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BIOCONTROL BASED IPM MODULE AGAINST INSECT PESTS OF CAULIFLOWER

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ABSTRACT

The present study attempts developing a biocontrol based IPM module using parasitoids, predators and biopesticide formulations for the management of insect pests of cauliflower. The results revealed that during 2013-14 and 2014-15; November to March, the incidence of cabbage butterfly *Pieris brassicae* L. and mustard aphid *Lipaphiserysimi* (Kaltenbach) was observed, and these appeared in February. No incidence of diamondback moth *Plutellaxylostella* L. was observed. Three treatments viz., 1. Biocontrol based IPM module; 2. Chemical control (Success 2.5 SC- Spinosad@ 625 ml/ ha against *P. brassicae*, malathion 50 EC @ 800 ml/ ha against aphids; and 3. Control (no treatment) were evaluated. The pre-treatment count of P. *brassicae* larvae was 12.21, 55.87 and 54.60/ plant in the plots of bio-control based IPM, chemical control and untreated control, respectively; and for *L. erysimi* it was 35.39, 32.20 and 38.33/ plant, respectively. Both biocontrol module and chemical control were found at par against *P. brassicae* larvae, with % reduction being 62.8 and 66.73%, respectively. Biocontrol module was found effective against *L. erysimi*, causing 62.5% reduction. The population of natural enemies such as coccinellids (67.9%), syrphid fly (35.0%) and *Cotesiaglomerata* (L.) (30.0%) were also more in the fields of biocontrol. The yield of curds in the biocontrol (102.4 q/ ha) and chemical control (113.6 q/ ha) were significantly higher than untreated control (72.08 q/ ha).

Key words: Biocontrol, cabbage butterfly, diamondback moth, *L. erysimi*, cauliflower, IPM, Biocontrol, parasitoids, predators, biopesticides, chemical control

Cauliflower (*Brassica oleracea* var *botrytis*) is an important vegetable crop in India (Anonymous, 2016).The attack of insect pests is one of the major limiting factors causing 40% yield loss (Muthukumar et al., 2007). Among insect pests, diamond back moth, *Plutellaxylostella* L., cabbage butterfly, *Pierisbrassicae* L. and aphidsare the major ones. Of these *P. xylostella* damages the crop by feeding on the leaves (Sachan and Gangwar, 1980; Srinivasan and Kumar, 1982); *P. brassicae* causes damage to seedlings and to the plants at vegetative and flowering stages (Raietal, 1985; Ali and Rizvi, 2007; Rizvi et al., 2007; Hasan, 2008). Aphids such as cabbage aphid, *Brevicorynebrassicae* L., mustard/ turnip aphid, *Lipaphiserysimi* (Kaltenbach), green peach aphid, *Myzuspersicae* (Sulzer) damage the crop as sucking pests (Joshi et al., 2010). The use of insecticides for control of these pests has their own toxic and residual effects (Weinberger and Srinivasan, 2009), and leads to development of resistance, health hazard etc.(Sharma and Gupta, 2009; Zhou et al., 2011). Hence, development of bio-control based IPM deploying parasitoids, predators and biopesticides are required.

There have been number of ants, flies, lacewings, hemipterans, beetles, spiders reported as natural enemies of the larvae of diamondback moth (DBM) (Alam, 1992; Reddy et al., 2004; Endersby and Cameron, 2004). Number of parasitoids belonging to genera *Cotesia* (Braconidae), *Diadegma* (Ichneumonidae), *Microplitis* (Braconidae), *Oomyzus* (Eulophidae) and *Diadromus* (Ichneumonidae) (Saucke *et al*., 2000; Chauhan and Sharma, 2004; Delvare, 2004; Sarfraz et al., 2005) and predator *Chrysoperlazastrowisillemi* (Esben-Peterson) (Reddy and Guerrero, 2000; Reddy et al., 2004) have biocontrol potential against DBM. Also, Bt formulations (Dipel 8L, Delfin, Biobit, Biolep, Bioasp), botanicals/ safe insecticides such as azadirachtin, spinosad, emamection benzoate, abamectin etc. against DBM are available (Klemm and Schmutterer, 1993; Malathi and Sriramulu, 2000; Elzen and James, 2002; Aroraetal., 2006; Ranjbarietal., 2012). The use of crude extracts of plants had also been recommended (Yankanchi and Patil, 2009; Amoabengetal., 2014).

