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REVIEW ARTICLE

Pesticide Residue and Bio-pesticides in Vegetable Crops

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Abstract

Intensive vegetable production using pesticides has biggest threat to growers and the consumers. In such instances the accumulation of pesticide residues is increased due to relatively short pre-harvest interval. Use of pesticides without knowing the label claim information increases the cost of production, increases the number of spray and labour cost, ultimately leading to decrease in farmers profitability. Hence, the adoption of pesticide as per label claim is very much essential. The level of residues should be below the maximum residue limit (MRL) at the time of harvest. Most of the detected pesticides in vegetables are not registered by Central Insecticide Board and Registration committee (CIBRC) for use on that specific vegetable which is the off label use of pesticides. Crops grouping is the development of a model that allows extrapolation of residue data from a few representative crops to many other crops in the same group. This allows establishment of residue tolerances for the entire group of crops based on the residue values from certain key crops that are similar. The acceptance of representative crop is a critical component of the savings from using the crop groups. IR-4's involvement with efforts to remove pesticide residues as a barrier for exports for US-grown specialty crops has been growing in importance over the last 20 years. By establishing a common MRL on a specialty crop from a particular crop protection product use, trade irritants between the two countries can be prevented before they have the potential to become a major problem for specialty crop growers on each side of the border. The U.S./Canadian specialty crop partnership has yielded valuable results for all the stakeholders involved. IR4 signed MOUs with Canada, New Zealand, Brazil, Costa Rica, and Colombia. This model is also much needed for India to regulate the pesticide label claims for numerous crops.

Key words: Vegetable, residue, maximum residue limit, pre-harvest interval, off-label pesticide.

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Introduction

In India, vegetables contribute 59.20% of total horticultural production. The area under vegetable cultivation is 11.28 million hectares (mha) with a total production of 204.61 million tonnes (mt) and productivity of 17.97 tonnes/hectare (https://pib.gov.in/PressReleasePage.aspx?PRID=1841480). Per capita availability of vegetables in India is 393.76g. Major vegetables leading in area, production and export were presented (Table 1) (Saxena *et al.* 2018). There are 43 vegetables covered under APEDA HortiNet system that can be exported *viz.*, 1. Ivy gourd, 2. drum stick, 3. tomato, 4. cowpea, 5. pointed gourd, 6. ridge gourd, 7. sponge gourd, 8. spine gourd, 9. ash gourd, 10. cucumber, 11. green banana, 12. green papaya, 13. capsicum, 14. basella spinach, 15. chochorus/jute leaves, 16. amarathes, 17. ipomoea leaves, 18. coriander leaves, 19. fenugreek leaves, 20. sweet potato, 21. arvi, 22. colocasia, 23. elephant's foot yam, 24. yam, 25. radish, 26. carrot, 27. beet root, 28. fresh turmeric, 29. fresh ginger, 30. green jack fruit, 31. flat beans, 32. long beans, 33. french beans, 34. cluster beans, 35. bottle gourd, 36. round gourd, 37. green chili, 38. sapota, 39. potato, 40. bitter gourd, 41. egg plant, 42. curry leaf, 43. okra. For the export

Table 1: Major vegetables leading in area and production

S. No.	*Crop*	*Area (million hectares)*	*Production (million metric tonnes)*	*Export (metric tonnes)*
1	Potato	2.14	51.31	395748.12
2	Onion	1.28	23.26	1588985.71
3	Tomato	0.79	19.76	47446.09
4	Brinjal	0.73	12.80	-
5	Cabbage	0.39	9.00	527.28
6	Cauliflower	0.45	8.67	177.86
7	Okra	0.51	6.10	-
8	Peas	0.54	5.42	410.11
9	Tapioca	0.17	4.95	-
10	Chili	0.31	3.54	-
11	Sweet potato	-	-	403.73

of vegetables, the exporters should follow the modules set by APEDA (Anonymous, 2021). Vegetables are substantial cash crops, via their multiplier effects, significantly boost the local and national economies. By switching from rice farming to agribusiness, the rural economy can be strengthened through labor- and resource-intensive cultivation. The development of the nation's horticulture has been hampered by pests and illnesses. Large quantities of pesticides and other agrochemicals are used to control pests and ensure the cultivation of high-quality products in order to deal with this issue (Mrema *et al*. 2017). In vegetables, numerous insects and pests attack as they are nutritious and palatable in nature. The mix of diseases, insect pests, and the degree of infestation at a location are among the agro-ecological elements that have a significant impact on production and farmers' revenue (Abang *et al*. 2014; Mariyono *et al*. 2018). Due to significant crop damage or reduced total crop productivity, these diseases badly raise the financial risk for farmers. Pesticides are used by most farmers to control illnesses and pests, which leads to intensive monoculture and an increase in the number of pests. Many studies support the presence of pesticide residues in vegetables, on average, this percentage is 50 to 70% in India as mentioned by Karanth, 2002; Charan *et al*., 2010; and Ranga, *et al*., 2009. These pesticides do not degrade completely and thus leave pesticide residue in soil (Majumder *et al*. 2022), water, soil micro-fauna and other animals (Nishant *et al*., 2016).

Pesticide residues are the active ingredients, metabolites, or breakdown products that remain in the environment after a pesticide has been applied. Remains analysis offers a measurement of the kind, extent, and durability of any chemical contamination of the environment. Human exposure to the administered pesticides and/or their breakdown products may persist as residues in the agricultural products (Dasika *et al*., 2012). The primary source of essential nutrients is agricultural produce. However, it is disheartening to see that these fruits and vegetables carry pesticide residues, endanger consumers' health, and fail to meet nutritional needs. These chemicals have been found in the environment all over the world due to the persistence of some highly hazardous pesticides, or possibly due to the illegal use of banned or restricted pesticides (Narendran *et al* 2020).

Because of the tremendous pesticide application, food quality has become a severe problem. Although farmers have a conventional understanding of agriculture, they are vulnerable because they lack technical knowledge of pesticides, their uses, and safety considerations (FAO, 2014). As a result, synthetic chemical usage increases past the recommended levels. Due to the world's expanding population and quickening urbanization, pesticide consumption has increased over the previous ten years (FAOSTAT, 2019). Therefore, the use of restricted pesticides is a worry, particularly in the case of vegetables. Numerous studies confirm the presence of pesticide residues in vegetables; according to Kumari *et al*., 2019; Gowda *et al*., 2020 Ghosh *et al*., 2021, Majumder *et al*., 2020 and Majumder *et al*., 2022. These food residues, which are accumulations of pesticide-active components, metabolites, or breakdown products, may be harmful to human health. Therefore, it is essential to inform consumers of the potential risks associated with consuming these pesticides in their usual diet (Boobis *et al*., 2008). Several studies point to the danger of ingesting various pesticides with various modes of action. Prolonged exposure to pesticides has been linked to depression, neurological deficits, diabetes, respiratory illnesses like rhinitis, and in severe cases, cancer, fetal death, spontaneous abortion, and genetic diseases (Ntzani, Ntritsos, Chondrogiorgi, Evangelou, & Tzoulaki, 2013; Mehmood *et al*., 2021). It is obvious that exposure to these pesticides has impacts on human health in addition to ingestion, particularly for spray workers (Azmi, Naqvi, Azmi, & Aslam, 2006).

