There are vagaries of insect pest that are attack on these crops and our plant protection groups our main concerned is to save the crops from this situation.
- The pest management strategy in India is mainly relying on chemical pesticides.
- The quick and effective management of pests by insecticides convinces the farmers against the non-chemical methods of pest management.
- More often insecticides proved the only solution to combat a sudden outbreak of pests.
- The lack of knowledge in these aspects, led the Indian farmers to use insecticides indiscriminately. However, its indiscriminate use leads to the problem of 3R's i.e., resistance, resurgence and residue. This has limited the application of single insecticide and resort to ready-mix insecticides (Das, 2014) [6].
- Enhancement of crop production can be achieved only by the application of new pesticides. Ready-mix formulations are cost effective and have high efficiency of controlling the pest as compared to single insecticide. The pre-combination pesticide mixtures appear to be advantageous than single compound or tank mixtures since these give broad spectrum of activity, additive joint action, economic in pest control and application, multiple mode of action and overcoming delayed resistance to pesticides (Dharumarajan, 2009).

❖ What is ready-mix insecticide?

- Ready-mix insecticide is a combination of two insecticides having different mode of action into a single spray solution which expose insect pests to each insecticide simultaneously in readily available form. (Cloyd, 2011) [5].
- A mixture may give best management 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 3R's and how can such mixtures be screened for crop protection is always remained a cause of concern (Cloyd, 2011) [5].

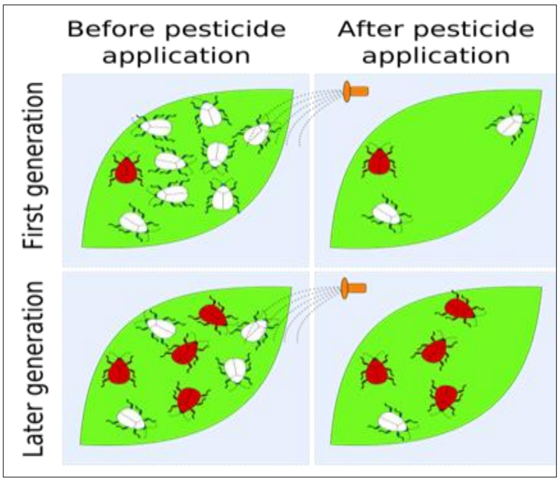
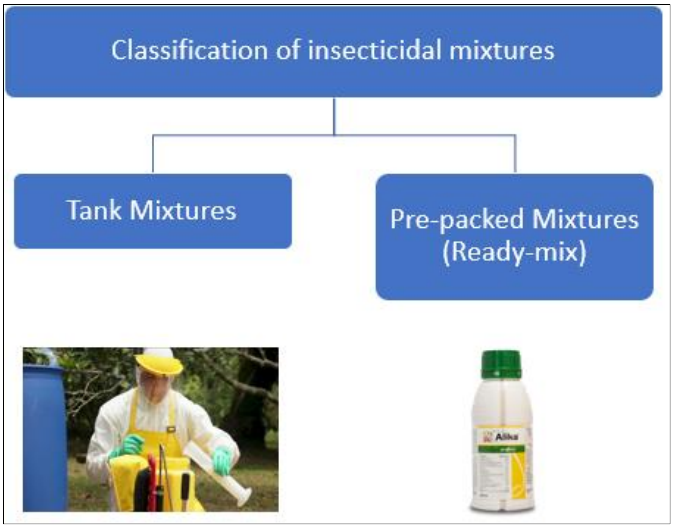


Fig 1: How to develop the resistance in the insect.

❖ In the first generation, before the application of pesticides, there is a large population of susceptible insects, which is denoted by the color white, and a small population of resistant insects, which is denoted by the color red, and some insects that do not die after pesticide application, and then they interbreed within the remaining resistance and susceptible populations, and later generations, their resistance population increases when the same single pesticide is used repeatedly by developing resistance. This problem can be mitigated by using ready-mix insecticides, because these mixtures contain two insecticides with different modes of action, causing resistance to be delayed (Fig. 1).

❖ **Classification of insecticidal mixtures**



Insecticidal mixture can be classified into two type: 1. Tank mixture and 2. Pre-packed mixture (Ready-mix)

1. Tank mixtures

- Insecticides are mixed in the tank directly by the farmers without knowing its compatibility so that sometimes after mixing this chemical reduce the efficacy, phytotoxicity of mixture may arise and residual problems also developed.
- Physical incompatibility - mixture may curdle, precipitation of flakes, crystals, gel or become sludge like.
- Chemical incompatibility - a chemical reaction takes place and produces new substances.
- Clogs equipment, pumps and tanks.

