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Pesticide use and residue management in vegetables

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PREFACE

India is second largest producer of vegetables in the world. Different agroclimatic zones, vast tracts of different kinds of soil types, tropical to temperate climate ensure that there is large diversity of vegetables in this country. Vegetables form an important part of Indian diet, more so, as Indians are predominantly vegetarian. Due to improved cultivation practices, increase in tunnel, polyhouse and nethouse cultivation of vegetables, off season and exotic vegetables are also available in Indian markets. However, indiscriminate application of pesticides on vegetables during their cultivation for control of myriads of pests has resulted in persistence of toxic residues of pesticides on the produce. The consumers within or outside the country are becoming more and more quality conscious. They are ready to pay a premium price for vegetables if the same are free from pesticide residues and other contaminants.

Work has been carried out at ICAR-IIHR since its inception on determination of safe waiting periods for harvest of vegetables, use of IPM in vegetable cultivation ensuring residues within permissible levels, methods for dislodging surface residues of pesticides from vegetables, dissipation rate of pesticide residues in polyhouse grown vegetables vis-a vis those grown under open field conditions etc. It was therefore felt by the Institute Research Council that a comprehensive technical bulletin on pesticide residue management in vegetables be brought out. I am glad that the concerned scientists of this Institute could compile and edit a variety of useful information in this bulletin, viz. waiting periods of commonly used pesticides in vegetables, FSSAI permissible limits of pesticides in vegetables, approved uses of pesticides etc.

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Place : Bengaluru
Date : 04 October,2018

(M. R. Dinesh)
Director, ICAR-IIHR

Introduction

Increasing awareness regarding good nutrition through quality food is creating a rise in the demand for vegetables. In India, the production of vegetables has risen significantly in the recent past with the help improved varieties and production technologies. Crops like potato, tomato, onion, brinjal, cabbage, cauliflower, and okra comprise the major part in vegetable production (Fig. 1). Currently, India produces close to 175 million tonnes of vegetables from an area of 10.30 million hectares (NHB, 2017) and is the second highest producer of vegetables globally, next only to China. Though there has been a phenomenal increase in area, production and productivity of vegetables in our country during the last 6 decades, still there is a huge gap between present production and future requirements. This necessitates increasing vegetable productivity or reducing losses in their production for meeting current and future demands.

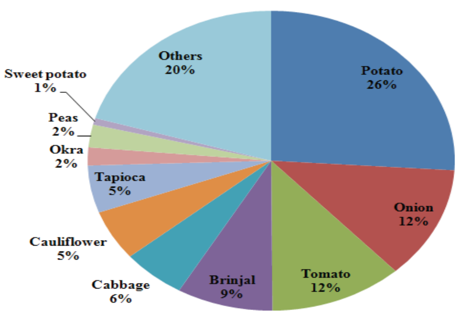

Fig. 1: Production share of major vegetables in India during 2013-14

Pest problems and use of pesticides in vegetables

The insect-pest and disease problem is a key constraint in producing quality vegetables in large quantities. Due to insect-pests, vegetable growers are losing crop yield to the extent of 10 to 30%. The losses are higher in some crops. Diamond back moth causes 52% crop damage in case of cabbage (Krishnamoorthy, 2004). Devjani and Singh (1999) and Ayalew (2006) recorded 50-80% annual loss in the marketable yield of cabbage due to diamond back moth infestation. Onion thrips can cause up to 50% damage to onion (More, 1977), brinjal fruit and shoot borer to up to 60% to brinjal (Gangwar and Sachan, 1981), and tomato fruit borer in tomato by more than 50% (Dhandapani *et al.*, 2003). Complete loss of bitter gourd yield by fruit flies has also been observed (Srivastava and Butani, 1998). Similarly, crop losses due to various diseases are caused by fungi, viz. *Rhizoctonia, Sclerotium, Pythium, Alternaria, Cercospora, Colletotrichum* etc.; bacteria, viz. *Xanthomonas, Corynebacteria, Pseudomonaes, Ralstonia* etc. and viruses, viz. leaf curl, yellow mosaic virus. Rai *et al.* (2014) enumerated the crop losses caused by pathogens. In tomato, the yield losses due to early blight (*Alternaria solani*), wilt (*Fusarium oxysporum*), and wilt (*Verticillium dehalie*) are 78%, 10-60%, and 20-30%, respectively. In chilli, the yield losses are 30-80% due to anthracnose (*Colletotrichum* spp.), and 5-50% due to bud rot (*Choanephora cucurbitarum*). *Xanthomonas campestris* pv. *campestris,* the causal organism for black rot disease of cabbage, causes a yield loss of up to 50%.

At the time of such insect-pest attack or disease incidence, farmers have a tendency to use synthetic insecticides or fungicides indiscriminately. This indiscriminate use may be harmful to human health as well as to the ecosystem. In the present situation, farmers do not have many effective alternatives to avoid the use of synthetic pesticides. Judicious application of available pesticides as per scientific recommendations and label claim is needed to minimize pesticide residue problems and safe vegetable production. At present for combating insect-pests and diseases in India, we have 184 registered insecticides and fungicides and 75 combination products. Among these, few low dose and low mammalian toxicity insecticides are also being marketed.

Recommendation and use of pesticides in vegetables

Pesticide use in vegetable crops

Among the different classes of pesticides used in India, the per cent share of insecticides (60%) is the highest followed by the shares of fungicides (19%), herbicides (16%), biopesticides (3%) and others (3%). It is estimated that around 13-14% of the total pesticides used in the country is applied to fruits and vegetables, of which insecticides accounted for two-thirds of the total. Among different vegetable crops the maximum pesticide usage is in chilli (5.13 kg a.i./ha) followed by brinjal (4.60 kg a.i./ha), cole crops (3.73 kg a.i./ha) and okra (2-3 kg a.i./ha) (Kodandaram *et al*., 2013). Farmers often apply pesticides at doses higher than recommended. Use of non label claim pesticides and sale of spurious pesticides add to the problem of residue contamination in vegetables. According to Agrochemicals Policy Group (APG), a pesticide industry body, spurious and substandard pesticides accounted for approximately 40% of the pesticides sold in India in the financial year 2012 (Panchal *et al*., 2013). Pesticide contaminated vegetables may affect our health directly or indirectly. Sizeable quantity of different vegetables are also being exported earning foreign currency, but detection of pesticide residues in these may lead to rejection of the consignment by importing countries.

Recommendations of pesticide use in vegetables

During registration of a pesticide, the registrant company declares its use in the label claim. The crop(s) and the application rate(s) mentioned in the label claim are selected on the basis of bio-efficacy data obtained from the experiments conducted by SAUs, ICAR institutes or other recognized laboratories. The actual recommendations on use of pesticides are developed on the basis of evaluation in the laboratory and in the field against the target species. Such studies also take care of metabolism, persistence and degradation of the pesticides so as to develop a proper dose regime, which reduce risk to non target species and users. There have been issues countrywide about the inadequate knowledge on the label claims of pesticides and their utilization and a large portion of usage of pesticides is without approved label claims. These lead to presence of residues of those pesticides, which are not approved for use on particular crops. The Registration Committee, constituted by the Government of India brought out a compilation of approved uses of pesticides in the best possible way. Recommendations of approved pesticide use in India are given crop-wise for vegetable crops in the following tables:

Table 1. Approved uses of registered pesticides on vegetables

Tomato

Pesticide	Pest	a. i. (g/ha)	Formulation (g or mL/ha)	Dilution (L)	Waiting period (days)
Insecticide					
Azadirachtin 1% (10000 ppm)	Fruit borer (*Helicoverpa armigera*)	-	1000-1500	500	3

Carbofuran 3% CG	White fly	1200	40000	-	-
Dazomet technical (in nursery)	Root-knot nematode	30-40	30-40	-	-
Dimethoate 30% EC	Aphids White fly	200 300	660 990	500-100	-
Fenazaquin 10% EC	Two spotted spider mite	125	1250	500	7
Flubendamide 20% WG / Flubendamide 39.35% M/M	Fruit borer	48	100	375-500	5
Imidacloprid 17.8% SL	Whitefly	30-35	150-175	500	3
Indoxacarb 14.5% SC	Fruit borer	60-75	400-500	300-600	5
Lambda-cyhalothrin 4.9% CS	Fruit borer	15	300	500	5
Lambda-cyhalothrin 5% EC	Fruit borer	15	300	400-600	4
Malathion 50% EC	White fly	750	1500	500-1000	-
Methomyl 40% SP	Pod borers	300-450	750-1125	500-1000	5/6
Novaluron 10% EC	Fruit borer	75	750	500-1000	1-3
Nuclear Polyhedrosis Virus 0.43% AS	*Helicoverpa armigera*		1500	400-600	-
Nuclear Polyhedrosis Virus 2.0% AS	Fruit borer	-	250-500	500	-
Oxydemiton-methyl 25% EC	White fly	250	1000	500-1000	-
*Phorate 10% CG	White fly	1500	15000	-	-
Phosalone 35% EC	Fruit borer	450	1285	500-1000	-
Quinalphos 25% AF	Fruit borer	300-350	1500-1750	750-1000	7
Quinalphos 25% EC	Fruit borer	250	1000	500-1000	-
Spiromesifen 22.9% SC	Whiteflies, Mites	150	625	500	3
Thiomethoxam 25% WG	White flies	50	200	500	5

Trichlorofon 5% GR, 5% Dust, 50% EC	Fruit and shoot borer Diamond back moth Tobacco caterpillar Red pumpkin beetle	500 500 750 500	-	-	-
Novaluron 5.25% + Indoxacarb 4.5% SC	Fruit borer, Leaf eating caterpillar	43.31 + 37.13 - 45.94 + 39.38	825-875	500	5
Fungicides					
Azoxystrobin 23% SC	Early and Late blight	125	500	500	3
Captan 50% WP	Early blight	1250	2500	750-1000	-
	Late blight	1250	2500	750-1000	-
Captan 75% WP	Damping off (nursery)	0.25%	2500	1000 Soil drench in nursery	NA
	Early blight	1250	1667	1000	6
	Late blight	1250	1667	1000	6
Captan 75% WS	Damping off	15-25 per kg seed	20-30 per kg seed	1	-
Copper oxychloride 50% WP	Early blight	1250	2500	750-1000	-
	Late blight	1250	2500	750-1000	-
	Leaf spot	1250	2500	750-1000	-
Cyazafamid 34.5% SC	Late blight	80	200	500	3-5
Iprodione 50% WP	Early blight	750	1500	500	15
Kitazin 48% EC	Early blight	100 g in 100 L of water	200 mL in 200 L of water	As required depending upon crop stage and plant protection equipment used	5
Mancozeb 35% SC	Early blight, Late blight	175 g/100 L water	500 g/100 L water	500 L water or as required depending upon crop stage and equipment used	10

Mancozeb 75% WG	Early blight	750	1000	500	5-6
Mancozeb 75% WP	Late blight	1125-1500	1500-2000	750	-
	Buck eye rot	1125-1500	1500-2000	750	-
	Leaf spot	1125-1500	1500-2000	750	-
Mandipropamid 23.4% SC	Late blght	100	400	500	5
Metalaxyl-M 31.8% ES	Late blght	1700	2500	500	5
Metiram 70% WG (seed dresser)	Damping off	640	2000	-	-
Metiram 70% WG	Alternaria blight (*Alternaria solani*)	1750	2500	500-750 lt	6
Propineb 70% WP	Buck eye rot	1000	1500	500 (As required depending upon crop stage and plant protection equipment used)	10
Pyraclostrobin 20% WG	Early blight	75-100	375-500	500	3
Streptomycin sulphate 90% + Tetracyline hydro-cloride 10% SP	Bacterial leaf spot	Spray seedlings with streptocycline 40 to100 ppm solution in seed beds and fields after the appearance of first true leaves. Two sprays of streptocycline, one before transplanting and another after are effective for controlling the disease.			

