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Evaluation of chemical and biological insecticides for the management of cabbage butterfly, *Pieris brassicae* (Linn.) (Lepidoptera: Pieridae) - A review

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Abstract
Cabbage is one of the most popular winter vegetables grown in India (Cabbage Farming- Agro Farming). *Pieris brassicae* Linn. (Lepidoptera: Pieridae) is one of the major constraints in commercial cultivation of the crop in hill and plain areas of Uttarakhand and also it is reported in some parts of East Uttar Pradesh. Different control measures are recommended to control this pest among which chemical control is also important. Many researches applied different chemical and biological insecticides for the management of cabbage butterfly, *Pieris brassicae* (L.). Deshmukh and Adarsh studied the toxicity of commercial grade insecticides against larvae of *Pieris brassicae.* Among which, carbofuran proved to be the most toxic at LC_{50} and LC_{95} levels, while the other insecticides differed in their order of toxicity at the two levels. Szwejda conducted a field and laboratory studies for two years and reported that, all tested pesticides at 0.05% a.i. gave good control of *Pieris brassicae*.Varma reported that four different preparations of *Bacillus thuringiensis* were tested, each at 0.5, 1 and 1.5 g/litre, against larvae of *Pieris brassicae* (L.) on cauliflower leaves in petri dishes. Treated leaves were replaced with untreated ones after 48h, and mortality counts were made 2-6 days after offering the treated leaves. All the bacterial preparations and concentrations were significantly superior to control treatment and gave 100% mortality at six days after treatment. Tatchell and Payne tested a purified granulosis virus isolated from *Pieris brassicae* against *Artogeia rapae (L.)*. Within 10 days of a spray application of the virus, there was a significant reduction in the mean larval population in all the treated plots as compared with untreated plots.

Keywords: Pest, *Pieris brassicae*, Cabbage, Larvae

Introduction
Cabbage is the second most important Cole crop, which originated in Europe and in the Mediterranean region after cauliflower. Cabbage is one of the most popular winter vegetables grown in India (Cabbage Farming- Agro Farming). *Pieris brassicae* Linn. (Lepidoptera: Pieridae) is one of the major constraints in commercial cultivation of the crop in hill and plain areas of Uttarakhand (Mishra and Ram, 1997 and Singh *et al*., 2003) [37, 56] and also it is reported in some parts of East Uttar Pradesh (Bhati *et al.*, 2015) [9]. *Pieris brassicae* (Lepidoptera: Pieridae) is a serious pest of cabbage (Bhalla and Pawar, 1977) [7] and the insect pest alone causes more than 40% of yield loss of vegetables annually (Ali and Rizvi, 2007) [1]. Different control measures are recommended to control this pest among which chemical control is also important. It has become necessary to use such insecticides which are eco-friendly and safe for natural enemies.

Evaluation of chemical and biological insecticides for the management of cabbage butterfly, *Pieris brassicae* (L.)
Lipa *et al*. (1970) [33] assessed the effectiveness of *B. thuringiensis* (Thuricide 90TS) for the control of *Pieris brassicae* (L.) on cabbage, as compared with trichlorphon (Foschlor plynny 50), fenitrothion (Folithion), methoxy-DDT (Metox plynny 30) and Entobakterin 3. In laboratory, Thuricide at 1% gave 100% mortality of first instar larvae in three days, while Foschlor at 0.2% also gave same results in 1 day and Metox at 0.6% in 4 days and it was slightly slower in action than the other materials against fourth-instar larvae. Both Thuricide and Entobakterin at 0.5 and 1% gave complete kill of eggs in 24 hours. In the field, both Thuricide at 1% and Foschlor at 0.2% gave complete kill of first and fourth instar larvae.
Deshmukh and Adarsh (1971) [14] studied the toxicity of commercial grade insecticides against larvae of *Pieris brassicae.* Among which, carbofuran proved to be the most toxic at LC_{50} and LC_{95} levels, while the other insecticides differed in their order of toxicity at the two levels. Malathion as the standard (1.00), the order of decreasing toxicity at the LC_{50} level was

carbofuran (121.10), monocrotophos (64.47), fenitrothion (45.93), endosulfan (6.69), tetrachlorvinphos (6.24), menazon (4.43), dichlorvos (3.80), Cytrolane (2.58), carbaryl 1.89, diazinon 1.49 and dimethoate 0.75. At LC_{95} level, the order was carbofuran (45.21), monocrotophos (20.96), fenitrothion (16.95), tetrachlorvinphos (8.19), endosulfan (5.05), Cytrolane (1.11), carbaryl (1.09), diazinon (0.57), menazon (0.23), dimethoate (0.23) and dichlorvos (0.17).

Kowalska (1971) conducted a laboratory tests with sprays of Entobakterin-3 [containing 20 X 10^9 spores of *Bacillus thuringiensis var. galleriae* and 20 X 10^9 toxic protein crystals/g], Bathurin [2.5% Czechoslovak preparation of spores of *B. thuringiensis*] and Thuricide 90 TS [containing 30 X 10^9 spores of *B. thuringiensis var. thuringiensis*/g] for the control of the larvae of *Pieris brassicae* infesting cabbage. In the laboratory, all the three preparations at 0.5 and 2.5% gave 100% mortality after nine days.

Szwejda (1973) [59] conducted a field and laboratory studies for two years and reported that, all tested pesticides at 0.05% a.i. gave good control of *Pieris brassicae*. Birlane® [chlorfenvinphos], Nexion® [bromophos], Sumithion® [fenitrothion] and Metation® [fenitrothion], being persistent they are recommended for use in early cabbage cultivrs. Phosdrin [mevinphos], Vapona® [dichlorvos] and Winylofos, with little persistence, were recommended for use inlate sowing.

Varma *et al.* (1974) [66] reported that four different preparations of *Bacillus thuringiensis* were tested, each at 0.5, 1 and 1.5 g/litre, against larvae of *Pieris brassicae* (L.) on cauliflower leaves in petri dishes. Treated leaves were replaced with untreated ones after 48 h, and mortality counts were made 2-6 days after offering the treated leaves. All the bacterial preparations and concentrations were significantly superior to control treatment and gave 100% mortality at six days after treatment.