Status of Pesticides used in Vegetable Crops

The estimated losses due to pests and diseases in horticultural crops is approximately Rs. 40,000–50,000 crores and around 13–14% of total pesticides used in the country are applied on vegetables, of which insecticides account for about two-thirds of total pesticides used in vegetables. The average consumption of pesticide in vegetable crops in India is 0.678 Kg a.i./ha. Among different vegetable crops, the maximum pesticide usage is in chili (5.13%) followed by brinjal (4.60%), Cole crops (3.73%) and okra (2–3%). The pesticides that have a label claim for the use in vegetables are mostly old generic molecules exhibiting a higher mammalian toxicity and beckon an immediate replacement/ substitution with chemicals having a low mammalian toxicity and green chemistry. Total Pesticide production in our country is 192000 mt (Annual report 2019-20, Ministry of Chemicals & Fertilizer, Govt of India). In India, the Central Insecticides Board & Registration Committee (CIBRC) is the authority that governs the registration of agrochemicals to be used for a particular crop in India. Out of 267 registered pesticides, approximately 98 pesticides (insecticides and fungicides) are approved for use in vegetable crops (Source: CIBRC). The number of pesticides having label claim for vegetable crops with CIBRC is presented in Table 2. It has been now realized that the indiscriminate applications of pesticides have disturbed the balance of agroecosystems and created new problems in pest management. The new problems may be an increase in resistance of pests, pollution, residual hazards, low productivity and production. Use of insecticides without knowing the insecticide as per label claim increases the cost of production, reduces the yield increasing the number of sprays and labor cost ultimately decreasing the farmers' profitability. Hence, the adoption of pesticides as per the label claim is very much essential. There are many new molecules that do not have label claims for the particular crops but the farmers are using that pesticide to control the pest (Table 3).

Off Label Pesticide Detection in Vegetables

The intensive use of pesticides to control the pests in vegetables leads to the presence of pesticide residues (Banerjee *et al.,* 2012). The level of these residues should be below the maximum residue limit (MRL) at the time of harvest. Most of the detected pesticides in vegetables are not registered by CIBRC for use on that specific vegetable which is the off-label use of pesticides. In most of the collected samples, 25 to 30% of the samples were contaminated with pesticides. This may differ from area to area and crop to crop. The pesticides detected in different vegetables are presented in Table 4. In Nilgiris of Tamilnadu, out of the 33 samples of agricultural/horticultural commodities, Chlorpyriphos was the most commonly detected followed by profenophos. Chlorpyriphos, profenophos and ethion detected in curry leaf exceeded 4% of ADI (Average daily intake) value which was considered the margin indicating chronic health risk (Nair *et al.,* 2013). Pesticides such as chlorpyrifos, monocrotophos, endosulfan, DDT and lindane were found in most of the vegetables. Extremely adulterated vegetables were okra, brinjal, lettuce, cucumber, and tomato (Nishant and Upadhyay, 2016).

In Andaman and Nicobar Islands 75 to 80% of total pesticide consumption is used for vegetables alone against the national average of 10 to 12%. Out of 14 organophosphorus compounds analyzed in vegetable samples in this island, residues of chlorpyriphos, profenophos, monocrotophos, triazophos and acephate were found in 54% samples. Chlorpyrifos was the dominant pesticide contributing 42% followed by triazofos and profenofos. In green chilies and okra profenofos was mainly detected for which MRL is not specified so far (Swarnam, 2013). In Western Rajasthan farmgate samples of chili, out of the 50 samples tested 9 samples with Aldrin, 10 samples with Dieldrin, 18 samples with endosulfan and 18 samples with Lindane exceeded MRL (Parihar, 2015). In chili samples of Karnataka, 33 out of 40 samples were contaminated with pesticides out of which acetamiprid and fenzaquin were present in more samples but below MRL (Balasubramani, 2019).

Maximum Residue Limits

Maximum residue limits (MRLs) are defined as the maximum concentration of pesticide residue (expressed as mg of residue per kg of food/animal feeding stuff, mg/ kg) likely to occur in or on food as a result of the use of pesticides according to good agricultural practice (GAP) and product label recommendations. The FAO/WHO CODEX Alimentarious Commission establishes MRLs for various pesticides at the international level. In the 1990s there was an issue with the harmonization of MRLs based on CODEX due to the absence of an international standard and importer acceptance of the exporter's MRL. Since that time many countries have been establishing nationally based MRLs. MRL values are also needed to establish the waiting periods or pre-harvest intervals of the crops. Every pesticide has different MRL values for different crops (Table 5). When a pesticide has been registered on a particular crop, the MRL for the pesticide in/on the crop is usually set at a value determined from supervised field residue trials. However, if a pesticide has not been approved for use on a crop, the MRL can be set at the limit of determination (LoD). In EU, the default lowest LoD is 0.01 mg/kg. For fixation of MRL of a pesticide in a specific commodity, two types of trials are required (Fig 1). Several studies based on MRL level have been conducted in last few decades *viz.*, Yu *et al.* (2016) found methamidophos, dichlorvos, omethoate, phorate, dimethoate, diazinon, parathion-methyl, fenitrothion,

Table 2: CIB & RC label claim new pesticide molecules for vegetables

Pesticide/ Formulation	*CIBRC label claim*		
	CIBRC recommended crop	*Waiting period (days)*	*Target Pest*
Spinetoram 11.70% SC	Chili	7	Thrips, fruit borer, tobacco caterpillar
spiromesifen 22.90% SC	Brinjal	5	Red spider mite
	Chili	7	Chili yellow mite
	Okra	3	Red spider mite
	Tomato	3	Whiteflies & mites
spirotetramat 15.31% w/w OD	Chili	5	Thrips & aphids
chlorantraniliprole 18.50% SC	Cabbage	3	Diamond back moth (DBM)
	Tomato	3	Fruit borer
	Chili	3	Fruit borer
	Brinjal	22	Shoot & fruit borer
	Bitter gourd	7	Fruit borers & caterpillars
	Okra	5	Fruit borer
cyantraniliprole 10.26% OD	Cabbage	5	Cabbage aphid, mustard aphid, diamond back moth and tobacco caterpillar
	Chili	3	Thrips, fruit borer and tobacco caterpillar
	Tomato	3	Leaf miner, aphids, thrips, whitefly and fruit borer
	Gherkins	5	Leaf miner, red pumpkin beetle, aphids, thrips, whitefly, pumpkin caterpillar, fruit fly
chlorfenapyr 10% SC	Cabbage	7	Diamond back moth
	Chili	5	Mites
dinotefuran 20% SG	Paddy	21	Brown plant hopper
	Cotton	15	Whitefly, jassids, aphids &thrips
sulfoxaflor 21.8% w/w SC	Paddy	14	Brown plant hopper, white backed plant hopper
	Cotton	14	Jassids, aphids and whitefly
flonicamid 50% WG	Paddy	36	Brown plant hopper, white backed plant hopper, green leaf hopper
	Cotton	25	Aphids, jassids, thrips & whiteflies
pyriproxyfen 10% EC	Brinjal	7	White fly & jassids
	Chili	7	Whitefly, aphids
	Okra	7	White fly & jassids
Spinosad 45 % SC	Chili	3	Fruit borer, thrips
	Brinjal	3	Fruit & shoot borer
Combination Product			
Chlorantraniliprole 09.30 % + Lambda-cyhalothrin 04.60 % ZC	Brinjal	5	Shoot and fruit borer, jassids
	Okra	3	Shoot and fruit borer, jassids
chlorantraniliprole 08.80 % + Thiamethoxam 17.50 % w/w SC	Tomato	36	Leaf miner, whitefly, fruit borer

