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Formulation and evaluation of different IPM modules against sucking insect pests of cabbage *viz.*, aphids and whiteflies

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Abstract
The investigation on "Formulation and evaluation of different IPM modules against sucking insect pests of cabbage *viz.,* Aphids and Whiteflies" was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka, India during rabi season of the academic year 2017-18. The experiment was laid out in randomized block design with four replications. The treatments included recommended IPM module (T_1), bio-intensive IPM module (T_2), adoptable IPM module (T_3), Chemi-intensive module (T_4) and an untreated control plot (T_5). Observations on pest and natural enemies were recorded on main crop and border crop respectively before and after different sprays. Among the different IPM modules formulated and evaluated against sucking insect pests of cabbage, Adoptable IPM module consisting of the components like, sowing of mustard as an trap crop and maize as a border crop, scheduled spray of botanical pesticide like Neemazol 10000ppm @1ml/l, spray of entomopathogenic fungi like *Lecanicillium lecani* 2×10^8 CFU/ml and @2g/l, *Metarhizium rileyi* 2×10^8 CFU/ml @2g/l and spray of chemical pesticide, Rynaxypyr 18.5 SC @0.1ml/l registered lowest average population of aphids, whiteflies and was followed by Recommended IPM module and Chemi-intensive module. Further, border cropping with insectary plants like maize and mustard increased the potentiality of natural enemies *viz.,* Ladybird beetles and hoverflies.

Keywords: IPM modules, trap crop, border crop, entomopathogenic fungi, Rynaxypyr 18.5 SC, aphids

Introduction
Cabbage, *Brassica oleracea* var. *capitata* belongs to the family Cruciferae having the chromosome no. 2n =18. Cabbage is locally known as Elekosu in Karnataka and it was originated in Western Europe, with temperate climates. It is a cool season crop with a high cold tolerance, used as both fresh and processed products. Cabbage is one of the important salad vegetables and boiled vegetable. It can be used in preparing curries, pickles, dehydrated vegetables. It can be successfully cultivated where winters are very long. In India this crop is mainly cultivated in larger areas in northern India and in some parts of south India. India stands second in production of cabbage followed by China. In India Cabbage is grown on an area of 407 thousand hectares with a production of 8971 million tonnes with a productivity of 22 tonnes per hectare. In Karnataka, it is mainly grown in Mandya, Belagavi, Kolar, Haveri, Chikkaballapur and Bengaluru local districts with an area of 11.11 thousand hactares, production of 238.15 million tonnes and productivity of 21.44 tonnes per hectare (Anon., 2017) [1]. Currently, Belagavi is one of the major producers of cabbage among the cabbage growing districts of Karnataka.

The yields of cabbage are reduced due to many constraints. Among the insect pests of cabbage, diamond back moth, aphids, whiteflies, *Spodoptera litura*, head borer and semilooper are causing significant reductions in yield. Among major pests of cabbage, diamondback moths is the serious pest and infest the crop from nursery level onwards up to harvest causing 52 per cent of losses in marketable yield (Krishna Kumar *et al.*, 1983) [2]. Besides other, diamondback moth, cabbage aphids, tobacco cutworm and cabbage head borer are the major insect pests of Brassica (Nyambo and Pekke, 1995) [3]. Severe infestation by these pests results in 100 per cent yield loss.

Control of these insects currently relies mainly on the application of various classes of chemical insecticides including carbamates, pyrethroides and organophosphates.

It is recognized that widespread continuous use of these chemical insecticides causes environmental problems, development of insect resistance and emergence of secondary pests. Indiscriminate application of broad spectrum chemical pesticides exterminates these susceptible natural enemies and leaves behind the pests that are more resistant to pesticides. Besides periodical application of insecticides resulted in contamination of final produce due to presence of pesticide residues. Therefore, to overcome all these problems, development of eco-friendly components for the management of insect pests of cabbage is essential.

Hence, it is desirable to develop integrated pest management (IPM) modules consisting entomopathogens as a prime component and some insectary plants as border crops. With this brief introduction, the present study was being undertaken to evaluate the efficacy of different IPM modules against cabbage pests.

