Effect of Integrated Pest Management Modules against Diamond Back Moth *Plutella xylostella* (L) and parasitoid *Cotesia plutellae* (Kurdjumov)

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Abstract: Two field experiments were carried out during *Kharif* 2012 and *Rabi* 2013 to assess the effect of IPM module against Diamond Back Moth, (DBM) *Plutella* xylostella (L) and its parasitoid *Cotesia plutellae* (Kurdjumov). Among five IPM modules tested, the suggestive module was found effective against DBM *P. xylostella* irrespective of the seasons. The suggestive module (M4) has recorded the lowest mean larval population (0.90 and 0.75 nos. / head) and registered 66 and 64. 76 percent reduction in damage over control besides recorded the highest yield of 35.13 and 35.67 t/ha and incremental cost benefit ratio of 3:26 in *Kharif* 2012 and *Rabi* 2013 respectively. Further, a maximum parasitization by *C. plutellae* to the tune of 30.00 percent was noticed in Suggestive module when cabbage was intercropped with onion.

Keywords: *Plutella xylostella*, *Cotesia plutellae,* cabbage, IPM.

INTRODUCTION

Of late diamond back moth, *Plutella xylostella* (L) has become a serious pest on cruciferous crops Worldwide [1]. The yield loss due to DBM up to 52% is reported in India [2]. To mitigate the losses due to this pest, farmers used large quantities of pesticides in vegetable crops like cabbage [3]. The intensive and indiscriminate use of pesticides has led to many problems like insecticide resistance in insects, development of secondary pests, adverse effect on non- target organisms, pesticide residues and health hazards. Recent advances in research being directed towards development of safer and eco-friendly methods such as botanicals, biopesticides and some newer molecules like avermectins, spinosyns and microbes which are relatively safe to natural enemies and reduces pesticide load in environment. Keeping this in view, investigations were undertaken to test the Integrated Pest Management (IPM) modules comprising of newer insecticides, chitin inhibitors, neem products and biopesticides against major insect pests of cabbage in Madurai and Theni districts.

MATERIALS AND METHODS

Two field experiments were conducted at Theni district *viz*., Duraisamypuram during August to November 2012 and Ellaipatti during December to January 2012-2013, to evaluate four different IPM modules *viz*., Bio–intensive, Farmer's practice, Recommended and Suggestive modules for the management of DBM on cabbage. Each IPM module was laid with 0.20 ac. Observations were recorded in three places in each module, considering each one as replicate. Ten plants per replication were randomly selected for assessing the pest and natural enemy population. The plant protection measures were carried out in different IPM modules as detailed below,

BIO-INTENSIVE MODULE (M1)

- Application of Neem oil 2% or Nimbecidine 2ml/lit with Teepol 1ml/lit.
- Foliar application of SlNPV @ 250 LE/ha at 20 and 40 DAT.
- Foliar application of *Bacillus thuringiensis* var. *kurstaki* @ 2 g / lit. at primordial stage
- Foliar application of Neem Seed Kernel Extract 5% after primordial stage.

FARMER'S PRACTICE (M2)

Alternate spraying with the following insecticides at weekly intervals.

- Methomyl 40 SP @ 2g/lit.
- Phosalone 35EC @ 2ml/lit.
- Chlorpyriphos 20EC @ 2ml/lit.
- Quinalphos 25EC @ 1ml/lit.

RECOMMENDED MODULE (M3)

- Soil application of Quinalphos 1.5 D @ 20 kg/ha in soil before planting.
- Collection and destruction of affected parts.
- Installation of yellow sticky trap and pheromone trap each @12/ha
- *Bacillus thuringiensis* var. *kurstaki* @ 2g/lit at primordial stage
- Foliar application of Neem Seed Kernel Extract 5% after primordial stage.
- Spray application of dimethoate @ 2 ml /lit

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E-ISSN: 2311-858X/14

SUGGESTIVE MODULES (M4)