Indoxacarb 14.50 % + Acetamiprid 07.70 % w/w SC	Chili	5	Thrips, fruit borer
fenamidone 10% + Mancozeb 50% WG	Potato	30	Late blight
	Gherkin	5	Downy mildew
fluopyram 17.7% w/w + Tebuconazole 17.7% w/w SC	Chili	5	Powdery mildew and anthracnose

(Source: CIB & RC)

Table 3: Required label claim expansion for vegetable crops

Pesticide/Formulation	*Required label claim expansion*		
	Target crop	*Target pest*	*Waiting period (days)*
Spinetoram 11.70% SC	Brinjal	Shoot & fruit borer	?
	Okra	Shoot & fruit borer	?
	Cabbage	DBM	?
Spiromesifen 22.90% SC	Bitter gourd	Whiteflies	?
	Cowpea	Whiteflies & mites	?
Spirotetramat 15.31% w/w OD	Cauliflower	Aphids	?
Chlorantraniliprole 18.50% SC	Cowpea	Pod borer	?
	Bean	Pod borer	?
Cyantraniliprole 10.26% OD	Brinjal	BSFB	?
	Cowpea	Pod borer	?
	Bitter gourd	White fly and thrips	?
Chlorfenapyr 10% SC	Okra	Mites	?
	Brinjal	Mites	?
	Cowpea	Mites	
Dinotefuran 20% SG	Okra	Whitefly, jassids,	?
	Tomato	Aphids, whitefly & thrips	?
Sulfoxaflor 21.8% w/w SC	Okra	Whitefly, jassids,	?
	Tomato	Aphids, whitefly & thrips	?
Flonicamid 50% WG	Tomato	Whitefly, hoppers	?
	Brinjal	Whitefly, hoppers	?
Pyriproxyfen 10% EC	Tomato	Aphids, whitefly	?
	Bitter gourd	White fly and thrips	?
	Cabbage	Aphids	?
	Cucumber	White fly	?
Spinosad 45% SC	Okra	Shoot & fruitborer	?
	Cabbage	DBM	?
Combination Product			
Chlorantraniliprole 09.30% + Lambda-cyhalothrin 04.60% ZC	Cabbage and cauliflower	DBM Helicoverpa	?
	Tomato	Fruit borer	?
Chlorantraniliprole 08.80% + Thiamethoxam 17.50% w/w SC	Tomato,	Fruit borer	?
	cucurbits	Diaphenia, red pumpkin bettle	
	Pea	Pod borer	?

Indoxacarb 14.50 % + Acetamiprid 07.70 % w/w SC	Okra and brinjal	Fruit borer	?
Fenamidone 10% + Mancozeb 50% WG	Cucurbits		?
	Tomato		?
	Capsicum		?
Fluopyram 17.7% w/w + Tebuconazole 17.7% w/w SC	Pea		?
	Cowpea		?

Table 4: List of pesticides detected in different vegetables

Crop	*Pesticides detected*	*Residue (mg/kg)*	*Sample location*	*Reference*
Curry leaf	Chlorpyriphos	1.34	Tamilnadu	Nair *et al.* 2013
	Profenophos	25.63		
	Ethion	1.15		
	Malathion	0.439		
	Quinalphos	BMRL		
	Methyl parathion	BMRL		
	Profenophos	BMRL		
	Cypermethrin	1.44		
	Bifenthrin	0.104		
	Fenpropathrin	BMRL		
	Alpha endosulphan	BMRL		
Capsicum	Profenophos	BMRL	Tamilnadu	Nair *et al.* 2013
	Chlorpyriphos	BMRL		
Okra	Profenophos		Tamilnadu	Nair *et al.* 2013
	Malathion			
	Cypermethrin	0.347	Bihar	Sah *et al.* 2018
	Quinalphos	0.462		
	Chlorpyriphos			
	Dimethoate			
	Cypermethrin			
	Endosulphan			
	Malathion			
	Fenvalerate		Central Aravali Region	Charan *et al.* 2010
	Quinalphos			
	Methyl parathion	0.22		
Lettuce,	Spinosad		Tamilnadu	Nair *et al.* 2013
Broccoli, Red Cabbage	flubendiamide			
	Chlorantraniliprole			
	Imidachloprid			
	Acephate			
	Endosulfan		Bihar	Sah *et al.* (2018)
	Quinalphos			

Beans	Aldrin		Karnataka	Gowda *et al.* 2012
	Dieldrin			
	Endosulfan-α			
	Endosulfan-β			
	Endosulfansulfate			
	HCH-α			
	HCH- β			
	HCH-γ			
	Heptachlor			
	Acephate			
	Chlorpyriphos			
	Dichlorvas (DDVP)			
	Monocrotophos	1.5448		
	Phorate	0.2554		
Brinjal	Aldrin		Karnataka	Gowda *et al.* 2012
	Dieldrin			
	Endosulfan-α			
	Endosulfan-β			
	Endosulfansulfate			
	HCH-α			
	HCH- β			
	HCH-γ			
	Heptachlor			
	Acephate			
	Chlorpyriphos			
	Dichlorvas (DDVP)			
	Phorate	0.2448		
	Profenofos			
	Cyfluthrin-β			
	Cyhalothrin-λ			
	Cypermethrin			
	Delta methrin			
	Fenvalerate			
	Cypermethrin	0.407	Bihar	Sah *et al.* 2018
	Chlorpyriphos			
Cabbage	Aldrin		Karnataka	Gowda *et al.* 2012
	Dieldrin			
	Endosulfan-α			
	Endosulfan-β			
	Endosulfansulfate			
	HCH-α			

	HCH- β			
	HCH-γ			
	Heptachlor			
	Acephate			
	Chlorpyriphos	0.3557		
	Dichlorvas (DDVP)	0.6687		
	Monocrotophos			
	Phorate	0.1084		
	Cyfluthrin-β			
	Cyhalothrin-λ			
	Fenvalerate			
	Cypermethrin		Bihar	Sah *et al.* 2018
	Chlorpyriphos			
Carrot	Aldrin		Karnataka	Gowda *et al.* 2012
	Dieldrin			
	Endosulfan-α			
	Endosulfan-β			
	Endosulfansulfate			
	HCH-α			
	HCH-γ			
	Heptachlor			
	Acephate			
	Chlorpyriphos	0.992		
	Dichlorvas (DDVP)			
	Monocrotophos			
	Phorate	0.8057		
	Profenofos			
	Cyfluthrin-β			
	Cyhalothrin-λ			
	Fenvalerate			
Tomato	Acephate		Bihar	Sah *et al.* 2018
	Cyfluthrin-β			
	Deltamethrin			
	Dichlorvos			
	Fenvalerate			
	Monocrotophos			
	Phorate			
Capsicum	Acephate	0.333	Karnataka	Shylesha *et al.* 2021
	Chlorpyrifos	0.153		
	Cyfluthrin-β	0.045		
	Deltamethrin	0.381		