Brinjal

Pesticide	Pest	a. i. (g/ha)	Formulation (g or mL/ha)	Dilution (L)	Wait-ing period (days)
Insecticides					
Azadirachtin 1% (10000 ppm)	Fruit and shoot borer (*Leucinodes orbonalis*)	-	1000-1500	500	3
Azadirachtin 0.03% (300 ppm) Neem Oil Based WSP Containing	Shoot and fruit borer, beetles	-	2500-5000	500-1000	7
Carbofuran 3% CG	Root knot nematode, Reniform nematode	2000	66600	-	-
Chlorpyrifos 20% EC	Shoot and fruit borer	200	1000	500-1000	-

Cypermethrin 0.25% DP	Fruit and shoot borer	50-60	20000-24000	-	3
Cypermethrin 10% EC	Fruit and shoot borer	50-70	550-760	150-400	-
Cypermethrin 25% EC	Shoot and fruit borer, Jassids, *Epilachna* grub	37-50	150-200	500	1
*Dichlorvos 76% EC	Red spider mite	250-500	1350-2700	500-1000	15-20
Dicofol 18.5% EC	Red spider mite	250-500	1350-2700	500-1000	15-20
Difenthiuron 50% EC	Whitefly	300	600	500-750	3
Dimethoate 30% EC	Shoot borer	200	660	500-1000	-
Emamectin-benzoate 5% SG	Fruit and Shoot borer	10	200	500	3
Endosulfan 2% DP	Fruit and shoot borer	500	25000	-	7
Fenazaquin 10% EC	Red spider mite	125	1250	500	7
Fenpropathrin 30% EC	Whitefly, Shoot and Fruit borer, Mites	75-100	250-340	750-1000	10
Fenvalerate 20% EC	Shoot and fruit borer Aphids	75-100 75-100	375-500 375-500	600-800 600-800	5 5
Flumite (Flufenazine) 20% SC	Mite	80-100	400-500	500-1000	5
Lambda-cyhalothrin 4.9% CS	Shoot and fruit borer	15	300	500	5
Lambda-cyhalothrin 5% EC	Shoot and fruit borer	15	300	400-600	4
Malathion 50% EC	Mites	750	1500	500-1000	-
*Phorate 10% CG	Aphid, Jassids, Lace wing bug Red spider mite, Thrips	1500 1000	15000 10000	-	-
Phosalone 35% EC	Fruit borer	500	1428	500-1000	-
*Phosphamidon 40% SL	Jassids, Aphids, White fly	250-300	625-750	500	10
Profenofos 50% EC	Two spotted spider mite	570	1000	400	6
Quinalphos 25% AF	Shoot/Fruit borer, Jassids, Epilachna beetle	300-350	1500-1750	750-1000	7
Quinalphos 25% EC	Leaf hopper Shoot/Fruit borer	250 375	1000 1500	500-1000 500-1000	-
Spiromesifen 22.9% SC	Red spider mite	96	400	500	5

Thiacloprid 21.7% SC	Shoot and fruit borer	180	750	500	5
Thiodicarb 75% WP	Shoot and fruit borer	470 to 750	625 to 1000	500	6
Thiomethoxam 25% WG	White flies	50	200	500	3
Trichlorofon 5% GR, 5% Dust, 50% EC	Fruit and shoot borer Diamond back moth Tobacco caterpillar Red pumpkin beetle	500 500 750 500	-	-	-
*Triazophos 40% EC	Shoot and Fruit borer, Epilachna beetle	500	1250	500	5
Betacyfluthrin 8.49% + Imidacloprid 19.81% OD	Aphids, Jassids Shoot and fruit borer	15.75+36.75 – 18 + 42	175-200	500	7
Cypermethrin 3% + Quinalphos 20% EC	Shoot and Fruit borer		350-400	500-600	7
Deltamethrin 1% + Trizophos 35%EC	Shoot and Fruit borer, Jassids, Aphids, Epilachna beetle	10+350- 12.5+450	1000-1250	500	3
Fungicides					
**Benomyl 50 % WP	Powdery mildew	100	200	600	-
Captan 75% WP	Damping off (nursery)	0.25%	2500	1000 Soil drench in the nursery	NA
Carbendazim 50% WP	Leaf spot	150	300	600	-
	Fruit rot	150	300	600	-

Okra

Pesticide	Pest	a. i. (g/ha)	Formulation (g or mL/ha)	Dilution (L)	Waiting period (days)
Azadirachtin 0.03% (300 ppm) Neem Oil Based WSP Containing	Fruit borer, White flies, Leaf hopper	-	2500-5000	500-1000	7
**Carbaryl 5% DP	Jassids	1000	20000		8
** Carbaryl 10% DP	Fruit borer, Jassids	-	2500	25000	-
Carbofuran 3% CG	Aphid	-	1000	33300	-
Cypermethrin 10% EC	Fruit borer	50-70	550-760	150-400	-
Cypermethrin 25% EC	Shoot and fruit borer, Jassids	37-50	150-200	500	3
Deltamethrin 2.8% EC	Shoot and fruit borer Jassid	10-15 10	400-600 400	400-600 400-600	1 1

Dichlorvos 76% EC	Red Spider mite	250-500	1350-2700	500-1000	15-20
Dicofol 18.5% EC	Spider Red mite	250-500	1350-2700	500-1000	15-20
Dimethoate 30% EC	Aphids Leaf hopper Jassids	700 600 600	2310 1980 1980	500-1000 500-1000 500-1000	-
Emamectin benzoate 5% SG	Fruit and Shoot Borer	6.75-8.50	135-170	500	5
Endosulfan 2% DP	Fruit and shoot borer	500	25000	-	4
Endosulfan 4% DP	Aphids, Jassids	140-175	3500-4400	-	21
Endosulfan 35% EC	Aphid	140	400	500-1000	21
Fenazaquin 10% EC	Red spider mite	125	1250	500	7
Fenpropathrin 30% EC	Whitefly, Shoot and Fruit borer, Mites	75-100	250-340	750-1000	7
Fenvalerate 20% EC	Shoot and fruit borer Jassids	60-75 60-75	300-375 300-375	600-750 600-750	7 7
Imidacloprid 70% WP	Jassids, Aphids, Thrips	21 - 24.5	30 - 35	375 - 500	3
Imidacloprid 48% FS	Jassid, Aphids	300 – 540	500 – 900 (per 100 kg seed)	-	-
Imidacloprid 70% WS	Jassids, Aphids	350 – 700	500 – 1000 (per 100 kg seed)	-	-
Imidacloprid 17% SL	Aphids, Jassids, Thrips	20	100	500	3
Lambda-cyhalothrin 4.9% CS	Fruit borer	15	300	500	5
Lambda-cyhalothrin 5% EC	Jassids, Shoot borer	15	300	300-400	4
Malathion 50% EC	Aphids, Jassids, Spotted boll worm	500 625 750	1000 1250 1500	500-1000 500-1000 500-1000	-
Oxydemeton-methyl 25% EC	White fly Jassid/ Leaf beetle	250 400	1000 1600	500-1000 500-1000	-
Permethrin 25% EC	Fruit borer Aphid Jassids	100-125 100-125 100-125	400-500 400-500 400-500	750-1000 750-1000 750-1000	-
Phosalone 35% EC	Fruit borer	525	1500	500-1000	-
Pyridalyl 10% EC	Fruit and shoot borer	50-75	500-750	500-750	3
Quinalphos 25% AF	Shoot/Fruit borer	250-300	1250-1500	750-1000	7
Quinalphos 25% EC	Fruit borer Leaf hopper Mite	200 250 250	800 1000 1000	500-1000 500-1000 500-1000	-
Spiromesifen 22.9% SC	Red spider mite	96-120	400-500	500	3

Thiomethoxam 70% WS	Aphids, Jassids	200	286	-	-
Thiomethoxam 25% WG	Jassids, Aphids, White flies	25	100	500-1000	5

Chilli

Pesticide	Pest	a. i. (g/ha)	Formulation (g or mL/ha)	Dilution (L)	Wait-ing period (days)
Insecticide					
Buprofezin 25% SC	Yellow mite	75-150	300-600	500-750	5
Carbofuran 3% CG	Thrips	1000	33300	-	-
Carbosulfan 25% EC	White aphid	200-250	800-1000	500-1000	8
Chlorfenapyr 10% SC	Mites (*Polyphagotarson-emus latus*)	75-100	750-1000	500	5
Deltamethrin 2.8% EC	Fruit borer	10-12.5	400-500	400-600	5
Difenthiuron 50% EC	Mites	300	600	500-750	3
Dimethoate 30% EC	Mites	300	990	500-100	-
Emamectin-benzoate 5% SG	Fruit borer, Thrips, Mites	10	200	500	3
Endosulfan 35% EC	Aphids	140	400	500-1000	21
Endosulfan 4% DP	Aphids, Jassids	140-175	3500-4400	-	21
Ethion 50% EC	Mites, Thrips	750-1000	1500-2000	500-1000	05
Fenazaquin 10% EC	Yellow mite	125	1250	400-600	10
Fenpropathrin 30% EC	Thrips, Whitefly, Mites	75-100	250-340	750-1000	7
Fenpyroxymate 5% EC	Yellow mite	15-30	300-600	300-500	7
Fipronil 5% SC	Thrips, Aphids, Fruit borers	40-50	800-1000	500	7
Flubendamide 39.35% M/M	Fruit borer	48-60	100-125	500	7
Hexythiazox 5.45% EC	Yellow mites	15-25	300-500	625	3
Imidacloprid 70% WS	Jassid, Aphid, Thrips	700 – 1050	1000 – 1500 (per 100 kg seed)	-	-
Imidacloprid 17.8% SL	Jassids, Aphids, Thrips	25 – 50	125-250	500-700	40
Indoxacarb 14.5% SC	Fruit borer	50-60	333-400	300-600	5
Lambda-cyhalothrin 4.9% CS	Thrips, Pod borer	25	500	500	5