- Use of designer seeds Chemical used for seed treatment: (Thiram & Carbendazim).
- Inter crop (Cabbage + Onion @ 4:1).
- Set up pheromone trap @ 12 nos/ha.
- Foliar application of Neem Seed Kernel Extract 5% after primordial stage.
- Insecticides Indoxacarb 14.5 % SC @ 3.5 ml/ 10 lit of water and Emamectin benzoate 5% SG 4g/10 lit of water + *Bacillus thuringiensis* @ 1kg/ha.
- Spray application of Spinosad 2.5% SC@ 25g a.i/ha

Assessment of larval populations and damage incidences of diamond back moth were done on ten randomly selected plants from each plot. The damage by DBM was identified based on the symptoms of damage on head and plant parts of cabbage. The total number of heads and the number of damaged heads were counted and percent head damage was worked out. The randomly selected ten plants were thoroughly observed for natural enemy population. The damaged head along with the larvae for the emergence of parasitoids were noted.

At harvest, both the damaged and undamaged heads were collected at weekly intervals and the total head yield was expressed as t / ha. The data on the population of insects were subjected to $\sqrt{x+1}$ transformation, while the percent damage data were transformed in to arcsine values and analyzed statistically. The treatments mean values were compared by Duncan's Multiple Range Test (DMRT) at 5 percent probability [4] to access the effective treatment.

RESULTS AND DISCUSSION

In first season, the study on the effectiveness of various IPM modules revealed that mean larval population of *P. xylostella* on cabbage was significantly the lowest in Suggestive module (M_4) (0.90 nos./ head) when compared to 3.35 nos./head in control, that had resulted 73.13 percent decrease in larval population over control (Table **1**). The next in the order were Recommended module (M_3) (1.33 nos./head), Bio-intensive module (M_1) (1.57 nos./head) and Farmer's practice (M_2) (1.68 nos./plant) respectively. Thus the Suggestive module (M_4) registered 66 percent reduction in damage levels of *P. xylostella* respectively and recorded the highest yield of 35.13 t/ha as against 18.92 t / ha in control, registering 85.68 percent increase in yield over control (Table **1**). Next in the order of efficacy were Recommended module (M_3), (63.84%), Bio-intensive module (M_1) (43.55%) and Farmers' practice (M_2) (33.87%) increase over control. Regardless of pests, suggestive module was found to be superior to rest of the modules.

From the Table **2**, it's evident that the percent parasitism ranged from 10.14 to 30.10 indicating that *Cotesia plutellae* was the most predominant and most effective natural enemy. The maximum parasitization was noticed in Suggestive module when cabbage was intercropped with onion at the ratio of 4:1.

The second season data on the effect of IPM module against *P. xylostella* are presented in Table **3**. The mean larval population before treatment was more or less same, while after treatment the larval population

Table 1: Effect of IPM Modules against larvae of *Plutella xylostella* (Field Experiment-I)

Module		Average larvae / head		Percent decrease over control	Damage (%)	Percent reduction over control	Yield** (t / ha)
		Before treatment #	After treatment				
M_1	Bio-intensive	3.53 (1.88)	17.46 (24.65)^{d}	53.14	14.92* (22.71)^{c}	47.68	27.16^{c}
M_2	Farmer's Practice	3.77 (1.95)	13.78 (21.72)^{b}	49.85	17.46 (24.65)^{d}	38.77	25.33^{d}
M_3	Recommended	3.20 (1.78)	9.50 (17.95)^{a}	60.23	13.78 (21.72)^{b}	51.68	31.00^{b}
M_4	Suggestive	3.47 (1.86)	28.52 (32.27)^{e}	73.13	9.50 (17.95)^{a}	66.69	35.13^{a}
M_5	Control	3.65 (1.91)	3.35 (1.83)^{e}	-	28.52 (32.27)^{e}		18.92^{e}

*Mean of fifteen observations
** Mean of four replications
Figures in parentheses are square root transformed values
Means in a column followed by same letters are not significantly different (P = 0.05) by DMRT.
- Not significant

Table 2: Effect of IPM Modules on DBM infestation and parasitization by *Cotesia plutellae* (Field Experiment-I)