The role of parasitoids, predators and biopesticides against *P. brassicae* are of great consequence (Balevski et al., 2007; Pfiffner et al., 2009). The egg parasitoids (*Trichogrammabrassicae* Bezdenko and *T. evanescans* Westwood) (Fatouros et al., 2007; Huigens et al., 2010), larval parasitoids (*Cotesiaglomerata* L., *Cotesiarubecula* Marshall, *Pteromaluspuparum* L., *Brachymeriafemorata* Panzer) (Benson et al., 2003; Van Driesche, 2008; Razmi et al., 2011; Kumar, 2012) had shown potential against *P. brassicae*. Also, predators like green lacewing *C.zastrowisillemi*, *Episyrphusbalteatus* (de Geer), *Coccinellaseptempunctata* L. and *Polisteshebreus* (F.) are known (Sood et al., 1995; Huang and Enkegaard, 2010). Safer microbial biopesticides (*Bacillus thuringiensis* (Bt), *Beauveriabassiana* and NPV), botanicals (Annonin, Azadirachtin, neem seed kernel extract, garlic extract, karanjin, *Meliaazedarach* L., *Lantana camara* L. Moldenke., *Cannabis sativa* L., *Neriumindicum* Mill., *Eucalyptus* sp., *Ricinuscommunis* Linn. and *Solanumnigrum* L.) had also been found effective (Shternshis et al., 2002; Zafar et al., 2002; Klokočar-Šmit et al., 2007; Sharma and Gupta, 2009; Sharma et al., 2011; Rangad et al., 2014). Use of spinosad 45 SC, emamectin benzoate, cartap hydrochloride, indoxacarb etc. safer to natural enemies is also advocated (Muthukumar et al., 2007; Venkateswarlu et al., 2011).

Joshi et al. (2010) reviewed the biological control of aphids, and many hymenopteran parasitoids are available (Pike et al., 1999; Jankowska and Weich, 2003; Bayhan et al., 2007; Desneuxetal., 2009; Pons et al., 2011; Stara et al., 2011; Elliott et al., 2014).Among the predators showing high potential for aphids include mainly spiders, hoverflies and ladybird beetles (Frazer, 1989; Hart et al., 1997; Roy and Wajenberg, 2008; Joshi et al., 2010; Amoabeng et al., 2013 and Fening et al., 2013). The entomopathogenic fungi *Verticilliumlecanii* (Zimmerman) had been also recommended (Hall, 1980; Khalil et al., 1983; Grunbergetal., 1988; Fournier and Brodeur, 1999).

Therefore, the present study aimed to develop a biocontrol IPM module using parasitoids, predators and biopesticide formulations for the management of major insect pests of caulifloweri.e. *P. brassicae*, *P. xylostella* and aphids.

MATERIALS AND METHODS

The experiment was conducted on cauliflower (S-41 hybrid) during late November to March during 2013-14 and 2014-15 (November to March) at the Entomological Research Farm, Punjab Agricultural University, Ludhiana. There were three treatments: Biocontrol based IPM module (A), chemical control (B) and untreated control (C) as given below:

Biocontrol based IPM module: consisting of - Planting of mustard crop as border crop; Mechanical collection and destruction of eggs and larvae of *Pieris brassicae* L. at weekly interval; *Trichogramma pieridis* @ 1,00,000/ ha at seven days interval against eggs of *P. brassicae*; *Chrysoperlazastrowisillemi* @ 5 grubs/ plant at weekly interval against *Lipaphis erysimi* (Kaltenbach); Neemazal (5%) at 10 days interval; and Bt formulation: Delfin WG @ 300 gm/ acre at weekly interval against larvae of cabbage butterfly and diamond back moth.

Chemical control with - Success 2.5 SC (Spinosad) @ 250 ml/ acre (Dow Agro Sciences Pvt. Ltd. Mumbai, India) against cabbage butterfly and diamond back moth, and Malathion 50 EC @ 300 ml/ acre (Hindustan Insecticides Limited, India) against aphids at 10 days interval

Control: no treatment

During the period of study, the incidence of *P. brassicae* and aphids was recorded which appeared in February. The aphids infesting were identified as *Lipaphiserysimi* (Kaltenbach). However, there was no attack of *P. xylostella* reported in the experimental fields. Therefore, all the treatments of bioagents and chemicals were applied against cabbage butterfly and *L. erisimi*. The bioagents *T. pieridis* and *C. zastrowisillemi* were released three times in the biocontrol plots, whereas the spray of Neemazal was two times and that of Delfin WG, Success 2.5 SC and Malathion 50 EC were three times in their respective plots. There were three replications and under each replication there were five subplots. The data was recorded at 10 days interval from five plants in each subplot and subjected to ANOVAusing Randomized Block Design (RBD) and the treatment means were compared by least significant difference test (LSD) at p=0.05 (Gomez and Gomez, 1984). The method of Henderson and Tilton (1955) was applied to calculate the % reduction over control.

