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Assessment of chemical and biological Insecticides for the management of cabbage butterfly, *Pieris brassicae* (L.) under laboratory conditions - A review

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Abstract
The cabbage white butterfly, *Pieris brassicae* Linn. (Lepidoptera: Pieridae) is a serious pest of cabbage and the insect pest alone causes more than 40% of yield loss of vegetables annually. It causes extensive damage in almost all parts of India including north eastern states, during seedling, vegetative and flowering stages of cole crops. There are some chemical and biological insecticides for the management of cabbage butterfly, *Pieris brassicae* (L.) under laboratory conditions. It had been studied that the insecticidal effect of a liquid of *Bacillus thuringiensis* applied to the egg stage in *Plutella xylostella*, *Spodoptera litura*, and *Pieris rapae* under laboratory conditions.In all of the three insect pests tested, *Bt* applied to the egg stage had no effect on eclosion, but caused substantial mortality of the larvae coming out of the Bt-treated eggs. Tariq observed that *Helicoverpa armigera* was resistant to conventional insecticides, so there should be new insecticides which can manage the pest in more efficient and economical manner. Aggarwal reported that the maximum mortality of 58 and 27% was obtained in *Bta* +NA treatments in case of 2nd and 4th instar larvae of *H. armigera* under laboratory conditions followed by *Bta*(50 and 14%) and NA (34 and 7%) alone treatments. The results indicated that *Bta*and NA have the potential to the control of *H. armigera* and *S. exigua* either independently or in combination, when used at the right stage of the field populations. There are many chemical and biological insecticides management of cabbage butterfly, *Pieris brassicae* (L.) under laboratory conditions.

Keywords: Brassica, Population, *Pieris brassicae*, Cabbage, Insecticide

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). India is the second largest producer of cabbage in the world after china (Anonymous, 2014) [5]. India produces 9039.2 million tonnes of cabbage in an area of 400.1 hectares with a productivity of 22.6 MT/ha. Highest cabbage producing states of India are west Bengal, Orissa and Bihar, 2197.20, 1150.9 and 735.0 tonnes respectively (Indian Horticulture Database, 2014) [10]. Major cabbage growing states in the country are West Bengal, Orissa, Bihar, Gujarat, Assam, Madhya Pradesh, Jharkhand, Maharashtra, Chhattisgarh, Haryana and Karnataka (Vegetable Production Map Based on the "Crop-wise Production Pattern (2012-13).

The cabbage white butterfly, *Pieris brassicae* Linn. (Lepidoptera: Pieridae) is a serious pest of cabbage (Bhalla and Pawar, 1977) [6] and the insect pest alone causes more than 40% of yield loss of vegetables annually (Ali and Rizvi, 2007) [4]. It causes extensive damage in almost all parts of India including north eastern states, during seedling, vegetative and flowering stages of cole crops (Lal and Bhajan, 2004; Younas *et al.*, 2004) [14, 23].

Evaluation of chemical and biological insecticides for the management of cabbage butterfly, *Pieris brassicae* (L.) under laboratory conditions.

Reddy and Manjunatha (2000) [16] revealed that egg parasitism in the laboratory by *Trichogrammachilonis* 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.

Sheng and Guang (2002) [8] studied the insecticidal effect of a liquid of *Bacillus thuringiensis* applied to the egg stage in *Plutella xylostella*, *Spodoptera litura*, and *Pierisrapae*under laboratory conditions. In all of the three insect pests tested, Bt applied to the egg stage had no effect on eclosion, but caused substantial mortality of the larvae coming out of the Bt-treated eggs. With the recommended rates of concentration for field application, the rates of newly-emerged larvae reached 42%, 91% and 54% in the three insects, respectively. In *Plutella xylostella*, it was further determined that, rates of mortality of larvae increased with increase of Bt dosage, but decreased with the age of eggs at treatment. The results of this study suggested that very high effect of Bt against these insect pests could be obtained in the field with applications timed at peaks of oviposition and eclosion.