Here, we can clearly see in this photograph farmers are mixing two insecticides without knowing is effect and compatibility of mixing these chemicals. So that reduce these problems which are arise in the tank mixture we can use ready-mix insecticides instead of tank mixture.

2. Pre-packed mixtures (Ready-mix)

- It is scientifically developed and tested product based on compatibility.
- Final product is "ready to use" material.
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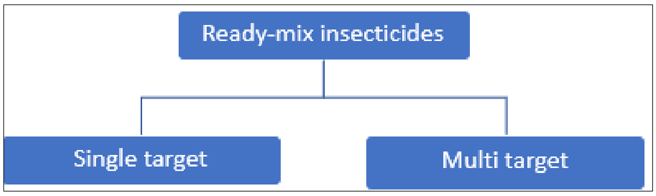


Here, ready-mix insecticides also two types:

1. Single target

✓ Control same type of insect species and biological stage.
✓ Target population is fully susceptible to all toxicants in the mixture.
✓ E.g. Novaluron 5.25% + indoxacarb 4.50% SC use in tomato crops we control only chewing type of insect like fruit borer.

2. Multi target

✓ Used **against two different insect pests** such as **chewing and sucking** individuals.
✓ One of the compounds - effective against chewing insects + interferes with the normal physiology of sucking pests making them more susceptible to 2nd compound
✓ 2nd compound -specific against sucking pests.

✓ E.g. Beta cyfluthrin 8.49% + imidacloprid 19.81% OD use in brinjal crops we control sucking and chewing type of insects because imidacloprid control the sucking insects and beta-cyfluthrin control chewing type of insects. So that we can control both type of insects simultaneously in single spray and no need to spray individual.

❖ **Significance of ready-mix insecticide**

- Reduce resurgence of pest.
- In ready-mix insecticides chances for the development of cross resistance is less or it may take long time.
- Ready-mix insecticides benefit for IRM (Insecticide Resistance Management) when appropriately incorporated into rotation strategies with additional mode(s) of action.

Mechanism of ready-mix insecticides

After knowing types and significance of ready-mix insecticides, question may arise. On which mechanism ready-mix insecticides are perform/ works?

Antagonism	• Combine effect of two or more compounds is less toxic than the individual effects	2 + 2 < 4
Additive effect	• Combined effect of two or more chemicals is equal to the sum of the effect of each agent given alone • Do not interact in a direct way • Most common	2 + 2 = 4
Synergistic effect	• Combined effect of two chemicals is much greater than the sum of the effects of each agent given alone	2 + 2 > 4
Potentiation	• Toxic substance added to toxic chemical making second chemical much more toxic	2 + 2 >> 4 (10 times or more)

When any two chemicals are mix some effects are produced like antagonism, additive, synergistic, and potentiation. Among these four types any mechanism is perform. But here another question may arise among these four types which mechanism are present in ready-mix insecticides. The answer is potentiation action.

❑ **Potentiation action**

➢ **Combined effect of two chemicals is much greater than the sum of effects of each component given alone** (Das, 2014) [6].

(2 + 2 >>> 4)

E.g. Synthetic pyrethroids (enhances activity of OP) + OP compounds

Here, when two insecticides are mix potentiation effects are happened increase the effect of both the insecticides in mixture than then the individual one. After knowing the mechanism of ready-mix insecticides, we will see the mode of action of ready-mix insecticides.

Mode of action (MoA) of ready-mix insecticides

Here, we will see the two mixtures and how these mixtures work when two insecticides are mixed. So, in the first mixture, we use synthetic pyrethroids and organophosphate insecticides.

- In the normal physiology of insects, after entering the action potentials in the pre-synaptic neuron region, acetylcholine is released in synaptic gaps and then after this join or bind on the receptors that are present in the post-synaptic region of the neuron and signals are passed to the next neuron. After passing the signals, acetylcholine esterase enzymes are released in the synapse gap and break down the acetylcholine binding on the receptors, which stops the signals. So, that insect is in normal condition, but in the presence of our organophosphate (OP's) insecticides, the Ach esterase enzymes bind with the acetylcholine so that these enzymes do not break down the acetylcholine, so that with the continuous passing of signals, insects are overexcited, and due to this mechanism, insects may die. This mechanism is clearly depicted in the image below (Fig. 2).