Lambda-cyhalothrin 5% EC	Thrips, Mites, Pod borer	15	300	400-600	5
Lufenuron 5.4% EC	Fruit borer	30	600	500	5
Methomyl 40% SP	Pod borers, Thrips	300-400	750-1125	500-1000	5/6
Milbemectin 1% EC	Yellow /whitemite	3.25	325	500	7
Novaluron 10% EC	Fruit borer, Tobacco caterpillar	33.5	375	500	3
Oxydemiton-methyl 25% EC	Aphids Mites Thrips	400 500 250	1600 2000 1000	500-1000 500-1000 500-1000	-
Phorate 10% CG	Aphids, Mites, Thrips	1000	10000	-	-
Phosalone 35% EC	Aphids Mites Thrips	700 450 700	2000 1285 2000	500-1000 500-1000 500-1000	-
Profenofos 50% EC	Mites	850	1500	500-625	7
Quinalphos 1.5% DP	Aphids	300	20000	-	-
Spinosad 45.0% SC	Fruit borer, Thrips	73	160	500	3
Spiromesifen 22.9% SC	Chilli yellow mite	96	400	500 -750	7
Thiacloprid 21.7% SC	Thrips	54-72	225-300	500	5
Thiodicarb 75% WP	Fruit borer	470 to 750	626 to 1000	500	6
Thiomethoxam 25% WG	Thrips	2.1	7.0	-	-
Indoxacarb 14.5% +Acetamiprid 7.7% w/w SC	Thrips, Fruit borer	88.8-111	400-500	500	5
Fungicide					
Azoxystrobin 23% SC	Fruit rot, Powdery mildew	125	500	500 - 750	5
** Benomyl 50 % WP	Powdery mildew	100	200	600	-
	Fruit rot	100	200	600	-
	Leaf spot	100	200	600	-
Captan 50% WG	Fruit rot (Anthracnose)	750	1500	500	5
Captan 75% WP	Damping off (Nursery)	0.25%	2500	1000 Soil drench in the nursery	-
	Early blight	1250	1667	1000	8
	Fruit rot	1500	2000	1000	8
Captan 75% WS	Damping off (soil drench)	15-25 g per kg seed	20-30 per kg seed	1	-

Copper oxychloride 50% WP	Leaf spot	1.25	2.5	750-1000	-
	Fruit rot	1.25	2.5	750-1000	-
Copper hydroxide 53.8% DF	Anthracnose	350	1500	62	22
Difenoconazole 25% EC	Die back Fruit rot	12.5 g/100 L water	50 mL/100 L water	500	15
Flusilazole 40% EC	Powdery mildew	40-60	100-150	500	5
Hexaconazole 2% SC	Powdery mildew, Fruit rot	60 g	3.0 L	500	7
Kitazin 48% EC	Fruit rot, Die back	100 g in 100 L of water	200 mL in 200 L of water	As required depending upon crop stage and plant protection equipment used	3
Mancozeb 75% WP	Damping off	2.25	3 g (soil drench)	1	-
	Fruit rot	1125 -1500	1500-2000	750	-
	Ripe rot	1125 -1500	1500-2000	750	-
	Leaf spot	1125 -1500	1500-2000	750	-
Metalaxyl-M 31.8% ES (seed dresser)	Damping off	0.64	2.0		
Myclobutanil 10% WP	Powdery mildew, Leaf spot, Die back	0.004%	0.04%	500	03
Propineb 70% WP	Die back	350 g/100 L water	500 g/100 L water	As required depending upon crop stage and plant protection equipment used	10

Cabbage

Pesticide	Pest	a. i. (g/ha)	Formulation (g or mL/ha)	Dilution (L)	Waiting period (days)
Insecticide					
Azadirachtin 0.03% (300 ppm) Neem Oil Based WSP	Aphids, Diamond back moth, Cabbage worm, Cabbage looper	-	2500-5000	500-1000	7
Bacillus thuringiensis var. Kurstaki (3a, 3b, 3c) 5% WP	Diamond back moth	25.00-50.00	500-1000	500-1000	-
** Carbaryl 5% DP	Cabbage borer	600	20000	-	8

** Carbaryl 10% DP	Diamond back moth, Army worm	-	2500	25000	-
Carbofuran 3% CG	Nematode	-	1000	50000	-
Chlorantraniliprole 18.5% SC	Diamond back moth	10	50	500	3
Chlorfenapyr 10% SC	Diamond back moth	75-100	750-1000	500	7
Chlorpyrifos 20% EC	Diamond back moth	400	2000	500-1000	-
Cypermethrin 10% EC	Diamond black moth	60-70	650-760	100-400	-
Difenthiuron 50% EC	Diamond black moth	300	600	500-750	7
Dimethoate 30% EC	Aphid, Painted bug, Mustard aphid	200	660	500-1000	-
Emamectin-benzoate 5% SG	Diamond black moth	7.5-10.0	150-200	500	3
Fenvalerate 20% EC	Diamond back moth	18.24	37.5-50	375-500	7
Fipronil 5% SC	Diamond back moth	40-50	800-1000	500	7
Flubendamide 39.35% M/M	Diamond back moth	18.24	37.5-50	375-500	7
Flufenoxuron 10% DC	Diamond back moth	40	400	500-1000	7
Indoxacarb 14.5% SC	Diamond back moth	30-40	200-266	400-750	7
Indoxacarb 15.8% EC	Diamond back moth	40	266	500-1000	5
Lufenuron 5.4% EC	Diamond backmoth	30	600	500	14
Malathion 50% EC	Mustard aphid	750	1500	500-1000	-
Metaflumizone 22% SC	Diamond back moth	165-220	750-1000	500	3
Novaluron 10% EC	Diamond back moth	75	750	500-1000	5
Phosalone 35% EC	Aphid	500	1428	500-1000	-
Pyridalyl 10% EC	Diamond back moth	50-75	500-750	500-750	3
Quinalphos 25% EC	Aphid Stem borer	250 500	1000 2000	500-1000 500-1000	-
Spinosad 2.5% SC	Diamond back moth	15.0-17.5	600-700	500	3
Thiodicarb 75% WP	Diamond back moth	750 to 1000	1000 to 1330	500	7
Trichlorofon 5% GR, 5% Dust, 50% EC	Fruit and shoot borer Diamond back moth Tobacco caterpillar Red pumpkin beetle	500 500 750 500	-	-	-
Fungicide					
Captan 75% WP	Damping off (nursery)	0.25%	2500	1000 Soil drench in the nursery	-
Captan 75% WS	Damping off	15-25 per kg seed	20-30 per kg seed	1	-

Cauliflower

Pesticide	Pest	a. i. (g/ha)	Formulation (g or mL/ha)	Dilution (L)	Waiting period (days)
Insecticide					
** Carbaryl 5% DP	Cabbage borer	600	12000	-	8
Dimethoate 30% EC	Aphid, Painted bug, Mustard aphid	200	660	500-1000	-
Fenvalerate 20% EC	Diamond back moth, American boll worm, Aphids, Jassids	60-75	300-375	600-750	7
Lufenuron 5.4% EC	Diamond back moth	30	600	500	5
Malathion 50% EC	Head borer	750	1500	500-1000	-
Permethrin 25% EC	Diamond back moth	50-125	200-500	750-1000	-
*Phorate 10% CG	Aphids	2000	20000	-	-
Quinalphos 25% EC	Stem borer	500	2000	500-1000	-
Spinosad 2.5% SC	Diamond back moth	15.0-17.5	600-700	500	3
Fungicide					
Captan 75% WP	Damping off (nursery)	0.25%	2500	1000 Soil drench in the nursery	-
Mancozeb 75% WP	Collar rot	2.25	3	1	-
	Leaf spot	1125-1500	1500-2000	750	-

Onion

Pesticide	Pest	a. i. (g/ha)	Formulation (g or mL/ha)	Dilution (L)	Waiting period (days)
Insecticide					
Chlorpyrifos 20% EC	Root grub	1000	5000	500-1000	-
Dimethoate 30% EC	Thrips	200	660	500-100	-
Endosulfan 4% DP	Aphids, Jassids	140-175	3500-4400	-	21
Lamda cyhalothrin 5% EC	Thrips	15	300	300-400	5
Oxydemeton-methyl 25% EC	Thrips	300	1200	500-1000	-
Quinalphos 25% EC	Thrips	300	1200	500-1000	-

Fungicide					
Difenoconazole 25% EC	Purple blotch *(Alternaria porri)*	25 g/100 L water	100 mL/100 L water	500	20
Kitazin 48% EC	Purple blotch	100 g in 100 L of water	200 mL in 200 L of water	As required depending upon crop stage and plant protection equipment used	63
Mancozeb 75% WP	Leaf blight	1125-1500	1500-2000	750	-

Cucurbits

	Crop	Pest	a. i. (g/ha)	Formulation (g or mL/ha)	Dilu-tion (L)	Waiting period (days)
Insecticide						
*Dichlorvos 76% EC	Cucurbit	Red pumpkin beetle	500	627	500-1000	-
	Bottle and Bitter gourd	Red spider mite	250-500	1350-2700	500-1000	15-20
Dicofol 18.5% EC	Bottle and Bitter gourd	Red spider mite	250-500	1350-2700	500-1000	15-20
Imidacloprid 70% WG	Cucumber	Aphids, Jassids	24.5	35.0	500	5
Metaldehyde (Available in ready to use 2.5% Dust)	Vegetables	Snails, Slugs, Giant African Snails	-	-	-	-
Fungicide						
Azoxystrobin 23% SC	Cucumber	Downey mildew and Powdery mildew	125	500	500	5
**Benomyl 50 % WP	Cucurbits	Powdery mildew	100	200	600	-
		Anthracnose	100	200	600	-
Carbendazim 50% WP	Cucurbits	Powdery mildew	150	300	600	-
		Anthracnose	150	300	600	-

Peas and beans

	Crop	Pest	a. i. (g/ha)	Formulation (g or mL/ha)	Dilution (L)	Waiting period (days)
Insecticide						
Carbofuran 3% CG	French bean	White grub	-	700	23300	-
	Pea	Shoot fly, Aphid	-	1000	33.10 g/plant	-
Chlorpyrifos 20% EC	Beans	Pod borer, Black bug	600	3000	500-1000	-
Fungicide						
**Benomyl 50 % WP	Beans	Powdery mildew	100	200	600	-
		Anthracnose	100	200	600	-
	Peas	Powdery mildew	100	200	600	2
Captan 75% WP	Beans	Damping off (nursery)	0.25%	2500	1000 Soil drench in the nursery	NA
Carbendazim 50% WP	Peas	Powdery mildew	125	250	600	-
	Cluster beans	Powdery mildew	175	350	750	-
	Beans	Rust	1% in conventional sprayers: 2-5 L/ha	-		
Sulphur 40% WP	Beans	Powdery mildew	2250-3000	5650-7500	750-1000	-
Antibiotics						
Streptomycin sulphate 90% + Tetracyline hydrocloride 10% SP	Beans	Halo blight	Spray Streptocycline 100 to 150 ppm solution thrice at interval of 7 days. Apply first spray 10 days after emergence of leaf for prevention.			

Radish, turnip, sugar beet

	Crop	Pest	a. i. (g/ha)	Formulation (g or mL/ha)	Dilution (L)	Waiting period (days)
Insecticide						
Malathion 50% EC	Radish	Stem borer	750	1500	500-1000	-
	Turnip	Tobacco caterpillar	600	1200	500-1000	-
Metaldehyde (available in ready to use 2.5% Dust)	Vegetables	Snails, Slugs, Giant African snails	-	-	-	-
Fungicide						
Carbendazim 50% WP	Sugar beet	Leaf spot	100	200	400	-
		Powdery mildew	100	200	400	-

Definition of pesticide residue: The residue of any pesticide is defined by the World Health Organization (WHO) as, "Any substance or mixture of substances in food for man or animals resulting from the use of a pesticide and includes any specified derivaties, such as degradation and conversion products, metabolites, reaction products, and impurities that are considered to be of toxicological significance."

