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Development of IPM package with safe pesticide residue: 1. Cabbage

Debi Sharma, A. Krishnamoorthy[1], P. N. Krishna Moorthy[1], Girija Ganesan[2], A. K. Ahuja and M. D. Awasthi
Division of Soil Science & Agricultural Chemistry
Indian Institute of Horticultural Research
Hessaraghatta Lake Post, Bangalore-560089, India.
E-mail: dsharma@iihr.ernet.in

ABSTRACT

An IPM module with safe pesticide residues on cabbage, with already proven treatments such as carbosulfan, dimethoate, cypermethrin+ profenofos and mancozeb under chemical method of control; NSP, *Bacillus thuringiensis* and *Trichogramma bactrae* under non chemical method of control were revalidated individually and in combination. Six releases of parasitoid *T. bactrae* at weekly intervals starting from 12 days after transplanting or spray of NSP 4% at 10-15 days interval, 4 times, starting from 20 days after transplanting, foliar spray of dimethoate and mancozeb gave good control of aphids, leaf blight and black rot respectively.Based on the effectiveness of the treatment and pesticide residues below their permissible levels in cabbage at harvest, a module was developed and tested in the field. The IPM package thus developed was found to control the pests effectively and at the same time the residues on the crop were within the safe limits.

Key words: Cabbage, biological control, IPM, pesticide residues

INTRODUCTION

Cabbage (*Brassica oleracea* L. var. capitata) is an important vegetable crop, grown throughout the year and in many parts of India, under assured irrigation. The hybrids grown under intensive cultivation, indiscriminately receive very high doses of pesticides resulting in development of resistance in many pests, outbreak of secondary pests and accumulation of pesticide residues in the final produce. Pesticide residue studies carried out under All India Co-ordinated Research Project on Pesticide residues, ICAR, India, revealed that 62.6% of the farm gate samples of cabbage contained residues of which 7% were above legally permissible levels (Agnihotri, 1999). These residues on cabbage pose a health hazard for the consumer since it is consumed raw as salad and also added to a variety of preparations. International market standards demand very low or zero pesticide residues in exportable vegetables. Therefore, development of integrated pest management (IPM) package for vegetables having pesticide residues at or below permissible levels is necessary in the national context. While a great deal of work has been carried out on IPM of cabbage in India (Krishnaiah *et al*, 1981; Krishna Moorthy and Krishna Kumar, 2000, 2001) and abroad (Becker, 1989; Finch, 1993; Pollard, 1991), all of these deal with control of either a particular insect or disease. There is no single package for the integrated control of insects and diseases together while ensuring low pesticide residues in cabbage at harvest. The present study is thus aimed at development of an IPM package for cabbage with safe pesticide residue level.

MATERIAL AND METHODS

A study on the development of pesticide residue free IPM package for cabbage was carried out during the period 2000 – 2003 at Indian Institute of Horticultural Research, Hessaraghatta, Bangalore (12" 58' N, 77" 35' E). The major pests and diseases dealt with during the study were diamondback moth (DBM), *Plutella xylostella* (L.); borers, *Helicoverpa armigera* (Hubner), *Spodoptera litura* (F.), aphid, *Brevicoryne brassicae* (L.), Alternaria leaf blight, *Alternaria brassicae* (Berk.) and black rot, *Xanthomonas campestris* pv *campestris*. Cabbage variety Krishna (F_1 hybrid) was grown as per recommended package of practices. Seedlings in the nursery were well protected using 80 mesh nylon net to avoid egg laying by DBM at seedling stage itself. The seedlings were transplanted in an area of 150 m^2 after dipping in a solution containing cypermethrin (0.5 ml/l) and mancozeb (2 g/l) for 30 minutes. A spacing of 50 cm x 50 cm was followed and a dose of 120 N: 80 P: 80 K was applied to the soil. A paired row of Indian mustard

[1]Division of Entomology and Nematology
[2]Division of Plant Pathology

was sown for every 25 rows of cabbage at the time of transplanting (Srinivasan and Krishna Moorthy, 1991).

Chemical Control

Although several insecticides were used for the control of pests on cabbage, carbosulfan (Brown and Hargreaves, 1979) and cypermethrin + profenofos (Mohan, 1987) were evaluated using exploded design. In the first trial, carbosulfan @ 0.025% was sprayed on the crop at fortnightly intervals from 7th day after planting (DAP) for control of all the pests. A total of 5 sprays were given. To assess the efficacy of the pesticide, a control treatment with 25 m^2 area was also maintained simultaneously without any pesticide spray. Observations were made on the population of DBM, aphids and a DBM parasitoid, *Cotesia plutellae* Kurdj.