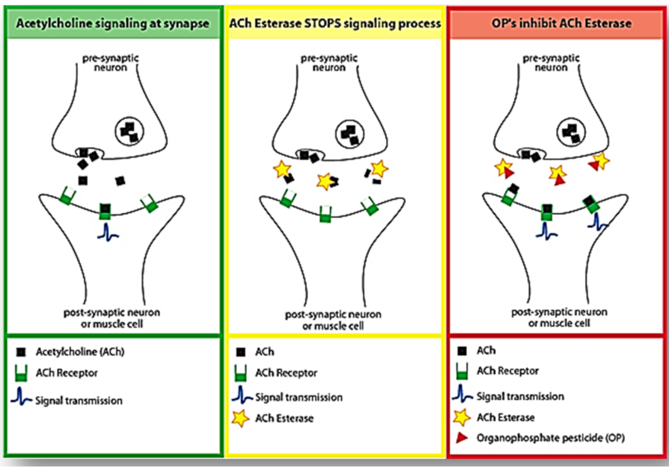


Fig 2: Organophosphates (Chlorpyriphos)

- But in these synthetic pyrethroids (SP's) it works in a different place. So that due to the different MOAs of different insecticides in the mixture, it delays the development of resistance.
- Here, in the axons of the neuron, Na+ enters the nerve and increases the membrane potentials, and then the gate shuts down and Na+ travels inside to allow the cell to reset for the next neural impulse. This is the normal

physiology of insects.

- But in the presence of SP after entering Na+ into the nerve gate, it cannot shut because SP binds with this gate, and due to this, Na+ continues to travel into the cell and the nerve cannot reset itself, continuously passing signals due to this mechanism insects may die.
- This is clearly seen in the below pictures (Fig. 3).
- So that combined MoA (Chlorpyriphos + cypermethrin) and insect may confuse due to this combined MoA and its effect, the insect may die and also reduce time for developing the resistance.
- In the second example, we can use neonicotinoids and diamides group of insecticides.
- Here, also in the mixture both the insecticides have different MoA.
- Neonicotinoids act as agonists of Ach or mimic of Ach.
- Neonicotinoid binds to the receptors present on the post-synaptic neuron instead of Ach and passes the signals, and after passing the signals, Ach esterase enzymes are released and break the Ach but not the neonicotinoid.
- Due to this neonicotinoid continuous passing of signals and due to this mechanism insects may die.
- This is clearly seen in the below picture (Fig. 4).

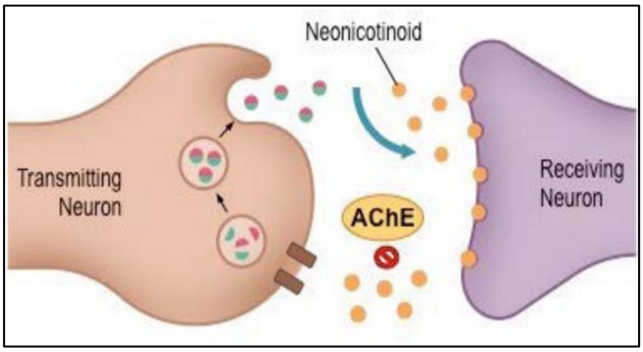


Fig 4: Neonicotinoids (Thiamethoxam)

But, Diamides have different MoA then the neonicotinoids.

- I n normal conditions, after the entry of action potentials, Ca++ enters and then, after glutamate release in the synapse, gaps and binds to the receptors that are present on post synaptic muscle and then after due to depolarization, action potentials pass to the next muscle cell.
- But diamide mainly works on muscle cells with Ca++ channels and in the presence of diamide, this Ca++ channel is not close and due to this continuous passing of signals and due to this process insects may die.

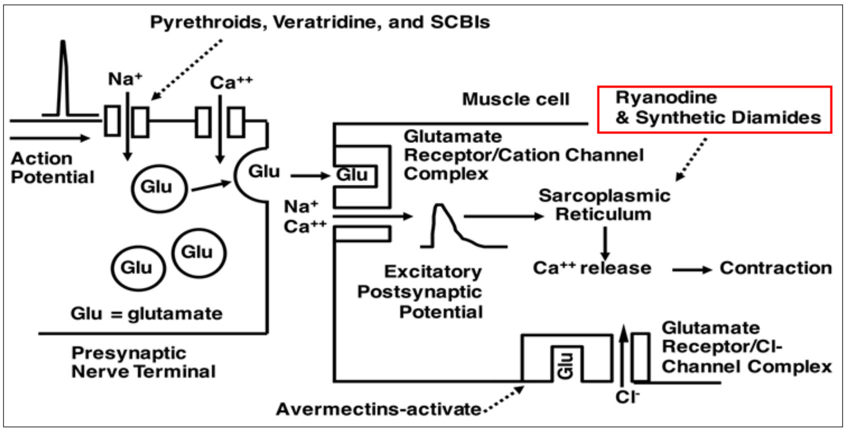


Fig 5: Diamides (Chlorantraniliprole)

After knowing all mechanism and MoA of ready-mix insecticides some.