Key safety parameters for pesticide residues: Any of the short term or long term health hazards caused by the pesticide residues present in the food is dose-dependent. The quantity of pesticide intake per kg body weight of consumer decides the possibility of health hazards. The maximum amount of pesticide residues that can be ingested daily over a lifetime without an appreciable risk is known as 'Acceptable Daily Intake' (ADI). The ADI is based upon scientific judgement of all facts known at the time of evaluation in order to define a limit, below which no harmful effects would be expected. The unit for the ADI is milligrams of substance per kilogram of body weight. A value for the ADI is the one hundredth of the highest dose of the pesticide administered in the feed of test animal causing no adverse effect in the most sensitive test species. The factor one hundredth arises from the precautionary assumptions that humans are 10 times more sensitive than other warm-blooded animals and that the most sensitive humans are 10 times more sensitive than average (Hamilton, 2008). Some situations may arise where the intake of residues could exceed the ADI in the short term, but not in the long term. In that case, the acute reference dose (ARfD), derived from a no-observed-adverse-effect-level (NOAEL) in short-term feeding studies is considered for assessment of risks from short-term intake. Thus, the risk due to the intake of pesticide is determined by comparing the dietary exposure with the insecticide ADI and ARfD.

The Joint FAO/WHO Meeting on Pesticide Residues (JMPR) evaluates residue data to estimate likely maximum residue levels in food commodities resulting from pesticide use according to good agricultural practices (GAP). Maximum residue levels are the highest levels of residues expected to be in the food when the pesticide is used according to authorized agricultural practices (EFSA 2010). If the value of the maximum residue level is comparable to the values of ARfD and ADI for the same pesticide, the Joint FAO/WHO Meeting on Pesticide Residues (JMPR) establishes it as the final Codex Maximum Residue Limit (MRL). Thus, the MRL of a pesticide for a food commodity is the maximum concentration of the pesticide residue resulting from its use according to good agricultural practices (GAP) directly or indirectly for the production and/or protection of the commodity for which the limit is recommended. The consumption of the food commodity containing an amount of pesticide residues below its MRL is usually not of concern to human health. MRL setting can be the responsibility of one or more authorities in a country and normally involves the health, agriculture and environmental agencies. MRL setting is based on the national registered good agriculture practices (GAP) data combined with the estimated likely residue from the supervised trials mean residue (STMR), ADI and ARfD. The information is then evaluated by the risk assessment agency like European Food Safety Authority (EFSA) EFSA in EU or JMPR for CODEX Alimentarius or the Food Safety and Standards Authority of India (FSSAI).

Where national or regional MRLs are not available, internationally recognised bodies such as the United Nations Codex Alimentarius Commission MRLs can be used as guidance. The MRL values for some pesticides in different crops in our country are being set by the FSSAI (Table 2). FSSAI has been established under Food Safety and Standards Act, 2006 for laying down science based standards for articles of food and to regulate their manufacture, storage, distribution, sale and import to ensure availability of safe and wholesome food for human consumption. Since MRL for a large number of pesticide-crop combinations are not available in India, GoI is shortly going to come out with crop groupings so that a single MRL will be valid for a class of vegetables, thereby making risk assessment of pesticides applied easier on a large number of crops.

Table 2: The maximum residue limits (MRLs) for different pesticides in various vegetable crops set by the Food Safety and Standards Authority of India (FSSAI)

Sl. No.	Name of the pesticide	Crop	MRL (mg/kg)
1.	2,4-Dichlorophenoxy acetic acid	Potato	0.2
2.	Acetamiprid	Chilli	0.01
		Okra	0.1
		Cabbage	0.03
3.	Alpha naphthyl acetic acid	Tomato	0.1
		Chilli	0.2
4.	Ametroctradin	Potato	0.05
		Cucumber	0.3
5.	Azoxystrobin	Tomato	1.0
		Chilli	1.0
		Cucumber	0.05*
		Potato	0.05
6.	Benomyl	Vegetables	0.5
		Sugar beet	0.1
7.	Beta cyfluthrin	Okra	0.01
		Brinjal	0.01
8.	Buprofezin	Chilli	0.01
		Okra	0.01*
9.	Captan	Fruit and Vegetables	15
10.	Carbaryl	Okra and leafy vegetables	10
		Potato	0.2
		Other vegetables	5.0
		Chilli	5.0
11.	Carbendazim	Vegetables	0.5
		Sugar beet	0.1
		Potato	0.01*
12.	Carbofuran (sum of 3-hydroxy carbofuran expressed as carbofuran)	Fruit and Vegetables	0.1
		Pea	0.01**
13.	Carbosulfan	Chilli	2.0
14.	Chlorantraniliprole	Bitter Gourd	0.03*
		Okra	0.3
		Tomato	0.03*
		Chilli	0.03*
		Brinjal	0.03*
		Cabbage	0.03

15.	Chlorfenapyr	Chilli	0.05
		Cabbage	0.05
16.	Chlorfluazuron	Cabbage	0.1*
17.	Chlormequat chloride (CCC)	Potato	0.1
		Brinjal	0.1
18.	Chlorothalonil	Potato	0.1
19.	Chlorpropham	Potato	30
20.	Chlorpyriphos	Beans	0.01**
		Potatoes and Onions	0.01
		Cauliflower and Cabbage	0.01
		Other vegetables	0.2
21.	Copper hydroxide	Potato	0.1*
22.	Copper oxychloride (determined as copper)	Potato	1.0
		Other vegetables	20
		Pepper	0.01**
23.	Copper sulphate	Pea	0.01
24.	Cuprous Oxide	Potato	0.01**
		Chilli	0.01**
25.	Cyantranilipole	Cabbage	0.01
		Chilli	0.05
		Tomato	0.03
		Gherkin	0.01
26.	Cyazofamid	Potato	0.02*
		Tomato	0.01*
27.	Cymoxanil	Tomato	0.01*
		Potato	0.01
28.	Cypermethrin (sum of isomers) (Fat soluble residue)	Brinjal	0.2
		Cabbage	2.0
		Okra	0.2
29.	Deltamethrin (Decamethrin)	Chilli	0.05
		Okra	0.05
		Tomato	0.05
		Brinjal	0.3
30.	Diafenthiuron	Brinjal	1.0
		Chilli green	0.05
		Chilli red	0.05
		Cabbage	1.0
31.	Diazinon	Vegetables	0.5
32.	Dichlorvos (DDVP)	Vegetables	0.15
33.	Dicofol	Fruits and Vegetables	5.0
		Chilli	1.0
34.	Difenoconazole	Chilli	0.01
		Tomato	0.2
35.	Dimethoate	Fruits and Vegetables	2.0
		Chilli	0.5
36.	Dimethomorph	Potato	0.05
		Cucumber	0.2
37.	Dithiocarbamates	Chilli	0.2
		Dry chilli	2.0
		Potato	0.1
	(a) Dimethyl dithio carbamates residue resulting from the use of ferbam or ziram, and	Tomato	3.0
	(a) Ethylene bis-dithio carbamates resulting from the use of mancozeb, maneb or zineb (including zineb derived from nabam plus zinc sulphate)		

	(c) Mancozeb	Chilli	1.0
		Cauliflower	0.02
		Gherkin	0.1*
	(d) metiram as CS_2	Green chilli	0.05*
		Dry chilli	0.5
		Potato	0.05*
		Tomato	5.0
		Onion	0.05*
	(e) Zineb as CS_2	Brinjal	0.01**
38.	Emamectin-benzoate	Okra	0.05
39.	Ethephon	Tomato	2.0
40.	Ethion	Cucumber and Squash	0.5
		Other Vegetables	1.0
41.	Etoxazole	Brinjal	0.2
42.	Famoxadone	Potato	0.05
		Tomato	0.01*
43.	Fenamidone	Potato	0.01
		Gherkin	0.2
44.	Fenazaquin	Chilli (green)	0.5
		Okra	0.01
		Brinjal	0.01
		Tomato	0.01
45.	Fenitrothion	Vegetables	0.3
46.	Fenpropathrin	Brinjal	0.2
		Okra	0.5
		Chilli	0.2
47.	Fenpyroximate	Chilli	1.0
48.	Fenthion (sum of fenthion, its oxygen analogue and their sulphoxides and sulphones expressed as Fenthion)	Onion	0.1
		Potato	0.05
		Beans	0.1
		Peas	0.5
		Tomato	0.5
		Other vegetables	1.0
49.	Fenvalerate	Cauliflower	2.0
		Brinjal	2.0
		Okra	2.0
		Cabbage	0.01**
		Tomato	0.01**
50.	Fipronil	Chilli	0.01
		Cabbage	0.01
		Cottonseed oil	0.02*
51.	Flubendiamide	Brinjal	0.1
		Cabbage	0.05
		Tomato	0.07
		Chilli	0.02
52.	Fluchloralin	Onion	0.01**
		Okra	0.01**
		Potato	0.01**
		Brinjal	0.01**
		Cabbage	0.01**
53.	Flusilazole	Chilli	0.01
54.	Hexaconazole	Chilli	0.5
		Potato	0.02
55.	Hexythiazox	Chilli (green)	0.01
		Dried chilli	0.01

56.	Imidacloprid	Okra	2.0
		Chilli	0.3
		Tomato	1.0
		Cucumber	0.2
		Brinjal	0.01
57.	Indoxacarb	Tomato	0.05
		Chilli	0.01
		Cabbage	0.1
58.	Iprodione	Tomato	5.0
59.	Kasugamycin	Tomato	0.05
60.	Lambda cyhalothrin	Brinjal	0.2
		Tomato	0.1
		Okra	2.0
		Chilli Green	0.05
		Chilli Red	0.01
		Onion	0.01
61.	Linuron	Pea	0.05
		Potato	0.01**
62.	Lufenuron	Cauliflower	0.1
		Chilli	0.05
		Cabbage	0.3
63.	Malathion (Malathion to be determined and expressed as combined residues of malathion and malaoxon)	Vegetables	3.0
64.	Mandipropamid	Tomato	0.05*
		Potato	0.05*
65.	Mepiquat chloride	Potato	0.1
66.	Metaflumizone	Cabbage	0.05
67.	Metalaxyl-M	Potato	0.01
		Chilli	0.02
68.	Methomyl	Tomato	0.05
		Chilli	0.05
69.	Metribuzin	Tomato	0.05*
		Potato	0.05*
70.	Milbemectin	Chilli green	0.01
		Chilli red	0.01
71.	Monocrotophos	Carrot, Turnip, Potatoes and Sugar beet	0.05
		Onion and Peas	0.1
		Other Vegetables	0.2
		Chilli	0.2
72.	Myclobutanil	Chilli	0.2
73.	Novaluron	Chilli	0.01
		Tomato	0.01
		Cabbage	0.01
74.	Oxadiargyl	Onion	0.1
75.	Oxadiazon	Onion	0.01**
76.	Oxydemeton-methyl	Chilli	2.0
		Dry chilli	20
77.	Oxyfluorfen	Potato	0.01
		Onion	0.05
78.	Paraquat dichloride (Determined as Paraquat cations)	Potato	0.2
		Other vegetables	0.05
79.	Pendimethalin	Chilli	0.05*
		Onion	0.01**
80.	Permethrin	Cucumber	0.5