Materials and Method

The field experiment on formulation and evaluation of different IPM modules against sucking insect pests of cabbage was conducted at Kittur Rani Channamma College of Horticulture, Arabhavi during *rabi* season, 2017. The cabbage seedlings were planted at a spacing of 40cm × 30cm in a RCBD design with five treatments and four replications in a plot size of 10 m × 10 m. The crop was raised by following the agronomic practices as per the recommended package of practices of UHS, Bagalkot. Ten plants from main crop and border planted crop were selected randomly for the observation. Number of aphids and whiteflies per top three leaves. Similarly, population of natural enemies per plant on main crop and border crop were observed and recorded. Observations were recorded on two weekly intervals before and after different sprays. The data recorded on the pests, natural enemies and yield were subjected to statistical analysis in Randomised complete block design. The data was analysed using WASP application and subjected to square root transformation. The level of significance used in the 'F' test was p=0.05. Critical difference values were calculated whenever 'F' test was significant.

Table 1: Treatment details for formulation and evaluation of different IPM modules against major pests of cabbage

Treatments	Trap crop/border crop	Treatment details			
		First spray (@ 2WAT)	**Second spray (@ 4WAT)**	**Third spray (@ 6WAT)**	**Fourth spray (@ 7WAT)**
T_1: Recommended IPM module	Sowing paired row of mustard as a trap crop	Dichlorvos 76EC @1 ml/l	Rynaxypyr 18.5SC @0.1 ml/l	Rynaxypyr 18.5SC @0.1 ml/l	Rynaxypyr 18.5SC @0.1 ml/l
T_2: Bio-intensive IPM module	Sowing paired row of mustard as a trap crop and maize as a border crop	Neemazal (10000ppm) @1 ml/l	*Lecanicillium lecani* 2×10^8 CFU/ml @2 g/l	*Metarhizium rileyi* 2×10^8 CFU/ml @2 g/l	Neemazal (10000ppm) @1 ml/l
T_3: Adoptable IPM module	Sowing paired row of mustard as a trap crop and maize as a border crop	Neemazal (10000ppm) @1 ml/l	*Lecanicillium lecani* 2×10^8 CFU/ml @2 g/l	*Metarhizium rileyi* 2×10^8 CFU/ml @2 g/l	Rynaxypyr 18.5SC @0.1 ml/l
T_4: Chemi-intensive IPM module	-	Dimethoate 30EC @1.7 ml/l	Lambda cyhalothrin 5SC @0.5 ml/l	Spinosad 45SC @0.5 ml/l	Emamectin benzoate 5SG @0.5 g/l
T_5: Control	-	-	-	-	-

Results and Discussion

Evaluation of IPM modules for the management of cabbage aphids

Based on the observation on average aphids incidence after first spray, it was found that, among various treatments, T4 (Dimethoate @1.7ml/l) lowest average number of aphids (0.80 number/leaf) and was on par with T3 (0.83 number/leaf), T1 (0.87 number/leaf) and T2 (1.06 number/leaf) and found superior to T5 (2.63 number/leaf). The present results were because, dimethoate is one of the best chemicals having translaminar action which is effective against aphids. The results are in agreement with Choudhary *et al*. (2017)[4] revealed that, the treatment of dimethoate was found effective next to thiamethoxam in reducing the population of aphid *A. craccivora* on cowpea crop.

With respect to observations on average aphids incidence after second spray, it was found that, among various treatments, T3 (*Lecanicillium lecani* 2×10^8 CFU @2g/l) recorded lowest average number of aphids (0.33 number/leaf) and was on par with T2 (0.36 number/leaf), T4 (0.42 number/leaf), T1 (0.60 number/leaf) and found significantly superior to T5 (1.24 number/leaf). This results were because, *Lecanicillium lecani* is best biopesticide in controlling sucking insect pests. The results are in conformity with Al-Keridis (2016) [5] treatment with suspensions of *Lecanicillium lecanii* (Verticillin®) and *Beauveria bassiana* (Boverin®) has resulted in efficient control of aphids and whitefly.

Observations recorded on average aphids incidence after third spray indicated that, among various treatments, T3 (*Metarhizium rileyi* 2×10^8 CFU @2g/l) recorded lowest average number of aphids (0.04 number/leaf) and was on par with T2 (0.087 number/leaf), T1 (0.091 number/leaf), T4 (0.093 number/leaf) and found significantly superior to T5 (1.57 number/leaf). This was because, *Metarhizium rileyi* is also efficient in controlling sucking pests. The results are in conformity with Pal *et al.* (2014) [6], reported that, treatments of *B. bassiana* and *N. rileyi* alone and in combination with each other found moderately effective against aphids on lucerne.

