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RESEARCH ARTICLE

Influence of fungicides on the bio-efficacy of insecticides against diamondback moth, *Plutella xylostella* L.

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ABSTRACT

All the fungicides tested at four concentrations (25, 50, 100 and 200 ppm) against *Plutella xylostella* (L.) possessed insecticidal properties. Among the fungicides, clorothalonil at 200 ppm concentration caused highest mortality of 18.51 per cent while, mancozeb and quintal caused 12.59 and 10.37 per cent mortality at the same concentration. The insecticides *viz.*, endasulfan, fipronil, profenophos, indoxacarb and spinosad were compatible with the fungicide clorothalonil where its efficacy was increased considerably with co-toxicity co-efficient (CC) values of 1.32, 1.31, 1.26, 1.17 and 1.14, respectively. However, novaluron and thiodicarb were incompatible with clorothalonil with CC values of 0.81 and 0.97, respectively. Regarding the compatibility of insecticides with mancozeb; endosulfan, spinosad, porofenophos, novaluron and fipronil were clearly compatible with mancozeb with CC values of 1.39, 1.14, 1.12, and 1.10, respectively. However, incompatibility was noticed between indoxacarb+mancozeb and thiodicarb+mancozeb combinations with CC values of 0.82 and 0.73, respectively. The insecticides *viz.*, profenophos, novaluron, indoxacarb, fipronil and endosulfan were compatible with quintal with CC values of 1.67, 1.42, 1.30, 1.21 and 1.18, respectively. However, spinosad+quintal and thiodicarb+quintal combinations exhibited antagonistic effect with CC values of 0.88 and 0.84, respectively indicating incompatibility.

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INTRODUCTION

Cole crops are an important group of vegetables consumed all over the world. Cole crops like cabbage, cauliflower, turnip, kale. broccoli, brussel sprouts, etc., are grown in hills and plains of India. Among them, cabbage and cauliflower are economically important vegetables in India. In recent years, the production of crucifers has been seriously affected by steady increase in insect pest infestation, especially the diamondback moth (DBM), *Plutetla xylostelta* (L.) (Srinivasan and Krishnamoorthy, 1992) and the leaf spot disease caused by the fungus, *Alternaria brassicae*. The DBM larvae feed on the foliage from seedling stage up to harvest, greatly reducing both yield and quality of the produce. The pest poses a serious problem because of its high reproductive potential, rapid turnover of generations, and ability to develop resistance to insecticides and intensive cultivation of crucifers involving more number of crops in sequence during a year. In India it has been estimated that the pest causes losses up to 52 per cent in marketable yield of cabbage (Chellaiah and Srinivas, 1986).

Alternaria leaf spot caused by the fungus, *Alternaria brassicae* affects almost all crucifers and has created serious problem on cabbage and cauliflower in India. Losses occur mostly in the form of reduced quality of heads, although in some cases the pathogen is destructive for seed growers,

where the pathogen can shrivel seeds within the pods or kill pod stalks before seed formation. In addition to destruction of seed crops, the pathogen can live within the seed, spread the disease to other fields and cause loss of seedlings (Rangel, 1945).

Pesticides have a great impact on human health, production and preservation of food, fibre and other cash crops. Though, different control methods are available for suppression of pests on crops, none of them match in their efficacy, speed and cost of operations with chemical control measures. However, the over dependence on chemicals and their indiscriminate use in cabbage ecosystem has led to some serious problems such as, increased cost of plant protection, insecticide resistance in some pests and pathogens, resurgence of certain pest species, apart from the environmental hazards associated with their use. The problem is also compounded by the occurrence of pests and diseases simultaneously in the field, and it is more common in commercial crops. Any delay in the application of pesticides results in heavy crop losses. To save time and to get quick curative action, the farmers often, mix different pesticides without considering their compatibility.

The number of chemicals involved in plant protection are too many and the information on compatibility of individual chemical is scattered in the literature. Common growers find difficulty in ascertaining their compatibility. Hence, based on experience Gray (1914) prepared a chart showing compatibility of some of the insecticides and fungicides, then in use. Later several such charts were developed or up-dated by Frear (1948) and Gruzdyev *et al*. (1983) for the chemicals in use with additional information regarding incompatibility under certain situations and crops. Such information led an understanding that the compatibility might vary with crops, season, aging of mixtures and many other factors. Later, Baicu (1980) suggested studying compatibility in different stages including determination of chemical and physical properties, biological activity of compounds, field tests of effectiveness, phytotoxicity and yield after treatment. However, very few studies, have gone in to the problem of compatibility to such an extent.