	Dichlorvos	0.042		
	Fenvalerate	0.168		
	Phorate	0.089		
Tomato	Acephate	0.346	Karnataka	Shylesha *et al.* 2021
	Dichlorvas	0.189		
	Fenvalerate	0.057		
	Phorate	0.072		
	Chlorpyriphos			
	Cyfluthrin-g			
	Cypermethrin			
Chili	Difenthiuron		Karnataka	Balasubramani *et al.* 2019
	Cypermethrin			
	Spinosad-D			
	Spinosad-A			
	Imidachloprid			
	Tebuconazole			
	Dimethoate			
	Spinosad (A+D)			
	Chlorpyriphos			
	Difenconazole			
	Fenazaquin			
	Acetamprid			
	Chlorantrinipole			
	Metalaxyl			
	Azoxystrobin			
Cauliflower	Methyl Parathion	0.33	Central Aravali Region	Charan *et al.* 2010
	Quinolphos	0.44		
	Chlorpyriphos			
	Endosulfan	1.25		
	Cypermethrin			
Potato	Dichlorvos	0.82	Central Aravali Region	Charan *et al.* 2010

Note: Of all the pesticide residues detected in different vegetables listed above only Spinosad and Chlorantriniprole in chili crop have label claim.
BMRL= Below MRL

malathion, fenthion and parathion contaminations with 3.2% level above the standard MRL in most of these pesticides. Ranga Rao *et al*. (2009) in Delhi also mentioned about the presence of monocrotophos, chlorpyrifos, endosulfan and cypermethrin pesticide residues in their samples of tomato. Similarly, Swarnam and Velmurugan (2013) in the Andaman Islands found cypermethrin residues with 0.028 mg/kg average value, Osei-Fosu *et al*. (2014) measured dimethoate presence in the range of 550 to 700% above the recommended MRL value in vegetables.

Authorities that fix MRL

In India, MRL is fixed by Food Safety and Standard Authority of India (FSSAI) which is an independent body comes under the ministry of Health and Family Welfare, Government of India. Internationally MRL is fixed by FAO/

Table 5 : MRLs of pesticides in vegetable crops

S. No.	*Name of the pesticide*	*Crop*	*Maximum residues limit in mg/kg*
1.	Acetamiprid	Chili	2
		Okra	0.1
		Cabbage	0.7
2.	Alphanaphthyl acetic acid	Tomato	0.1
		Chili	0.2
3.	Ametroctradin	Cucumber	0.4
		Tomato	0.3
4.	Azoxystrobin	Tomato	1
		Chili	1
		Cucumber	0.05*
5.	Benomyl	Vegetables	0.5
6.	beta cyfluthrin	Okra	0.01*
		Brinjal	0.2
7.	Buprofezin	Chili	2
		Okra	0.01*
8.	Carbaryl	Okra and leafy vegetables	10
		Chili	5
10.	Carbendazim	Vegetables	0.5
11.	Carbosulfan	Chili	2
12	Chlorantraniliprole	Bitter Gourd	0.03*
		Tomato	0.03*
		Chili	0.03*
		Brinjal	0.03*
		Cabbage	2
13	Chlorfenapyr	chili & Cabbage	0.05
14	Chlorfluazuron	Cabbage	0.1*
15	Chlormequat chloride (CCC)	Brinjal	0.1
16	Chlorpyriphos	Beans	0.01**
		Cauliflower and cabbage	1
		Other vegetables	0.2
17	Copper oxychloride (determined as copper)	Other vegetables	20
18	Copper sulphate	Pea	0.01
19	Cuprous oxide	Chili	0.01**
20	Cyantranilipole	Cabbage	2
		Chili	0.05
		Tomato	0.03
		Gherkin	0.01
		Okra	0.2
		Brinjal	0.06
21	Cyazofamid	Tomato	0.01*
22	Cymoxanil	Tomato	0.01*
		Gherkin	0.05*
		Cucumber	0.1
	Cypermethrin (sum of isomers) (Fat soluble residue)	Brinjal	0.2
		Cabbage	2
		Okra	0.5
24	Deltamethrin (Decamethrin)	Chili	0.05
		Okra	0.05
		Tomato	0.3
		Brinjal	0.3
25	Diafenthiuron	Brinjal	1
		Chili green	0.05
		Cabbage	1
26	Dichlorvos (DDVP) (content of di-chloroacetaldehyde (D.C.A.) be reported where possible)	Vegetables	0.15
27	Dicofol	Fruits and vegetables	5
		Chili	1
28	Difenoconazole	Chili	0.01
		Tomato	0.2
29	Dimethoate (residue to be determined as dimethoate and expressed as dimethoate)	Fruits and vegetables	2
		Chili	0.5
30	Dimethomorph	Cucumber	0.2
		Tomato	0.2
31	Dithiocarbamates(the residue tolerance limit are determined and expressed as mg/CS2/kg and refer separately to the residues arising from any or each group of dithiocarbamates)	Green chili	1

	(a) Mancozeb	Chili	1
		Cauliflower	0.02
		Gherkin	0.1*
		Onion	4
		Cucumber	0.4
	(b) metiram as CS_2	Green chili	1
		Tomato	5
		Onion	0.05*
	(c) Zineb as CS_2	Brinjal	0.01**
32	Ethephon	Tomato	2
33	Ethion (Residues to be determined as ethion and its oxygen analogue and expressed as ethion)	Cucumber and squash	0.5
		Other vegetables	1
34	Etoxazole	Brinjal	0.2
35	Famoxadone	Tomato	2
		Gherkin	0.3
36	Fenamidone	Gherkin	0.2
		Tomato	0.7
37	Fenazaquin	Chili (green)	0.5
		Okra	0.01
		Brinjal	0.01
		Tomato	0.01
38	Fenoxaprop-p-ethyl	Onion	0.05*
39	Fenpropathrin	Brinjal	0.2
		Okra	0.5
		Chili	0.2
40	Fenpyroximate	Chili	1
41	Fenvalerate (Fat soluble residue)	Cauliflower	2
		Brinjal	2
		Okra	2
		Cabbage	0.01**
		Tomato	0.01**
42	Fipronil	Chili	0.01
		Cabbage	0.02
43	Fipronil and its metabolites (MB- 46513, MB-45950, MB-46136)	Onion	0.04
44	Flubendiamide	Brinjal	0.1
		Cabbage	4
		Tomato	2
		Chili	0.02
45	Fluchloralin	Onion	0.01**
		Okra	0.01**
		Brinjal	0.01**
		Cabbage	0.01**
46	Flusilazole	Chili	0.01
47	Hexaconazole	Chili	0.5
48	Hexythiazox	Chili (green)	0.01
49	Imidacloprid	Okra	2
		Chili	0.3
		Tomato	1
		Cucumber	1
		Brinjal	0.2
50	Indoxacarb	Tomato	0.5
		Chili	0.01
		Cabbage	3
51	Iprodione	Tomato	5
52	Kasugamycin	Tomato	0.05
53	Kresoxim Methyl	Chili	0.15
54	Lambdacyhalothrin	Brinjal	0.2
		Tomato	0.1
		Okra	2
		Chili green	0.05
		Onion	0.01
55	Linuron	Pea	0.05
56	Lufenuron	Cauliflower	0.1
		Chili	0.05
		Cabbage	0.3
57	Malathion (Malathion to be determined and expressed as combined residues of malathion and malaoxon)	Vegetables	3
58	Mandipropamid	Tomato	0.3
59	Metaflumizone	Cabbage	0.05
60	Metalaxyl-M	Chili	0.02
		Tomato	0.5
61	Methomyl	Tomato	1
		Chili	0.05
62	Milbemectin	Chili green	0.01
63	Monocrotophos	Chili	0.2
64	Myclobutanil	Chili	0.2