81.	Phorate (sum of Phorate, its oxygen analogue and their sulphoxides and sulphones, expressed as phorate)	Tomato	0.1
82.	Phosalone	Potato	0.1
		Other vegetables	1.0
83.	Phosphamidon residues (expressed as the sum of phosphamidon and its desethyl derivative)	Fruits and Vegetables	0.2
84.	Propaquizafop	Onion	0.01*
85.	Propargite	Brinjal	2.0
		Chilli	2.0
86.	Propineb	Tomato	1.0
		Potato	0.5
		Green Chilli	2.0
87.	Pyraclostrobin	Potato	0.05*
		Tomato	0.01
		Green chilli	0.05*
		Dry chilli	0.5
		Onion	0.05*
88.	Pyrethrins (pyrethrum) (sum of pyrethrins I & II)	Fruits and Vegetables	1.0
89.	Pyridalyl	Cabbage	0.02
		Okra	0.02
		Chilli	0.02
90.	Pyriproxyfen	Brinjal	0.02
		Okra	0.03
		Chilli green	0.02
		Chilli red	0.02
91.	Quinalphos	Cauliflower	0.1
		Potato	0.01**
92.	Quizalofop-ethyl	Onion	0.01*
93.	Spinosad	Cabbage	0.02
		Cauliflower	0.02
		Chilli	0.01
94.	Spiromesifen	Tomato	0.3
		Brinjal	0.5
		Chilli	0.1
		Okra	0.03
95.	Tebuconazole	Green chilli	0.2
		Tomato	2.0
		Onion	0.5
		Brinjal	0.3
		Chilli (green)	0.02
		Chilli (red)	0.02
96.	Thiodicarb	Cabbage	0.02
		Brinjal	0.05
		Chilli	0.01
97.	Thiamethoxam	Okra	0.5
		Brinjal	0.3
		Tomato	0.01
98.	Thiometon (Residues determined as thiometon its sulfoxide and sulphone expressed as thiometon)	Potato, Carrots and Sugar beets	0.05
		Other vegetables	0.5
99.	Thiophanate-methyl	Bottle gourd	0.4
		Cucumber	0.2
100.	Tolfenpyrad	Cabbage	0.01*
		Okra	0.7

101.	Trichlorfon	Sugar beet	0.05
		Fruits & Vegetables	0.1
102.	Triadimefon	Pea	0.1
		Chilli	0.4
103.	Trifloxystrobin and its metabolites (carboxylic acid-CGA321113)	Tomato	1.0
104.	Triazophos	Chilli	0.2

* MRL fixed at 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

* * * * *

Pesticide residue monitoring in India

Government of India has taken several measures for proper use of pesticides by the farmers in the country. The Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture is regularly monitoring the pesticide residues in food commodities and environmental samples under the central sector scheme, "Monitoring of Pesticide Residues at National Level" which was initiated during 2005-06 and has 25 participating laboratories representing Ministry of Agriculture, Indian Council of Agricultural Research, Ministry of Health and Family Welfare, Ministry of Environment and Forest, Council of Scientific and Industrial Research, Ministry of Chemical and Fertilizer, Ministry of Commerce and State Agricultural Universities. The participating laboratories collect food commodity samples from various Agriculture Produce Marketing Committee markets, public distribution systems, farm gates. Also, potable water and soil samples are collected from agricultural fields across various parts of the country. The samples are analyzed for the presence of possible pesticide residues in various food commodities such as vegetables, fruits, cereals, spices, pulses, milk, butter, irrigated water, fish, meat, tea etc. The pesticide residue data generated under the above scheme are shared with State Governments and concerned Ministries/Organizations to initiate corrective action for judicious and proper use of pesticides on crops with an Integrated Pest Management approach and to generate awareness amongst farmers.

Under this scheme, during the period April, 2010 to March, 2013, out of the 18,704 samples of vegetables, 540 (2.9%) of the samples were found to contain pesticide residues above their permissible levels (FSSAI). The pesticides detected most commonly above MRL were chlorpyrifos, cypermethrin, phorate and ethion. During the years 2013-14, 221 out of 7,591 vegetable samples were found to have pesticide residues above MRL. Among all the vegetable samples analysed, capsicum, green chilli and cauliflower samples were found having high number of above MRL residues followed by samples of cabbage, brinjal, tomato, okra, bitter gourd, cucumber, green pea and coriander leaves. (Anonymous, 2015) Also, a high percentage of so-called pesticide-free organic vegetables were found with residues above MRL. Of 166 samples of so called "organic" vegetables collected from Hyderabad, West Bengal, Bengaluru, Lucknow, Kerala, Delhi and Chennai in 2014-15, residues were detected in 27% of the samples and in 4.8% of the cases the traces were above the maximum permitted levels. (Anonymous, 2016). Since farmers are becoming conscious about the selection of pesticides for pest management, presence of residues can be avoided in vegetables by following recommended application rates and right time of harvesting of crops. During the time of harvesting, harvested vegetables should not carry pesticide residues above permissible limit. The duration between the time of application of pesticides and harvesting time is known as 'waiting period (WP)' or 'pre-harvest interval (PHI)'. At ICAR-IIHR, WPs for most commonly used pesticides applied on various vegetables including exotic vegetables have been established (Table 3).

Table 3. Waiting periods of some commonly used pesticides in vegetables evaluated at IIHR

Commodity	Insecticides recommended for major pests	Pests controlled	Recommended dose in a.i./ha	WP (PHI) in days	MRL in (mg/kg) (source)
Brinjal	Acephate 75 SP	Aphids, Jassids, Whitefly	500 g	10	0.01(EU)
	Chlorantraniliprole 18.5 SC	BSFB	40 g	1	2.0 (FAO / WHO)
	Chlorpyrifos 20EC	BSFB	200 g	15	0.5 (EU)
	Lambda cyhalothrin 5EC	BSFB, Thrips, Mite, Jassids	15 g	7	0.2 (FAO/ WHO)
	*Triazophos	BSFB	500 g	15	0.01 (EU)
	Quinalphos 25 EC	BFSB	375 g	4	0.05 (EU)
Cabbage and Cauliflower	Abamectin 0.15 EC	Diamond back moth	14.4 g	1	0.01 (EU)
	Chlorpyrifos 20EC	Aphids, Maggots	125 g	21	0.5 (EU)
	Cypermethrin 10 EC	Diamond back moth	60 g	7	0.5 (EU)
	Dimethoate 30 EC	Aphid, leafhopper, thrips	700 g	6	0.2 (FAO/ WHO)
	Fenvalerate 20 EC	Diamond back moth, borers	60 g	11	0.1(EU)
	Fipronil 80G	Diamond back moth	75g	13	0.02(EU)
	Flubendiamide 480SC	Lepidopteran species	24 g	10	0.01(LOQ)
	Lambda cyhalothrin 5EC	Diamond back moth	15g	5	0.2 (FAO/ WHO)
	Quinalphos 25 EC	Diamond back moth	500 g	17	0.05 (EU)
Capsicum*	Abamectin 1.9 EC	Mites	14.4 g	3	0.01(EU)
	Acephate 75 SP	Thrips	500 g	16	0.02(EU)
	Dimethoate 30 EC	Thrips	200 g	10	0.02 (EU)
	Ethion 50 EC	Mites	750 g	15	0.01 (EU)
	Imidacloprid 17.8 SL	Aphids	25 g	7	0.5 (EU)
	Dimethomorph	Phytophthora leaf blight	250 g	34	1.0 (EU)
	Tebuconazole	Wilt	150 g	29	0.6(EU)
	Carbendazim	Fruit rot	250 g	11	0.1(EU)
Chilli	Abamectin 1.9 EC	Mites	14.4 g	3	0.05(EU)
	Acephate 75 SP	Aphid, Pod borer, Mites, Thrips,whitefly	750 g	20	0.01(EU)
	Dicofol 18.5 SC	Red spider mite	300 g	9	0.1(FAO/WHO)
	Dimethoate 30 EC	Whitefly	300 g	14	0.02 (EU)
	Fipronil 80 G	Fruit borer	45 g	17	0.005(EU)
	Flubendiamide 480 SC	Fruit borer	60 g	10	0.2 (EU)

	Flubendiamide + Thiacloprid 480SC	Fruit borer	60 + 60 g	10	0.2 & 1.0(EU)
	Imidacloprid 17.8SL	Aphid, Whitefly	30 g	5	1.0 (EU)
	Indoxacarb	Fruit borer	50 g	4	0.3 (EU)
	Mancozeb 75 WP	Leaf Spot	150 g	5	5.0 (EU)
	Oxydemeton methyl 25 EC	Aphids	500 g	19	0.02(EU)
	*Phosphamidon 40 SL	Jassids, Aphids	250g	12	0.01 (EU)
	Quinalphos 25 EC	Fruit borer	1000 mL	15	0.05(EU)
	Thiamethoxam 25WG	Aphids	25 g	12	0.7 (EU)
	Lambda cyhalothrin 5 EC	Cucumber beetles	15 g	6	0.1 (EU)
	Spiromesifen 240 SC	Whitefly, Mites	144 g	4	0.3 (EU)
French bean	Dimethoate 30 EC	Aphid, Whitefly	300 g	4	0.02 (EU)
	*Phosphamidon 40 SL	Jassids, Aphids	250 g	12	0.01(EU)
	Quinalphos 25EC	Pod borer	250 g	15	0.05(EU)
Okra	Abamectin 1.9 EC	Red spider mite	14.4 g	2	0.01(EU)
	Acephate 75 SP	Aphids, Jassids	250 g	6	0.01(EU)
	Cypermethrin 10 EC		60 g	3	0.5(EU)
	Imidacloprid 17.8 SL	Leafhopper¸ Thrips, Jasssids, Whiteflies	25g	3	0.5 (EU)
	Thiamethoxam 25 WG			1	0.25(US-EPA)
	*Triazophos 40 EC	Fruit borer	500 g	8	0.07(FAO/ WHO)
	Quinalphos 25 EC	Fruit borer	250 g	12	0.05(EU)
Tomato	Acephate 75 SP	Thrips	500 g	15	1.0 (FAO/ WHO)
	Fipronil 80 G	Fruit borer	45 g	16	0.005 (EU)
	Flubendiamide 480 SC	Fruit borer	48 g	20	0.01 (LOQ)
	Flubendaimide + Thiacloprid 480 SC	Fruit borer	48 + 48 g	4	0.2 (EU) 1.0 (EU)
	Fluopicolide + Propamocarb 68.75 SC	Fruit borer	93.75 + 937.5 g	1	2 and 1 (FAO/ WHO)
	Indoxacarb 25 SC	Fruit borer	350 mL	1	0.5(FAO/WHO)
	Dimethoate 30 EC	Thrips	625 mL	7	0.02 (EU)
	Fipronil 80 G	Thrips	60 g	15	0.02 (EU)
Zucchini*	Acephate 75SP	Aphids	500 g	15	0.01(EU)
	Lambda cyhalothrin 5EC	Aphids	18.75 g	10	0.01(EU)
	Dinocap 50EC	Powdery mildew	250 g	16	0.05(EU)
	Imidacloprid 17.8SL	Aphids	35 g	3	1.00(EU)
	Acetamiprid 20SP	CMV	20 g	4	0.3 (EU)
	Profenofos 50EC	Pumpkin fruit fly	250 g	16	0.01(EU)
	Fenazaquin10EC	Mites	50 g	16	0.01(EU)