Similarly, observations recorded on average aphids incidence after forth spray indicated that, among various treatments, T3 (Rynaxypyr 18.5SC @0.1ml/l) recorded lowest average number of aphids (0.007 number/leaf) and was on par with T2 (0.007 number/leaf), T4 (0.01 number/leaf) consisting the spray of Emamectin benzoate 5SG @ 0.5ml per litre, T1 (0.01 number/leaf) and found significantly superior to T5 (0.18 number/leaf). These results were because, in present days Rynaxypyr is one of the best novel molecules used against insect pests. The results are in agreement with the Shiberu and Negeri (2016) [7] revealed that, the results in all locations indicated that the mortality rate percentage of the two newly introduced insecticides Emamectin benzoate (Cutter 112 E.CTM) and Lambda Cyhalothrin (Triger 5 E.CTM) were comparable and effective when compared to the standard check (Diazinon 60 E.CTM) in reducing the number of cabbage aphid population.

Table 2: Effect of different treatments on population of aphids on cabbage

Treatments	Before first spray	First spray				Second spray			
	Mean (no./leaf)	1 DAS (no./leaf)	3 DAS (no./leaf)	Mean (no./leaf)	Per cent reduction over control (%)	1 DAS (no./leaf)	3 DAS (no./leaf)	Mean (no./leaf)	Per cent reduction over control (%)
T_1-Recommended IPM module	2.01 (1.40)	1.17 (1.07)	0.58 (0.75)^{b}	0.87	66.72	0.80 (0.88)^{b}	0.40 (0.62)^{b}	0.60	51.40
T_2-Bio-intensive IPM module	2.13 (1.44)	1.36 (1.12)	0.75 (0.85)^{b}	1.06	59.81	0.54 (0.73)^{bc}	0.19 (0.43)^{c}	0.36	70.48
T_3-Adoptable IPM module	1.70 (1.30)	1.16 (1.06)	0.50 (0.70)^{b}	0.83	68.34	0.44 (0.66)^{c}	0.22 (0.46)^{c}	0.33	73.09
T_4-Chemi-intensive IPM module	1.89 (1.32)	1.13 (1.03)	0.48 (0.64)^{b}	0.80	69.38	0.56 (0.74)^{bc}	0.29 (0.53)^{bc}	0.42	65.66
T_5-Untreated control	2.43 (1.54)	2.15 (1.42)	3.12 (1.75)^{a}	2.63	-	1.40 (1.17)^{a}	1.08 (1.03)^{a}	1.24	-
S.Em±	-	-	0.09	-	-	0.06	0.05	-	-
CD (5%)	NS	NS	0.28	-	-	0.18	0.16	-	-

*The values in parenthesis are transformed (√x+0.5)

Note: CV; coefficient of variance, SEM±; standard error mean, CD; critical difference

Table 2: Cont. Effect of different treatments on population of aphids on cabbage

Treatments	Third spray				Fourth spray			
	1 DAS (no./leaf)	3 DAS (no./leaf)	Mean (no./leaf)	Per cent reduction over control (%)	1 DAS (no./leaf)	3 DAS (no./leaf)	Mean (no./leaf)	Per cent reduction over control (%)
T_1-Recommended IPM module	0.13 (0.35)^{b}	0.052 (0.28)^{b}	0.091	94.20	0.01 (0.71)^{b}	0.005 (0.71)^{b}	0.01	94.52
T_2-Bio-intensive IPM module	0.08 (0.29)^{bc}	0.095 (0.30)^{b}	0.087	94.42	0.01 (0.71)^{b}	0.00 (0.70)^{b}	0.007	95.89
T_3-Adoptable IPM module	0.035 (0.19)^{c}	0.045 (0.20)^{c}	0.04	97.45	0.01 (0.71)^{b}	0.000 (0.70)^{b}	0.007	95.89
T_4-Chemi-intensive IPM module	0.11 (0.31)^{bc}	0.080 (0.29)^{b}	0.093	94.10	0.02 (0.72)^{b}	0.005 (0.71)^{b}	0.01	91.78
T_5-Untreated control	1.40 (1.17)^{a}	1.75 (1.32)^{a}	1.57	-	0.29 (0.88)^{a}	0.07 (0.75)^{a}	0.18	-
S.Em±	0.04	0.02	-	-	0.01	0.003	-	-
CD (5%)	0.15	0.05	-	-	0.03	0.01	-	-