Secondly, the chemicals have been developed primarily to control target pest, may be an insect or pathogenic organism, but their toxic effects on unrelated organisms are not well known. There are few reports of fungicides possessing insecticidal properties on insects and insecticides having fungicidal properties on pathogens. But such information on majority of chemicals is desired. A chemical possessing both insecticidal and fungicidal properties, if identified would help in reducing pesticidal load on the environment.

Detailed study to understand the desirable and undesirable effects of mixing two chemicals assume practical significance as several combinations may result in loss of effect of either or both the chemicals or it may result in synergism between the chemical combinations. It may also lead to variation in the relative toxicity of mixtures when compared to individual chemicals, induce toxicity to plants, or interfere with growth and metabolism resulting in decreased crop yields. Keeping these things in view, the present study was undertaken to assess the compatibility of insecticides and fungicides under cabbage ecosystem.

MATERIAL AND METHODS

Laboratory studies were carried out at the Department of Agricultural Entomology, University of Agricultural Sciences, GKVK, Bangalore during 2004-2005.

Laboratory culture of *P. xylostella* :

In all the bioassay and bio-efficacy experiments carried out under laboratory conditions, only the F_1 progeny reared from field collected *P. xylostella* population was used. The insect was reared on mustard seedlings by employing the method of Liu and Sun (1984) with suitable modifications. The late instar larvae and pupae were collected from infested cabbage fields around Bangalore and were reared to pupal stage on mustard seedlings raised in plastic Petridishes (10 × 1.5 cm). Pupae were placed in the oviposition cage (35 × 10 × 35 cm) for emergence. One day-old moths were provided with three-four days old mustard seedlings to facilitate oviposition. Ten per cent sugar solution on cotton wads was given to moths during oviposition as adult food. After 24 hours, seedlings were transferred to rearing trays placed on wooden stands. Fresh seedlings were provided every day for oviposition.

In rearing trays, eggs hatched in about three to four days and the young larvae fed on the leaves first by mining and then on the entire leaves. When the seedlings had been largely consumed, fresh seedlings were placed in the rearing tray. Larvae migrated to the fresh seedlings on their own or they were transferred gently by tapping the consumed seedlings and lifting the hanging larvae on to the fresh seedlings with the help of a camel hair brush. Fresh seedlings were provided as and when required. The rearing was done at the room temperature. The rearing trays and culture room were disinfected with four per cent formaldehyde to avoid bacterial infections. All the precautions were taken to keep away the ants and lizards.

lnsecticidal action of fungicides againsl *P. xylostella* :

A study was carried out to know the insecticidal property of selected fungicides. The DBM larvae collected from cabbage field around Bangalore were reared to F_1 progeny on mustard seedlings as described above. The third instar larvae were exposed to all the contact fungicides namely, mancozeb, chlorothalonil and quintal each at 25, 50, 100 and 200 ppm

concentration of the formulation.

Fresh, uniform sized mustard leaves were dipped in aqueous fungicides dilutions containing 0.1 per cent liquid soap for ten seconds and then air dried under shade for about an hour. The cut ends of petioles of treated leaves were provided with wet cotton wads and wrapped with aluminum foil to retain the succulence. The treated mustard leaves were placed in Petridishes. For control, leaves were dipped in water with 0.1 per cent soap. Fifteen early third instar larvae of the test insect were released on treated leaves in each Petridish and each treatment was replicated thrice. The treated larvae were maintained at 25±1^{0}C in BOD incubator and the mortality counts were recorded at 24 and 48 hours after the treatment.

Effect of fungicides on the bio-efficacy of insecticides against *P. xylostella* :

The toxicity of individual insecticides as well as the mixtures of insecticide and fungicide to the test insect was assessed in the laboratory based on the median lethal concentration by employing 'leaf-dip' method of bioassay. The median lethal concentrations were determined for insecticides alone and for insecticide-fungicide mixtures. The details of pesticides used in the study are presented in Table A.