RESULTS AND DISCUSSION

During the period of study, there was no attack of *P. xylostella* recorded in the fields. Therefore, the data of *P. brassicae* and *L. erysimi* were recorded during the period of experiment and their results are mentioned and discussed below.

During 2013-14, after the regular releases of *T. pieridis* or spray of Bt formulation or mechanical collection of the larvaefor three times at weekly interval in the bio-control field and three times spray of insecticide Spinosad (Success 2.5 SC) at 10 days interval in the field of chemical control, the population of *P. brassicae* larvae was reduced in these fields (Table 1). The mean population of *P. brassicae* larvae in bio-control field was low (14.85 larvae/ plant) which were at par with that in the field of chemical control (13.45 larvae/ plant). Both the treatments of bio-control based IPM and chemical control were significantly better than untreated control where the population of *P. brassicae* larvae was high (43.83 larvae/ plant). The % reduction of larvae in the bio-control and chemical control plots over the untreated control was 66.12 and 69.31%, respectively.

During 2014-15, similar results were observed. The mean population of *P. brassicae* larvae in bio-control, chemical control anduntreated fields was 25.30 larvae / plant, 22.45 larvae/ plantand 64.10 larvae/plant, respectively.The% reduction of larvae in the bio-control and chemical control plots over the untreated control was 60.53 and 64.97%, respectively.When the data of both the years i.e. 2013-14 and 2014-15 was pooled (Table 1), both bio-control based IPM as well as chemical control were found effective in controlling *P. brassicae* larvae. The % reduction of larvae in the bio-control and chemical control plots over the untreated control was 62.8 and 66.73%, respectively.

During the experiment period, an attack of *L. erysimi* was observed and therefore, accordingly effect of neemazal and *C. zastrowisillemi* in biocontrol plots and malathion in chemical control plots was recorded. The population of aphids became significantly low during two years in biocontrol plots (16.89 aphids/ plant) and it was significantly at par with chemical control (18.76 aphids/ plant). The population of aphids in untreated control was significantly high (45.10 aphids/ plant). The % reduction of aphids over control in bio-control and chemical control plots was 62.5 and 58.4% (Table 2).

The biocontrol based IPM practices against *P.*

Table 1: Field evaluation of bio-control based IPM module against *Pierisbrassicae* of cauliflower

S.No.	Treatments	Mean number of *Pieris* larvae / plant*			Percent reduction of larvae over control		
		2013-14	2014-15	Mean	2013-14	2014-15	Mean
1.	Bio-control based IPM module	14.85[a] (3.98)	25.30[a] (5.12)	20.07[a] (4.55)	66.12	60.53	62.80
2.	Chemical control (Success 2.5 SC @ 250 ml/ acre)	13.45[a] (3.80)	22.45[a] (4.84)	17.95[a] (4.32)	69.31	64.97	66.73
3.	Untreated control	43.83[b] (6.69)	64.10[b] (8.06)	53.96[b] (7.38)	-	-	- -
	CD (5%)	(0..62)	(0.55)	(0.26)	-	-	-

Note: * Mean of three replications and there were five sub-plotsin each replication; number of larvae was recorded from five plants from each sub-plot under one replication; Values in parentheses are square root () transformations

Table 2: Field evaluation of bio-control based IPM module against mustard aphid *Lipaphiserysimi* of cauliflower

S.No.	Treatments	Mean number of aphids/ plant*			Percent reduction of aphids over control		
		2013-14	2014-15	Mean	2013-14	2014-15	Mean
1.	Bio-control based IPM module	17.64[a] (4.31)	16.14[a] (4.13)	16.89[a] (4.22)	53.1	69.3	62.5
2.	Chemical control (Malathion 50 EC @ 300 ml/ acre)	19.01[a] (4.47)	18.51[a] (4.41)	18.76[a] (4.44)	49.4	64.8	58.4
3.	Untreated control	37.60[b] (6.20)	52.60[b] (7.32)	45.10[b] (6.76)	-	-	-
	CD (5%)	(1.36)	(0.60)	(0.79)	-	-	-