Points to be considered while preparing ready-mix insecticides

- **Recommended dosage**
- **Mode of action**
- **Cross resistance**
- **Residual insecticidal activity**

❖ **Recommended dosage**

➢ Emamectin benzoate 5% + lufenuron 40% WG

❑ Dosage: 3 + 24 g a. i./ ha

❖ The main focus here is on the 3 + 24 g a.i./ha dosage because we cannot change it because doing so sometimes compromises phytotoxicity and efficacy.

❖ **Mode of action**

➢ Chlorpyrifos + aldicarb or methomyl

➢ Beta cyfluthrin + imidacloprid and labmda-cyhalothrin + chlorantraniliprole

➢ Here, when we mix any two chemicals in a mixture both chemicals have a different MoA and, if they have the same MoA, the chance to develop resistance faster. So that chlorpyrifos + aldicarb or methomyl are not used in mixture because both the insecticides have similar types of MoA but we use beta-cyfluthrin + imidacloprid and lamda-cyhalothrin + chlorantraniliprole due to their different MoA.

Cross resistance

➢ When using mixtures, consider any known cross resistance issues between the individual compounds selected for use as a mixture.

➢ Control of pests is possible only when there is no cross resistance for any compound in the mixture.

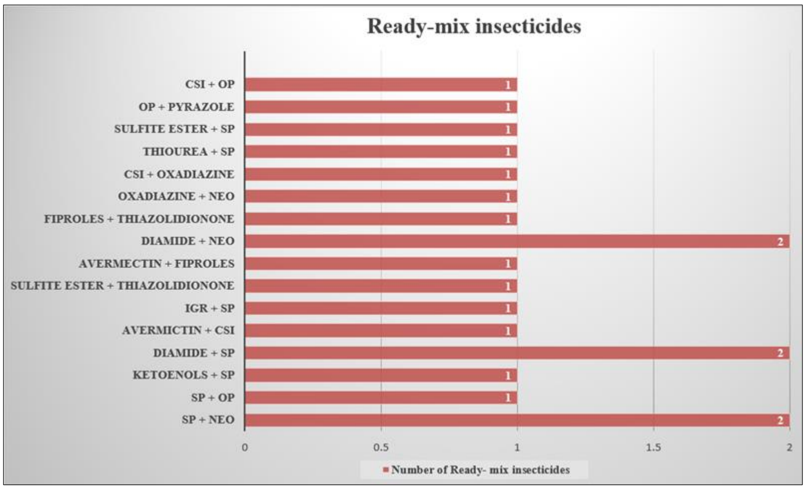
❖ **Residual insecticidal activity**

➢ The IRM benefits of an insecticide mixture are greatest if the two components have similar periods of residual insecticidal activity.

➢ Mixtures of insecticides with unequal periods of residual insecticide activity may offer an IRM benefit for the period where both insecticides are active.

Registered ready-mix insecticides

- As on July 01, 2021, total 299 pesticides have been registered under section 9(3) of the Insecticides Act, 1968 for use in India.
- Among them 56 ready-mix insecticides are for agricultural crops
- While, for horticultural crops only 19 ready-mix insecticides are registered.



Among these 19 ready-mix insecticides only 3 groups having 2 products and remaining have only 1 product. We can clearly see in this upper picture.

Ready-mix insecticides registered for use in horticultural crops

After knowing how much ready-mix registered. Here, crop wise registered ready-mix insecticides are listed below.

Table 1: Ready-mix insecticides registered for use in Horticultural Crops in India in CIB & RC