A combined insecticidal formulation containing cypermethrin and profenofos (Mohan, 1987) was sprayed @ 0.08% from 12 DAP at fortnightly intervals for the control of pests of cabbage in the second trial. A total of 5 sprays were given. Two foliar sprays of dimethoate @ 0.5 ml/l (Mallapur *et al*, 1994) at an interval of 15 days was given to control aphids. Foliar spray of the fungicide mancozeb @ 2.0 g/l was given at 60 days after transplanting to check the incidence of *Alternaria* leaf blight and black rot (Jayakumar *et al*, 1995). Disease scoring was done as per the 0-5 scale (Wheeler, 1969).

Validation of non-chemical control

Several botanical insecticides and biocontrol agents were evaluated singly or in combination for control of cabbage pests in the third trial. These were (i) neem seed powder (NSP) 4% (Krishna Moorthy and Krishna Kumar, 2000) - 4 sprays, (ii) *Bacillus thuringiensis* var. k*urstaki* (Bt) (Krishnamoorthy *et al*, 2003) -4 sprays @1 g/l, (supplied by Wockhardt life Sciences Ltd. Mumbai, India) (iii) 6 releases of laboratory mass-bred egg parasitoid, *Trichogrammatoidea bactrae* Nagaraja and Nagarkatti @ 40,000 to 60,000 adults/ha (Singh *et al*, 2004) at weekly interval from 12 DAP for the control of DBM and (iv) three sprays of Bt and six releases of *T. bactrae*. (Anon., 2001). Statistical analysis of the data obtained was carried out between treatment and control, in each case.

Residue analysis

The pesticides used in chemical control trials were evaluated to find whether such applications resulted in persistence of harmful residues on the cabbage heads at harvest. Cabbage heads ready to harvest were collected after 3 and 5 days of the last foliar spray treatment of each pesticide. These were chopped into ~ 1 cm pieces, mixed and quadrisected. A representative sample of 50 g was drawn in triplicate for analysis of residues of each pesticide. Residues of carbosulfan and its major metabolite carbofuran were determined by blending the cabbage sample in hexane – isopropanol (1: 1, V/V) solvent mixture in a Waring blender. The residues were thereafter partitioned into hexane, cleaned up from other co-extractives by florisil adsorption column chromatography and determined by GLC (Leppert *et al*, 1983). Residues of dimethoate in cabbage heads were analyzed by GLC (Anon., 1984). The residues of mancozeb were extracted by hydrochloric acid digestion followed by trapping of evolved carbon disulfide (CS_2) into Viles reagent. The residues were finally determined as total quantity of CS_2 evolved by spectrophotometric method (Keppel, 1971). The residues of ethylene thiourea (ETU), a toxic metabolite of mancozeb, were also analyzed in the samples by HPLC (Smith *et al*, 1982). The residues of profenofos were analyzed by extraction in acetone + hexane and determined by GLC as per Chen *et al* (2001). All the analytical methods were standardized in the laboratory and their efficiency ascertained by suitable recovery experiments.

RESULTS AND DISCUSSION

Chemical control

In the first trial (2000 –2001), DBM population was observed throughout the cropping period but at low level. The mean population of DBM was 1.66/plant in treatment as compared to 0.89/plant in control. Similarly, population of aphids was higher in treated plot (0.16/plant) as compared to control (0.00/plant) (Table 1). Carbosulfan treatment seemed to suppress the population of parasitoid, *C. plutellae* in cabbage as no cocoons of *Cotesia* were observed in treated plots (Table 1). Observations made on the population of *S. litura, H. armigera* and leaf webber showed that the population of these were uniformly low in all the trials.

In the second trial, it was observed that the aphid population in cypermethrin + profenofos treated plot ranged from 0 to 4 with a mean value of 0.62/plant throughout the crop period, whereas, in control it ranged from 0.2 to 14 with a mean of 4.32/plant. The mean DBM population, however was higher in treated plot (1.08/plant) as compared to the control plot (0.31/plant). The combination insecticide had no effect on the population of *Cotesia* (Table 1). Thus, carbosulfan and combination insecticide, cypermethrin + profenofos, had no effect in controlling these pests of cabbage with the former having deleterious effect on the

Table 1. Effect of various treatments on the incidence of DBM, cabbage aphid and DBM parasitoid in cabbage.