Bioassay :

For every insecticide and fungicide mixture and individual insecticide, a preliminary test *i.e.*, bracketing was

Table A : Details of pesticides used in the study

Common name	Chemical name	Trade name and formulation	Manufacturing company
Insecticides			
Thiodicarb	3,7,9,13 tetra methyl -5,11- dioxa-2,8,14-trithia-4,7,9,12-tetra azapentadeca -3,12-diene-6, 10-dione.	Larvin 75 WP	Bayer Crop Science India Ltd., Mumbai
Indoxacarb	Methyl (S)-N-[7-chloro-2,3,4a,5- tetrahydro-4a-Hethoxycarbonyl] indeno [1,2-e]-[1,3,4] oxadiazin-2-ylcarbonyl]-4-(trifluoromethoxy) carbinilate.	Avaunt 14.5 WP	E.I.Dupont India Pvt. Ltd., Gurgaon, Haryana
Fipronil	5-amino-1-[2, 6-dichloro-4-(trifluoromethyl) phenyl]-4-(trifluoromethyl sulfinyl)- *1*H –pyrazole- 3- carbonitrile.	Regent 5 WP	Bayer Crop Science India Ltd., Mumbai
Profenophos	O-(4-Bromo-2-chlorophenyl) –O-ethyl- S-propyl phosphorothioate.	Curacron 50 EC	Syngenta India Ltd., Mumbai
Spinosad	Spinosyn A=2-((6-deoxy-2,3,4-tri-O-methyl-a-L-mannopyranosyl)oxy)-13-(((5-dimethylamino) tetrahydro-6 methyl-*2*H-pyran-2-yl)oxy)-9-ethyl-2,3,3a,5a,5b,6,9, 10,11,12,13,14,16a,16b-tetradecahydro-14-methyl-*1*H-as-indaceno(3,2 d) oxacyclododecin-7,15-dione. Spinosyn D=2-((6-deoxy-2,3,4-tri-O-methyl-a-L-mannopyranosyl)oxy)-13-(((5-dimethylamino) tetrahydro-6-methyl-*2*H-pyran-2-yl)oxy)-9-ethy1-2,3,3a,5a,5b,6, 9,10,11,12,13, 14,16a,16b- tetradecahydro-4, 14-dimethyl-*1*H-as-indaceno (3,2-d) oxacyclododecin-7,15-dione.	Success 2.5 SC	DE –NOCIL Crop Protection Pvt. Ltd., Mumbai
Endosulfan	6,7,8,9,10,10-Hexachloro-1,5,5a,6,9,9a- hexahydro-6, 9-methano-2,4,3-benzodioxathiepin-3-oxide	Endocel 35 EC	Excel Industries limited, Mumbai
Novaluron	1-03-Chloro-4-(1,1,2-trifluoro-2-trifluoromethoxy ethoxy) phenyl	Rimon 10 EC	Indofil Chemical Company, Mumbai
Fungicides			
Quintal	Iprodione=3-(3,5-dichlorophenyl)-N- isopropyl-2,4-dioxoimidazolidine-1- carboxamide + Carbendazim=Methyl-[2-^{14}C] benzimidazol-2-yl-carbamate	Quintal 50 WP	Bayer Crop Science India Ltd., Mumbai
Chlorothalonil	2,4,5,6-tetrachloroisophthalonitrile	Kavach75 WP	Syngenta India Ltd., Mumbai
Mancozeb	Manganese and zinc–[1, 2-^{14}C] ethylene-bis-dithiocarbamate	Indofil-M-45 75 WP	Indofil Chemical Company, Mumbai

done to fix the appropriate dosage range causing 5 to 95 per cent mortality of test insect larvae. At least five concentrations of the test products in geometric progression were used for each bioassay. For every dose, three batches of 15 third instar larvae were maintained.

Fresh and uniform sized mustard leaves were dipped in aqueous insecticide dilutions containing 0.1 per cent liquid soap for ten seconds and then air dried under shade for about an hour, The cut ends of petioles of treated leaves were provided with wet cotton wads to retain the succulence. The treated mustard leaves were placed in Petridishes along with control. Fifteen early third instar larvae of the test insect were released on treated leaves in each Petridish. The treated larvae were maintained at 25±1^{0}C in BOD incubator and the mortality counts were recorded at 24 and 48 hours after the treatment.

Observed mortality data were converted to percentages and corrected for control mortality according to Abbott (1925). The corrected mortality values were subjected to probit analysis (Finney, 1971) for obtaining regression equations for dosage mortality response and to determine the LC_{50} values.