Ready-mix insecticides	Common name of the pests	Dosage/ha a.i. (g)	Dosage/ha Formulation (gm/ml)	Dosage/ha Dilution (Litre)	Waiting period (days)
Brinjal					
Beta-cyfluthrin 8.49% + imidacloprid 19.81% OD	Aphids, Jassids, Shoot & fruit borer	15.75 + 36.75 - 18 + 42	175 - 200	500	07
Chlorantraniliprole 9.30% + lambda cyhalothrin 04.60% ZC	Shoot & fruit borer, Jassids	28	200	500	05
Cypermethrin 3% + quinalphos 20% EC	Shoot & fruit borer	-	350 - 400	500 - 600	07
Pyriproxyfen 5% + fenpropathrin 15% EC	Whitefly, Shoot & fruit borer	25 + 75 - 37.5 + 112.5	500 - 750	500 - 750	07
Spirotetramat 11.01% + imidacloprid 11.01% SC	Whitefly, Red spider mite	60 + 60	500	500	05
Cauliflower					
Emamectin benzoate 5% + lufenuron 40% WG	Diamond back moth, Fruit borer	27 (3.0 + 24.0)	60	500	03
Chilli					
Diafenthiuron 47% + bifenthrin 9.40 % SC	Thrips, Aphids	293.75 + 58.7	625	500	07
Emamectin benzoate 1.50% + fipronil 3.50% SC	Thrips, Fruit borer	07.5 + 17.5 - 11.25 + 26.25	500 - 750	500	03 (day) or 48 (Hrs) Reentry period after each Application
Emamectin benzoate 5% + lufenuron40% WG	Fruit borer, Thrips, Mite	27 (3.0 + 24.0)	60	500	03
Fipronil 7% + hexythiazox 2% SC	Mites and Thrips	70 + 20	1000	500	07
Flubendiamide 19.92% + thiacloprid 19.92% SC	Thrips, Fruit borer	48 + 48 - 60 + 60	200 - 250	500	05
Indoxacarb 14.50% + acetamiprid 7.70% SC	Thrips, Fruit borer	88.8 - 111	400 – 500	500	05
Novaluron 5.25% + indoxacarb 4.50% SC	Fruit borer complex (*Helicoverpa armigera, Spodoptera litura*)	43.31 + 37.13 - 45.94 + 39.38	825 - 875	500	07
Profenofos 40% + fenpyroximate 2.50% EC	Thrips, Mites, Fruit borer	0.4 + 0.025	1000	500	07
Pyriproxyfen 5% + fenpropathrin 15% EC	Whitefly, Shoot & fruit borer	25 + 75 - 37.5 + 112.5	500 - 750	500 - 750	07
Thiamethoxam 12.60% + lambda cyhalothrin	Thrips, Fruit borer	33	150	500	03

9.50% ZC					
Cucumber					
Flubendiamide 8.33% + deltamethrin 5.56% SC	Cucumber beetle, Fruit fly	18 + 12 - 22.50 + 15	200 - 250	500	05
Mango					
Spirotetramat 11.01% + imidacloprid 11.01% SC	Mealy bug	0.018%	0.075%	Spray fluid as required Depending upon size of tree.	15
Okra					
Chlorantraniliprole 9.30% + lambda cyhalothrin 4.60% ZC	Shoot and fruit borer, Jassids	28	200	500	03
Propargite 50% + bifenthrin 5% SE	Mite, White fly & Jassids	594 + 59.4 - 621 + 62.1	1100 – 1150	500	05
Pyriproxyfen 5% + fenpropathrin 15% EC	Whitefly, Shoot & fruit borer	25 + 75 - 37.5 + 112.5	500 - 750	500 - 750	07
Spirotetramat 11.01% + imidacloprid 11.01% SC	Red spider mites	60 + 60	500	500	05
Tea					
Propargite 42% + hexythiazox 2% EC	Red spider Mites	525 + 25	1250	400 - 500	07
Thiamethoxam 12.60% + lambda cyhalothrin 9.50% ZC	Tea mosquito bug, Thrips, Semilooper	33	150	400	01
Tomato					
Chlorantraniliprole 8.80% + thiamethoxam 17.50% SC	Leaf miner, Whitefly, Fruit borer	150	500 Application method-Soil drench (Single application), Application time-8-10 days after transplanting	50 - 100 ml/ plant	36
Novaluron 5.25% + indoxacarb 4.50% SC	Fruit borer (*Helicoverpa armigera*) & Leaf eating caterpillar (*Spodoptera litura*)	43.31 + 37.13 - 45.94 + 39.38	825 - 875	500	05
Propargite 50% + bifenthrin 5% SE	Mite, White fly & Jassids	594 + 59.4 - 621 + 62.1	1100 - 1150	500	05
Thiamethoxam 12.60% + lambda cyhalothrin 9.50% ZC	Thrips, Whitefly & Fruit borer	27.5	125	500	05

Protagonist role of ready-mix insecticides

After knowing all this relates to ready-mix insecticides, here we discuss the how these ready-mix insecticides are best compared to single insecticides. Here question may arise what is protagonist? The answer is leading role in bio-efficacy, safer to beneficial insects and also fewer residual properties compare to the single insecticides.

When any chemicals come to market first of all these products tested for its bio-efficacy then after it check against natural enemies and then after go for residual effect. So that we can see bio-efficacy of ready-mix insecticides compare to single insecticides.

(A) Bio-efficacy

❑ **Fruit crops**

- Fruits are used mainly for their vitamins and nutrients. Fruit crops are also damaged by the number of insect pests and their control with ready-mix insecticides is much faster than with single insecticides.