Note: * Mean of three replications and there were five sub-plots in each replication; number of aphids was recorded from five plantsfrom each sub-plot under one replication; Values in parentheses are square root () transformations *brassicae* and *L. erysimi* during two years also enhanced the population of the natural enemies in the bio-control fields of cauliflower (Table 3). The natural enemies such as coccinellids, syrphid fly larvae and cocoon cluster of *Cotesiaglomerata* (L.) were recorded in the fields of biocontrol based IPM during 2013-14 (2.38 coccinellids, 1.0 syrphid larva, 1.0 cocoon cluster of *Cotesia*/ plant) and untreated control (2.0 coccinellids and 1.0 cocoon cluster of *Cotesia* per plant). In 2014-15, coccinellids (4.41, 2.0), syrphid fly larvae (2.5) and cocoon clusters of *Cotesia* (2.0, 1.5)/ plant were recorded in biocontrol based IPM and untreated control, respectively. However, there was no population of natural enemies in the field of chemical control. Overall, the population of biogents was higher in the plots of biocontrol based IPM as compared to untreated control. There was 67.9% coccinellids, 35% syrphid fly larvae and 30% cocoons of *C. glomerata*inthe bio-control plots which was higher than untreated control plots where only 40 and 25% coccinellids and cocoons of *C. glomerata*, respectively (Fig. 1).

The biocontrol based IPM practices during 2013-14 and 2014-15 also enhanced the yield of curds which was statistically at par with yield in the chemical control, whereas the yield in the untreated control field was comparatively very less. During 2013-14, 38.81, 43.57 and 28.11 q/ acre yield of curds was recordedin the plots of bio-control based IPM, chemical control and untreated control, respectively (Table 4). During 2014-15, the yield of curds in the fields of bio-control based IPM and chemical control was 43.12 and 47.32 q/acre, respectively which was better than untreated control (29.56 q/acre) (Table 4). The pooled data of yield of two years also showed higher yield in the bio-control based IPM (40.96 q/acre) and chemical control (45.44 q/acre) fields as compared to untreated control (28.83 q/acre) (Table 4).

Thus, the biocontrol based IPM module was at par with chemical control in minimizing the population of *P. brassicae* and increasing the marketable yield. The application of *C. zastrowisillemi* and neem formulation reduced the population of *L. erysimi*.The present

Table 3: Effect of bio-control based IPM module on the natural enemies of insect pests of cauliflower

S. No.	Treatments	Natural enemies	Mean population of natural enemies/ plant	
			2013-14	2014-15
1.	Bio-control based IPM module	Coccinellids	2.38	4.41
		Syrphid fly	1	2.5
		Cocoons of *Cotesiaglomerata*	1	2
2.	Chemical control	Coccinellids	-	-
		Syrphid fly	-	-
		Cocoons of *Cotesiaglomerata*	-	-
3.	Untreated control	Coccinellids	2	2
		Syrphid fly	-	-
		Cocoons of *Cotesiaglomerata*	1	1.5

Table 4: Effect of bio-control based IPM module on the marketable yield of cauliflower

S. No.	Treatments	Mean marketable yield** (q / acre)		
		2013-14	2014-15	Mean
1.	Bio-control based IPM module	38.81[a]	43.12[a]	40.96[b]
2.	Chemical control (Success 2.5 SC @ 250 ml/ acre and Malathion 50 EC @ 300 ml/ acre)	43.57[a]	47.32[a]	45.44[a]
3.	Untreated control	28.11[b]	29.56[b]	28.83[c]
	CD (5%)	11.76	13.28	2.79

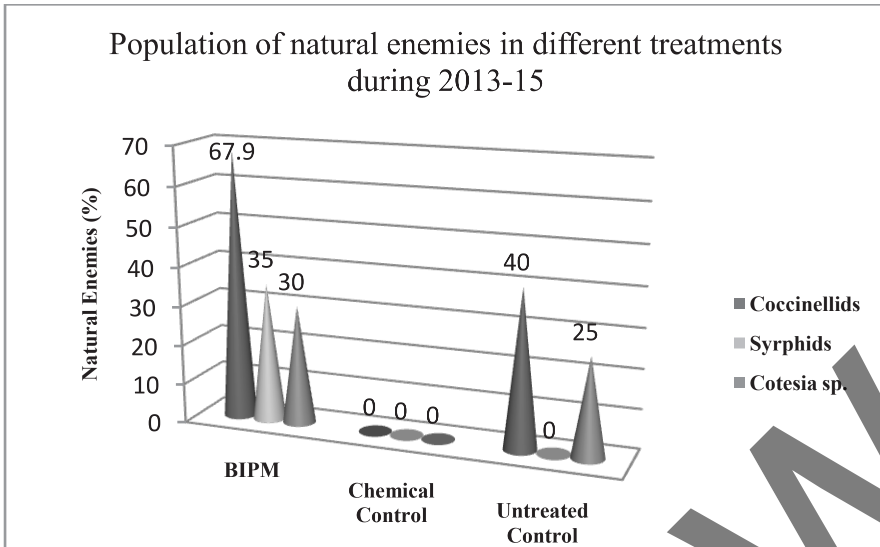

Fig. 1. Effect of bio-control based IPM module on natural enemies of insect pests of cauliflower