Treatment	No of DBM / plot		No. of cabbage aphid / plot		No. of DBM parasitoid *Cotesia plutellae* / plot	
	Treated	Control	Treated	Control	Treated	Control
Carbosulfan	1.66	0.89	0.16	0.00	0.00	0.10
Profenofos + Cypermethrin	1.08	0.31	0.62	4.38	0.16	0.10
NSP	0.61	2.88	0.27	3.07	0.00	0.20
Bt	0.76	2.88	1.15	3.07	0.07	0.20
T. bactrae	1.53	2.88	10.48	3.07	0.10	0.20
NSP + *T. bactrae*	0.48	1.43	1.36	5.71	0.02	0.14
Bt + *T. bactrae*	0.51	1.43	4.71	5.71	0.06	0.14

principal natural enemy, *C. plutellae*. It was not possible to assess the efficacy of carbosulfan against aphid population as no aphid population was observed in control for comparison. However, combination insecticide profenofos + cypermethrin was found to be effectively controlling aphid in a separate trial. Spray of mancozeb resulted in considerable reduction of the incidence of disease, *Alternaria* leaf blight in treatment as compared to that in control (Table 2). Similar observations for disease incidence of black rot of cabbage also showed reduction of disease incidence in treatment as compared to control. The per cent disease index (PDI) for blight was 19.25 as compared to 52.25 in control while the same for black rot was 15.45 as against 36.01 in control.

Non-chemical control

The incidence of DBM was less in treatments in which NSP 4%, Bt and egg parasitoid (*T. bactrae*) were used alone or in combination, compared to control. These treatments were also better than the chemical control (Table 1). Among non-chemical methods of control, NSP 4 % controlled DBM as well as aphids better than egg parasitoid and Bt applications. The aphid population in treatments where egg parasitoid or Bt was used remained the same or slightly higher. There were fewer cocoons of *C. plutellae* available in treatments than in control. But it was not due to direct toxic effect on *C. plutellae*; rather, there was indirect deleterious effect of NSP on egg parasitoid. The population of *C. plutellae* was found to be less because of fewer number of DBM larvae available for the larval parasitoid to parasitise in these treatments. However, among the various treatments, use of egg parasitoids along with Bt or NSP resulted in better reduction of DBM population than release of egg parasitoid alone.

Residue analysis

The results obtained from residue analysis (Table 3) revealed that repeated foliar application of carbosulfan resulted in persistence of carbosulfan as well as its toxic metabolite, carbofuran in cabbage heads above the prescribed maximum residue limit of 0.1 ppm. It is thus not advisable to apply carbosulfan on cabbage heads at harvest as its residues (0. 14 – 0.65 ppm) persist at non permissible levels for upto 5 days after the last spray . Carbosulfan residues (0.05 – 0.27 ppm), have been similarly found to persist above permissible levels even on 15th day after last spray in brinjal (Rajeswaran *et al*, 2004). Treatments of combination pesticide cypermethrin + profenofos resulted in persistence of 1.26 and 0.72 ppm of residues of profenofos at harvest carried out at 3 and 5 days after last treatment (DALT) respectively. The MRL of profenofos in cabbage is 1 ppm; therefore, the cabbage heads were safe only at 5 DALT from the point of residue persistence of profenofos. Residues of 0.025 ppm of profenofos have been found on the 6 DALT in spring onion (Talebi and Ghassami, 2004), however, no reports regarding profenofos residues in cabbage have been found in literature. Cypermethrin residues present on cabbage heads were 0.389 and 0.216 ppm at 3 DALT and 5 DALT respectively, and since MRL of cypermethrin in brassica and leafy vegetables (MRL of cypermethrin in cabbage heads is not yet established) is 1 ppm, the cabbage heads could be considered safe for consumption at 3 DALT itself from the point of view of residue persistence of cypermethrin on cabbage heads. Similar results have earlier been obtained by Babu *et al* (2001) who recommended a

Table 2. Effect of mancozeb on *Alternaria* leaf blight and black rot in cabbage

Sl. No.	Treatment	Treatment (Mean PDI)		Control (Mean PDI)	
		Alternaria leaf blight	Black rot	*Alternaria* leaf blight	Black rot
1	Before mancozeb spray	30.05	20.53	40.35	30.03
2	Three days after mancozeb spray	19.25	15.45	52.25	36.01
3	Per cent reduction in disease incidence	33.00	20.56	—	—