Module	Number of DBM larvae / head on DAP					Parasitization (%) on DAP				
	40	55	70	Mean	Percent reduction over control	40	55	70	Mean	Percent increase over control
M1-Bio-intensive	7.23 **(2.68)[a]	12.43 (3.52)[a]	10.12 (3.18)[a]	*9.93 (3.15)[a]	19.98	22.54 ***(28.32)[c]	25.20 (30.13)[c]	30.10 (33.27)[d]	25.94 (30.59)[c]	40.83
M2-Farmer's practice	8.19 (2.86)[b]	12.39 (3.51)[a]	11.39 (3.37)[a]	10.66 (3.26)[a]	14.10	20.00 (26.57)[b]	24.23 (29.47)[c]	25.21 (30.13)[c]	23.14 (28.73)[b]	28.91
M3-Recommended	12.7 3.56)[a]	19.25 (4.38)[c]	14.27 (3.77)[a]	15.41 (3.92)[b]	24.17	10.14 (18.53)[a]	11.10 (19.46)[a]	13.23 (21.30)[a]	11.49 (19.73)[a]	35.98
M4- Suggestive	6.31 (2.51)[a]	11.24 (3.35)[a]	9.23 (3.03)[a]	8.92 (2.98)[a]	28.12	21.29 (27.42)[b]	25.37 (30.20)[c]	29.43 (32.85)[d]	26.36 (30.85)[d]	46.85
M5-Control	9.24 (3.03)[c]	14.12 (3.75)[b]	13.89 (3.72)[a]	12.41 (3.52)[b]	---	11.16 (19.46)[a]	19.47 (26.13)[b]	23.22 (28.79)[b]	17.95 (25.03)[b]	---

DAP: Days after planting
*Mean of fifteen observations
**Figures in parentheses are square root transformed values
***Figures in parentheses are arc sine transformed values
Means in a column followed by same letters are not significantly different (P = 0.05) by DMRT.

Table 3: Effect of IPM modules against larvae of *Plutella xylostella* (Field Experiment-II)

Module		Average larvae / head		Percent decrease over control	Damage (%)	Percent reduction over control	Yield** (t / ha)
		Before treatment #	After treatment				
M_1	Bio-intensive	3.50* (1.87)	1.61 (1.26)[c]	52.23	14.39* (22.22)[c]	43.41	27.89[d]
M_2	Farmer's Practice	3.61 (1.90)	1.70 (1.30)[d]	49.55	16.14 (23.66)[d]	36.53	25.96[c]
M_3	Recommended	3.38 (1.83)	1.29 (1.13)[b]	61.72	12.49 (20.62)[b]	50.88	30.18[b]
M_4	Suggestive	3.42 (1.85)	0.75 (0.86)[a]	77.74	8.96 (17.36)[a]	64.76	35.67.[a]
M_5	Control	3.68 (1.91)	3.37 (1.84)[e]	-	25.43 (30.26)[e]	-	18.34[e]

*Mean of fifteen observations
** Mean of four replications
Figures in parentheses are square root transformed values
Means in a column followed by same letters are not significantly different (P = 0.05) by DMRT.
- Not significant

ranged from 0.75 nos./head to 3.37 nos./head and was significantly different from each other. Among different modules, again the suggestive module (M_4) recorded the lowest larval population (0.75) and resulted 77.74 percent decrease over control followed by Recommended module (M_3) (61.72), Bio-intensive module (M_1) (52.23) and Farmer's practice (M_2) (49.55) respectively. In general, Suggestive module (M_4) has recorded 64.76 percent reduction in damage levels by *P. xylostella* and recorded the highest yield of 35.67 t / ha as against 18.34 t / ha in control, registering 94.49 percent increased yield over control (Table **1**).

From the second season data, it is evident that the percent parasitism ranged from 10.12 to 27.32 indicating that *Cotesia plutellae* was the most predominant and most effective entomophage. The maximum parasitization was noticed in the Suggestive module (Table **4**).