*The values in parenthesis are transformed (√x+0.5)

Note: CV; coefficient of variance, SEM±; standard error mean, CD; critical difference

Evaluation of IPM modules for the management of cabbage whiteflies

The observations recorded on average whiteflies incidence after first spray indicated that, among various treatments, T3 (Neemazol 10000ppm @1ml/l) recorded lowest average number of whiteflies (0.55 number/leaf) and was on par with T4 (0.69 number/leaf), T1 (0.74 number/leaf), T2 (0.85 number/leaf) and significantly superior to T5 (1.69 number/leaf). This was because, Neemazol is efficient in controlling sucking insect pests. The results are in conformity with Gupta and Pathak (2009) [8] reported that, among the treatments, tank mixed treatment, NSKE (in cow urine) 3% + dimethoate 0.03% were found to be most effective in controlling the incidence of whiteflies. Further, observations recorded on average whiteflies incidence after second spray indicated that, among various treatments, T3 (*Lecanicillium lecani* 2×10^{8} CFU @2g/l) recorded lowest average number of whiteflies (0.22 number/leaf) and was on par with T2 (0.36 number/leaf), T1 (0.39 number/leaf), T4 (0.40 number/leaf) and found significantly superior to T5 (1.07 number/leaf). This result were because, *Lecanicillium lecani* is best biopesticide in controlling sucking insect pests. The result was in agreement with the experimental results of Ghosal (2018) [9], it was observed that *Beauveria bassiana* and *Verticillium lecanii* were considered as highly potent microbial insecticides against whitefly.

Based on observations recorded on average whiteflies incidence after third spray indicated that, among various treatments, T3 (*Metarhizium rileyi* 2×10^{8} CFU @2g/l) recorded lowest average number of whiteflies (0.03 number/leaf) and was on par with T1 (0.05 number/leaf), T4 (0.06 number/leaf), T2 (0.08 number/leaf) and found significantly superior to T5 (0.20 number/leaf). This was because, *Metarhizium rileyi* is also efficient in controlling sucking pests. Similarly, observations recorded on average whiteflies incidence after fourth spray indicated that, among various treatments, T3 (Rynaxypyr 18.5SC @0.1ml/l) recorded lowest average number of whiteflies (0.00 number/leaf) and was on par with T1 (0.00 number/leaf), T4 (0.00 number/leaf), T2 (0.0025 number/leaf) and found significantly superior to T5 (0.03 number/leaf). These results were because, in present days Rynaxypyr is one of the best novel broad spectrum molecules used against insect pests. The results are in agreement with Barrania and Abou-Taleb (2014)[10] revealed that, Chlorantraniliprole one of the best chemicals among various novel insecticides *viz.*, pyriproxyfen, novaluron, thiamethoxam, imidacloprid, acetamiprid in effective control of incidence of whiteflies and aphids on cotton.

Table 3: Effect of different treatments on population of whiteflies on cabbage

Treatments	Before first spray	First spray				Second spray			
	Mean (no./leaf)	1 DAS (no./leaf)	3 DAS (no./leaf)	Mean (no./leaf)	Per cent reduction over control (%)	1 DAS (no./leaf)	3 DAS (no./leaf)	Mean (no./leaf)	Per cent Reduction over control (%)
T_1-Recommended IPM module	1.37 (1.15)	0.77 (0.830)	0.70 (0.792)^{b}	0.74	56.37	0.52 (0.710)^{b}	0.25 (0.498)^{bc}	0.39	64.01
T_2-Bio-intensive IPM module	1.28 (1.11)	1.00 (0.969)	0.70 (0.829)^{b}	0.85	49.55	0.44 (0.652)^{b}	0.27 (0.512)^{b}	0.36	66.82
T_3-Adoptable IPM module	1.30 (1.12)	0.67 (0.789)	0.43 (0.637)^{b}	0.55	67.35	0.28 (0.526)^{c}	0.16 (0.380)^{c}	0.22	79.43
T_4-Chemi-intensive IPM module	1.31 (1.11)	0.79 (0.853)	0.58 (0.759)^{b}	0.69	59.34	0.53 (0.723)^{b}	0.27 (0.513)^{b}	0.40	62.61
T_5-Untreated control	1.52 (1.20)	1.32 (1.014)	2.05 (1.424)^{a}	1.69	-	1.05 (1.011)^{a}	1.09 (1.039)^{a}	1.07	-
S.Em±	-	-	0.05	-	-	0.04	0.04	-	-
CD (5%)	NS	NS	0.16	-	-	0.13	0.12	-	-