Table 3. Persistence pattern of pesticide residues in cabbage heads

Sl.No.	Pesticide	Rate of application	No. of sprays	Mean residues (mg kg^{-1})		MRL (mg kg^{-1})	Remarks
				3 DALT	5 DALT		
1	Mancozeb	2.0 g/l	1	BDL	BDL	3.00	Safe
	ETU (Metabolite)			BDL	BDL		
2	Carbosulfan	1.0 ml/l	5	0.650	0.140	0.10	Unsafe
	Carbofuran (Metabolite)			0.340	0.560	0.10	
3	Profenofos	1.5 ml/l	5	1.261	0.720	1.0	Safe at 5 DALT
	Cypermethrin		5	0.389	0.216	1.0	Safe
4	Dimethoate	0.5 ml/l	2	1.264	0.647	1.0	Safe at 5 DALT

BDL = Below detectable limit; DALT = Days after last treatment

Table 4. Pesticide residue free/safe IPM module for cabbage (seed treated previously)

Sl.No.	Stage	Operation	Target pests
1	Nursery preparation	Drench nursery with captan @ 2g/l	Damping off
		Apply carbofuran @ 0.5 kg a.i/ha to nursery	Soil borne insects like ants, termites etc.
2	Nursery	Spray nursery with copper oxychloride @ 3 g/l on 15th and 30th days after sowing	Damping off and downy mildew
		Spray nursery with Bt @ 1 g/l on 10th days after sowing	DBM
		Netting with 80 mesh	DBM etc.
3	Nursery one day before transplanting	Spray nursery with Bt @ 1 g/l and metalaxyl-mancozeb @ 2 g/l	DBM Downy Mildew
4	Transplanting	1. Sow paired row of mustard for every 25 rows of cabbage at the time of transplanting.	DBM and other pestsLike aphids, leaf webber etc., (optional).
		2. Plant cabbage at 50 x 50 cm instead of 50 x 45 cm as followed by farmers.	Bacterial rot and *Alternaria*.
5	Transplanted crop	Six releases of parasitoid *Trichogrammatoidea bactrae* (50,000 adults/ha) at weekly intervals from 12 days after transplanting.	DBM
		Or	
		Spray pulverized NSP 4 % at 10-15 days interval 3-4 times from 20 DAP.	DBM and other pests like aphids, leaf webber etc.
		Or	
		Spray Bt @ 1g/l at 10-15 days interval 3-4 times 20 DAP.	DBM and other lepidopterous pests.
		Spray dimethoate, 0.5ml/l	Aphid (need based)
		Two to three sprays of dichlorvos, 1 ml/l to border mustard to protect the foliage as and when required (2 - 3 sprays).	Saw fly and other pests (optional)
		Removing basal disease affected leaves in the morning	Bacterial rot, *Alternaria* and Downy mildew
		Need based application of mancozeb 0.25 %	Bacterial rot, *Alternaria* and Downy Mildew.

waiting period of 3 days for cypermethrin in cabbage. 1.26 and 0.65 ppm were the residues of dimethoate present in cabbage heads at 3 and 5 DALT respectively. The MRL of dimethoate in cabbage is 1 ppm, therefore, the cabbage heads were safe for consumption at 5 DALT if sprayed with dimethoate. In Rumania, a study had recommended a waiting period of 7 days for dimethoate residues in tomatoes, cucumbers and egg plants (Floru and Isac,1972). The residues of mancozeb and its major metabolite, ethylene thiourea were found to be below detectable limit at 3 and 5 DALT (Table 3). Jayakumar *et al* (1995) had also recommended a waiting period of 2 days for mancozeb residues in tomato. Thus, it was observed that considering residual persistence among the chemicals used for control of cabbage pests, dimethoate can be recommended for control of aphids and mancozeb can be used for the control of *Alternaria* leaf blight and bacterial rot as these are safe to be applied at harvest stage of cabbage.

Thus, it was seen that, six releases of parasitoid, *T. bactrae* (50,000 adults/ha) at weekly intervals from 12 days

after transplanting or spray of NSP 4 % at 10-15 days interval (4 times) from 20 DAP gave good control of pests. Among insecticides, dimethoate could be used for the control of aphids as need based pesticide in all parasitoid release plots as its residue is within the safe limit at 5 DALT (Table 3). Incorporating the above results a pesticide residue free or safe IPM module was developed (Table 4).

Earlier, numerous reports have indicated the efficacy of various plant protection agents for cabbage IPM, for instance, Bt products in combination with insect growth regulator, chlorfluazuron, have been highly recommended for control of DBM in Papua New Guinea (Saucke, 1994) and as an important option for IPM in cabbage. Similarly, Setiawati (2000) indicated that Spinosad 25 SC was suitable for controlling DBM and cabbage head caterpillar. However, in this study, for the first time a complete cabbage IPM module was developed taking consumer safety into account. The cabbage heads grown using this module will be free from harmful pesticide residues.

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