Determination of co-toxicity co-efficient :

Co-toxicity co-efficients were worked out to ascertain the level potentiation (synergism) or antagonism of toxicity of insecticide and fungicide mixtures using the formula (Sarup, *et al.*, 1980) :

$$\text{Co-toxicity co-efficient} = \frac{LC_{50} \text{ insecticide alone}}{LC_{50} \text{ of insecticide + fungicide combination}}$$

Determination of relative toxicity :

The relative toxicity of the insecticide and fungicide combinations and individual insecticides to the test insect was calculated taking the LC_{50} of the least toxic chemical (with highest LC_{50} value) as unity.

$$\text{Relative toxicity} = \frac{LC_{50} \text{ of the least toxic individual insecticide or combination with fungicide}}{LC_{50} \text{ of the other individual insecticides or combination with fungicide}}$$

RESULTS AND DISCUSSION

Initially the fungicides were evaluated for their insecticidal properties. Later the bio-efficacy of the insecticide+ fungicide combinations and individual insecticides against third instar larvae of *P. xylostella* was investigated by adopting 'leaf dip bio-assay' method under laboratory conditions'.

Insecticidal properties of selected fungicides against *P. xylostella* :

Three fungicides were tested at four concentrations for their insecticidal property against third instar larvae of *P. xytostelta*. Mustard leaves dipped in fungicide dilutions were provided to the larvae. Observations on larval mortality were recorded at 24 and 48 hours after treatment. The per cent cumulative larval mortality at different hours after treatment is presented in Table 1.

The result revealed that all the fungicides possessed insecticidal properties and the mortality was significantly more at higher concentrations. Among the fungicides, chlorothalonil was possessing significantly higher insecticidal property followed by mancozeb and quintal. Twenty four hours after treatment, the fungicide chlorothalonil at 200 ppm caused highest mortality of 14.88 per cent and was superior to other fungicides. This was followed by mancozeb and quintal which caused mortality of 11.11 and 8.88 per cent, respectively

Table 1 : Insecticidal properties of selected fungicides against third instar larvae of *P. xylostella* under laboratory conditions

Fungicides	Concentration (ppm)	Percent larval mortality at different hours after treatment	
		24	48
Chlorothalonil	25	0.00 (0.00)^a	2.22 (8.53)^b
	50	7.40 (15.79)^e	8.14 (16.54)^e
	100	9.62 (18.05)^f	11.11 (19.46)^g
	200	14.88 (22.71)^h	18.51 (25.48)^i
Mancozeb	25	0.00 (0.00)^a	0.00 (0.00)^a
	50	0.00 (0.00)^a	0.00 (0.00)^a
	100	4.40 (12.11)^c	5.18 (13.05)^c
	200	11.11 (19.46)^g	12.59 (20.79)^h
Quintal	25	0.00 (0.00)^a	0.00 (0.00)^a
	50	2.22 (8.53)^b	2.22 (8.53)^b
	100	5.18 (13.05)^d	6.66 (14.89)^d
	200	8.88 (17.26)^e	10.37 (18.72)^f
Control	00	0.00 (0.00)^a	0.00(0.00)^a

Figures in parenthesis are arc sine √ per cent transformed values. Mean denoted by the same letter on each column are not significantly different by (P=0.05) DMRT

at same concentration. Mancozeb and quintal were non-toxic at lower doses (25 ppm). At 48 hours after treatment, chlorothalonil at 200 ppm caused maximum mortality of 18.51 per cent followed by mancozeb (12.59%) and quintal 10.37%). Mancozeb and quintal at lower concentration (25 ppm) did not have any insecticidal property where as chlorothalonil possessed least insecticidal property causing 2.22 per cent larval mortality.

Certain compounds are marketed as fungicides to be used exclusively against fungal diseases. However, many workers have reported such compounds to possess insecticidal activity also. Same way Livingston *et al.* (1978) reported that clorothalonil was toxic against three insect species tested *viz.*, *Tichoplusia ni*, *Pseudoplusia includens* and *Helicoverpa zea* and the size of the larvae on fungicide treated diet were smaller and slow developmental rates were exhibited when compared to untreated controls. Likewise insecticidal properties of mancozeb against various insect pests have been reported by Mcmuilan and Jong (1971) and who revealed that Mancozeb 9 kg toxicant per hectare was effective in controlling nymphs of *Psylla pyricola* on pear. Similarly, insecticidal activity of carbendazim has been documented. Carbendazim at 0.07 per cent caused 64 per cent reduction in reproduction of alate, *Schizaphis craminium* on wheat (Hendi and Kansouh, 1986) and ovicidal effect on *Scirphophaga incertulus* at 0.01 per cent concentration (Raju *et al.*, 1988).