Zahid and Hamed (2003) [24] tested Larvin 80DF, Lannate 40SP, Lorsban 40EC, Fastac 5EC, Decis 10EC and Fury-F18.1EC with recommended doses against 3rd instar larvae of American bollworm, *Helicoverpa armigera* under controlled laboratory conditions. Lorsban 40EC showed maximum efficacy 92.0% in terms of mortality after 24 hours. Maximum mortality was shown by Lorsban 40EC (100%) followed by Larvin 80DF (72.0%), Lannate 40SP (52.0%), Decis 10EC & Fastac 5EC (16.0%) and Fury-F 18.1EC (8.0%) after 48 hours of application. Similarly, the maximum effectiveness was shown by Lorsban 40EC (100%) after 72 hours followed by Larvin 80DF (80.0%), Lannate 40SP, Fury-F 18.1EC (60.0%), Decis 10EC (52.0%) and Fastac 5EC (44.0%). It was concluded from the results that Lorsban 40EC is the most effective insecticide compared to other carbamate and pyrethroid groups of insecticides against 3rd instar larvae of American bollworm, *H. armigera*.

Tariq *et al.* (2005) [19] observed that *Helicoverpa armigera* was resistant to conventional insecticides, so there should be new insecticides which can manage the pest in more efficient and economical manner. Deltaphos 360 EC, Tracer 240 SC, Steward 150 EC, Emamectin 1.9 SC, Lorsban 40 EC and Curacron 500 EC were used to control *Helicoverpa armigera.* According to the result, Tracer 240 SC was found to be the most effective for the control of *Helicoverpa armigera.*

Aggarwal *et al.* (2006) [2] reported that the maximum mortality of 58 and 27 % was obtained in *Bta*+ NA treatments in case of 2nd and 4th instar larvae of *H. armigera* under laboratory conditions followed by *Bta* (50 and 14 %) and NA (34 and 7%) alone treatments. Under greenhouse conditions, a mortality of 69 and 26% was observed in case of *Bta*+ NA treatments in 2nd and 4th instar larvae of *H. armigera* followed by *Bta* (67 and 20%) and NA (56 and 10 %) alone. The mortality of *H. armigera* larvae was higher under greenhouse conditions. There was a significant difference in the mortality between 2nd and 4th instar larvae both under laboratory and greenhouse conditions. The mortality of *H. armigera* was higher in 2nd instar than in the 4th instar larvae in all treatments. Similar results were obtained in case of *S. exigu a*both under laboratory and greenhouse conditions. The results indicated that *Bta* and NA have the potential to the control of *H. armigera* and *S. exigua* either independently or in combination, when used at the right stage of the field populations. The *Quassia* extracts tested did not show a high efficacy against larvae of *H. armigera* and *S. exigua.*

Loc and Chi (2007) [15] conducted studies on *Metarhizium anisopliae* and *Beauveria bassiana* to exploit their potential for controlling the diamondback moth. The results in laboratory and greenhouse showed that all of four selected isolates of *M.anisopliae* and *B. bassiana* which have been isolated from different naturally infected insects were found to be pathogenic to the tested DBM. The *M.a* (OM3-STO) isolate which was isolated from naturally infected DBM exhibited the highest infectivity to DBM. In the field experiments, all of four selected isolates of *M. anisopliae* and *B. bassiana* were found to be effective for controlling the DBM. The efficacy could be seen from 5 DAT. Among them, *M.a* (OM3-STO) isolate, which was isolated from naturally infected DBM exhibited highest efficacy for controlling the DBM, next is *B.b* (OM2-SDO) and then *M.a* (OM1-R). The cauliflower yield of the three above fungal treatments was not significantly different as compared to that of the specific bioinsecticide (Crymax 35WP) treatment. There was 73.2, 68.2 and 66.7 per cent increased in cauliflower yield in *M.a* (OM3-STO), *B.b* (OM2-SDO) and *M.a* (OM1-R) treatment, respectively, as compared to untreated control. These results indicated that *M.a* (OM3-STO), *M.a* (OM1-R) and *B.b* (OM2-SDO) have good potential as microbial control agents for diamondback moth of cruciferous crops.

Hole *et al.* (2009) [9] reported that all the insecticidal treatments were significantly superior over untreated control in reducing the larval damage. The treatment with profenofhos 0.1% gave maximum protection when recorded up to 7 days after application and reported 6.5% foliage damage. The highest residual toxicity to tobacco caterpillar at 24, 48, 72 hrs and one week after application was exhibited in the treatment of profenofhos 0.1% under laboratory to field weathered deposits. Among the different insecticidal treatments tested in field, profenofhos 0.1% alone showed significantly superiority in controlling larval population and thereby, reduction in leaf damage and increasing the grain yield.