*The values in parenthesis are transformed (√x+0.5)

Note: CV; coefficient of variance, SEM**±;** standard error mean, CD; critical difference

Table 3: Cont. Effect of different treatments on population of whiteflies on cabbage

Treatments	Third spray				Fourth spray			
	1 DAS (no./leaf)	3 DAS (no./leaf)	Mean (no./leaf)	Per cent reduction over control (%)	1 DAS (no./leaf)	3 DAS (no./leaf)	Mean (no./leaf)	Per cent reduction over control (%)
T_1-Recommended IPM module	0.07 (0.248)^{bc}	0.02 (0.715)^{bc}	0.05	78.57	0.00 (0.70)^{b}	0.000 (0.70)^{b}	0	100
T_2-Bio-intensive IPM module	0.11 (0.313)^{b}	0.05 (0.731)^{b}	0.08	61.90	0.005 (0.71)^{b}	0.00 (0.70)^{b}	0.0025	91.66
T_3-Adoptable IPM module	0.04 (0.191)^{c}	0.01 (0.713)^{c}	0.03	88.09	0.00 (0.70)^{b}	0.00 (0.70)^{b}	0	100
T_4-Chemi-intensive IPM module	0.08 (0.285)^{bc}	0.03 (0.727)^{bc}	0.06	73.80	0.00 (0.70)^{b}	0.00 (0.70)^{b}	0	100
T_5-Untreated control	0.34 (0.570)^{a}	0.08 (0.756)^{a}	0.21	-	0.035 (0.73)^{a}	0.025 (0.72)^{a}	0.03	-
S.Em±	0.03	0.005	-	-	0.002	0.0005	-	-
CD (5%)	0.11	0.02	-	-	0.006	0.002	-	-

*The values in parenthesis are transformed (√x+0.5)

Note: CV; coefficient of variance, SEM±; standard error mean, CD; critical difference

Potentiality of ladybird beetles on maize plants.

Based on observations recorded on average Ladybird beetles activity on maize plants after first spray, it was found that, among various treatments, T2 (Maize) recorded highest average number of Ladybird beetles (0.27 number/plant), which was on par with T3 (0.26 number/plant) and significantly superior to T1 (0.00 number/plant), T4 (0.00 number/plant) and T5 (0.00 number/plant).

With respect to the observations on average Ladybird beetles activity on maize plants after second spray, among various treatments, T3 (Maize) recorded highest average number of Ladybird beetles (0.28 number/plant), which was on par with T3 (0.26 number/plant) and significantly superior to T1 (0.00 number/plant), T4 (0.00 number/plant) and T5 (0.00 number/plant). Observations recorded on average Ladybird beetles activity on maize plants after third spray, indicated that, among various treatments, T3 (Maize) recorded highest average number of Ladybird beetles (0.46 number/plant), which was on par with T2 (0.43 number/plant) and significantly superior to T1 (0.00 number/plant), T4 (0.00 number/plant) and T5 (0.00 number/plant).

Similarly, observation recorded on average Ladybird beetles activity on maize plants after fourth spray, indicated that, among various treatments, T3 (Maize) recorded highest average number of Ladybird beetles (0.11 number/plant), which was on par with T2 (0.11 number/plant) and significantly superior to T1 (0.00 number/plant), T4 (0.00 number/plant) and T5 (0.00 number/plant).

This may be due to the presence of aphids on maize plants, more number of coccinellids were attracted. The results are in agreement with Abbas *et al.* (2013) [11] reported that, diversity of Coccinellidae was evaluated on the major crops and compared with each other, fodder was recorded significantly different from all other crops (p = 0.000). Wheat was found significantly different from sugarcane (p = 0.000) while nonsignificant was recorded for maize and vegetable as well as sugarcane non-significantly different from maize and vegetable, maize and vegetable.