Ryakhovskii *et al*. (1981) [50] evaluvated the effectiveness of bio preparations Bitoxibacillin® [*Bacillus thuringiensis* subsp. *thuringiensis*] at 0.3%, Dipel® [*B. thuringiensis* subsp. *kurstaki*] at 0.3% and Entobakterin® [*B. thuringiensis* subsp. *galleriae*] at 0.5% alone and with sublethal doses of trichlorphon (chlorophos) against cabbage moth and the cabbage butterfly larvae. Entobakterin® proved to be most effective against *M. brassicae.* All bio preparations were more effective aginst *P. brassicae* without trichlorphon, giving 91-98% mortality after 5 days.

Balgurunathan and Lebrun (1983) [3] observed the effectiveness of *Bacillus thuringiensis* against the larvae of *Pieris brassicae* and *Mamestra brassicae* on cabbage and Brussels sprouts. On both crops, significant mortality rates were obtained on treated plots, with no significant difference between the higher and lower doses. It was concluded that, the timely applications of the bacterial preparation effectively controlled young larvae of *M. brassicae* and significantly increased crop yield. The results for *P. brassicae* were less conclusive, owing to the very low numbers found on both crops during both trials.

Tatchell and Payne (1984) [61] tested a purified granulosis virus isolated from *Pieris brassicae* against *Artogeia rapae* (L.). Within 10 days of a spray application of the virus, there was a significant reduction in the mean larval population in all the treated plots as compared with untreated plots.

Gupta *et al*. (1985) [22] applied seven insecticides when the floral buds were about to open to control *Plutella xylostella, Pieris brassicae*, *Heliothis armigera* and *Thrips flavus*. After treatment, the best controlwas obtained with 0.05% chlorpyrifos, 0.05% isofenphos or methamidophos against *P. brassicae*. *H. armigera* with 0.05% chlorpyrifos, and for *P. Xylostella*, with 0.05% chlorpyrifos or 0.05% phosalone. Eight days after treatment 0.05% isofenphos gave the best control for *T. flavus*.

Rai *et al*. (1985) [45] conducted field trials for two years and evaluated 10 insecticides against *P. brassicae* on cauliflowers. Caterpillar mortality was assessed on 7 dates between 1 and 30 days after treatment. Among the insecticides tested, malathion (0.05%), diazinon (0.03%), parathion methyl (0.03%) and dichlorvos (0.05%) were effective for 10-15 days, whereas carbaryl (0.1%), DDT 25% emulsion, endosulfan (0.035%) and monocrotophos (0.03%) were effective for 25 days after treatment.

Tompkins *et al. (*1986) [64] observed the effectiveness of several microbial agents for control of the noctuid *Trichoplusia ni* and the pierid *Pieris rapae* on collards. The agents included several nuclear polyhedrosis viruses, a microsporidian, granulosis viruses of *T. ni* and *P. brassicae* and commercial preparations and environmental isolates of *B. thuringiensis*. Methomyl and fenvalerate were regarded as standards. Some nuclear polyhedrosis virus formulations and *B. thuringiensis* proved as good control of *T. ni* as methomyl. Reduced rates of *B. thuringiensis* and nuclear polyhedrosis viruses, when combined proved better control than normal rates of either.

Singh *et al*. (1987) [54] observed the repellent effect of seed kernel suspension (at 0.1, 0.2 and 0.4%), oil emulsion (at 0.2, 0.4 and 0.8%) and leaf water extract (at 0.5, 1.0 and 2.0%) of neem (*Azadirachta indica*) against 2nd and 3rd instar larvae of *Pieris brassicae* on cabbages and cauliflowers. All 3 concentrations of seed kernel suspension and oil emulsion and 2% leaf water extract had a significant antifeedant effect, reducing the mean leaf area consumed by 40-50%.

Rituma (1987) [49] observed during field tests in the Latvian SSR, USSR, in 1980-85, the bacterial preparations Dendrobacillin® [*Bacillus thuringiensis* subsp. dendrolimus] and Entobacterin® [B. *thuringiensis subsp. galleriae*] at 3 kg/ha and Bitoxibacillin® at 3-4 kg/ha gave 97, 94 and 68-74% control of cabbage butterfly larvae.

Choudhary *et al*. (1988) [13] reported that fenvalerate and endosulfan were the most toxic to 3rd-instar larvae of *Pieris brassicae*.

Zaman (1989) [69] reported that formothion EC (24.75 ml a.i./100 litres water) and pirimicarb DP (25 g) were found to be consistently effective against *Brevicoryne brassicae* on rape in Pakistan in 1985-86. Alphamethrin [alpha-cypermethrin] EC (7.5 ml) and fenobucarb EC (50 ml) were effective for a short period against the aphid. Alpha-cypermethrin (5 ml) and cyfluthrin (2.5 ml) caused immediate mortality of larvae, while diflubenzuron WP (15 g) and triflumuron WP (15 g) were chronically effective against larvae. Aphids, however, were not controlled by these insecticides, probably because of washing effects of rain.

Cameron (1989) [11] tested the most frequently used insecticides against *Plutella xylostella* and *Pieris brassicae*. Cabbages treated with permethrin (50 g a.i./ha), methamidophos (900 g a.i./ha), CME 134 (60 g a.i./ha) and the microbial insecticides Bactospeine FC [*Bacillus thuringiensis* subsp. *thuringiensis*] and Thuricide® HP [*B. t. subsp. kurstaki*]. Cabbages were harvested 11 weeks after planting and their quality was assessed. 100 and 78% of permethrin and methamidophos treated cabbages of premium quality. The other treatments significantly improved cabbage quality compared with untreated cabbages.

Raj and Kanwar (1990) [46] reported that Endosulfan at 0.05%, methyl-demeton [demeton-S-methyl] at 0.025% and Malathion at 0.05% was found to effectively check the population build-up of *Brevicoryne brassicae* infesting a cauliflower seed crop in Himachal Pradesh, India. This was more pronounced under lower doses of fertilizers. Further escalation in aphid population after March could be curtailed by promoting the role of the predator *Coccinella septempunctata*. Attack by *Pieris brassicae*, which appeared towards the end of April, was also found to be influenced by initial combination of treatments could be effectively checked by spraying 0.05% endosulfan at fortnightly intervals during May.