Quantification of potentiation of toxicity of insecticides to *P. xylostella* when mixed with fungicides:

The toxicity of insecticides with fungicides and individual insecticides to test insect was quantified by adopting 'leaf dip bioassay' method under laboratory conditions. The probit analysis of dosage-mortality response of *P. xylostella* to insecticide+fungicide combination and individual insecticides are presented in Tables 2 to 5.

The median lethal concentrations of seven insecticides *viz.*, endosulfan, fipronil, indoxacarb, novaluron, profenophos, spinosad and thiodicarb were 2660.30, 11.40, 3.40, 8.00, 863.90, 2.40 and 78.60 ppm, respectively (Table 2).

In combination with chlorothalonil the LC_{50} values of five insecticides *viz.*, endosulfan, fipronil, indoxacarb, profenophos and spinosad were reduced to 2013.10, 8.70, 2.90, 681.80 and 2.10 ppm, respectively. But chlorothalonil interacted

Table 2 : The probit analysis of dosage mortality response of *P. xylostella* to selected insecticides

Insecticides	χ^2	Regression equation Y=	LC_{50} (ppm)	Fiducial limits at 95% (ppm)	LC_{99} (ppm)
Endosulfan	4.20	0.98±0.11x	2660.30	2185.6-3209.0	61349.50
Fipronil	4.87	5.24±0.50x	11.40	9.5-13.6	230.02
Indoxacarb	4.45	6.11±0.51x	3.40	2.8-4.1	70.40
Novaluron	3.55	6.60±0.53x	8.00	6.9-9.4	98.80
Profenophos	12.99	1.28±0.13x	863.90	542.8-1393.1	73330.40
Spinosad	6.82	7.20±0.64x	2.40	2.0-2.8	35.00
Thiodicarb	4.26	3.25±0.28x	78.60	62.8-97.1	2498.60

Table 3 : The probit analysis of dosage mortality response of *P. xylostella* to selected insecticides in combination with Chlorothalonil

Pesticidal combinations	χ^2	Regression equation Y=	LC_{50} (ppm)	Fiducial limits at 95% (ppm)	LC_{99} (ppm)	*CC
Endosulfan	4.20	0.98±0.11x	2660.30	2185.6 3209.0	61349.80	--
Endosulfan + Chlorothalonil (100 ppm)	2.95	1.18±0.11x	2013.10	1625.5-2438.4	47399.50	1.32
Fipronil	4.87	5.24±0.50x	11.40	9.5-13.6	230.02	--
Fipronil + Chlorothalonil (100 ppm)	4.84	5.63±0.53x	8.70	7.2-10.3	159.03	1.31
Indoxacarb	4.45	6.11±0.51x	3.40	2.8-4.1	70.40	--
Indoxacarb + Chlorothalonil (100 ppm)	4.00	6.15±0.52x	2.90	2.4-3.5	6.30	1.17
Novaluron	3.55	6.60±0.53x	8.00	6.9-9.4	98.80	--
Novaluron + Chlorothalonil (100 ppm)	0.93	5.89±0.49x	9.80	8.3-11.5	150.30	0.81
Profenophos	12.99	1.28±0.13x	863.90	542.8-1393.1	73330.40	--
Profenophos + Chlorothalonil (100 ppm)	13.58	1.46±0.15x	681.80	426.1-1091.1	48907.90	1.26
Spinosad	6.82	7.20±0.64x	2.40	2.0-2.8	35.00	--
Spinosad + Chlorothalonil (100 ppm)	6.68	7.15±0.65x	2.10	1.8-2.5	33.10	1.14
Thiodicarb	4.26	3.25±0.28x	78.60	62.8-97.1	2498.60	-
Thiodicarb + Chlorothalonil (100 ppm)	2.35	2.74±0.25x	80.30	62.2-612.2	4786.50	0.97