Mohapatra *et al*. (2019) [11] observed that the bio-efficacy of various insecticides against hoppers, *Amritodus atkinsoni* infesting mango and found the thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC at 0.0088% concentration and found the lowest no. of hopper/ panicle (1.52) and also found the highest yield (145.44 q/ha) and it was at par with acephate 50% + imidacloprid 35% EC at 0.1% with the 137.45 q/ha.

Chundawat and his co-workers conducted a study in the year 2020 in Mandsaur, MP. They found that using emamectin benzoate 5% + lufenuron 40% WG at a dosage of 31.5 g a.i./ha resulted in the lowest fruit damage by ber fruit borer, *Meridarchis scyrodesat* harvest, which was 19.71% and 18.23% in the years 2017-18 and 2018-19, respectively. This represented an 80.71% and 83.52% reduction over control (ROC%), respectively. They also found that this treatment resulted in the highest yield, which was 53.87 and 55.89 kg/plant in the respective years. Additionally, they found that the same insecticides were at par with the medium dosage.

Sapteshwariya and his co-workers studied in the year 2020 from Anand, Gujarat and found that buprofezin 15% + acephate 34% WP against mealybug in custard apple had the lower number of nymph and adult mealybug/fruit, which was 5.45, and it was at par with thiamethoxam 12.6% + lambda-cyhalothrin 9.5% ZC, with a number of nymph and adult mealybug/fruit of 6.58.

Appala et al. (2021) found that the application of spirotetramate 11.01% + imidacloprid 11.01% SC at a dosage of 0.3ml/L against pomegranate aphid, *Aphis punicae* resulted in the lowest number of aphids per shoot in pomegranate, which was 3.99. The effectiveness of this treatment was high, with an ROC value of 82.93%.

In 2021, Prasanthi and colleagues from Tirupati, AP, found that imidacloprid 40% + ethiprole 40% WG had the highest percentage of ROC, which was 94.87%. This was comparable to thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC, which had an ROC of 94.25% against mango hopper.

- **Vegetable crops**
- Vegetables mostly used in our daily life for subji and other recipes. Vagaries of insect pest attack on vegetables and better control by ready-mix insecticides.

In the year 2016, Ghosal and his co-workers from Kolkata, WB found that novaluron 5.25% + indoxacarb 4.5% SC, at a dosage of 85.32 g a.i./ ha, resulted in the lowest percentage reduction in the larval population of *Spodoptera litura* in tomato at the 3rd and 10th day after spray, which was 91% and 100%, respectively. They also found that the highest fruit yield of 154.4 q/ ha was achieved with this dosage, which was at par with the medium dosage that resulted in a fruit yield of 152.6 q/ ha.

Giraddi and his co-workers conducted research in 2017 in Dharwad, Karnataka, and discovered that beta-cyfluthrin 90% + imidacloprid 210% OD, at a dosage of 93 g a.i./ha against insect pest of chilli, resulted in lower whitefly density per six leaves compared to the control group. They also found the lowest leaf curl grade and gall midge fly damage percentage, which were both below 2%. In the same year, at the same place, the same scientists found the highest green chili yield in the same treatments, which was better and amounted to 5275 kg/ha as compare to single insecticides also.

In 2017, Rajmal and his co-workers conducted a study in Varanasi, UP and found that the application of propargite 50% + bifenthrin 5% at a dosage of 683.1 g a.i./ha resulted in the lowest fruit damage caused by Helicoverpa armigera infesting tomato, which was 9.63% and 4.71% in the 1st and 2nd spray, respectively. They also found the highest yield of 27625 kg/ha, which represented a 72.56% increase over the control. The application of propargite 50% + bifenthrin 5% at a dosage of 653.4 g a.i./ha showed similar results with a 72.56% increase over the control in yield.

In 2017, Sen and his co-workers from Nadia, West Bengal found that chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% ZC, at a dosage of 35 g a.i./ha, resulted in the lowest fruit infestation by brinjal shoot and fruit borer (*Leucinodes orbonalis*) at 2.49%, which is 89.94% ROC. This was comparable to the medium dose, which had an 88% ROC. They also recorded fruit yield and found that the highest yield, 150.88 q/ha, was obtained with the same treatment, which was better than all other evaluated treatments. The medium dose was at par with the highest yield, with a fruit yield of 143.91 q/ha.