65	Novaluron	Chili	0.01
		Tomato	0.01
		Cabbage	0.7
66	Oxadiargyl	Onion	0.1
67	Oxadiazon	Onion	0.01**
68	Oxydemeton-Methyl	Green chili	2
69	Oxyfluorfen	Onion	0.05
70	Paraquat dichloride (Determined as Paraquatcations)	Other vegetables	0.05
71	Pendimethalin	Chili	0.05*
		Onion	0.4#
72	Permethrin	Cucumber	0.5
73	Phorate (sum of Phorate, its oxygen analogue and their sulphoxides and sulphones, expressed as phorate)	Tomato	0.1
74	Phosalone	Other vegetables	1
75	Picoxystrobin	Chili	0.05*
76	Propaquizafop	Onion	0.01*
77	Propargite	Brinjal	2
		Chili	2
78	Propineb	Tomato	1
		Green chili	2
79	Pyraclostrobin	Tomato	0.3
		Green chili	0.05*
		Onion	1.5
		Cucumber	0.2
		Chili	0.2
80	Pyrethrins (pyrethrum) (sum of pyrethrins I & II and other structurally related insecticide Ingredients of pyrethrum	Fruits and vegetables	1
81	Pyridalyl	Cabbage	0.02
		Okra	0.02
		Chili	0.02
82	Pyriproxyfen	Brinjal	0.02
		Okra	0.03
		Chili green	0.02
		Chili red	0.02
83	Quinalphos	Cauliflower	0.1
		Chili	0.2
84	Quizalofop ethyl	Onion	0.01*
85	Spinosad	Cabbage	2
		Cauliflower	0.02
		Chili	0.01
86	Spiromesifen	Tomato	0.7#
		Brinjal	0.5
		Chili	0.1
		Okra	0.03
87	Tebuconazole	Tomato	2
		Onion	0.5
		Green chilies	0.4
		Cabbage	0.05*
88	Thiacloprid	Brinjal	0.7
		Chili (green)	0.02
89	Thiodicarb	Cabbage	0.02
		Brinjal	0.05
		Chili	0.01
90	Thiamethoxam	Okra	0.5
		Brinjal	0.3
		Tomato	0.01
91	Thiamethoxam and its metabolite (CGA 322704)	Green chili	0.5
92	Thiometon (Residues determined as thiometon its sulfoxide and sulphone expressed as thiometon)	Potato, carrots and sugar beets	0.05
		Other vegetables	0.5
93	Thiophanate-Methyl	Bottle gourd	0.01**
		Bottle gourd	0.4
		Cucumber	0.2
94	Tolfenpyrad	Cabbage	0.01*
		Okra	0.7
95	Trichlorfon	Sugar beet	0.05
		Fruits & vegetables	0.1
96	Triadimefon	Pea	0.1
		Chili	0.4
97	Trifloxystrobin and its metabolites (carboxylic acid-CGA321113)	Tomato	1
		Green chilies	0. 4

		Cabbage	0.1
98	Triazophos	Chili	0.2
99	Tricyclazole	Chili	0.3
100	Spinetoram and its metabolites (Spinosyn-J and Spinosyn-L)	Chili	0.05
101	Sodium Para Nitro Phenolate	Tomato	0.3
102	Spirotetramate and its metabolite BYI 08330 cis-enol	Okra	0.3
		Brinjal	0.3
		Green chili	2
103	Tetraconazole	Watermelon	0.01*
104	Abamectin	Green chili	0.05*
105	Flupyradiflurone and its metabolites difluroacetic acid and difluroethylamino-furanone	Okra	0.8

Note: * MRL fixed at Limit of Quantification (LOQ)
** Insecticides are registered under the Insecticide Act, 1968 (46 of 1968) but label claim for the said commodity are not fixed hence MRL fixed at LOQ

WHO CODEX Alimentarious Commission. Codex works on fixing international food standards, protecting consumers' health and removing international barriers for trade of food commodities. Till now, the Codex Alimentarius Commission has 189 Codex Members made up of 188 Member Countries and 1 Member Organization (The European Union).

Interregional Research Project No.4 (IR4 Project) & Crop grouping

The lack of crop protection products for specialty crops and minor uses on major crops is referred to as the "Minor Use Problem" and was the basis for the IR-4 Project being formed in 1963 as a means to solve this problem for US growers (Baron *et al.* 2016). Specialty crops include fruits and vegetables, dried fruits, tree nuts, horticulture, and nursery crops (including floriculture) that are cultivated or managed and used by people for food, medicinal purposes, and/or aesthetic gratification (IR4, 2022a). The IR-4 Project's main emphasis has been to support the regulatory approval of crop protection chemicals for specialty food crops and minor uses on major food crops (Baron *et al.* 2016).

Crop grouping was the development of a model that allows the extrapolation of residue data from a few representative crops to many other crops in the same group. This allows the establishment of residue tolerances for the entire group of crops based on the residue values from certain key crops that were similar. The acceptance of representative crops is the critical component of the savings from using the crop groups (Baron *et al.* 2016).

IR-4's involvement with efforts to remove pesticide residues as a barrier for exports for US-grown specialty crops has been growing in importance over the last 20 years. By establishing a common MRL on a specialty crop from a particular crop protection product use, trade irritants between the two countries can be prevented before they have the potential to become a major problem for specialty crop growers on each side of the border. The U.S./Canadian specialty crop partnership has yielded valuable results for all stakeholders involved (Baron *et al.* 2016). IR4 signed MOUs with Canada, New Zealand, Brazil, Costa Rica, and Colombia. The crop grouping of IR4 is as follows (Table 6) (IR4, 2022b)

Biopesticide in Vegetable crop

Pesticide use has certainly contributed towards improving agricultural production, in terms of both yield and quality, thus increasing agricultural income, particularly in developed countries. However, careless use of pesticides without adhering to the safety norms and recommended practices has posed serious health risks to humans, other living organisms, and the environment, from on-farm workers' exposure and release of chemicals into the air and water, to commodities containing pesticide residues. Therefore, there has been a growing demand for food safety and quality in recent decades, as reflected in the tight safety regulations on imports of products and strict regulations on the amount of pesticide residues on commodities. Moreover, increasingly high standards regarding product quality are continuously being set. Indiscriminate pesticide use is detrimental to the environment and human health and increases insects' resistance to pesticides. Alternative pest management strategies are warranted to reduce the misuse of chemical pesticides in vegetables. Despite several constraints, biopesticides are being used in vegetable production systems

Biopesticides or biological pesticides based on pathogenic microorganisms specific to a target pest offer an ecologically sound and effective solution to pest problems. They pose less threat to the environment and to human health. The most commonly used biopesticides are living organisms, which are pathogenic for the pest of interest. These include bio fungicides (*Trichoderma*), bioherbicides (*Phytophthora*) and bioinsecticides (*Bacillus thuringiensis*). The potential benefits to agriculture and public health programs through the use of biopesticides are considerable. Several biopesticides have been introduced and used for controlling many pests and diseases in vegetable crops (Table 7). The interest in biopesticides is based on the advantages associated with such products which are: (i) inherently less harmful and less environmental load, (ii) designed to affect only one specific pest or, in some cases, a few target organisms, (iii) often effective in very small

Table 6: Crop grouping by IR4 for specialty crops (IR4, 2022b)