*CC= Co- toxicity Co-efficient (L C_{50} of insecticide alone. ÷ L C_{50} of insecticide and fungicide combination)

antagonistically with novaluron and thiodicarb where the LC_{50} values of novaluron and thiodicarb increased to 9.80 and 80.30 ppm, respectively. The extent of potentiation of toxicity of insecticides in combination with fungicide chlorothalonil revealed that toxicity of endosulfan, fipronil and profenophos to *P. xylostella* larvae increased to the maximum extent by chlorothalonil with the co-toxicity co-efficient (CC) values of 1.32, 1.31 and 1.26, respectively. While chlorothalonil slightly enhanced the toxicity of indoxacarb (CC: 1.17) and spinosad (CC: 1.14). But chlorothalonil exhibited antagonistic action with novaluron and thiodicarb with CC values of 0.81 and 0.97, respectively (Table 3).

In combination with mancozeb the LC_{50} values of endosulfan, fipronil, novaluron, profenophos and spinosad was reduced to 1913.10, 10.30, 7.10, 769.00 and 2.10 ppm, respectively. But combination with mancozeb LC_{50} values of indoxacarb and thiodicarb were increased to 4.10 and 107.60 ppm, respectively. The extent of potentiation of toxicity of main insecticides in combination with the fungicide mancozeb indicated that highest level of potentiation in case of endosulfan+ mancozeb with co-toxicity co-efficient value of 1.39. While chlorothalonil slightly enhanced the toxicity of spinosad, profenophos, novaluron and fipronil with CC values of 1.14, 1.12, 1.12 and 1.10 , respectively. Mancozeb exhibited

Table 4 : The probit analysis of dosage mortality response of *P. xylostella* to selected insecticides in combination with Mancozeb

Pesticidal combination	χ^2	Regression Equation Y=	LC_{50} (ppm)	Fiducial limits at 95% (ppm)	LC_{99} (ppm)	*CC
Endosulfan	4.20	0.98±0.11x	2660.30	2185.6 3209.0	61349.80	--
Endosulfan + Mancozeb (100 ppm)	4.92	1.27±0.12x	1913.10	1553-2305	39382.70	1.39
Fipronil	4.87	5.24±0.50x	11.40	9.5-13.6	230.02	--
Fipronil + Mancozeb (100 ppm)	4.69	5.50±0.52x	10.30	8.6-12.2	182.90	1.10
Indoxacarb	4.45	6.11±0.51x	3.40	2.8-4.1	70.40	--
Indoxacarb + Mancozeb (100 ppm)	1.06	5.58±0.47x	4.10	3.3-5.0	105.60	0.82
Novaluron	3.55	6.60±0.53x	8.00	6.9-9.4	98.80	--
Novaluron + Mancozeb (100 ppm)	5.25	7.03±0.56x	7.10	6.1-8.2	77.70	1.12
Profenophos	12.96	1.28±0.13x	863.90	542.8-1393.1	73330.40	--
Profenophos + Mancozeb (100 ppm)	14.86	1.39±0.14x	769.00	472.9-1266.5	54718.40	1.12
Spinosad	6.82	7.20±0.64x	2.40	2.0-2.8	35.00	--
Spinosad + Mancozeb (100 ppm)	5.14	7.43±0.66x	2.10	1.7-2.4	29.30	1.14
Thiodicarb	4.26	3.25±0.28x	78.60	62.8-97.1	2498.60	--
Thiodicarb + Mancozeb (100 ppm)	3.78	2.97±0.27x	107.60	86.4-133.5	3731.40	0.73

*CC= Co- toxicity Co-efficient (L C_{50} of insecticide alone ÷L C_{50} of insecticide and fungicide combination)

Table 5 : The probit analysis of dosage mortality response of P. xylostella to selected insecticides in combination with Quintal