Broccoli*	Profenofos 50EC	Aphids	250 g	29	0.05(EU)
	Fenazaquin10EC	Mites	50 g	25	0.05(EU)
	Myclobutanil 10WP	White rust	50 g	20	0.05(EU)
	Lambda Cyhalothrin 5EC	Aphids	18.75 g	16	0.05(EU)
	Captan 80WDG	Damping off	400 g	16	0.05(EU)
	Imidacloprid 17.8EC	Aphids	35 g	8	0.5(EU)
	Carbendazim 50WP	Black leg	250 g	19	0.1(EU)
	Fipronil 5EC	DBM	37.5 g	35	0.01(EU)
	Chlorantraniliprole 18.5SC	DBM	27.75 g	18	0.3 (EU)
Red cabbage*	Imidacloprid 17.8SL	Aphids	35 g	7	0.05(EU)
	Fenazaquin 10EC	Mites	50 g	17	0.05(EU)
	Myclobutanil 10WP	White rust	50 g	5	0.05(EU)
	Fipronil 5SC	Thrips	37.5 g	6	0.05(EU)
	Chlorantraniliprole 18.5SC	DBM	27.75 g	16	0.005(EU)
	Carbendazim 50WP	Black leg	250 g	11	0.01(EU)
Lettuce*	Carbendazim50WP	Leaf spot	250 g	29	0.1(EU)
	Imidacloprid 17.8SL	Aphids	35 g	5	2.0(EU)
	Metalaxyl 64 WP	Rhizoctonia root rot	640 g	1	3.0(EU)
	Profenofos 50EC	Aphids	250 g	23	0.01(EU)
	Fenazaquin 10EC	Mites	50 g	23	0.01(EU)
	Thiophanate methyl 70WP	Rhizoctonia root rot	350 g	25	0.10(EU)
English cucumber*	Imidacloprid 17.8SL	Sucking pests	35 g	3	0.01(EU)
	Acetamiprid 20SP		20 g	1	0.01(EU)
	Fipronil 5SC		37.5 g	16	0.01(EU)
	Dimethomorph 50WP	Downy mildew	250 g	4	0.01(EU)
	Fenazaquin 10EC	Mites	50 g	6	0.01(EU)
	Azoxystrobin 23 SC	Broad spectrum fungicide	230 g	3	0.01(EU)
	Tebuconazole 25WG	Powdery mildew	75 g	9	0.01(EU)
	Trifloxystrobin 25WG		75 g	5	0.01(EU)
	Carbendazim50WP	Broad spectrum fungicide	250 g	15	0.005(EU)

* Crops grown in polyhouse, WP= Waiting period, PHI = Pre harvest interval, BSFB = Brinjal shoot and fruit borer, CMV = Cucumber mosaic virus

Safe use of pesticides to minimise their residues in vegetables

Due to lack of sufficient number of non-chemical alternatives for insect-pest management in fruits and vegetables, farmers depend on the application of synthetic insecticides. To avoid the hazard due to toxic insecticides, there is a need to shift from the conventional approach to the safer synthetic alternatives. Some of the ways in which safer pesticides have been developed and resistance developed by pests to them are described below.

Low dose, low toxicity pesticides: The application rates of conventional insecticides are very high, very often more than 1 kg per ha. But their use is in decreasing trend, as they are being replaced by new generation insecticides. The application rate of imidacloprid, a widely used insecticide on fruits and vegetables is within 21-45 g/ha and the rates for emamectin-benzoate and milbemectin are further lower. Most of the newly introduced insecticides are safer in terms of toxicity to non-targets. Modern pesticides registered in our country, such as chlorantraniliprole, hexythiazox, lufenuron, pyridalyl, etc. are of low mammalian toxicity (Table 4). A majority of them do not persist for a long time in the environment. These safer pesticides will probably replace all of the conventional ones in near future giving absolute protection to crop without disturbing biodiversity in future.

Table 4: A comparison on application rate and toxicity between some conventional and low dose pesticides

Conventional pesticides			Low dose pesticides		
Pesticides	Dose (g/ha)	$LD_{50,acute,oral,rat}$ (mg/kg body weight)	Pesticides	Dose (g/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	Chlorantranilipreol	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

Pesticides with newer mode of action to combat resistance: Insect-pests have developed resistance against many insecticides. The resistant insects are able to metabolize the insecticide, thereby reducing its concentration within the insect to an ineffective level. To avoid this problem, farmers need to change insecticides with different modes of action. Earlier pesticides with very few modes of action were only available viz., organophosphates and carbamates, which acted by blocking acetyl choline esterase (ACHE) enzyme in the nervous system. Organochlorines and pyrethroids acted by opening up the sodium ion channels in neurons resulting in hyperactivity of the nerves or by inhibiting normal chloride channel function at the GABA receptor-ionophore complex of the nervous system. In recent years many new classes of pesticides have been developed which have different modes of after action viz, neonicotnoid insecticides, which bind to several types of post-synaptic nicotinic acetylcholine receptors in the central nervous system. Benzoylureas inhibit chitin biosynthesis in insects, diamides activate muscle ryanodine receptors causing paralysis, pesticides such as diafenthiuron, propargite, tetradifon inhibit the mitochondrial enzyme that synthesizes ATP etc. Grape anthracnose disease cannot be controlled by the application of carbendazim, as the causal organism *Elsinoe ampelina* has developed resistance against the fungicide probably through the specific alterations in the binding sites on the ß-tubulin protein. But the combination products of carbendazim and mancozeb (Appendix-II) is very effective to manage this resistance developed by Elsinoe. Similarly, to break the resistance developed by metalaxyl-tolerant strains of *Phytophthora infestans* causing late blight disease in potato, a number of alternative chemicals, viz. azoxystrobin, dimethomorph, cymoxanil + mancozeb etc. are available now. Many of these new pesticides with novel modes of action are more polar and less persistent thereby being less damaging to the ecosystem. Also use of pesticides with different modes of action delays development of resistance to any pesticide by the target pest.

Botanicals as pesticides and leads to newer pesticides: Plants are the rich source of bioactive organic compounds and have been productively exploited for the extraction of plant protection chemicals. The bean of African calabar plant is a source of a toxic compound physostigmine, also known as esserine, based upon which the chemistry of organo carbamate insecticides was developed. Several *Chrysanthemum* species of African and Asian origin were well known for their insecticidal properties. Six naturally occurring terpenoid esters, collectively known as pyrethrins present in chrysanthemum flowers possess very good knock down effect against many insects. Nevertheless natural products are not very active under outdoor field condition due their photolabile nature under sunlight. The chemical alteration in the structures of natural pyrethrins through chemical synthesis resulted in a large number of photostable pyrethrin-like compounds, as a group known as 'synthetic pyrethroids'. Neem seed kernel contains azadirachtin, a strong antifeedant, which is being exploited in plant protection. It was initially difficult to make use of azadirachtin as it is photosensitive in nature and does not persist for required time. The problem has been solved by using sun screen in the formulation and it is now an integral part of the integrated pest management programme. Metabolites of animal origin have also been utilized as insecticides directly or indirectly e.g. nereistoxin analogues were designed and developed from the lead molecule nereistoxin, which was isolated from a marine annelid, *Lumbriconereis heteropoda*. The mammalian toxicities of all the analogues are much lower than that of the parent molecule nereistoxin. It is possible to discover new lead molecules by exploiting unutilized or underutilized microbes, plants and animals. These bioactive natural products may lead to synthesis of new molecules with low mammalian toxicity, low dose (high potency) and environmentally safer molecules.

Biopesticides: Biological control of insects by using live insect pathogens is an eco-friendly self-sustaining insect management strategy. Once a component of this strategy gets established in the crop field, a continuous pressure builds upon the target insect to keep its population below economic threshold level although these formulations of living organisms have some limitations. Examples of such biocontrol agents for pest control are some formulations of *Bacillus thuringiensis* bacteria, Nuclear Polyhedrosis Virus (NPV) etc., which usually form important components of integrated pest management programmes.

Selection of insecticide, rate of application and application method: Farmers need to choose the pesticide and the proper method of application by scouting the area to estimate the extent of the damage by insects. Every pesticide label available with the formulation package specifies application rate, time and method of application, and cautions required during and after application. Frequent check and maintenance of spray nozzles, hoses, gauges and tanks is needed. Proper calibration of sprayer is the key to applying accurate rates of pesticides. Use of good quality calibrated sprayers ensures uniform application of pesticides. Pesticides are most susceptible to be washed off from target sites by heavy rains during the first several hours after application. Therefore, one should avoid insecticide application in case of heavy rain forecast. Wind speed, temperature and humidity affect pesticide spray drift. Drift can be reduced by lowering boom heights and using nozzles that produce large size droplet.

Education of farmer: In the present situation, farmers have a number of non-chemical tools to manage insect-pests of fruits and vegetables minimizing the risk due to pesticides. The greatest challenge is to train the farmers for safe use of pesticides. The success of developing safer know-how depends on its adoption by users. Every stake holder of the system is accountable for the transformation. Strong and effective networks between research organizations, extension groups and farmers are to be built up for reducing the use of pesticides, producing safe food and protecting the environment.

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References

Anonymous (2015) http://economictimes.com/articleshow/46108223.cms?utmsource =contentofinterest & utm_medium=text&utm_campaign=cppst accessed on 27/08/2018

Anonymous (2016) https://www.smartindianagriculture.com/ accessed on 27/08/2018

Ayalew G (2006) Comparison of yield loss on cabbage from diamondback moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae) using two insecticides. *Crop Protection* **25**: 915-919.

Devjani P and Singh TK (1999) Field density and biology of diamondback moth, Plutella xylostella L. (Lepidoptera:Yponomeutidae) on cauliflower in Manipur. *Journal of Advanced Zoology* **20**(1): 53-55.

Dhandapani NU, Shekhar R and Murugan M (2003) Bio-intensive pest management (BIPM) in major vegetable crops: an Indian perspective. *Food, Agriculture and Environment* **1**: 333-339.

Gangwar SK and Sachan JN (1981) Seasonal incidence and control of insect-pests of brinjal with special reference to shoot and fruit borer, Leucinodes orbonalis Guen. in Meghalaya. *Journal of Research Assam Agriculture University* **2**(2): 87-92.

Kodandaram MH, Saha S, Rai AB and Naik PS (2013) Compendium on pesticide use in vegetables. IIVR Extension Bulletin No. 50, IIVR, Varanasi, pp. 133.

Krishnamoorthy A (2004) Biological control of diamondback moth, *Plutella xylostella* (Linn.) and Indian scenario with reference to past and future strategies. In: Kirk, A.A., Bordat, D. (Eds). Proceedings of the International Symposium, 21-24 October, 2002. Montpallier, France, CIRAD. pp. 204-211.

National Horticulture Board (2017) Horticultural Statistics at a Glance 2017. National Horticulture Board, Ministry of Agriculture, Government of India, Gurgaon, India.

Panchal M, Kapoor C and Singh PS (2013) Indian Agrochemical Industry-Imperatives of growth. Knowledge and strategy paper prepared by TATA Strategic Management Group (TSMG) in association with Federation of Indian Chambers of Commerce and Industry (FICCI), released at 3rd National Agrochemical Conclave. July 2013.