Meadow *et al*. (1999) [35] conducted a series the experiment at the Plant Protection Centre in Norway; to evaluate neem extracts (extracts from seeds of the neem tree, *Azadirachta indica*) for the control of lepidopteran pests of cabbage. Promising results were obtained in laboratory experiments in which neem extracts were tested against larvae of *Mamestra brassicae, Plutella xylostella, Pieris rapae and P. brassicae*. Further studies were done using cabbage moths produced in a laboratory culture. One study showed that, in addition to possessing activity as an insect growth regulator (IGR), neem extracts have a repellent effect that can reduce oviposition. Antifeedant effects of neem on larvae were also demonstrated, as a systemic activity through water uptake by plants. When sprayed onto the plants, concentrations of azadirachtin above 2 ppm prevented larval development. Concentrations above 8 ppm prevented plant damage. After being sprayed, the plants were effectively protected from damage for 1-2 weeks.

Mumtaz *et al.* (1991) [38] observed that Sumicidin® [fenvalerate] (0.01%) effectively controlled *Pieris brassicae* and resulted in the greatest yields, followed by malathion (0.1%) and Nogos® [dichlorvos] (0.1%).

Mahabir *et al.* (1992) [34] reported the mortality at 24 hours after treatment. The order of toxicity to 2ndinstar larvae was permethrin > decamethrin [deltamethrin] > cypermethrin > endosulfan >malathion> fenvalerate. The order of toxicity to 3rd and 4thinstar larvae was the same, except that fenvalerate was more toxic than endosulfan and malathion.

Narkiewicz (1992) [40] observed the effectiveness of carbosulfan as Marshal 25 EC for the control of *Brevicoryne brassicae, Pieris brassicae and Laspeyresia nigricana [Cydia nigricana]* on cabbages and *Delia brassicae [D. radicum]* on peas. Marshal 25 EC applied at the rate of 0.6 litres/ha destroyed 95-100% of *B. brassicae*, *P. brassicae* and *C. nigricana*. Application at a rate of 15 mg of active ingredient per plant yielded 95% control of *D. radicum*.

Ram and Pathak (1992) [47] reported that Carbaryl, endosulfan, phosphamidon, dimethoate, malathion and fenitrothion effective in reducing *Pieris brassicae* infestation on cabbage in Manipur, India.

Hussain *et al*. (1992) [24] reported that, the two hymenopterous parasitoids, *Brachymeria femorata* and *Pteromalus puparum* were found to be effective in controlling the pierid. Parasitoids were found in crucifer fields parasitizing the pupal stage at 2 distinct periods, the 1st one extended from October to mid-January and the 2nd from March to April. The percentage parasitism by *B. femorata* and *P. puparum* ranged from 13.7 to 17.3, and 16.1 to 20.7, respectively. The percentage parasitism appeared to be dependent on the type of crop grown, the prevailing season and the population density of the pierid.

Halimie *et al*. (1992) [23] evaluated the efficacy of Karate® [lambda-cyhalothrin], Apavap® [dichlorvos], Nogos® [dichlorvos], Sumicidin® [fenvalerate] and Pirimor® [pirimicarb] (@ 395 ml, 1235 ml, 741 ml, 494 ml and 617 g/ha, respectively) against *Brevicoryne brassicae.* Cascade® [flufenoxuron], Ataboron® [chlorfluazuron], Karate® and Sumicidin® (@ 494 ml, 395 ml and 494 ml/ha, respectively) against *Pieris brassicae*on cauliflowers.In the first experiment, Karate® was compared with Sumicidin® while Apavap® was compared with Nogos® and Pirimor® against *B. brassicae*. Both insecticides (Karate® and Apavap®) and the standards Sumicidin®, Nogos® and Pirimor® were equally effective against *B. brassicae*. They decreased the pest population by 89.03, 97.92, 93.71, 97.73 and 96.85% at three days after treatment, and by 93.91, 97.17, 96.86, 97.64 and 99.17% 7 days after treatment, respectively. In the second experiment, Cascade®, Ataboron® and Karate® were compared with Sumicidin® (standard) against *P. brassicae*. They decreased the pest population by 90.47, 92.68, 96.14 and 92.86% 3 days after treatment and by 99.19, 100.00, 100.00 and 99.38% 7 days after application, respectively.

Sharma *et al*. (1993) [51] conducted the field experiments at Palampur, Himachal Pradesh, India, in the winter season of 1988-89 to establish the residual toxicity to *Pieris brassicae* and persistence on cauliflowers of cypermethrin, decamethrin [deltamethrin], fenvalerate, permethrin, dichlorvos, endosulfan, malathion and monocrotopohos. Persistence was estimated using a *Drosophila melanogaster* bioassay. Data for residual toxicity are tabulated for 0, 1, 3, 5, 7, 10 and 15 days, which indicate that deltamethrin and dichlorvos were initially most toxic, but monocrotophos and endosulfan have a much longer residual toxicity.

Rahim (1993) [43] reported that the cabbage butterfly, *Pieris brassicae L*, is a serious pest of cruciferous crops, namely cauliflower, cabbage, Knol-khol *etc*., in the Punjab. However, the natural enemies were absent or in very low numbers at Taxilla. Therefore two parasites, *Diadegma pierisae* and *Apanteles glomeratus L.* were mass bred in the laboratory and released at these localities. Infestation was reduced to 21% against the control where the infestation was 45% at the time of ripening of the crop.

Khan and Siddiqui (1994) [26] studies were carried out at Faculty of Agriculture, Gomal University, to figure out the pesticidal activity of some indigenous plants in different solvents against the larvae of cabbage butterfly. Six plants *viz.* Neem (leaves, seeds), Bakain (leaves), Kaner (leaves), Ak (whole plant), Dodhak (whole plant), Garlic (rhizome) in five different solvents, *i.e.*, Benzene, Chloroform, Acetone, Methanol and water were used during this work. The effect of different extracts on larvae of cabbage butterfly after 24, 48 and 72 hours with various solvents showed significance response by giving the highest per cent mortality of the test insect. Leaves and seeds of various plant materials in benzene, chloroform and methanol showed tremendous insecticidal activity than whole plants and rhizome of Garlic.