Crop group	*Representative crops*
1.Root and tuber vegetables	Carrot, potato, radish and sugar beet
2. Leaves of root and tuber vegetables (human food or animal feed)	Turnip and garden beet or sugar beet
3. Bulb vegetables	Onion, green and onion, dry bulb
4. Leafy vegetables (except brassica vegetables)	Celery, head lettuce, leaf lettuce, and spinach
5. Brassica (cole) leafy vegetables	Broccoli or cauliflower, cabbage, and mustard greens
6. Legume vegetables (succulent or dried)	Bean (*Phaseolus* spp.) (succulent & dried), pea (*Pisum* spp.) (succulent & dried) and soybean
7. Foliage of legume vegetables	Any cultivar of bean (*Phaseolus* spp.) Field pea (*Pisum* spp.), and soybean (*Glycine max*)
8. Fruiting vegetables (except cucurbits)	Tomato, bell pepper and one cultivar of non-bell pepper
9. Cucurbit vegetables	Cucumber, muskmelon and summer squash
10. Citrus fruits	Sweet orange, lemon and grapefruit
11. Pome fruits	Apple and pear
12. Stone fruits	Sweet or tart cherry, peach and plum or fresh prune
13. Berries	Any one blackberry or any one raspberry and blueberry
14. Tree nuts	Almond and pecan
15. Cereal grains	Corn (fresh sweet corn and dried field corn), rice, sorghum, and wheat
16. Forage, fodder and straw of cereal grains	Corn, wheat and any other cereal grain crop
17. Corn, wheat and any other cereal grain crop	Bermuda grass, bluegrass and bromegrass or fescue
18. Nongrass animal feeds (forage, fodder, straw and hay)	Alfalfa and clover (*Trifolium* spp.)
19. Herbs and spices	Basil (fresh & dried), black pepper, chive and celery seed or dill seed
20. Oilseed group	Rapeseed (canola varieties only); sunflower, seed; and cottonseed
21. Edible fungi	White button mushroom and any one oyster mushroom or any Shiitake mushroom
22. Stalk, stem and leaf petiole vegetable group	Asparagus and celery
23. Tropical and subtropical fruit, edible peel group	Date, fig, guava and olive
24. Tropical and subtropical fruit, inedible peel group	Atemoya or sugar apple, avocado, banana or pomegranate, dragon fruit, lychee, passionfruit, pineapple and prickly pear, fruit
25. Herb crop group	Basil, fresh leaves and mint, fresh leaves; basil, dried leaves and mint, dried leaves
26. Spices crop group	Dill seed or celery seed

quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding the pollution problems and (iv) when used as a component of integrated pest management (IPM) programs, biopesticides can contribute greatly**.** Biopesticides fall into three major categories: (1) Microbial pesticides contain a microorganism (bacterium, fungus, virus, protozoan or alga) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pests. For example, there are fungi that control certain weeds, and other fungi that kill specific insects. The most widely known microbial pesticides are varieties of the bacterium *Bacillus thuringiensis*, or Bt, which can control certain insects in cabbage, potatoes, and other crops. Bt produces a protein that is harmful to specific insect pests. Certain other microbial pesticides act by out-competing pest organisms. Microbial pesticides need to be continuously monitored to ensure they do not become capable of harming non-target organisms, including humans. (2) Plant pesticides are pesticidal substances that plants produce from genetic material that has been added to the plant. For example, scientists can take the gene for the Bt pesticidal protein, and introduce the gene into the plant's own genetic material. Then the plant, instead of the

Table 7: Uses of biopesticide in vegetable crops

Biopesticide	*Vegetable*	*Against the disease*	*Dosage*	*Remarks*
Ampelomyces quisqualis 2.0% WP	Okra	Powdery mildew (*Erysiphe cichoracearum*)	2.5 kg/ha	
Azadirachtin 0.030% (300 ppm)	Okra	Powdery mildew	2–2.50/ha	
Pseudomonas fluorescens 1.75% WP	Tomato	Early blight	05 g/kg seed (Seed treatment) & 3 kg per ha (06 g/litre water) (Foliar spray)	
P. fluorescens 0.5% WP	Chili	Damping off (*Pythium aphanidermatum*)	10 g/kg seed	
P. fluorescens 0.5% WP	Tomato	Wilt (*Fusarium oxysporum F.sp.*)	10 gm/kg of seeds	Soil Treatment: 2.5 kg of *P. fluorescens* 0.5% WP Spread uniformly over a hectare of land
P. fluorescens 1.0% WP	Tomato	Wilt (*F. oxysporum*), Damping Off (*Pythium aphanidermatum*), Root rot (*Rhizoctonia spp.*)	5 gm/kg of seed	Seedling root dip treatment: Mix 10 gm in one litre of water and dip the tomato seedling
P. fluorescens 1.0% WP	Tomato	Wilt (*F. oxysporum*)	Treat the seed with *P. fluorescens* 20 gm/kg of seeds & treat the nursery beds with the *P. fluorescens* @ 50gm/sq.m and apply *P. fluorescens* @ 5 kg/ha enriched FYM @ 5 tons/ha to the soil before transplanting.	
P. fluorescens 1.0% WP	Brinjal	Wilt (*F. oxysporum*)	Treat the seed with *P. fluorescens* @ 20 gm/kg of seeds & treat the nursery beds with the *P. seudomonas* @ 50 gm/sq.m a	
P. fluorescens 1.0% WP	Okra	Wilt (*F. oxysporum*)	20 gm/kg of seeds	apply *Pseudomonas* @5 kg/ha enriched FYM @5 tons/ha to the soil before sowing
P. fluorescens 1.0% WP	Carrot	Root rot (*Athelia rolfsii*)	20 gm/kg of seeds	apply *Pseudomonas* 5 kg/ha enriched FYM @5 tons/ha to the soil before sowing.
Trichoderma harzianum 1.0% WP	Tomato	Wilt (*F. oxysporum*)	Treat the seed with *Trichoderma* @ 20 gm/kg of seeds & treat the nursery beds with the *Trichoderma* @50 gm/sq.m and apply T. harzianum @5 kg/ha enriched FYM @5 tons/ha to the soil before transplanting.	
T. harzianum 1.0% WP	Brinjal	Wilt (*F. oxysporum*)	Treat the seed with *T. harzianum* @ 20 gm/kg of seeds & treat the nursery beds @50 gm/sq.m and apply *Trichoderma* @5 kg/ha enriched FYM @5 tons/ha to the soil before transplanting.	
T. harzianum 1.0% WP	Carrot	Root rot (*Sclerotium rolfsii*)	20 gm/kg of seeds	
T. harzianum 1.0% WP	Okra	Wilt (*F. oxysporum*)	20 gm/kg of seeds	
T. viride 1.0% WP	Cowpea	Root rot	4 g/kg of seed	
T. viride 1.0% WP	Chili	Damping off	4 g/kg of seed	