In 2018, Rohokale and his co-workers from Parbhani, Maharashtra, found that chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% ZC at 0.006% and flubendiamide 19.92% + thiacloprid 19.92% SC had the lowest shoot infestation caused by L. orbonalis. The infestation was cent per cent after 1st and 3rd days of spray after both the sprays. They also recorded the fruit infestation and found it to be lowest in number and weight basis, which was 12.23% and 8.70% in number basis and 10.36% and 8.10% in weight basis, respectively, in chlorantraniliprole 8.8% + thiamethoxam 17.5% SC at 0.026%. This was at par with flubendiamide 19.92% + thiacloprid 19.92% SC

Subbireddy and his co-workers from Anand, Gujarat, conducted a study in 2018 and found that the combination of chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% ZC at 0.0067% resulted in the lowest number of larvae per plant for *H. armigera* and *E. vittella* in okra. The numbers were 0.72 and 0.80, respectively, during the summer season and 1.14 and 0.34, respectively, during the kharif season. This treatment was at par with indoxacarb 14.5% + acetamiprid 7.7% SC. The researchers also recorded the yield and found that the highest yield was obtained with the same treatments, which were 68.44 and 151.12 q/ha during the summer and kharif seasons, respectively. In contrast, the indoxacarb 14.5% + acetamiprid 7.7% SC treatment plot gave 62.72 and 145.83 q/ha fruit yield in the two seasons, respectively.

In the year 2019, Floret and Regupathy from Chidambaram, TN, conducted a study on tomato leaf miner. They found that the application of chlorantraniliprole 9.3% + lambda cyhalothrin 4.6% SC at a dosage of 41.7 g a.i./ ha resulted in the lowest number of mines per plant, which was 0.86 after two sprays and showed a 68.7% reduction in the rate of occurrence. Moreover, the medium dose was found to be at par with the higher dose, with a 65.8% reduction in the rate of occurrence.

Akolkar and his co-workers, from Rahuri, Maharashtra in the year 2021, conducted a study on *E. vittella* in okra. They found that the application of flubendiamide 90% + deltamethrin 60% SC at 60 g a.i./ ha resulted in a lower number of larvae per plant, which was 0.81 and showed a 77.12% reduction in the rate of occurrence. Additionally, they carried out experiments to assess fruit damage and observed that the flubendiamide 90% + deltamethrin 60% SC had the lowest fruit damage percentage of 4.59%, indicating an 84.59% reduction in the rate of occurrence. They also found that this treatment resulted in the highest fruit yield of 9.64 t/ha, which was a significant 99.58% increase over the control.

Siddesha and their co-workers, who conducted research in Rahuri, Maharashtra in 2021, found that the spirotetramate 11.01% + imidacloprid 11.01% SC resulted in a lower number of thrips per leaf in chili, with a pooled average of 0.72 across sprays and seasons, and an ROC of 90.73%. They also recorded the highest yield in the same treatment, which was 2.10 t/ha, representing an 81.03% increase over the control.

- **Plantation and spice crops**
- Mainly spice and plantation crops are used for beverages, aroma and flavour purposes.

Samanta and his co-workers conducted a study in Nadia, West Bengal in 2017. They found that a combination of thiamethoxam 12.6% and lambda cyhalothrin 9.5% ZC, applied at a dosage of 33 g a.i./ha, resulted in the highest percentage reduction of thrips in tea after 10 days of spraying, with reductions of 83.14% and 93.67% observed in 2012 and 2013, respectively. For semilooper, thiamethoxam 12.6% and lambda cyhalothrin 9.5% ZC resulted in reductions of 86.20% and 87.14% in 2012 and 2013, respectively. Thiamethoxam 12.6% and lambda cyhalothrin 9.5% ZC also resulted in the lowest percentage of shoot infested by tea mosquito bug, with 9.30% and 7.63% observed in 2012 and 2013, respectively.

While, applied at a medium dosage, showed similar results and at par with higher dose.

In 2019, a group of scientists from Anand, Gujarat conducted a study and found that a combination of thiamethoxam 12.6% and lambda cyhalothrin 9.5% ZC, resulted in the lowest number of thrips per plant in cumin, with a count of 3.40 and a rate of control (ROC) of 80.23% and applied at a medium dosage, showed similar results with a ROC of 78.30% and it was at par with higher dose.

(B) Toxicity to beneficial insects

After discussing the higher bio-efficacy, it was concluded that ready-mix insecticides are not only effective, but also safer for beneficial insects.

In 2017, Giraddi and his co-workers from Dharwad, Karnataka, found non-significant results, indicating that all treatments were more or less similar to the control. As a result, the number of coccinellids per plant was similar to the control. So that no any adverse effect of ready-mix insecticides on coccinellids in chilli in both the year and it was safer to them.