Vaidya *et al*. (1995) [65] evaluated a commercial formulation of *B. thuringiensis* subsp. *Aizawai* against 3rd instar larvae of *Pieris brassicae* under laboratory conditions. Out of three combinations, treated larvae and treated food gave highest mortality (40.00 to 100%) at 0.025, 0.05 and 0.1% concn. after 24, 48 and 72 hours of treatment in comparison to untreated larvae released on treated food (21.93 to 100%) and treated larvae released on untreated food (13.33 to 86.67%), respectively.

Battu (1995) [6] observed the infection of nuclear polyhedrosis virus on *Pieris brassicae* feeding on Brassicae crop.

Thakur (1996) [62] conducted a field study in 1991-92 at Upper

Shillong; Meghalaya, India with cabbage cv. Pride of India, 68.5% of the marketable yield was affected by attack by larvae of *Pieris brassicae*. Larval population and yield correlation indicate that, the damage was significant 22-25 days and 40-47 days after sowing. The most effective treatment for control of the pest was application of 75 g a.i./ha of fenvalerate 20 and 40 days old after sowing.

Sood and Bhalla (1996) [58] reported that the ecological studies on *Pieris brassicae* in Himachal Pradesh, India showed that the pest completed three generations in a year, the duration of which varied from 32-64 days. The first two generations during February-May inflicted severe damage to cabbage and cauliflower. High temperature and more sunshine hours accompanied with low relative humidity and rainfall favoured population buildup. Parasitoids, *Apanteles glomeratus [Cotesia glomerata]* and *Hypersota ebeninius [Hyposoter ebeninus]*, the predatory syrphid fly, *Episyrphus balteatus* and the entomopathogens, *Bacillus* sp., *Entomophthora* sp. and *Serratia marcescens*, the natural enemies associated with larvae and pupae of *P. brassicae*, caused mortality to the extent of 31%.

Wawrzyniak (1996) [67] investigated the group of plants extracts activity in relation to the large white butterfly. The extracts from *Ajuga repens*, *Calendula officinalis* and all of the tested plant extracts from Solanaceae and Umbelliferaceae family showed the most antifeedant activity and restricted the development of the pest. The feeding of the cabbage worm was most inhibited by the extracts from *Geranium robertianum, Ruta graveolens and Polygonum convolvulus*. The tested water extracts of Umbelliferaceae, Solanaceae, Polygonaceae and Centaurea cyanus, *Helichrysum avenarium, Calendula officinalis, Artemisia absinthium* (Compositae) in field conditions, protected the plants against eggs laid by the large white.

Bhalla *et al*. (1997) [8] recorded the infestation of *Pieris brassicae* in *Brassica spp*., *B. juncea*, *B. napus, B. nigra and B. carinata* in Issapur, Delhi, in February 1996. Its incidence was unusual, being primarily a pest in mountainous areas. Sixteen different *Brassica spp*. cultivars found infested and were categorized on the basis of infestation index among the 150 accessions (both exotic and indigenous). The late cultivars with green leafy stage coinciding with the period of pest activity were preferred while those with early maturity escaped infestation. Both intraspecific and interspecific variations in the acceptance of the food plants were observed. Amongst 12 *B. juncea* cultivars, the infestation index ranged from 1.25 in resistant Pusa Jai Kisan to 4.50 in highly susceptible EC-333568. EC-367885 and EC-333572 were moderately susceptible, whereas EC-322090, EC-367882, EC-322092, EC-333592, EC-367880 and EC-322093 were susceptible to *P. brassicae*. Other highly susceptible *B. juncea* cultivars included EC-333571 and EC-333594. *B. napus* cultivar, BEC-335 exhibited moderate susceptibility, the infestation index being 2.13, while *B. nigra cultivar* EC-289660 was susceptible (3.30). *B. carinata cultivar* EC-223405was susceptible but EC-151995 A was highly susceptible to the pest. The physical factors of the host plant such as leaf texture and leaf colour were unrelated with the larval preference. Probably, the chemical factors of the host plant acting both as phagostimulants and phagodeterrents influenced host plant selection.

Zambaux *et al*. (1997) [70] carried out field studies during 1991-96 in France to test etofenprox against *Mamestra brassicae, Pieris brassicae, P. rapae* and *Plutella xylostella* in cabbage. Etofenprox (150 g/ha) showed a regular efficacy comparable with the control (7.5 g/ha deltamethrin). Persistence was at the same level or even better (for *Pieris brassicae*) than the control.

Krnjajic *et al*. (1997) [29] conducted the laboratory and field trials to evaluate the efficacy of combinations of 3 biological control agents (*Bacillus thuringiensis subsp. kurstaki*, nuclear polyhedrosis virus (NPV) of *Mamestra brassicae,* and *Trichogramma evanescens*) for controlling cabbage pests. Biological preparations based on *B. t. subsp. kurstaki* were effective in controlling *Pieris brassicae, P. rapae, Plutella xylostella* and *Autographa gamma*, but were ineffective against *M. brassicae*. At 30°C, the LT50 for *M. brassicae* larvae period was 5.6 days, indicating that the larvae did not damage cabbage leaves significantly. 75000 parasitic wasps (*T. evanescens*) were released in 3 repetitions in a 1.5 ha cabbage plot, which reduced the attack of *M. brassicae*, *Pieris rapae* and *Plutella xylostella* by 47, 42 and 60%, respectively, compared to the control. It is concluded that *T. evanescens* alone cannot control cabbage pests in Yugoslavia and it should be used in combination with biological preparations based on baculoviruses or *B. t.* Sub sp. *kurstaki*.

Lakwah *et al*. (1998) [31] conducted a studies during 1995-1996 and 1996-1997 in Egypt to investigate the effects of two plant extracts in acetone (Datura leaves and black pepperseeds), botanical insecticide, Neemazal-T and organophosphorus insecticide, chlorpyrifos-methyl (alone or in combination with the three previously mentioned treatments at its half recommended rate) on cabbage infesting insects (cabbage aphid (*Brevicoryne brassicae*), cabbage butterfly (*Pieris brassicae*) and diamondback moth (*Plutella maculipennis) [Plutella xylostella])*.