Table 4: Effect of different treatments on potentiality of Ladybird beetle on maize

Treatments	First spray			Second spray		
	1 DAS (no./plant)	3 DAS (no./plant)	Mean (no./plant)	1 DAS (no./plant)	3 DAS (no./plant)	Mean (no./plant)
T_1-Recommended IPM module	0.00 (0.70)^{b}	0.00 (0.70)^{b}	0	0.00 (0.70)^{b}	0.00 (0.70)^{b}	0
T_2-Bio-intensive IPM module	0.27 (0.87)^{a}	0.27 (0.87)^{a}	0.275	0.17 (0.81)^{a}	0.35 (0.91)^{a}	0.26
T_3-Adoptable IPM module	0.22 (0.84)^{a}	0.30 (0.88)^{a}	0.2625	0.20 (0.83)^{a}	0.37 (0.93)^{a}	0.28
T_4-Chemi-intensive IPM module	0.00 (0.70)^{b}	0.00 (0.70)^{b}	0	0.00 (0.70)^{b}	0.00 (0.70)^{b}	0
T_5-Untreated control	0.00 (0.70)^{b}	0.00 (0.70)^{b}	0	0.00 (0.70)^{b}	0.00 (0.70)^{b}	0
S.Em±	0.04	0.05	-	0.027	0.03	-
CD (5%)	0.11	0.14	-	0.08	0.08	-

*The values in parenthesis are transformed (√x+0.5)

Note: CV; coefficient of variance, SEM**±;** standard error mean, CD; critical difference

Table 4: Cont. Effect of different treatments on potentiality of Ladybird beetle on maize

Treatments	Third spray			Fourth spray		
	1 DAS (no./plant)	3 DAS (no./plant)	Mean (no./plant)	1 DAS (no./plant)	3 DAS (no./plant)	Mean (no./plant)
T_1-Recommended IPM module	0.00 (0.70)^{c}	0.00 (0.70)^{b}	0	0.00 (0.70)^{b}	0.00 (0.70)	0
T_2-Bio-intensive IPM module	0.45 (0.97)^{b}	0.42 (0.96)^{a}	0.43	0.17 (0.82)^{a}	0.05 (0.74)	0.11
T_3-Adoptable IPM module	0.55 (1.02)^{a}	0.37 (0.93)^{a}	0.46	0.20 (0.83)^{a}	0.02 (0.72)	0.11
T_4-Chemi-intensive IPM module	0.00 (0.70)^{c}	0.00 (0.70)^{b}	0	0.00 (0.70)^{b}	0.00 (0.70)	0
T_5-Untreated control	0.00 (0.70)^{c}	0.00 (0.70)^{b}	0	0.00 (0.70)^{b}	0.00 (0.70)	0
S.Em±	0.02	0.03	-	0.025	-	-
CD (5%)	0.06	0.07	-	0.09	NS	-

*The values in parenthesis are transformed (√x+0.5)

Note: CV; coefficient of variance, SEM±; standard error mean, CD; critical difference

Potentiality of ladybird beetles on mustard plants.

The observations recorded on average Ladybird beetles activity on mustard plants after second spray, indicated that, among various treatments, T1 (Mustard) recorded highest average number of Ladybird beetles (1.1 number/plant) which was on par with T2 (0.9 number/plant), T3 (0.55 number/plant) and significantly superior to T4 (0.00 number/plant) and T5 (0.00 number/plant).

With respect to observations on average Ladybird beetles activity on mustard plants after third spray, among various treatments, T1 (Mustard) recorded highest average number of Ladybird beetles (1.27 number/plant), which was on par with T2 (1.02 number/plant), T3 (0.87 number/plant) and significantly superior to T4 (0.00 number/plant) and T5 (0.00 number/plant). Further, from observations on average Ladybird beetles activity on mustard plants after fourth spray, indicated that, among various treatments, T3 (Mustard) recorded highest average number of Ladybird beetles (0.45 number/plant) which was on par with T1 (0.35 number/plant), T2 (0.35 number/plant) and significantly superior to T4 (0.00 number/plant) and T5 (0.00 number/plant).