Rai AB, Loganathan M, Halder Jaydeep, Venkataravanappa V and Naik Prakash S (2014) Eco-friendly Approaches for Sustainable Management of Vegetable Pests. IIVR Technical Bulletin No. 53, IIVR, Varanasi, pp. 104.

Srivastava KP and Butani DK 1998. Pest Management in Vegetable, Vol-1. Research Periodicals and Book Publishing House, India.

Indumathi HR, Sharma D, Awasthi MD and Siddaramappa R (2001) Uptake and dissipation of imidacloprid residues in okra. *Pest Management in Horticultural Ecosystem* **7**(2): 124-129.

Sharma D and Awasthi MD (2002) Persistence of lambda cyhalothrin residues in cauliflower. *Pesticide Research Journal* **14**(1): 195-198.

Sharma D, Choudhury BK and Awasthi MD (2002) Pesticide residues in chilli following Integrated Pest and Disease Management. In : Proceedings of International Conference of Vegetables, held on Nov.11-14, 2002 in Bangalore. pp.309 – 314, Pubs. PNASF, Bangalore.

Sharma D and Mohapatra S (2005) Dissipation pattern of indoxacarb and thiamethoxam residues in vegetables. *Vegetable Science* **32**(2): 166-168.

Sharma D, Mohapatra S, Ahuja AK (2006) Studies on persistence of fungicide residues in bitter gourd. Indian *Journal of Plant Protection* **34**(1): 140-142.

Ahuja AK, Mohapatra S, Sharma D and Awasthi MD (2006) Residue persistence of different formulations of lambda cyhalothrin in brinjal. *Indian Journal of Plant Protection* **34**(1): 122-123.

Reddy E, Krishna Kumar NK and Sharma D (2007) Residues of insecticides on sweet pepper and tomato grown under green house and open cultivation. *Pesticide Research Journal* **19**(2): 239-243.

Sharma D, Krishna Moorthy PN and Krishnamoorthy A (2009) Comparative study of pesticide residue pattern in vegetables grown using IPM and non-IPM practices. *Journal of Horticultural Science* **4**(2): 191-194.

Sharma D, Mohapatra S, Ahuja AK, Jyothi VD and Deepa M (2011) Comparative persistence of flubendiamide residues in chilli following application as individual and combination formulation. *Quality Assurance and Safety of Crops and Foods* **3**: 69-73.

Sharma D, Hebbar SS, Jyothi VD and Mohapatra S (2012) Residues of pesticides acephate and methamidophos in capsicum grown in greenhouse and open field. *Quality Assurance and Safety of Crops and Foods* **4**(5): e33–e37.

Sharma KK, Mohapatra S, Ahuja AK, Deepa M, Sharma D, Jagdish GK, Rashmi N, Battu RS, Sharma SK, Singh B, Parihar NS, Sharma BN, Kale VD, Nakat RV, Walnuj RN, Singh G, Ravivanshi KK, Suneeta Devi and Noniwal R (2014) Safety evaluation of flubendiamide and its metabolites on cabbage and persistence in soil in different agroclimatic zones of India. *Environmental Monitoring and Assessment* **186**(6): 3633-3639.

Sharma KK, Mukherjee I, Singh B, Sahoo SK, Parihar NS, Sharma BN, Kale VD, Nakat RV, Walunj AR, Mohapatra S, Ahuja AK, Sharma D, Singh G, Noniwal R, Sunita Devi (2014) Residual behavior and risk assessment of flubendiamide on tomato at different agro-climatic conditions in India. *Environmental Monitoring and Assessment* **186**(11): 7673-7682.

Sharma KK, Shukla VR, Patel AR, Vaghela KM, Patel HK, Shah PG, Banerjee H, Banerjee T, Hudait RK, Sharma D, Sahoo SK, Singh B, Tripathy V (2016) Multilocation field trials for risk assessment of a combination fungicide Fluopicolide + Propamocarb in tomato. *Environmental Monitoring and Assessment* **188**(11): 604

Appendix I: Brand names and manufacturers of major insecticides

Insecticide	Brand names and manufacturers
Abamectin	1.9 EC: Vertimec (Syngenta)
Acetamiprid	20% SC: Manik (Rallis) 20% SP: Harrier (Adama), Excel Acetacel (Excel), Lift (Indofil), Dhan Preet (Dhanuka), Pounce (FMC)
Acephate	75 SP: Starthene (Shaw Wallace), Asataf (Rallis), Lancer (UPL), Torpedo (Ishagro), Tamaron Gold (Bayer), Twinguard (Gharda), Asset (Syngenta), Acemain (Adama), Acefex (Excel), Oval (PI) 50 SP: Prawl (HeMan), Record (Crystal)
Alphacypermethrin	10% EC: Tata Alpha (Rallis), Gem (Indofil)
Azadirachtin (neem products)	Neemazal T/S 1% EC (EID Parry), Neemazal F 5% WSC (EID Parry), Indika 1500 ppm (EID Parry)
Beta cyfluthrin	2.45% SC: Responser (Bayer)
Benfuracarb	40 EC: Oncol (Coromandel) 3 G: Plantin (Plant Rem)
Bifenthrin	10% EC: Imperial (Adama), Markar (Dhanuka), Talster (FMC), Canister (Coromandel)
Buprofenzin	25% SC: Applaud (Rallis), Bipimain (Adama), PIBupro (PI), Flotis (Bayer), Buprodan (FMC), Banzo (Biostadt),
Carbaryl	Sevin (Rhone Poulenc), Hexavin (Parry chemicals), Killer Carbaryl (Paushak), Dhanurvin (Dhanuka)
Carbofuran	Furadan 36 (Rallis), Fury (NFCL), Hexafuran (Parry chemicals), Furatox (AIMCO), Carbocial (De'Nocil) 3% CG: Carbomain (Adama)
Carbosulfan	25 EC: Aatank (Dhanuka), Marshal (FMC), Aayudh (Coromandel)
Cartap hydrochloride	4% G: Cartox G (Rallis), Boregan G (Adama), Beacon Gr (Indofil), Caldan 4G (Dhanuka) 50% SP: Breacon SP (Indofil), Caldan (Dhanuka)
Chlorfenapyr	10% SC: Lepido (PI)
Chlorofenviphos	10G: Birlane (BASF); Steladone (Syngenta); Supona (BASF)

Chlorpyriphos	20 EC: Dursban (Dow), Nuchlor (DuPont), Classic (Cheminova), Tricel (Excel), Chloroban (UPL), Radar (Ishagro), Tafaban (Rallis), Tricel (Excel), Durmet (FMC) 10 G: Dursban (Dow), Pyriban (AIMCO), Radar (Ishagro) 1.5 DP: Radar (Ishagro), Force (Nagarjun), Pyriban (AIMCO) 50 EC: Dursban and Predator (Dow), Tarmex (Rallis), Pyriban (AIMCO), Ecogourd (Gharda) 2 RTU: Termicil (Dow)
Chlorpyriphos-methyl	40 EC: Reldan (Dow)
Chlorantraniliprole	Coragen (FMC)
Cyfluthrin	10% WP: Solfac (Bayer)
Cypermethrin	25% EC: Colt (PI)
Decamethrin (Deltamethrin)	10% EC: Decis (Bayer) 2.8% WP: K-Obiol (Bayer)
Diafenthiuron	50% WP: Agas (Adama), Derby (Biostadt), Ferotia (Coromandel), Pegasus (Syngenta)
Diazinon	20 EC: Suzon (Sudershan), Detaff (Rallis), 10 G: Detaff (Rallis), Basudin (Syngenta) 2 DP: Vinash (Sudershan)
Diclorvos (DDVP)	76% EC: Divap (PI), Marvex Super (Coromandel), Doom (UPL)
Dicofol	18.5% EC: Kelthane (Bayer), Tiktak (UPL), Dicofol (Northern Mineral), Colonel-S (Indifil)
Dimethoate	35% EC: Tafgor (Rallis), Rogar (Bayer)
Dinotefuran	20% SG: Osheen (PI), Token (Indofil), Ossum (Biostadt)
Emamectin-benzoate	1.9% EC: Affirm (Syngenta) 5% SG: Amnon (Adama), Robot (Excel), EM-1 (Dhanuka), Camry (FMC), Benzer (Coromandel), Proclaim (Syngenta)
Ethion	35% EC: Tafethion (Rallis) 50% EC: Fosmite (PI)
Ethofenprox (Etofenprox)	10% EC: Bombard (Dhanuka), Trebon Excel (Biostadt)
Fenobucarb (BPMC)	50% EC: Aandhi (Syngenta)
Fenvalerate	10% EC: Tatafen (Rallis), Bilfen (Bayer), Fenkil (UPL)
Fenpyroximate	5% SC: Sedna (Rallis), Pyromite (Excel)

Fipronil	80% WDG: Agadi Super (Adama), Jump (Bayer) 5% SC: Sonic Flo (Rallis), Agadi SC (Adama), Regent Sc (Bayer) 0.3% Gr: Agadi G (Adama), Regent Gr (Bayer)
Flonicamid	50% WG: Ulala (UPL), Panama (Swal)
Flubendiamide	20% WDG: Takumi (Rallis), Fluton (PI), Invade (UPL), Fame (Bayer)
Hexythiazox	5.45% EC: Maiden (Biostadt), Edurer (Coromandel)
Imidacloprid	17.8% SL: Confidor (Bayer), Tatamida (Rallis), Cohigan (Adama), Jumbo (PI), Atom (Indofil), Media (Dhanuka), Novastar (FMC) 70% WG: Ad-fyre (Dhanuka), Admire (Bayer) 48% FS: Gaucho (Bayer)
Indoxacarb	14.5% SC: Dakhs (Rallis), Avant (DuPont), Dhawa (Dhanuka) 15.8% EC: Dhawa Gold (Dhanuka)
Lambda cyhalothrin	2.5% EC: Reeva 2.5 (Rallis), Lamdex (Adama) 5% EC: Reeva 5 (Rallis), Lamdex Super (Adama), Agent Plus (Indofil)
Malathion	50% EC: Cythion (Coromandel)
Milbemectin	1% EC: Milbinak (Nagarjuna)
Metaflumizone	22% SC: Verismo (BASF)
Methomyl	40% SP: Dash (Indofil), Dunet (Dhanuka)
Methyl-parathion	Metacid (Bayer)
Monocrotophos	36% SL: Phoskill (UPL), Monophos (Coromandel)
Novaluron	10% EC: Rimon (Indofil)
Permethrin	25% EC: Permasect (Coromandel)
Phenthoate	50% EC: Phendal (Coromandel)
Phorate	10% CG: Foratox (PI)
Profenophos	50% EC: Carina (PI), Ajanta (Coromandel)
Propergite	57% EC: Simbaa (PI), Omite (Dhanuka)
Pymetrozine	50%WG: Chess (Syngenta)
Quinalphos	25% EC: Flash (Indofil)
Spinosad	40% SC: Spintor (Bayer), Taffin (Rallis)
Spiromesifen	22.9% EC: Voltage (PI), Oberon (Bayer)
Sulfur	40% SC: Share (Indofil)