Dhaliwal *et al.* (1998) [16] conducted a field studies with 2 formulations of neem: Achook® and Nimbecidine® for the control of insect pests on cabbage. The neem formulations were evaluated at 1, 2 and 4 kg/ha compared to 0.5 kg a.i./ha of endosulfan used as control. The mortality of insects was highest with 4 kg/ha of the neem formulations, 7 days after treatment. The mortality of *Lipaphis erysimi* in Achook, Nimbecidine and endosulfan was 95.77, 91.24 and 97.24%, respectively. Mortality of *Spodoptera litura* was 81.66, 70.66 and 85.66%, respectively, whereas with *Pieris brassicae* it was 80.00, 73.33 and 86.66%. Endosulfan was the most effective against all the insect pests, followed by Achook® and Nimbecidine®. The neem formulations were safer to the parasitoids, *Microplitis similis* and *Apanteles glomeratus* [*Cotesia glomerata*], which parasitized *S. litura* and *P. brassicae* larvae, respectively. The feeding efficiency of the coccinellid predator,*Coccinella septempunctata* on *L. erysimi*, treated with neem-based insecticides, was higher then for aphids treated with endosulfan.

Balikai and Mantur (1999) [4] reported that an outbreak of *Pieris brassicae* on *Cassia biflora* and *C. siamea*, growing on the campus of the College of Agriculture, Bijapur, during Sept. or Oct. 1997 and 1998.

Rahman *et al*. (1999) [44] studied the efficacy of four different insecticides Florbac, Atabron, Commondo and Nogos against *Pieris brassicae*. Results revealed that Nogos and Commondo gave higher mortality (99.69 and 98.29%) of the pest while Florbac (*Bacillus thuringiensis*) and Atabron were statistically similar in controlling the pest and caused 77.86 and 76.91%.

Reddy and Manjunatha (2000) [48] revealed that egg parasitism in the laboratory by *Trichogramma chilonis* was 75.6%. Among the insecticides tested against *T. chilonis* and the predator *Chrysoperla carnea*, nimbecidine (neem product) and dipel resulted in zero mortality, with only a low level of mortality by dimethoate, cypermethrin, fenvalerate, alphamethrin and monocrotophos. Combinations of nimbecidine with 2% NPV at 250 larval equivalents per ha and dipel with NPV @250 LE/ha were the most effective treatments against *H. armigera*. The integrated pest management components (*T. chilonis*, *C. carnea*, NPV, nimbecidine, dipel and synthetic chemicals) were imposed at different intervals on the basis of pheromone trap threshold level (7 moths / trap per night) on a consolidated block of 40 ha cotton. The results demonstrated a significant superiority of the IPM strategy in terms of both cost versus benefit and environmental safety over that used in the farmer's fields where only conventional control methods were followed to mortality of the pest.

Thakur and Parmar (2000) [63] conducted field trials in Himachal Pradesh and evaluated 8 different insecticides in which cypermethrin, decamethrin [deltamethrin] and fenvalerate gave complete protection to Brassica crop against *Pieris brassicae*.

Bassi *et al*. (2000) [5] reported that DPX-MP062 (Steward® 30%WG) is a novel insecticide containing indoxacarb, the first member of the new chemical group of oxadiazines, by DuPont. Featured by, high biological activity, low use rates and favourable ecotoxicology. Steward is selective to several key beneficials, including pollinators. In numerous field trials carried out from 1994 to 1999 in open fields and plastic houses, Steward at 25-37.5 g a.i./ha effectively controlled *H. armigera, S. littoralis, P. xylostella, P. gamma, O. nubilalis, P. rapae, P. brassicae, C. chalcites* on vegetable crops.

Tuubel *et al*. (2001) [32] evaluated the efficacy of the local pink pyrether, *Tanacetum parthenium*, and the commercial insecticide, Spruzit® [natural pyrethrin + piperonyl butoxide], against the larvae of the large white butterfly in cabbage fields. The larvae of *P. brassicae* were fed with cabbage leaves and subjected to the following treatments, 4 and 2% *T. parthenium* extract, 0.1 and 0.01% Spruzit® solution and an untreated control. The highest larval mortality was obtained with the 0.1% Spruzit treatment, while the rate of mortality in the other treatments was not significantly different from the control. In all treatments, the antifeedant and repellent effects of *T. parthenium* extract and Spruzit® were clearly evident. Although the antifeedant effect of the *T. parthenium* extract was lower than that obtained with 0.1% Spruzit, a significant differences from the control treatment were still observed. Larvae treated with 0.1% Spruzit exhibited longer moulting period, which caused uneven and later pupation compared with the control. The third instar larvae treated with 4% *T. parthenium* extract and 0.01% Spruzit underwent pupation at the same time with the control, but the pre-pupation period was shorter.

Devjani and Singh (2001) [15] evaluated the efficacy of five insecticides, *viz.* malathion (0.05%), phosalone (0.05%), dichlorvos (0.05%), fenvalerate (0.01%) and phosphamidon (0.03), against the insect pests of cauliflower (cv. Pusa Snowball K-1) for two consecutive crop seasons (1996 and 1997) in Manipur, India. The impact of these treatments on natural enemies was also assessed. Among the five insecticides tested, phosalone (0.05%), dichlorvos (0.05%) and fenvalerate (0.01%) were found effective in controlling the aphids infesting cauliflower (including *Myzus persicae*, *Lipaphis erysimi* and *Brevicoryne brassicae*) without harming the biological control agents, while the treatments showed poor performance against cabbage butterfly (*Pieris brassicae*), diamond back moth (*Plutella xylostella*) and leaf miner (Phytomyza horticola [*Chromatomyia horticola*]).