The present results were due to, attraction of coccinellids towards the flora of mustard plants. The results are in conformity with Mishra and Kanwat (2018)[12] reported that, the quantitative survey of predators showed that four species of Coccinellids *viz*; *Coccinella septempunctata* (Linn.), *Menochilus sexmaculalus* (Fabr.), *Coccinella transversalis* (Fabr.) and *Adonia variegate* (Goeze) and syrphid fly, *Xanthogramma scutellare* were found predating on mustard aphid during 2000-2001 and 2001-2002.

Table 5: Effect of different treatments on potentiality of Ladybird beetles on mustard

Treatments	Second spray			Third spray			Forth spray		
	1 DAS (no./plant)	3 DAS (no./plant)	Mean (no./plant)	1 DAS (no./plant)	3 DAS (no./plant)	Mean (no./plant)	1 DAS (no./plant)	3 DAS (no./plant)	Mean (no./plant)
T_1-Recommended IPM module	0.95 (1.13)^a	1.25 (1.31)^a	1.1	1.55 (1.42)^a	1.00 (1.22)^a	1.27	0.50 (0.99)^a	0.20 (0.83)^a	0.35
T_2-Bio-intensive IPM module	0.80 (1.12)^a	1.00 (1.22)^a	0.9	1.25 (1.32)^{ab}	0.80 (1.13)^a	1.02	0.50 (0.99)^a	0.20 (0.82)^a	0.35
T_3-Adoptable IPM module	0.55 (1.01)^{ab}	0.55 (1.02)^b	0.55	0.95 (1.19)^b	0.80 (1.13)^a	0.87	0.60 (1.04)^a	0.30 (0.88)^{ab}	0.45
T_4-Chemi-intensive IPM module	0.00 (0.70)^b	0.00 (0.70)^c	0	0.00 (0.70)^c	0.00 (0.70)^b	0	0.00 (0.70)^b	0.00 (0.70)^b	0
T_5-Untreated control	0.00 (0.70)^b	0.00 (0.70)^c	0	0.00 (0.70)^c	0.00 (0.70)^b	0	0.00 (0.70)^b	0.00 (0.70)^b	0
S.Em±	0.11	0.04	-	0.04	0.04	-	0.03	0.04	-
CD (5%)	0.32	0.12	-	0.13	0.12	-	0.10	0.12	-

*The values in parenthesis are transformed (√x+0.5)

Note: CV; coefficient of variance, SEM±; standard error mean, CD; critical difference

Potentiality of hoverflies on mustard

Based on the observations recorded on hoverflies activity on mustard plants after second spray, it was found that, among various treatments, T_3 recorded highest number of hoverflies (1.2 number/plant), which was on par with T_2 (0.8 number/plant), T_1 (0.73 number/plant) and significantly superior to T_4 and T_5 where, in these treatments activity of hoverflies was almost nil.

Further, observations on hoverflies activity on mustard plants after third spray, indicated that, among various treatments, T_3 recorded highest number of hoverflies (0.93 number/plant), which was on par with T_1 (0.70 number/plant), T_2 (0.60 number/plant) and significantly superior to T_4 and T_5 where, in these treatments activity of hoverflies was almost nil.

Similar results were obtained after third spray and it was found that, T_3 recorded highest average number of hoverflies (0.32 number/plant), which was on par with T_1 (0.15 number/plant), T_2 (0.13 number/plant) and significantly superior to T_4 and T_5 where in these treatments activity of hoverflies was almost nil. The present result was mainly due to presence of high amount of pollens and floral nectar which provided supplementary food for natural enemies in the flowers of mustard plants facilitated the attraction of more number of hoverflies. Hence, the activity of hoverflies was more on mustard plants.

The present results are in conformity with Bajiya and Abrol (2017) [13] reported the abundance of syrphids *viz*., *Eristalis* spp., *Episyrphus balteatus*, *Metasyrphus corolla* on mustard.