T. viride 0.5% WP	Tomato	Wilt (*Fusarium oxysporum*)	10 g/kg seed	
T. viride 1.15% WP	Chili	Root wilt	Seed Treatment: 5.0 gm/ kg seed Soil Application: 3.0 kg/ha	
T. viride 1.0% WP	Cowpea	Root Rot	5 gm/kg seed	Soil treatment: Mix 2.5 kg of *trichoderma* with 62.5 kg FYM and broadcast uniformly over a hectare of land and irrigate the field immediately
T. viride 1.0% WP	Chili	Damping off (*Pythium aphanidermatum*)	4 g/kg seed	
T. viride 1.5% LF	Tomato	Root wilt (*F. oxysporum f.sp. lycopersici*)	Seed treatment: 5 mL/kg seed Seedling dip: 5 mL/lit water Soil treatment: 3000 mL/ha	
T. viride 5.0% Liquid Formulation	Pea	Powdery mildew (*Microsphera alni*)	500 liter/ha (foliar spray)	
T. viride 5.0% SC	Chili (Nursery)	Damping off (*Pythium aphanidermatum*)	2 mL/kg seed	
T. viride 1.0% WP	Tomato	Seedling wilt (Fusarium oxysporum), Damping off (*Pythium aphanidermatum, Rhizoctonia solani*)	Seed Treatment: 9 g/kg Root zone application: 2.5 kg/ha	
T. viride 1.0% WP	Cauliflower	Stalk rot (*Sclerotinia sclerotiorum*)	4 gm/kg seed	
T. viride 1.0% WP	Brinjal	Root Rot/ Wilt/ Damping off (*Rhizoctonia bataticola, Sclerotium rolfsii, F. oxysporum, R. solani*)	5 gm/kg seeds Nursery Treatment: 250 gm/50 litre of water/400 sq. m	
T. viride 1.0% WP	Cabbage	Root rot/Collar rot (*R. solani*)	Root dip Treatment: 10 gm/litre of water Seedling Soil Treatment: 2.5 kg/ha	

Bt bacterium manufactures the substance that destroys the pest. Both the protein and its genetic material are regulated by EPA; the plant itself is not regulated. (3) Biochemical pesticides are naturally occurring substances that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are synthetic materials that usually kill or inactivate the pest. Biochemical pesticides include substances that interfere with growth or mating, such as plant growth regulators, or substances that repel or attract pests, such as pheromones. Because it is sometimes difficult to determine whether a natural pesticide controls the pest by a non-toxic mode of action, EPA has established a committee to determine whether a pesticide meets the criteria for a biochemical pesticide. The growth of total world production of biopesticides is rising and therefore demand and use is also increasing.

Safe use of pesticides to reduce the rate of residues in vegetables

Farmers rely on the use of synthetic insecticides since there aren't many non-chemical alternatives for managing insect pests in fruits and vegetables. It is necessary to switch from the traditional method to safer synthetic alternatives in order to prevent the risk associated with poisonous insecticides. The following is a description of some of the methods that safer pesticides have been created and how pests have evolved resistance to them.

Pesticides with low doses and low toxicity commonly more than 1-kg a.i. per ha are used at fairly high rates. However, when new-generation insecticides take their place, their use is on the decline. the frequency of application of the common insecticide imidacloprid is applied at a rate of 21 to 45 g/ha to fruits and vegetables, and the rates for milbemectin and emamectin-benzoate are even lower. The majority of recently launched pesticides are less hazardous to non-targets. Contemporary pesticides that have been approved for use in our country, such as chlorantraniliprole, hexythiazox, lufenuron, and pyridalyl, among others, have low mammalian toxicity (Table 8). Most of them don't survive in the environment for very long. In the near future, these safer pesticides will likely completely replace all of the currently used ones, providing crops with complete protection while not compromising biodiversity (Sharma and Choudhury, 2018).

Table 8: Toxicity level of traditional pesticides and modern pesticides

Traditional pesticides			*Modern pesticides*		
Pesticides	*Dose (g a.i./ha)*	*LD_{50}, acute, oral,rat (mg/kg body weight)*	*Pesticides*	*Dose (g a.i/ha)*	*LD_{50}, acute,oral,rat (mg/kg body weight)*
Carbofuran	750–1000	8.0	Emamectin-benzoate	6–10	1516
Chlorfenvinfos	1000–3000	9.7–38.0	Chlorantraniliprole	10–30	>5000
Dichlorvos	225–750	50	Clothianidin	25–30	>5000
Methyl-parathion	250–500	14–24	Hexythiazox	15–25	>5000
Monocrotophos	>500	18–20	Imidacloprid	21–25	450
Phorate	1000–2000	3.7	Lufenuron	30	2000
Phosphamidon	200–500	18–30	Milbemectin	3.25	456
Quinalphos	250–500	71	Pyridalyl	50–75	>5000
Captan	750–1250	>2000	Hexaconazole	60	2189

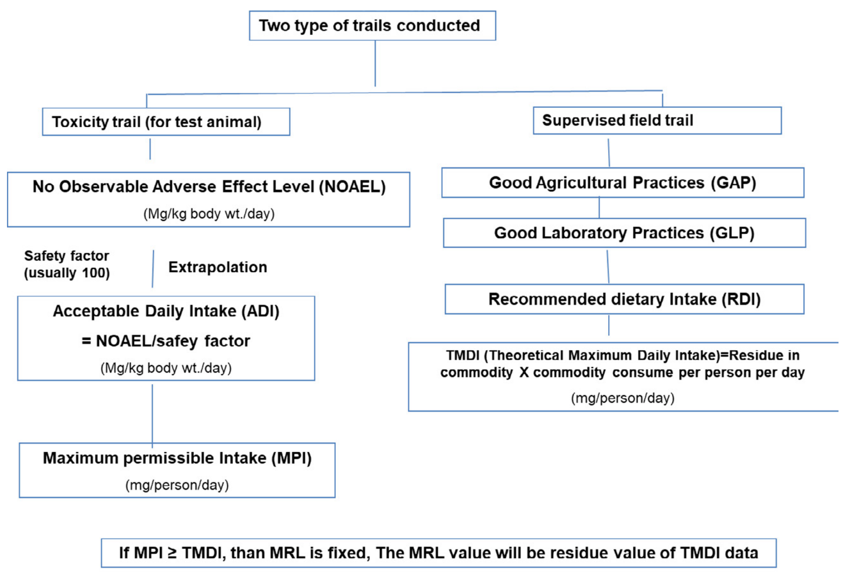

Fig. 1: Stepwise MRL fixation

Pesticides with newer mode of action to combat resistance

Severe resistance has been developed by insect pests against many insecticides. The insecticide can be metabolized by the resistant insects, which lowers its concentration inside the insect to an ineffective level. Farmers must switch to insecticides with various mechanisms of action to avoid this issue. In the past, only two types of pesticides were available: organophosphates and carbamates, which worked by inhibiting the nervous system's acetylcholine esterase (ACHE) enzyme. Organochlorines and pyrethroids acted by either suppressing normal chloride channel function at the GABA receptor-ionophore complex of the nervous system or by opening up the sodium ion channels in neurons, causing hyperactivity of the nerves. Neonicotinoid insecticides, for example, bind to various post-synaptic nicotinic acetylcholine receptor types in the central nervous system. Neonicotinoid insecticides are one of many novel families of pesticides that have been discovered in recent years with various after-action modes. Diamides activate muscle ryanodine receptors, producing paralysis, while pesticides like diafenthiuron, propargite, and tetradifon disrupt the mitochondrial enzyme that synthesizes ATP, among other things, all work to prevent the formation of chitin in insects. The fungicide carbendazim cannot be used to treat grape anthracnose disease because the causative organism *Elsinoe ampelina* has become resistant to it, most likely as a result of particular changes to the binding sites on the ß-tubulin protein. However, the combination product of carbendazim and mancozeb is particularly efficient in controlling this *Elsinoe* resistance. Similar to this, there are currently a number of other compounds, such as azoxystrobin, dimethomorph, cymoxanil + mancozeb, etc., that can be used to overcome the resistance generated by metalaxyl-tolerant strains of *Phytophthora infestans* that cause late blight disease in potato. The ecosystem is less harmed by many of these new pesticides with novel modes of action because they are more polar and less persistent. Also, using pesticides with various modes of action prevents the target pest from developing resistance to any chemical.