Zhang *et al*. (2001) [72] isolated the *V. lecanii* V-816 strain from the body of *Anoplophora chinensis* adults. A formulation of the V-816 strain containing 1% Tween-80 and 4 x 10^7spores/ litre were sprayed on *Brevicoryne brassicae, Plutella xylostella, Pieris brassicae* and *Tetranychus urticae*. Its pathogenicity to *T. urticae* and *B. brassicae* was significantly higher than that to *P. brassicae* and *P. maculipennis*. It had no pathogenicity to *Helicoverpa armigera* and *Ostrinia nubilalis*. The pathogenicity of the V-816 strain to insect pests increased with increase of spore content. The spore content of 4 x 10^5/litre resulted in the mortality of 26.4% of 2-3 instar *P. brassicae*, but the mortality reached 70.8% when spore content increased to 4 x 10^8/litre. The spore content of above 4 x 10^8/litre did not result in an obvious increase of the mortality of larvae. The pathogenicity of the V-816 strain to young larvae was greater than to older larvae. Temperature influenced the pathogenicity of the V-816 strain and the optimum temperature was 25-30 degrees ^{0}C

Sharma *et al*. (2001) [52] evaluated the efficacy of three insecticides, *viz.* diflubenzuron, cartap hydrochloride and azadirachtin in controlling pests infesting cabbages. Cartap hydrochloride (0.075%) and diflubenzuron (0.05%) were the most effective against *Pieris brassicae* while azadirachtin was the least effective. For the control of *Plutella xylostella*, cartap hydrochloride at 0.05 and 0.075%, diflubenzuron at 0.075%, 0.025 and 0.05% were the most effective. Azadirachtin (6.0 ppm) gave 65.01% mortality but were phytotoxic to the cabbage leaves.

Shternshis *et al*. (2002) [53] reported that *Bt* subsp. galleriae was shown to be the most relevant among the three Bt sub species against cabbage moth (*M. brassicae*), diamondback moth (*Plutella xylostella*) and large white butterfly (*Pieris brassicae*). Synergistic toxic effect against pests mentioned above was obtained when the *Bt* and chitinase were used together. *M. brassicae* larvae on cabbage were much less susceptible to *Bt* than other pests. It was necessary to include MbNPV in the mixture. Analysis of the different mixtures allowed to develope the optimum rates of 2.5x107 spores/ml of *Bt*, 1x107 polyhedra/ml of MbNPV and 0.5 mU/ml of chitinase. Such triple composition was much more effective against *M. brassicae* larvae than the mixture of *Bt* with chitinase and provided simultaneous biological control of all lepidopteran cabbage pests infesting host plants.

Szwejda *et al.* (2002) [60] reported the efficiency of the tank-mix application of Nurelle D 550 EC [chlorpyrifos-methyl+cypermethrin] (0.3 litre/ha instead of the recommended 0.6 litre/ha) with foliar fertilizers Supervit K (4 litre/ha) and Mikrosol U (6 litre/ha) against cabbage pests. The plants were treated twice at approximately 10 day interval. Both treatments significantly reduced cabbage aphid (*Brevicoryne brassicae*), large white butterfly (*Pieris brassicae*), small white butterfly (*P. rapae*), diamondback moth (*Plutella xylostella*), and flea beetle (*Phyllotreta spp.)* population (by 70-100%) compared to the control.

Zarinysh (2002) [71] reported that pesticides Phytoverm, Neem Azal, Neko, Virin-KS, Virin-KB were effective against plant pests (*Trialeurodes vaporariorum, Thrips tabaci, Myzodes persicae [Myzus persicae], Tetranychus urticae, Hylemya brassicae [Delia radicum], Pieris brassicae, Pieris rapae, Mamestra brassicae, Plutella maculipennis [Plutella xylostella]* and *Brevicoryne brassicae*) on the crops. The mentioned pesticides and fungicides were harmless to beneficials inhabiting these agroecosystems.

Dikshitand Prasad (2002) [17] carried out the bioefficacy, persistence and dissipation studies in New Delhi, India on Ethiopian mustard following foliar treatments of deltamethrin (20 and 40 g a.i./ha, Decis 2.8 EC) and beta -cyfluthrin (18.75 and 37.5 g a.i./ha, Bulldock®. 025 SC) at 50% pod formation stage. Residues of deltamethrin in Brassica herbage were at safe level after 7 and 10 days from lower and higher rates of application. After 10 days of spray treatment, 95.37 to 97.10% dissipation of beta-cyfluthrin was recorded on Brassica herbage. Both the insecticides were undetectable in mustard grains and soil samples collected after harvest of the crop. Both the insecticides effectively reduced the population of caterpillars of cabbage butterfly, *Pieris brassicae*, up to 7 days, *i.e.* 67 to 72% by deltamethrin and 75 to 80% by beta -cyfluthrin. The treatments did not exhibit any phytotoxicity.

Zafar *et al*. (2002) [68] tested CAMB *Bt.* based and fungus based biopesticides, commercial Bt. formulation from mycogen and a new chemical pesticide Methoxyfenozide (RH2485-240SC) on cauliflower field against cabbage butterfly. All pesticides successfully controlled the population of cabbage butterfly in cauliflower crop. The efficacy against I to V instar larvae and field stability of CAMB Bt. biopesticides was better than chemical and other biopesticides. So, CAMB *Bt.* can be safely recommended for pest management strategies against Lepidopteral pests on vegetables with no harmful effects on its predators as in case with chemical pesticides.

Gupta and Sood (2003) [21] investigated the control of *P. brassicae* using *B. thuringiensis* (Biobit, Biolep, Agree/Hill BTK, Dipel/Delfin, Halt and Endosulfan) on cabbage crops in Himachal Pradesh, India in 1994, 1995 and 1996. The natural mortality factors including parasitoids (*Hyposoter ebeninus*) were discussed. Results showed that Biobit, Biolep, Delfin, Halt and Hill BTK showed 20, 40, 10, 90 and 20% mortality, respectively in 48 h; and these increased to 8, 80, 60, 80 and 100% in 120 h.

Karmakar (2003) [25] studied the incidences of insect pests, natural enemies and yield performances of 4 promising cultivars (B-9, NC-1, RW-351 and PGS-1004) of rape and mustard, sown on 21 November, 7 December and 21 December 1998 under sub-Himalayan terai zone of West Bengal, India. Mustard aphid, *Lipaphis erysimi*, was the major pest causing substantial yield losses in both early and late-sown crops, while flea beetle (*Phyllotreta cruciferae*), mustard saw fly (*Athalia lugens proxima* [*A. lugens*]) and cabbage butterfly (*Pieris brassicae*) were considered as minor pests. The lowest aphid population was recorded on PGS-1004. Although good numbers of *Menochilus* sp. and *Coccinella sp.* were found to feed on aphids, they were never found to dominate the aphid population. All cultivars showed higher yield (11.86 q/ha) performances at the second date of sowing than at the first and third dates of sowing (8.48 and 8.88 q/ha, respectively).