resultsfind support from Ahujaet al. (2012) on safer biorational pesticides, insect growth regulators and cultural methods in the IPM against *Spodopteralitura* in cauliflower. There are number of reports of use of Bt formulation as effective biopesticides/ and spinosad against *P. brassicae* (Klokočar-Šmit et al., 2007; Zafar et al., 2002; Singh et al., 2015). Muthukumar et al. (2007) observed similar results with spinosad; also revealed that spinosad, Biolep, emamectin benzoate and neem oil are safer to natural enemies in the cauliflower. Venkateswarlu et al. (2011) suggested chlorantraniliprole most effective against *P. brassicae* followed by spinosad. Rangad et al. (2014) evaluated many ecofriendly insecticides/ biopesticides/ plant extracts against *P. brassicae* on cabbage, and observed that endosulfan, annonin and spinosad killed maximum number of larvae.

In the present studies large number of coccinellid predators was found on the aphid infested plants. This indicated that aphid population and infested plants might attract coccinellids. This was explained by Yoon et al. (2010) with a study on the Asian lady beetle,*Harmaniaaxyridis* (Pallas) attracted to Chinese cabbage infested by green peach aphid *M. persicae*. Similarly, the releases of larvae of green lace wing seemed to be very effective against *L. erysimi.* Sarwar (2014) found significant control of aphid *M. persicae* on canola plants with the augmentative releases of larvae of *C. zastrowisillemi*.

Based on the results obtained and discussed as above, use of biocontrol based IPM module consisting of mustard as border crop, Bt formulation (Dipel/ Delfin @ 300 gm/acre), neem formulation (5% Neemazal), parasitoid *T.pieridis*@ 1, 00,000/ ha and predator *C. zastrowisillemi*@ 5 grubs / plant, is as effective as use of chemicals alone in minimising the damage of cauliflower with *P. brassicae* larvae and increasing the marketable yield.

REFERENCES

Ahuja D B, AhujaU R, Srinivas P, Singh R V, Malik M, Sharma P, Bambawale O M. 2012. Development of farmer-led integrated management of major pests of cauliflower cultivated in rainy season in India. Journal of Agricultural Science 4: 79-90.

Alam M M. 1992. The diamondback moth and its natural enemies in Jamaica and other Carribean Islands. pp. 233-243. Talekar N S. (ed.). Diamondback moth and other crucifer pests. Proceedings. Second International Workshop, 10-14 December, 1992. Tainan, Taiwan: Asian Vegetable Research and Development Centre.

Ali A, Rizvi P Q. 2007. Development response of cabbage butterfly, *Pierisbrassicae* L on different cole crops under laboratory and field conditions. Asian Journal of Plant Sciences 6: 1241-1245.

Amoabeng B W, Gurr G M, Gitau C W, Nicol H I, Munyakazi L, Stevenson P C. 2013. Tritrophic insecticidal effects of African plants against cabbage pests. PLOS ONE 8(10). e78651. DOI: 10. 1371/journal.pone.0078651.

Amoabeng B W, Gurr G M, Gitau C W, StevensonP C. 2014. Cost: benefit analysis of botanical insecticide use in cabbage: Implications for small holder farmers in developing countries. Crop Protection57: 71-76.

Anonymous. 2016. Thirdadvance estimate of area and production of horticulture crops (2015-16). National Horticulture Board, Government of India, New Delhi.

Arora S, Koundal K R, Gopal M. 2006. Efficacy of commercial formulations of *Bacillus thuringiensis*s ubsp. *kurstaki* against

Plutellaxylostella. Indian Journal of Agricultural Sciences 76: 335-337.

Balevski N, Draganov H, Velichova-Kojuharova M, Draganova S. 2007. Beneficial organisms (entomopathogens and entomophagous) on pests in the biocenoses of cabbage in Bulgaria. Plant Science 44: 230-235.

Bayhan S O, Ulusoy M R, Bayhan E. 2007. Is the parasitisation rate of *Diaeretiellarapae* influenced when *Brevicorynebrassicae* feeds on *Brassica* plants? Phytoparasitica 35: 146-149.

Benson J, Van Driesche R G, Pasquale A, Elkinton J. 2003.Introduced braconid parasitoids and range reduction of a native butterfly in New England. Biological Control 28: 197-213.