Botanicals as pesticides and leads to newer pesticides

Plants have been successfully used for the extraction of plant protection chemicals because they are a rich source of bioactive organic molecules. The dangerous substance physostigmine, also known as esserin, which was the basis of organocarbamate insect chemistry, is found in the African fish roe. The insecticidal properties of some *Chrysanthemum* species from Africa and Asia were well known. Six naturally occurring terpenoid esters, collectively known as pyrethrins, effectively kill some insects in chrysanthemum flowers. However, since natural compounds are photosensitive in sunlight, they are not very active in outdoor conditions. A wide variety of photostable pyrethrin-like compounds, collectively known as "synthetic pyrethroids"; They were made by chemically modifying the structures of natural pyrethrins through chemical synthesis. Plant protection uses azadirachtin, a strong anti-eating substance found in the kernels of neem seeds. Although azadirachtin is photosensitive in nature and does not last for a suitable time, its use was initially difficult. Sunscreen was added to the formula to solve the problem and is now an integral part of integrated pest control. Animal compounds have also been used as pesticides either directly or indirectly. For example, nereitoxin analogs have been created from a parent compound obtained from the marine annelid *Lumbriconereis heteropoda*. The mammalian toxicity of all analogs is much lower than that of the original neretoxin. New lead molecules can be found using untapped or underutilized microbes, plants and animals. These bioactive natural products can lead to the synthesis of new molecules with low mammalian toxicity, low dose (high potency), and environmentally safer molecules.

Biopesticides

An environmentally beneficial, self-sustaining method of controlling insects is by employing live insect diseases. Although these formulations of living organisms have some limits, once a component of this method becomes established in the crop field, a constant pressure builds upon the target insect to keep its number below the economic threshold level. Certain formulations of the *Bacillus thuringiensis* bacteria, the nuclear polyhedrosis virus (NPV), and others are examples of such biocontrol agents for pest control. These agents typically play a significant role in integrated pest management programmes.

Selection of insecticide, rate of application and application method

Farmers must choose the insecticide and the correct method of application by measuring the area to assess the extent of insect damage. The pesticide label on each formula package specifies the amount, time and method of application, as well as the warnings required during and after application. Regular inspection and maintenance of sprinklers, pipes, gauges and tanks is required. Correct adjustment of the sprayer is the key to accurate pesticide application rates. The use of high-quality, calibrated sprayers ensures a uniform application of pesticides. Pesticides are most sensitively washed away from target areas by heavy rain within the first few hours after application. Therefore, the use of pesticides should be avoided when heavy rain is expected. Wind speed, temperature and humidity affect the transport of pesticides. Wear can be reduced by lowering the boom height and using large drop nozzles.

Education of farmers

In the current situation, farmers have several non-chemical means to control fruit and vegetable pests, which minimizes the risk of pesticides. The biggest challenge is training farmers to use pesticides safely. The success of developing more secure capabilities depends on how users adopt it. Each system stakeholder is responsible for the change. The goal is to create strong and effective networks between research institutions, extension groups and farmers to reduce pesticide use, produce safe food and protect the environment.

Conclusion

Pesticides have the potential to have major harmful impacts on humans, the significance of food quality has gained much attention. Pesticide residues in food commodities going through the international market have been one of the concerns of various governments. The Codex Alimentarius Commission of the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) have jointly established maximum residue limits (MRLs) for pesticides in various crops. While attempting to maintain food security, all organizations, both at the national and international levels, should collaborate to assure consumer safety. The safety of consumers should be prioritized above all other factors in the food industry, and this can only be done if the many food-related politicians carry out their duties faithfully and consistently to ensure the provision of safe meals. International agreements and rules of conduct exist to encourage nation-to-nation cooperation and the sharing of their responsibilities. To reduce the misuse of chemical pesticides in vegetables the use of alternative pest management strategies is important. Biopesticides are specific to a target pest and offer an ecologically sound and effective solution to pest problems. Despite several constraints, biopesticides are being used in vegetable production systems. They pose less threat to the environment and to human health.

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सारांश

कीटनाशकों के उपयोग से गहन सब्जी उत्पादन उत्पादकों और उपभोक्ताओं के लिए सबसे बड़ा खतरा है। मध्यान्तर में ऐसे उदाहरणों में अपेक्षाकृत कम पूर्व-फसल के कारण कीटनाशक अवशेषों का संचय बढ़ जाता है । लेबल दावे की जानकारी के बिना कीटनाशकों के उपयोग से लागत बढ़ जाती है उत्पादन, स्प्रे की संख्या और श्रम लागत में वृद्धि होती है, जिससे अंततः किसानों की लाभप्रदता संख्या में कमी आती है । इसलिए, लेबल दावे के अनुसार कीटनाशक को अपनाना बहुत आवश्यक है। फसल के समय अवशेष अधिकतम का स्तर अवशेष सीमा (एमआरएल) से कम होने चाहिए। सब्जियों में पाए जाने वाले कीटनाशकों को केंद्रीय कीटनाशक बोर्ड और पंजीकरण द्वारा पंजीकृत नहीं किया जाता है। (CIBRC) समिति को उस विशिष्ट सब्जी पर उपयोग के लिए जो कीटनाशकों का ऑफ लेबल उपयोग है। फसल ग्रुपिंग एक ऐसे मॉडल का विकास है जो एक ही समूह की कई अन्य फसलों की प्रतिनिधि फसलों के कुछ अवशेष डेटा से एक्सट्रपलेशन की अनुमति देता है । कुछ प्रमुख फसलों के अवशेष मूल्यों के आधार पर फसलों के पूरे समूह के लिए यह अवशेषों की स्थापना की अनुमति देता है। फसल समूह प्रतिनिधि फसल की स्वीकृति इसके उपयोग से होने वाली बचत का एक महत्वपूर्ण घटक है। निर्यात के लिए बाधा के रूप में कीटनाशक अवशेषों को हटाने के प्रयासों में आईआर-4 की भागीदारी अमेरिका में उगाई जाने वाली पिछले बीस वर्षों में विशेष फसलों का महत्व बढ़ रहा है। इससे पहले कि दोनों देशों के लिए बड़ी समस्या बनने की संभावना हो एक विशेष फसल पर सामान्य एमआरएल से एक विशेष फसल सुरक्षा उत्पाद का उपयोग की स्थापना करके, व्यापार तनाव के बीच रोका जा सकता है। यू.एस./कनाडाई सीमा के दोनों ओर विशेष फसल साझेदारी है। इसमें शामिल सभी विशेष फसल उत्पादक हितधारकों के लिए मूल्यवान परिणाम प्राप्त हुए। IR4 ने कनाडा, न्यू ज़ीलैंड, ब्राज़ील, कोस्टा रिका और कोलंबिया के साथ समझौता ज्ञापन पर हस्ताक्षर किए। भारत को अनेक फसलों के लिए कीटनाशक लेबल दावे विनियमित करने के लिए भी इस मॉडल की बहुत आवश्यकता है।