Singh *et al*. (2003) [56] evaluvated the efficacy of five new insecticides (profenofos at 0.05%, carbosulfan at 0.05%, Polytrin C (profenofos+cypermethrin) at 0.05%, imidacloprid at 0.007% and koranda (fenvalerate+acephate) at 0.05%), four conventional insecticides (endosulfan at 0.07%, quinalphos at 0.05%, monocrotophos at 0.04% and dichlorvos at 0.075%) and four neem based formulations (neem [*Azadirachta indica*] oil, Nimbicidine, Neemarin and Achook, each at 0.50%) against the early 3rdinstar larvae of butterfly. All the treatments were significantly superior over the control in reducing larval population. All the insecticides caused 100 per cent larval mortality after 72 h of spraying and were significantly superior compared to the neem-based formulations. Among the neem-based formulations, Neemarin gave the maximum larval mortality (50.00%) and was significantly effective to other neem products after 72 h of spraying. Neem oil was least effective, exhibiting 16.66% larval mortality after 72 h.

Sirajuddin and Faqir (2003) [57] revealed that, all the insecticides gave significant control of the pest. Mavrik 25 EC also comparatively increased the seed yield. Estimation of losses due to *Pieris brassicae* show that, the number of larvae per plant was increasing and seed yield was decreased. Maximum seed yield was recorded from those plants where, no larvae were released. Release of 2 larvae/plant reduce seed yield up to 22 kg/ha. If cost of cauliflower seed is Rs.150/kg, then the economic injury level will be 0.2 larva/plant or 1 larva per 5 plants. Thus chemical control of the pest at this stage should be done positively.

Chatterjee and Chaudhary (2003) [12] evaluvated the efficacy of *Bacillus thuringiensis subsp. kurstaki* (Btk-55 000 SU mg-1) at 0.1%, *B. thuringiensis subsp. kurstaki* (Btk-32 000 IU mg-1) at 0.1%, avermectin (1.8% w/v) at 0.1% and *Beauveria bassiana* (0.2%) against different larval stages of *P. brassicae* under laboratory conditions. Avermectin resulted in 100, 96.67, 88.33 and 73.22% mortality after 72 h of feeding to 2nd, 3rd, 4th and 5th instar, respectively, closely followed by Btk-55 000 SU mg^{-1}. The potential of the biological pesticides sequentially decreased with the increase in larval age. The decrease in the overall efficacy of avermectin, Btk-55 000 SU mg^{-1} and Btk-32000 IU mg^{-1}was 32.78, 41.55 and 61.27% from 2nd to 5th instar, respectively. Based on the LC50 values, avermectin was the most toxic (131.89, 271.29, 411.18 and 538.25 ppm, respectively), followed by Btk-55 000 SU mg-1. B. bassiana was the least toxic towards all the instars. The relative toxicity of avermectin, Btk-55 000 SU mg-1 and Btk-32 000 IU mg-1 against 2nd instar larvae was 25.97-, 17.71- and 8.67-fold greater.

Kotlinski (2003) [27] investigated the effect of winter cover crop mulch on pests in cauliflower and late type white cabbage production under Polish conditions. In 2000, the number of *Brevicoryne brassicae* on cauliflower, growing on plots with cover crop mulch, was significantly less than on plots with bare soil. In 2001, there were less *B. brassicae and Pieris rapae* larvae on late type white cabbage growing on plots with cover crop mulch than on bare soil. The differences in number of *Pieris brassicae* and *Plutella maculipennis* [*P. xylostella*] larvae on plots with cover crops and without cover crop were not observed.

Metspalu *et al*. (2003) [36] observed the larval mortality by fungus in the first, second and third variants were 21, 67 and 92%, respectively. In the same variants, the per cent of larvae decreased in which *C. glomerata* finished its development (45, 25 and 8%, respectively). On test fields, a form of microsporodiosis (*N. mesnili*) in the population of LWB was established, but *N. mesnili* completed its development cycle by forming spores when LWB was pupating. Both *C. glomerata* and *N. mesnili* perished before completing their development, together with larvae of LWB due to the disease caused by *Z. radicans*. The results predict that the number of LWB will increase in the test area in the next year, so far there have not been any parasitoids regulating the number of LWB or vertically transmitted microsporidia in the area.

Pankaj *et al.* (2004) [41] studied the larvicidal effect of cartap hydrochloride and azadirachtin against *P. brassicae* and *P. xylostella* under laboratory conditions during 1994-95. The studies revealed that cartap, hydrochloride and azadirachtin are effective larvicides. The LC50 values of cartap hydrochloride for second, third, fourth and fifth instars larvae of *P. brassicae* were 6.523, 16.013, 55.461 and 80.608 ppm, respectively. The corresponding values of LC50 against second to fourth instar larvae of *P. xylostella* were 5.070, 11.231 and 49.521 ppm, respectively. The LC50 values of azadirachtin against second to fourth instar larvae of *P. brassicae* were 1.581, 2.097 and 3.099 ppm, respectively, whereas against second and third larval instar of *P. xylostella*, the LC50 values were 1.242 and 1.802 ppm, respectively. Both the chemicals were found to be highly toxic to the larval instars; however, azadirachtin was more toxic of the two insecticides against used instars of both the test species.

Kumar *et al.* (2005) [30] tested the different concentrations of Malathion 0.25, 0.2, 0.1 and 0.05% for their efficacy against larvae of *P. brassicae* in cabbage cv. Golden Acre crop by spray application. Four sprays of insecticide were made with Knapsack sprayer at fortnightly intervals. Among the different concentrations tested, 0.25% recorded the lowest percentage of head infestation (2.24%) and the highest yield (140.33 q/acre) compared to other concentrations tested.