Based on the incremental benefit cost ratio, the IPM modules were ranked. Among IPM modules, Suggestive module (M_4) registered the highest benefit cost ratio of 3.26 as compared to 2.12 Farmer's practice (M_2) (Table **5**). While considering both

Table 4: Effect of IPM modules on DBM infestation and parasitization by *Cotesia plutellae* (Field Experiment-II)

Module	Number of DBM larvae / head on DAP					Parasitization (%) on DAP				
	40	55	70	Mean	Percent reduction over control	40	55	70	Mean	Percent increase over control
M1-Bio-intensive	10.23 **(3.19)[a]	12.89 (3.59)[a]	13.10 (3.61)[a]	*12.07 (3.47)[a]	41.03	21.17 ***(27.35)[c]	22.00 (27.9)[c]	24.13 (29.40)[a]	22.43 (28.25)[c]	44.70
M2-Farmer's practice	14.29 (3.78)[a]	15.28 (3.90)[a]	19.13 (4.37)[b]	16.23 (4.02)[b]	20.71	15.18 (22.87)[b]	19.15 (25.9)[b]	22.13 (28.04)[a]	18.82 (25.70)[b]	21.41
M3-Recommended	12.18 (3.48)[a]	13.28 (3.64)[a]	15.20 (3.89)[a]	13.55 (3.68)[a]	33.80	17.12 (24.43)[b]	21.19 (27.3)[c]	25.24 (30.13)[b]	21.18 (27.35)[c]	36.64
M4- Suggestive	9.20 (3.03)[a]	10.29 (3.20)[a]	11.12 (3.33)[a]	10.20 (3.19)[a]	50.17	20.19 (26.64)[c]	22.00 (22.9)[a]	27.32 (31.50)[b]	23.17 (28.73)[c]	49.48
M5-Control	19.12 (4.37)[b]	20.12 (4.48)[b]	22.19 (4.71)[b]	20.47 (4.52)[b]	-	10.12 (18.53)[a]	12.27 (20.4)[a]	24.13 (29.40)[a]	15.50 (23.18)[a]	-

DAP: Days after planting
*Mean of fifteen observations
**Figures in parentheses are square root transformed values
***Figures in parentheses are arc sine transformed values
Means in a column followed by same letters are not significantly different (P = 0.05) by DMRT.

Table 5: Economics of IPM modules against major pests of Cabbage

Modules		Mean yield (t/ ha)	Yield increase over control	Price of increased yield (Rs.)	Additional cost incurred towards each module	Benefit due to module	Incremental Benefit cost ratio
M_1	Bio-intensive	27.52	12.10	15730	4810	10920	2.27
M_2	Farmer's practice	25.64	10.22	13286	4264	9022	2.12
M_3	Recommended module	30.59	15.17	19721	5695	14026	2.46
M_4	Suggestive module	35.40	19.98	25794	6100	19874	3.26
M_5	Control	15.42	---	---	---	---	--

effectiveness and economics, the Suggestive module (M_4) stood first indicating its superiority over other modules. Recommended practice (M_3) (2.46) ranked next to Suggestive module (M_4). The Bio-intensive module (M_1) (2.27) and Farmer's practice (M_2) (2.12) ranked third and fourth in their incremental benefit cost ratio.

The suggestive module showed a greater impact not only against major pest *P. xylostella,* (Table **1** and **2**) but also on the parasitization by *Cotesia plutellae*. The lowest population of major pests in Suggestive module (M_4) indicates that integration of designer seed, inter cropping of cabbage with onion and newer insecticide molecules (Spinosad and Emamectin benzoate) would have efficiently managed DBM there by registered less damage and higher head yield. Further, the suggestive module has resulted in enhanced natural enemies activities. The better efficacy of Suggestive module (M_4) may be due to effective parasitization of *P. xylostella* larvae by *C. plutellae* accompanied by application of bio-pesticide, botanicals and newer insecticide which would have killed the *P. xylostella* larvae that had escaped from parasitization by *Cotesia plutellae*. The present finding was in conformity with the reports of Liu *et al.* [5] that *C. plutellae* was the key factor in the control of DBM under field conditions. Further, Hirashima *et al.* [6], Talekar and Yang [7], have also reported that use of parasitoids is one of the most effective and suitable methods for controlling resistant races of DBM. Kulkarni *et al.* [8] revealed that the treatment with Delfin 50 WG @ 0.5 kg/ha and Halt 1.0 kg/ha was found to be superior in reducing the DBM infestation at 3, 7 and 10 days after application and increasing the yield of cabbage and quality heads. Pokharkar *et al.* [9] opined that the *B.t* formulation to persist on the leaves of field grown cabbage plants for at least 5 days with OAR (Original Activity Remaining) thus providing high protection against DBM. Mukherjee and Singh [10] stated *B.t* to be the most effective treatment from 7th day onwards upto15 days. Forgone [11] opined that