Chauhan U, Sharma K C. 2004. Status of biocontrol agents of *Plutellaxylostella* (L.) (Lepidoptera: Yponomeutidae) in hilly areas of the north-west Himalayas, India. pp 153-157. Kirk A A, Bordat D. (eds). Improving biocontrol of *Plutellaxylostella*. Proceedings of the International Symposium.21-24 October 2002, CIRAD, Montpellier, France.

Delvare G. 2004. The taxonomic status and role of Hymenoptera in biological control of DBM, *Plutellaxylostella* (L.) (Lepidoptera: Plutellidae). pp 17-49. Kirk A A, Bordat D (eds). Improving biocontrol of *Plutellaxylostella*. Proceedings of the International Symposium 21-24 October 2002, CIRAD, Montpellier, France.

Desneux N, Stary P, Delebecque C J, Gariepy T D, Barta R J, Hoelmer K A, Heimpel G E. 2009. Cryptic species of parasitoids attacking the soybean aphid, *Aphis glycines* Matsumura (Hemiptera: Aphididae) in Asia: *Binodoxyscommunis* Gahan and *Binodoxyskoreanus* Starysp. n. (Hymenoptera: Braconidae: Aphidinae). Annals of Entomological Society of America 102: 925-936.

Elliott N C, Backoulov G F, Giles K L, Royer T A. 2014. Parasitism of aphids in canola fields in Central Oklahoma. Journal of Agricultural and Urban Entomology 30: 59-64.

Elzen G W, James R R. 2002. Responses of *Plutellaxylostella* and *Coloemegillamaculate* to selected insecticides in a residual insecticide bioassay. Southwestern Entomologist 27: 149-153.

Endersby N, Cameron P. 2004. Parasitism of *Nyctemeraamica* (White) (Lepidoptera: Arctidae) and *Plutellaxylostella* (L.) (Lepidoptera: Plutellidae) by *Cotesiaplutellidae* (Kurdjumov) (Hymenoptera: Braconidae). pp 265-268. Endersby NM, Ridland P M (eds). The management of diamondback moth and other crucifer pests. Proceedings. Fourth International Workshop, 26-29 November, 2001. Department of Natural Resources and Environment, Melbourne, Australia.

Fatouros N E, Kiss G B, Dicke M, Hilker M. 2007. The response specificity of *Trichogramma* egg parasitoid towards infochemicals during host location. Journal of Insect Behaviour 20: 53-65.

Fening K O, Amoabeng B W, AdamaI, Mochiah M B, Braimah H, Wusu-Akyaw M, Narveh E, Ekyem S O. 2013. Sustainable management of two key pests of cabbage, *Brassica oleraceae* var. *capitata* L. (Brassicaceae), using homemade extracts from garlic and hot pepper. Organic Agriculture 3: 163-173.

Fournier V, Brodeur J. 1999. Biological control of lettuce aphids with the entomopathogenic fungus *Vertcilliumlecanii* in greenhouses. Bulletin OILB/SROP 22: 77-80.

Frazer B D. 1989. Predators. pp. 217-230. Minks A K, Hourenijin, P (eds.) Aphids: their biology, natural enemies and control, Vol 2 B. Elsevier Publication, New York, USA. 364 pp.

Gomez K A, Gomez A A. 1984. Statistical procedures for agricultural research. International Rice Research Institute. John Wiley and Sons, New York. 690 pp.

Grunberg M, Adam H, Walter C, Hirte W F. 1988. Possibilities of using the entomopathogenic fungus *Verticilliumlecanii* (Zimm.) Viegas for the biological control of aphids under glass and plastic. Nachrichtenblatt fur den Pflanzenschutz in der DDR 42: 186-190.

HallR A. 1980. Comparison of laboratory infection of aphids by *Metarrhiziumanisopliae* and *Verticilliumlecanii*. Annals of Applied Biology 95: 159-162.

Hart A J, Bale J S, Fenlon J S. 1997. Developmental threshold, day-degree requirements and voltinism of the aphid predator *Episyrphusbalteatus* (Diptera: Syrphidae). Annals of Applied Biology 130: 427-437.

Hasan F. 2008. Studies on the bionomics of *Pierisbrassicae* (Linn.). M.Sc. Thesis, Aligarh Muslim University, Aligarh.

Henderson C F, Tilton E W. 1955. Tests with acaricides against the brow wheat mite. Journal of Economic Entomology 48: 157-161.

Huang N, Enkegaard A. 2010. Predation capacity and prey preference of *Chrysoperlacarnea* on Pierisbrassicae. BioControl55: 379-385.

Huigens M E, Woelke J B, Pashalidou F G, Bukovinszky T, Smid H M, Fatouros N E. 2010. Chemical espionage on species-specific butterfly anti-aphrodisiacs by hitchhiking *Trichogramma* wasps. Behavioural Ecology 21: 470-478.