Duchovskiene (2005) [18] reported the effects of biopesticide NeemAzal-T/S (10 g/litre azadirachtin A) on the abundance of sucking and chewing pest in ecologically grown white cabbages. Biological insecticide NeemAzal-T/S, at 0.5% water spraying solution, was effective against cabbage aphids *Brevicoryne brassicae*, caterpillars of *Plutella maculipennis* [*Plutella xylostella*] and *Pieris brassicae*. The mortality of pests was high. In the case of covering with agro-film, the risk of *B. brassicae, P. maculipennis* and *P. brassicae* infestation remains. NeemAzal-T/S at 0.5%, affected cabbage aphids on non-fertilized and covered cabbages by 85.10-77.46% after 5 days and 100-94.23% at 10 days after treatment. NeemAzal-T/S 0.5% affected cabbage aphids on fertilized and covered cabbages by 77.81-49.90% at 5 days and by 100-79.65% at 10 days after treatment. No statistical differences of aphid number were found between aphids on non-fertilized covered and fertilized covered cabbages. In 2003, the biological efficiency with NeemAzal-T/S to control *P. maculipennis* ranged from 53.33 to 66.67% in non-fertilized and fertilized cabbages and from 66.67 to 93.33% in non-fertilized and fertilized covered cabbages, respectively. In 2004, the biological efficiency of applications with NeemAzal-T/S to control *Pieris brassicae* was nearly 100% in non-fertilized and fertilized covered cabbages. Phytotoxicity symptoms of NeemAzal-T/S on plants were not found.

Perez and Shelton (2006) [42] conducted a survey of 125 farmers in 2005 in the Central and Western highlands of Kenya and the Kullu valley in the Western Himalayas, Himachal Pradesh, India, to investigate the pest management practices and constraints among farmers growing cruciferous vegetables. Lepidopteran insects were the most important pests affecting the crops and pest management relied primarily on application of pyrethroid or organophosphate insecticides with high environmental impact quotients averaging 65.6 in the Kenya highlands and 55.7 in the Kullu valley. Just over half (54.4%) of farmers based their decision to apply insecticides on the presence of the pest in the crop, around a third (30.4%) based it on a calendar, and 15.2% based it on both. Farmers cited their own experience (66.4%) and pesticide providers (44.8%) as the main sources of pest management information, while advice from extension (24%) and other farmers (15.2%) was less important. Most farmers interviewed (94%) were not aware of natural enemies. The insect pests mentioned by the farmers interviewed included *Plutella xylostella, Agrotis ipsilon, Pieris brassicae, Brevicoryne brassicae, Lipaphis erysimi, Myzus persicae, Heliothis armigera* [*Helicoverpa armigera*], and *Delia radicum*.

Gardezi (2006) [19] evaluvated 40 species of fungi and 2 species of bacteria for their insecticidal activities against maize stem borer (*Chilo partellus*). Eleven species (*Aspergillus flavus, A. fumigatus, A. oryzae, A. candidus, A. bisporus, A. tamarii, Metarhizium anisopliae, M. brunneum, Beauveria bassiana, Bacillus thuringiensis* and *B. sphaericus*) caused mortality in larvae, pupae, and dewaxed pupae and adults of maize stem borer. Eight species of insects were collected from natural conditions and their susceptibility was measured for all the described species of fungi and bacteria. *Tryporhyza incertulas* [*Scirpophaga incertulas*], *T. innotata* [*S. innotata*], *Cydia pomonella*, *Pieris brassicae* and *Mythimna separata* showed susceptibility to A. *flavus, A. fumigatus, A. oryzae, A. tamarii,A. bisporus, M. anisopliae, M. brunneum, Bacillus thuringiensis* and *B. sphaericus*. Food substrate of fungi and bacteria were also used against maize stem borer. Nine fungi and two bacterial species gave positive results. Field trials of fungi and bacteria were also performed against maize stem borer. All these species were effective against maize stem borer in maize fields.

Grisakova *et al*. (2006) [20] assessed the effects of Neem EC (1% azadirachtin) on the Large White Butterfly, a major pest of cruciferous plants, collected from Tartu, Estonia. The duration of the larval stage, mortality of larvae and prepupae, and weight of pupae was also studied. The time needed for completion of the larval stages by individuals fed on treated cabbage increased significantly, compared with the control: 16-37 days in the test variant versus 11-18 days in the control. Neem EC also induced high mortality, caused by lethal failures of larval-larval and larval-pupal ecdysis, which were typical for insecticides possessing morphogenetic activity commonly referred to as IGR activity. The mortality of larvae and prepupae in the test variant was significantly higher than in the control. Considerably fewer pupae were gained in the test variant than in the control variant. The pupae of larvae that had been feeding on the control were significantly heavier than those of the larvae feeding on the treated plants. The experiment revealed that Neem EC had toxic and antifeedant/deterrent effects but also acted as a growth regulator for *P. brassicae* larvae.

Arya and Dey (2007) [2] reported that all the insecticides were found effective in managing the population of the pest. Indoxacarb (0.005%) caused 100% mortality, followed by ethofenprox [etofenprox] (0.01%) which gave 99.76% mortality, followed by treatment with insecticide mixture of chlorpyrifos - cypermethrin (0.05%) and triazophos (0.05%) reduced larval population by 99.65% and 99.21% respectively. Benefit cost ratio was highest (15.42) for lambda cyhalothrin and lowest (4.82) for indoxacarb treatment.

Muthukumar *et al*. (2007) [39] reported that the, higher mean per cent reduction over control (PROC) was recorded against aphids 78.8 and 61.6 (imidacloprid), 80.8 and 58.5 (thiamethoxam) and 77.8 and 51.8 (cartap hydrochloride) after first and second spraying, respectively, during 2005-2006 and 80.8 and 68.2 (imidacloprid), 79.8 and 61.2 (thiamethoxam), and 78.5 and 50.9 (cartap hydrochloride after first and second spraying, respectively during 2006-2007. The mean of PROC recorded against DBM was 76.4 and 67.3 (spinosad) 80.3 and 78.8, (emamectin benzoate), 66.8 and 63.9 (cartap hydrochloride) and 70.8 and 70.9 (indoxacarb) after first and second spraying, respectively, during 2006-2007. The mean PROC recorded against cabbage butterfly was 78.7 and 57.7 (spinosad), 75.8 and 45.5 (emamectin benzoate), 71.5 and 43.4 (cartap hydrochloride) and 84.4 and 64.2 (indoxacarb) after first and second spraying, respectively, during 2005-2006 and 73.7 and 68.6 (spinosad), 76.2 and 75.3 (emamectin benzoate), 62.1 and 61.3 (cartap hydrochloride) and, 68.3 and 71.4 (indoxacarb) after first and second spraying, respectively during 2006-2007. Spinosad, Biolep, emamectin benzoate and neem oil proved safer to natural enemies in the cauliflower ecosystem.

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