NSKE was found to be as effective as deltamethrin against DBM in Chinese cabbage and cauliflower. Srinivasan and Krishnamoorthy [12] reported that NSKE consistently provided significant reduction of *P. xylostella* larvae on cabbage. Patel *et al.* [13] opined that NSKE 5% suspension was effective against *P. xylostella* while neem leaf extract 5 percent suspension was least effective. Three applications of NSKE 4% were adequate to reduce DBM population from more than 40 percent to negligible level [14]. Chavan *et al.* [15] reported that cabbage and tomato intercropping at 4:1 ratio along with four sprays of NSKE 3 percent and *B.t* at 0.1 percent alternatively at 15 days interval keep the DBM at low level. Peter *et al.* [16] reported spinosad 2.5 SC @ 15, 20 and 25g a.i./ha to be effective against DBM. Spinosad gave excellent control of *P. xylostella* when applied @15, 20 and 25 g a.i./ha in both cabbage and cauliflower up to 7 days [17]. Similar results were also obtained by other workers such as Dey and Somchoudhary [18-20].

NATURAL ENEMIES

In the present study *C. plutellae* was observed as major parasitoid on DBM in cabbage field during both seasons. However, we assume that this parasitoid species alone may not contribute much to DBM control because of high population levels of the pest. Therefore, not only augmentation but also conservation of parasitoids is necessary for sustainable biological control. The conservation of parasitoid was achieved by suggestive module. This is in agreement to the earlier reports where Joshi and Sharma [21] indicated the dominance of C*. plutellae* (36.6%) in Rajasthan. Chelliah and Srinivasan [22] observed 72 percent larval parasitization. Oh *et al.* [23] reported 9.8 percent parasitism in different seasons. Sivapragasam *et al.* [24] stated that intercropping of tomato with cabbage at 1:4 ratio significantly reduced DBM infestation and resulted in 29.61 percent parasitism by *C. plutellae*. Talekar and Yang [25] observed 55 percent parasitism on DBM larvae. Reddy and Singh [26] reported 13.13 to 36.17 percent parasitization in different generations of first instar and 18.33 to 43.33 in second instar. Uematsu and Yamashita [27] reported about 70 percent in Miyazaki, Southern Japan.

YIELD AND ECONOMICS

Economics of various IPM modules against DBM on cabbage was worked out. Among IPM modules, the suggestive module (M4) consisting of designer seeds of hybrid cabbage, inter cropping with onion, spraying of *Bt* at primordial stage and NSKE 5% after primordial stage followed by application of newer molecule namely Spinosad 2.5% SC @ 25g a.i / ha for the management of major pests of cabbage was found to be economically viable as it registered the highest yield (35.40 t/ha) and incremental benefit cost ratio (3.26) when compared to other modules (Table **5**). The present findings revealed that the suggestive module exhibited effective control and registered higher yield and cost benefit ratio which is in accordance with the earlier reports of Shukla and Ashok Kumar [28] and Gajanana *et al.* [29].

ACKNOWLEDGEMENT

The authors are thankful to TNSSC, Dote Campus, Chennai for the financial assistance through scholarship.

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* Original not cited.

Received on 08-04-2014 Accepted on 09-05-2014 Published on 31-12-2014

DOI: http://dx.doi.org/10.12974/2311-858X.2014.02.02.1