In 2017, Roy and his co-workers from Nadia, West Bengal, found that pyriproxyfen 5% + fenpropathrin 15% EC had the lowest reduction of prevailing predators, namely lacewings and spiders in 2015 and 2016, respectively in mango, with less than 5% reduction. Pyriproxyfen 5% + fenpropathrin 15% EC with medium dosage was at par with pyriproxyfen 5% + fenpropathrin 15% EC higher dose.

In 2017, Roy and his co-workers conducted research in Nadia, West Bengal, and found that the T1 pyriproxyfen 5% + fenpropathrin 15% EC had the highest LT50 at dosages of 1000, 500, 200, and 100 ppm, with values of 9, 13, 17, and 21 hours, respectively for Italian honey bee, *Apis mellifera* under laboratory condition.

Chundawat and his co-workers in the year of 2020 from mandsaur, MP found that the non-significant results in all ready-mix insecticides with single insecticides so that all the evaluated treatments are similar with the control and no adverse effect of insecticides on no. of spider/plant was observed.

(C) Residue

Ready-mix insecticides also less residual activity.

Three sprays of a ready-mix formulation of beta-cyfluthrin 90% + imidacloprid 210% OD were carried out at 10-day intervals starting from the button stage in mango at dosages of 0.025% and 0.05%. The study reported that beta-cyfluthrin dissipated relatively faster and reached below the determination limit (BDL) on 3 and 5 days after spraying (DAS), while imidacloprid residues, though short-lived, attained BDL after 7 and 10 DAS, respectively (Diwan *et al.*, 2019) [7].

Subbireddy and his coworkers conducted research in Anand, Gujarat in the year 2019. They found that the mixture of indoxacarb + acetamiprid and chlorantraniliprole + lambda cyhalothrin were the best treatments evaluated in okra. In the first mixture, indoxacarb reached below detectable limit (BDL) after 10 days, and acetamiprid reached BDL after 1 day of spraying. In the second mixture, chlorantraniliprole reached BDL after 10 days, and lambda cyhalothrin reached BDL after 3 days of spraying.

(D) Impact on economics

After knowing all things our main target is related to economics so that …

In 2019, Mohapatra and his co-workers from Anand, Gujarat found that the combination of thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC had the highest NICBR of 14.84 ₹ against hopper infestation in mango.

In 2020, Chandran and his co-workers from Padannakad, Kerala found that the treatment of chlorantraniliprole 8.8% + thiamethoxam 17.5% SC yielded the highest B:C ratio of 2.42 and 3.12 in the rabi and summer seasons, respectively, against okra shoot and fruit borer.

Pros of ready-mix insecticides

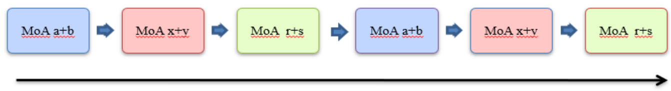
- Delay the development of insecticide resistance
- Reduce the number of applications
- Decreased labour costs
- Broad spectrum activity
- Effective against specific life stages of insects
- Higher efficacy and lesser dosage

Cons of ready-mix insecticides

- Comparatively high cost
- Structure activity relationship (SAR) of ready-mix insecticides cannot be determined.

Insecticide Resistance Management (IRM)

- Effective insecticide resistance management (IRM) strategies seek to **minimize the selection of resistance to any one type of insecticide**.
- In practice, **alternations, sequences or rotations** of compounds from different MoA groups provide sustainable and effective IRM.



Sequence of insecticides through season

After this pros and cons of ready-mix insecticides how we can use in IRM. We can use different MoA of ready-mix insecticides in different season so that reduce the development of resistance.

Newer ready-mix insecticides

Cartap hydrochloride 7.5% w/w + emamectin benzoate 0.25% w/w GR

Difenthiuron 25% + pyriproxyfen 5% SE.

Conclusion

Ready-mix insecticides play a leading role in managing the vagaries of insect pests in horticultural crops like brinjal, mango, custard apple, okra etc. Alongside its higher efficacy, it also serves to attain a higher yield against a broader range of insect pests. The residual activity of ready-mix formulations due to their composite nature is considerably less. Moreover, field applications of ready-mix insecticides are a safer and more viable option in conserving natural enemies. Ready mix insecticides often delay resistance, decrease the application as well as labour costs and thus proved to be a handy solution for insect pests management in horticultural crops.

Future thrusts

Need to….

- explore compatibility of ready-mix insecticides with botanicals as well as insect growth regulators for effective pest management
- evaluate different ready-mix insecticides in ornamental crops
- develop ready-mix insecticides for insect resistance management (IRM).

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