Table 6: Effect of different treatments on potentiality of hoverflies on mustard

Treatments	Second spray			Third spray			Forth spray		
	1 DAS (no./plant)	3 DAS (no./plant)	Mean (no./plant)	1 DAS (no./plant)	3 DAS (no./plant)	Mean (no./plant)	1 DAS (no./plant)	3 DAS (no./plant)	Mean (no./plant)
T_1-Recommended IPM module	0.55 (1.03)^c	0.90 (1.18)^b	0.73	0.90 (1.17)^b	0.50 (0.99)^{ab}	0.7	0.20 (0.83)^b	0.10 (0.78)^b	0.15
T_2-Bio-intensive IPM module	0.85 (1.16)^b	0.75 (1.12)^b	0.8	0.80 (1.13)^b	0.40 (0.95)^b	0.6	0.20 (0.83)^b	0.05 (0.73)^b	0.13
T_3-Adoptable IPM module	1.25 (1.32)^a	1.15 (1.29)^a	1.2	1.15 (1.29)^a	0.70 (1.10)^a	0.93	0.40 (0.95)^a	0.25 (0.87)^a	0.32
T_4-Chemi-intensive IPM module	0.00 (0.70)^d	0.00 (0.70)^c	0	0.00 (0.70)^c	0.00 (0.70)^c	0	0.00 (0.70)^c	0.00 (0.70)^b	0
T_5-Untreated control	0.00 (0.70)^d	0.00 (0.70)^c	0	0.00 (0.70)^c	0.00 (0.70)^c	0	0.00 (0.70)^c	0.00 (0.70)^b	0
S.Em±	0.03	0.03	-	0.04	0.03	-	0.03	0.04	-
CD (5%)	0.07	0.10	-	0.12	0.10	-	0.09	0.12	-

*The values in parenthesis are transformed (√x+0.5)

Note: CV; coefficient of variance, SEM±; standard error mean, CD; critical difference

Assessment of cabbage head yield (q/ha).

Among different treatments, it was found that, T_3 (Adoptable IPM module) recorded higher yield (226.80 q/ha) which was followed by T_1 (Recommended IPM module) (208.90 q/ha), T_4 (Chemi-intensive IPM module) (203.80 q/ha), T_2 (Bio-intensive IPM module) (200.90 q/ha) and T_5 (untreated control) (145.60 q/ha).

This higher yield in T_3 (Adoptable IPM module) was due to effective combination of various pest management components.

The present results of yields of cabbage are in agreement with Venkateswarlu *et al.* (2011) [14] reported that, based on yield performance, cost benefit ratio and also better performance against insect pests T_4 (acetamiprid- acetamiprid chlorantraniliprole -emamectin benzoate), T_9 (acetamiprid-acetamiprid- fipronil- spinosad) and T_8 (acetamiprid - acetamiprid- spinosad- emamectin benzoate) performed extremely well. Due to diverse mode of action naturally derived insecticides in above schedules could be excellent choice in a rotational strategy aimed at prolonging their efficacy by delaying the onset of resistance development (Vastrad *et al*., 2003) [15].

Table 7: Effect of different treatments on yield (q/ha)

Treatments	Average (q/ha)	Average (t/ha)	Per cent increase over control (%)
T_1-Recommended IPM module	208.90^b	20.89	30.30
T_2-Bio-intensive IPM module	200.90^d	20.09	27.53
T_3-Adoptable IPM module	226.80^a	22.68	35.80
T_4-Chemi-intensive IPM module	203.80^c	20.38	28.56
T_5-Untreated control	145.60^e	14.56	-
S.Em±	0.75	-	-
CD (5%)	2.15	-	-

*The values in parenthesis are transformed ($\sqrt{x+0.5}$)

Note: CV; coefficient of variance, SEM±; standard error mean, CD; critical difference

Summary and Conclusion

With the results obtained from the present investigation, it can be concluded that, mustard as an intercrop and maize as border crop could be effective in attracting the natural enemies of insect pests of cabbage *viz*., Ladybird beetles and hoverflies. With respect to entomopathogenic fungi, *Lecanicillium lecani* 2×10^8 CFU @2g/l and *Metarhizium rileyi* 2×10^8 CFU @2g/l were found effective against aphids and whiteflies. Neemazol 10000ppm @1ml/l can also be an effective botanical pesticide against sucking pests of cabbage. Among different chemical pesticides, Rynaxypyr 18.5 SC @0.1ml/l found best against sucking pests of cabbage. Overall, Adoptable IPM module and Recommended IPM modules were found best among different modules which recorded maximum yields of 226.80 q/ha and 208.90 q/ha respectively and these modules can be recommended to the farmers as best IPM strategies against insect pests of cabbage.

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