Jankowska B, Wiech K. 2003. Occurrence of *Diaeretiellarapae* (M'Intosh) (Aphidiidae) in the cabbage aphid (*Brevicorynaebrassicae* L.) colonies on the different crucifer crops. Sodininkyste. Ir. Darzininkyste 22: 155-163.

Joshi N, Rabindra R J, Rajendran T P. 2010. Biological control of aphids. Journal of Biological Control 24: 185-202.

Khalil S K, Taborsky V, Bartos J. 1983. Studies on *Verticilliumlecanii* for the biological control of aphids. Proceedings. 10th International Congress of Plant Protection, Brighton, England. 20-25 November. 788pp.

Klemm U, Schmutterer H. 1993. Effects of neem preparations on *Plutellaxylostella* Linn. and its natural enemies of the genus *Trichogramma*. Zeitshrift-fur-Pflanzenkrankheiten-und-Pflanzenschutz 100: 113-128.

Klokočar-ŠmitZlata D, IndićDušanka V, VukovićSlavica M, FilipovićMaja M, ČervenskiJanko F. 2007. Preliminary investigation on the effects of biological and synthetic insecticides on large white butterfly (*Pierisbrassicae* L.) larvae. ZbornikMaticaSrpskezaPrirodneNauke 112: 75-82.

Kumar S. 2012. *Cotesiaglomeratus*: A potential biocontrol agent for large white butterfly, *Pierisbrassicae* (Lepidoptera: Pieridae).Journal of Entomology 9: 171-177.

Malathi S, Sriramulu M. 2000. Laboratory efficacy of biotic insecticides against lepidopterous pests fed on treated cabbage leaves. Shashpa 7: 63-66.

Muthukumar M, Sharma R K, Sinha S R. 2007. Field efficacy of biopesticides and new insecticides against major insect pests and their effect on natural enemies in cauliflower. Pesticide Research Journal 19: 190-196.

Pfiffner L, Luka H, Schlatter C, Juen A, Traugott M. 2009.Impact of wildflower strips on biological control of cabbage lepidopterans. Agriculture, Ecosystems and Environment 129: 310-314.

Pike K S, Stary P, Miller T, Allison D, Graf G, Boydston L. 1999. Host range and habitats of the aphid parasitoid *Diaeretiellarapae*(Hymenoptera: Aphidiidae) in Washington State. Environmental Entomology 28: 61-71.

Pons X, Lumbierres B, Antoni R, Stary P. 2011.Parasitoid complex of alfalfa aphids in an IPM intensive crop system in Northern Catalonia. Journal of Pesticide Science 84: 437-445.

Rai K M, Gupta B P, Tripathi G M. 1985. Biology and control of cabbage white butterfly, *Pierisbrassicae* Linn (Lepidoptera: Pieridae). Progressive Horticulture 17: 376-381.

Rangad Rdalang W, Lytan, Damitre Waluniba, Firake D M. 2014. Bio-efficacy of eco-friendly insecticides against cabbage butterfly, *Pierisbrassicae* (L.) on cabbage in the mid altitudes hills of Meghalaya, North East India, Molecular Entomology 5: 1-3 (doi: 10.5376/me.2014.05.0008).

Ranjbari S, Safaralizadeh M H, Aramideh S. 2012. Insecticidal effect of spinosad on larvae of *Plutellaxylostella* L. (Lepidoptera: Plutellidae) under laboratory conditions. African Journal of Microbiology Research 6: 552-553.

Razmi M, Karimpour Y, Safaralizadeh M H, Safavi S A. 2011. Parasitoid complex of cabbage large butterfly *Pierisbrassicae* (L.) (Lepidoptera, Pieridae) in Urmia with new records from Iran. Journal of Plant Protection Research 51: 248-251.

Reddy G V P, Guerrero A. 2000. Pheromone-based integrated pest management to control the diamondback moth Plutellaxylostella in cabbage fields.Pest Management Science 56: 882-888.

Reddy G V P, Tabone E, Smith M T. 2004. Mediation of host selection and oviposition behaviour in the diamondback moth, *Plutellaxylostella* and its predator, *Chrysoperlacarnea* by chemical cues from cole crops. Biological Control 29: 270-277.

RizviP Q, Ali A, Khalid S. 2007. Age and stage specific life tables of cabbage butterfly, *Pierisbrassicae* (Linn) on various cole crops. Journal of Plant Protection Research 49: 145-150.