Thiodicarb	75% WP: Larvin (Bayer)
Thiomethoxam	25% WDG: Actara (Syngenta), Maxima (PI), Click (Indofil), Areva (Dhanuka) 35% SC: Cruiser (Syngenta)
Tolfenpyrad	15% EC: Keefun (PI)
*Triazophos	40% EC: Fullstop (Biostadt)
Acephate 50% + Imidacloprid 1.8% SP	Lancer gold (UPL)
Beta cyfluthrin 8.49% + Imidacloprid 19.81% OD	Solomon (Bayer)
Chlorpyriphos 50% + Cypermethrin 5% EC	Nurcombi (Cheminova), Ulka (Biostad), Nurel-D (Dow), Humla (Gharda), Stampede (Sudershan), Koranda 505 (Rallis)
Ethion 40% + Cypermethrin 5% EC	Nagata (Rallis), Colfos (PI)
Ethiprole 40% + Imidacloprid 40% (80% WG)	Glamore (Bayer)
Fipronil 40% + Imidacloprid 40% WG	Lesenta (Bayer)
Indoxacarb 14.5% + Acetamiprid7.7% SC	Mighty Balwan (Rallis)
Profenofos 40% + Cypermethrin 4% EC	Roket (PI), Ajanta Super (Coromandel)
Chlorantraniliprole 9.3% + Lambda cyhalothrin 4.6% ZC	Ampligo (Syngenta)
Thiamethoxam 12.6%+Lambda cyhalothrin 9.5%ZC	Alika (Syngenta)
Flubendiamide 19.92% w/w+ Thiacloprid 19.92% w/w	Belt Expert (Bayer)
Flubendiamide 3.5% + Hexaconazole 5%	Origin (Rallis)

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Appendix II: Brand names and manufacturers of major fungicides

Fungicides	Brand names and manufacturers
Azoxystrobin	23% : Amistar (Syngenta), Azogro (Coromandel)
Benomyl	50% WP: Benofit (Coromandel)
Bitertanol	25% WP: Baycor (Bayer)
Captan	50% WP: Captaf (Rallis), Captra (Indofil)
Carbendazim	50% WP: Benfil (Indofil), Bavistin (Crystal)
Carboxin	75% WP: Vitavax (Dhanuka), Hiltavax (HIL)
Chlorothalonil	75 %WP: Ishaan (Rallis), Jatayu (Coromandel), Kavach (Syngenta)
Copper hydroxide	77% WP: Kocide (DuPont), Isacide (Isagro)
Copper oxychloride	50% WG: Blitox (Rallis), Cuprina (PI), Trucop (Indofil), Blue copper (Syngenta)
Cuprous oxide	4% DP: Copper Sandoz (Syngenta)
Difenoconazole	25% EC: Indream (Biostadt), Score (Syngenta)
Dimethomorph	50% WP: Lurit (PI), Acrobat (BASF), Odin (Coromandel)
Dodine	65% WP: Noor (Indofil)
Flusilazole	40% EC: Cursor (Dhanuka), Nustar (DuPont)
Fosetyl-Al	80% WP: Aliette (Bayer)
Hexaconazole	5% EC: Contaf (Rallis) 2% SC: Samarth (Rallis), Sitara (Indofil) 5% SC: Sitara plus (Indofil)
Iprobenfos (Kitazin)	48% EC: Kitazin (PI)
Isoprothiolane	40% EC: Fujione (Rallis)
Mancozeb	75% WP: Tata M 45 (Rallis), Indofil M-45 (Indofil) 75% WG: Manfil WG (Indofil) 35% SC: Eurofil-NT (Indofil)
Mandipropamid	25% SC: Revus (Syngenta)
Metalaxyl	35% WS: Aprone (Syngenta), Krilaxyl (Krishi Rasayan)
Methoxy Ethyl Mercury Chloride (MEMC)	6% FS: Emisan 6 (Excel), Bagaloi-6 (UPL)
Myclobutanil	10% WP: Boon (Indofil), Cygnet (Biostadt)
Oxycarboxin	20% EC: Plantvax (Dhanuka)

Pencycuron	25% SC: Monceren (Bayer)
Fosetyl- aluminium	80% WP: Aliette (Bayer)
Propiconazole	25% EC: Perido (PI), Dhan (Indofil), Propicron (Coromandel), Tilt (Syngenta)
Propineb	70% WP: Sanipeb (PI), Antracol (Bayer), Addit (FMC), Dolby (Biostadt), Aaroosh (Coromandel)
Pyraclostrobin	10% CS: Header (PI) 20% WG: Headline (BASF) 44.3% SC: Ergon (Rallis)
Sulphur	80% WG: Sultaf (Rallis), Sulfil (Indofil), Wokovit (Biostadt)
Tebuconazole	25% EC: Folicur (Bayer), Tebustar (FMC) 2% WP: Raxil (Bayer)
Thiphanate-methyl	70% WP: Roko (Biostadt), Hexastop (Coromandel)
Thiram	75% WS: Thiram (Dhanuka), Vezfru Thiram (PI)
Triadimefon	25% WP: Baylayton (Bayer)
Tricyclazole	75% WP: Mantis (Rallis), Logik (PI), Indofil's baan (Indofil), Furazole (FMC), Agni (Coromandel)
Tridemorph	80% EC: Calixin (BASF)
Trifloxistrobin	50% WDG: Flint (Bayer) 50% SC: Twist (Bayer)
Zineb	75% WP: Indofil Z-78 (Indofil)
Ziram	27% : Cuman L (Syngenta)
Ametoctradin + Dimethomorph 20.27% w/w SC	Blend (Rallis)
Azoxytrobin 11% + Tebuconazole-18.3% SC W/W	Alliance (Biostadt)
Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC	Amistar Top (Syngenta)
Boscalid25.2%+Pyraclostrobin12.8%WG	Visma (PI)
Captan 70% + Hexaconazole 5% WP	Klinzo (Biostadt)
Carbendazim 12% + Mancozeb 63% WP	Companion (Indofil), Sicer (Dhanuka), Bendaco (Biostadt), Capeni (Coromandel), Saaf (UPL)
Carbendazim 25%+ Mancozeb 50% WS	Sprint (Indofil)

Carboxin 17.5% + Thiram 17.5% FF	Vitavax Ultra FF (Dhanuka)
Carboxin 37.5% + Thiram 37.5% DS	Vitavax Power (Dhanuka)
Cymoxanil 8% + Mancozeb 64% WP	Moximate (Indofil), DuoGuard (Biostadt)
Famoxadone 16.6% + Cymoxanil 22.1% SC	Equation Pro (DuPont)
Fenamidone 10% + Mancozeb 50% WG	Sectin (Bayer)
Fluopicolide 4.44% + Fosetyl aluminium 66.67%WG	Profiler (Bayer)
Hexaconzole 4% + Zineb 68% WP	Avatar (Indofil), Supermate (Biostadt)
Metalaxyl M 4% + Mancozeb 64% WP	Matco 8-64 (Indofil), Sanchar (Biostadt), Ridomil Gold (Syngenta)
Metalaxyl M 3.3% + Chlorothalonil 33.1% SC	Folio Gold (Syngenta)
Metalaxyl 8% + Mancozeb 64% WP	Master (Rallis)
Metiram 55% + Pyraclostrobin 5% WG	Clutch (PI), Colastro (Coromandel), Cabrio Top (BASF)
Propiconazole 13.9% + Difenoconazole 13.9% EC	Taspa (Syngenta)
Tebuconazole 50% + Trifloxystrobin 25% WG	Netivo (Bayer)

Appendix III: Brand names and manufacturers of major antibiotics

Antibiotics	Brand names and manufacturers
Aureofungin	46.15% SP : Aureofungin Sol (Hindustan Antibiotic)
Kasugamycin	3% SL: Kasu-B (Dhanuka), Biomycin (Biostadt), Kasumin (Coromandel)
Strteptomycin + Tetracycline	90:10 SP: Streptocycline (Hindustan Antibiotic), K-cycline (Karnataka Antibiotic),
Validamycin	3% L: Sheathmar (Dhanuka), Validan (Coromandel)

Appendix IV: Pesticides banned in India

(Source: Central Insecticide Board & Registration Committee, Directorate of Plant Protection, Quarantine & Storage, Faridabad; as on 20th October 2015 and Ministry of Agriculture and Farmers Welfare gazette notification, New Delhi, 8th August, 2018)

A. Pesticides banned for manufacture, import and use

1. Alachlor *	16. Endrin	31. Pentachloro nitrobenzene (PCNB)
2. Aldicarb	17. Ethyl mercury chloride	32. Pentachlorophenol
3. Aldrin	18. Ethyl parathion	33. Phenyl mercury acetate
4. Benzene hexachloride	19. Ethylenedibromide (EDB)	34. Phorate*
5. Benomyl**	20. Fenarimol**	35. Phosphamidon*
6. Calcium cyanide	21. Fenthion**	36. Sodium cyanide**
7. Carbaryl**	22. Heptachlor	37. Sodium methane arsonate
8. Chlorbenzilate	23. Lindane (Gamma-HCH)	38. Tetradifon
9. Chlordane	24. Linuron**	39. Thiometon**
10. Chlorofenvinphos	25. Maleic hydrazide	40. Toxaphene (Camphechlor)
11. Copper acetoarsenite	26. Menazon	41. Triazophos*
12. Diazinone**	27. Methoxy ethyl mercury chloride**	42. Trichlorfon*
13. Dibromochloropropane (DBCP)	28. Metoxuron	43. Trichloro acetic acid (TCA)
14. Dichlorvos*	29. Nitrofen	44. Tridemorph**
15. Dieldrin	30. Paraquat dimethyl sulphate	45. Trifluralin (except in wheat)**

** Recently banned w.e.f August 9, 2018

* Ban will be implemented from December 31, 2020

B. Pesticide formulations banned for import, manufacture and use

1. Carbofuron 50% SP
2. Methomyl 12.5% L
3. Methomyl 24% formulation
4. Phosphamidon 85% SL

C. Pesticide / Pesticide formulations banned for use but continued to manufacture for export

1. Captafol 80% Powder
2. Nicotin sulfate

D. Pesticides Withdrawn (Withdrawal may become inoperative as soon as required complete data as per the guidelines is generated and submitted by the Pesticide Industry to the Government and accepted by the Registration Committee)

1. Dalapon
2. Ferbam
3. Formothion
4. Nickel Chloride
5. Paradichlorobenzene (PDCB)
6. Simazine
7. Sirmate

Abbreviations

ADI: Acceptable Daily Intake

SG: Water Soluble Granule

a.i.: active ingredient

SL: Soluble Concentrate

CIB: Central Insecticides Board

w/v: weight by volume

CIB RC: Central Insecticides Board and Registration Committee

w/w: weight by weight

CS: Capsule Suspension

WG/WDG: Water Dispersible Granules

DF: Dry Flowable

WHO: World Health Organisation

EC: Emulsifiable Concentrate

WP: Wettable Powder

EW: Emulsion, Oil in Water

WSC: Water-Soluble Concentrate

EPA: Environmental Protection Agency

FAO: Food and Agricultural Organisation

FSSAI: Food Safety and Standards Authority of India

g: gram

GAP: Good Agricultural Practices

GOI: Government of India

Gr: Granule

ha: hectare

JMPR: Joint FAO/WHO Meetings on Pesticide resiues

kg: Kilo gram

L: Litre

LD_{50}: Lethal median dose

MRL: Maximum Residue Limit

PHI: Post Harvest Interval

SC: Suspension Concentrate

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