Pesticidal combination	X^2	Regression equation Y=	LC_{50} (ppm)	Fiducial limits at 95% (ppm)	LC_{99} (ppm)	*CC
Endosulfan	4.20	0.98±0.11x	2660.30	2185.6-3209.0	61349.80	--
Endosulfan + Quintal. (100ppm)	5.49	1.13±0.11x	2237.3	1830.8-2692.56	48032.7	1.18
Fipronil	4.87	5.24±0.50x	11.40	9.5-13.6	230.02	--
Fipronil quintal. (100ppm)	4.68	5.58±0.52x	9.4	7.9-11.2	171.7	1.21
Indoxacarb	4.45	6.11±0.51x	3.40	2.8-4.1	70.40	--
Indoxacarb quintal. (100ppm)	10.66	4.85±0.46x	2.6	2.0-3.3	135.7	1.30
Novaluron	3.55	6.60±0.53x	8.00	6.9-9.4	98.80	--
Novaluron quintal. (100ppm)	2.96	7.42±0.59x	5.6	4.8-6.5	58.6	1.42
Profenophos	12.99	1.28±0.13x	863.90	542.8-1393.1	73330.40	--
Profenophos quintal. (100ppm)	13.13	1.54±0.15x	515.9	310.4-822.2	45106.8	1.67
Spinosad	6.82	7.20±0.64x	2.40	2.0-2.8	35.00	--
Spinosad quintal. (100ppm)	6.08	6.99±0.57x	2.7	2.3-3.2	41.8	0.88
Thiodicarb	4.26	3.25±0.28x	78.60	62.8-97.1	2498.60	--
Thiodicarb quintal. (100ppm)	2.90	2.95±0.26x	93.1	74.0-116.1	678.9	0.84

*CC= Co- toxicity Co-efficient (L C_{50} of insecticide alone ÷L C_{50} of insecticide and fungicide combination)

antagonistic action with thiodicarb (CC: 0.73) and indoxacarb (CC: 0.82) (Table 4).

In combination with quintal the LC_{50} values of five insecticides *viz.*, endosulfan, fipronil, indoxacarb. novaluron and profenophos were reduced to 2237.30, 9.40, 2.60, 5.60 and 515.90 ppm, respectively. But in combination with quintal, LC_{50} values of spinosad and thiodicarb increased to 2.70 and 93.10 ppm, respectively. The extent of potentiation of toxicily of insecticides in combination with fungicide revealed that highest level of potentiation was observed in the case of profenophos+quintal, novaluron+quintal and indoxacarb+ quintal with CC values of 1.67, 1.42 and 1.30, respectively. While quintal slightly enhanced the toxicity of fipronil (CC: 1.21) and endosulfan (CC: 1.18), but quintal exhibited antagonistic action with the spinosad (CC: 0.88) and thiodicarb (CC: 0. 84) (Table 5).

From the above results it is clear that the combinations in which the co-toxicity co-efficient was more than one or equal to one will be treated as compatible because the insecticidal property was increased or not changed. Many authors quoted the insecticidal properties of fungicides and their influence on bio-efficacy of insecticides which is supportive to present study. It is evident from the available literature that mancozeb potentiated the toxicity of some insecticides. Aly (1997) revealed his laboratory investigations that mancozeb was more compatible with the insecticide karate (Lambda-cyhalothrin) and turadacupral against the adults of *Tibotium confusum*. Similarly Abbaih (1985) reported synergistic action of mancozeb with monocrotophos against *Drosophila melanogaster*. Likewise, mancozeb exhibited synergistic action with carbaryl, phosphomidon and dimethoate (Thripathi *et al.,* 1983), monocrotophos 0.075 per cent against chilli pest complex (Sitaramraju and Srinivasrao, 1984), endosulfan against *Aphis gossypii* and *Aspondylia sesarne* on sesamum (Abraham *et al.*, 1977), dimethoate against *Tribotium castaneum* (Premkumar, 1978), carbaryl in controlling *Heliothis amigera* and *Spodoptera litura* (Dodd, 1979) and fenvalerate 20 EC at the rate of 75 g and monocrotophos 36 SL @ 250 ml with mancozeb 75 WP @1500 g a.i., per hectare against leaf hopper, *Amrasca bigutulla bigutull*a (Nagia *et al.* 1993). However, Lakshminarayana and Subbaratnam (2000) in their laboratory studies reported that monocrotophos 0.52 ppm (LC_{50}) in combination with four test concentration of mancozeb *viz.*, 500, 1000, 2000 and 3000 ppm showed mortality of nymphs less than 50.0 per cent indicating antagonism between these two pesticides. Likewise, Tripathi *et al*. (1983) also reported antagonistic effect of monocrotophos and fenvalerate which is due to sedimentation of mancozeb. From the above studies it is clear that excluding indoxacarb and thiodicarb all other insecticides are compatible with mancozeb. The studies on this aspect are lacking in literature for comparison of potentiation of toxicity of insecticides by quinilol and hence, from the above studies it is clear that excluding spinosad and thiodicarb, all other insecticides are compatible with quinilol.

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