Roy, H. and Wajenberg, E. 2008. From biological control to invasion: the ladybird *Harmoniaaxyridis* as a model species. Biocontrol l53: 1-4.

Sachan J N, Gangwar S K. 1980. Vertical distribution of important pests of cole crops in Meghalaya as influenced by the environmental factors. Indian Journal of Entomology 42: 414-421.

Sarfraz M, Keddia A B, Dosdall L M. 2005. Biological control of the diamondback moth, *Plutellaxylostella*: A review. Biocontrol Science and Technology 15: 763-789.

Sarwar M. 2014. The propensity of different larval stages of lacewing *Chrysoperlacarnea* (Stephens) (Neuroptera: Chrysopidae) to control aphid *Myzuspersicae* (Sulzer) (Homoptera: Aphididae) evaluated on canola *Brassica napus* L. Songklanakarin. Journal of Science and Technology 36: 143-148.

Saucke H, Dori F, Schmutterer H. 2000. Biological and integrated control of *Plutellaxylostella* (Lep.,Yponomeutidae) and *Crocidolomiapavonana* (Lep., Pyralidae) in Brassica crops in Papua New Guinea. Biocontrol Science and Technology 10: 595-605.

Sharma A, Gupta R, Reecha. 2011. Repellent effect of some plant extracts against *Pierisbrassicae* (Linn). International Journal of Farm Sciences 1: 72-78.

SharmaA, Gupta R. 2009. Biological activity of some plant extracts against *Pierisbrassicae*. Journal of Biopesticides 2: 26-31.

Shternshis M V, Ovichinnikova L A, Duzhak A B, Tomilova OG. 2002. The efficiency of viral and bacterial entomopathogens formulated with chitinase for biocontrol of lepidopteran cabbage pests. Archives of Phytopathology and Plant Protection 35: 161-169.

Singh K I, Debbarma A, Singh H R. 2015. Field efficacy of certain microbial insecticides against *Plutellaxylostella* Linnaeus and *Pierisbrassicae* Linnaeus under cabbage-crop-ecosystem of Manipur. Journal of Biological Control 29: 194-202.

Sood A K, Bhalla O P, Sharma K C, Kumar A. 1995. Seasonal activity of *Pierisbrassicae* (Linnaeus) (Lepidoptera: Pireidae) in cauliflower seed crop ecosystem. Journal of Biological Control 9: 119-122.

Srinivasan K, Kumar N K K. 1982. Pest management in cabbage. Annual Report, 1981. Indian Institute of Horticultual Research, Bangalore. pp. 80-81.

StaraJ, Ourednickova J, Kocourek F. 2011. Laboratory evaluation of the side effects of insecticides on *Aphidiuscolemani* (Hymenoptera: Aphidiidae), *Aphidoletesaphidimyza* (Diptera: Cecidomyiidae) and *Neoseiuluscucumeris* (Acari: Phytoseidae). Journal of Pesticide Science 84: 25-31.

Van Driesche R G. 2008. Biological control of *Pierisrapae* in New England: Host suppression and displacement of *Cotesiaglomerata* by *Cotesiarubecula* (Hymenoptera: Braconidae). Florida Entomologist 9: 22-25.

Venkateswarlu V, Sharma R K, Sharma K. 2011. Evaluation of eco-friendly insecticides against major insect pests of cabbage. Pesticide Research Journal 23: 172-180.

Weinberger K, Srinivasan R. 2009. Farmers' management of cabbage and cauliflower pests in India and their approaches to crop protection. Journal of Asia Pacific Entomology 12: 253-259.

Yankanchi S R, Patil S R. 2009. Field efficacy of plant extracts on larval populations of *Plutellaxylostella* L. and *Helicoverpaarmigera* Hub. and their impact on cabbage infestation. Journal of Biopesticides 2: 32-36.

Yoon C, Seo D K, Yang J O, Kang S H, Kim G H. 2010. Attraction of the predator *Harmonia axyridis* (Coleoptera: Coccinellidae), to its prey, *Myzuspersicae* (Hemiptera: Aphididae), feeding on Chinese cabbage. Journal of Asia-Pacific Entomology 13: 255-260.

Zafar A U, NasirI A, Shahid A A, Rahi M S, Sheikh R. 2002. Performance evaluation of Camb biopesticides to control cabbage butterfly (*Pierisbrassicae*) in cauliflower crop. Pakistan Journal of Biological Sciences 5: 1041-1043.

Zhou L, Huang J, Xu H. 2011. Monitoring resistance of field populations of diamondback moth *Plutellaxylostella* L. (Lepidoptera: Yponomeutidae) to five insecticides in South China: A ten year case study. Crop Protection 30: 272-278.

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