Sharma and Gupta (2009) [17] tested the aqueous extract of *A. indica* and *M. azedarach* which repelled maximum number of larvae protected 94.0 per cent and 89.2 per cent cabbage foliage, respectively. Aqueous extract of *M. azedarach*, *N. Indicum* and *A. Indica* showed higher mortality of larvae (19.6, 19.6 and 18.5%, respectively) while *R. communis* was the least toxic resulting in 8.9 per cent larval mortality. In case of ethanol extract, seed extract of *M. azedarach* protected 58.3 per cent cabbage foliage while *Eucalyptus* sp. protected minimum cabbage foliage. The maximum protection to thecabbage foliage was provided at 5 per cent of *M. azedarach* (88.3%) and *A. indica* (82.5%). Ethanol extract of *A. indica* exhibited statistically higher larval mortality of 50.0 per cent and *N. Indicum* the lowest mortality of 3.2 per cent.

Khan *et al.* (2011) [11] evaluvated new and conventional insecticides againstthe armyworm under laboratory conditions. All the evaluated insecticides proved toxic to *S. litura* under laboratory conditions, but chlorpyrifos, profenofos, emamectin benzoate, spinosad, indoxacarb, methoxyfenozide and lufenuron proved highlytoxic as the exposure time was extended. After 3 days of the insecticide treatment, 100% mortality was observed in emamectin benzoate @ 100 and 110 ml/acre treatment, followed by chlorpyrifos @ 1100 ml/acre (96.56%), leufenuron @ 55 ml/acre (86.67%) and Methomyl @ 440 ml/acre (83.34%). However, chlorpyrifos and emamectin benzoate, at all the three doses, leufenuron at the higher and recommended dose and thiodicarb, spinosad and methoxyfenozide, at higher doses, were ranked highly toxic-as these insecticides caused thehighest mortality (>90%) in *S. litura*.

Kodjo *et al.* (2011) [13] tested the effect of different treatments of *R. communis* plant extract (20%) and oil emulsion (5% and 10%) and their persistence (0, 3 and 5 days after application; DAA) on mortality and oviposition behaviour of *P. xylostella* in laboratory and field cage experiments. In general, *R. communis* products have strong larvicidal effect on *P. xylostella*, with 100% mortality recorded on 3rd instar larvae treated with 10% oil emulsion in both ingestion and contact toxicity tests. Aqueous extracts were significantly less toxic with the highest mortality rates (67.49±1.98% and 70.86±0.85%) with seed kernel extract and the lowest with the root extract (53.98±1.21% and 54.87±1.88%), in topical toxicity and ingestion toxicity experiments, respectively. The adult emergence was significantly affected with the lowest emergence rate recorded in 5% oil emulsion, 57.72±72% and 49.98±0.98% in topical toxicity and ingestion toxicity tests, respectively. No significant difference was noted between Dursban and aqueous extract treatments. Among emerged adults from larvae treated with oil and aqueous extracts, a 44–79% abnormal development as wings and legs deformation were observed. The sex ratio was skewed in favour of males among F1 progeny from Durban and *R. communis* treated insects and in favour of females in controls. In field-cage experiments, treated plants had strong larvicidal and oviposition deterrent index on *P. xylostella*. The oviposition deterrence index was highest with castor bean oil at a concentration of 10%. Diamondback females clearly discriminated between plants sprayed with *R. communis* products and those with water. Treating diamondback infested cabbage plants with plant extracts and oil emulsions resulted in more than 59% mortality 7 DAA. Experiment on the residual effects revealed a significant decrease in larval mortality with time between the botanical application and insect release.

Wakil *et al.* (2012) [22] studied the insecticidal efficacy of formulations of *Azadirachta indica*, a *Nucleopolyhedrovirus* (NPV), and new anthranilicdiamide insecticide (chlorantraniliprole) formulations was determined against 2nd, through 5th larval instars of *H. armigera* collected from diverse geographical locations in the Punjab province, Pakistan. *Azadirachta indica* was applied at 5 μL L-1; NPV at 2.1×10^5 polyhedral occlusion bodies (POB) mL^{-1} and chlorantraniliprole at 0.01 μL L^{-1}, either alone or in combinations with each other. The bioassays were conducted at 27±1°C and 65±5% relative humidity. The mortality varied greatly among treatments, larval instars, and locations. The combinations of NPV with *A. indica* and chlorantraniliprole caused higher mortality, pupation and produced an additive effect compared to their application singly in all the tested populations. The population from Rawalpindi was always susceptible while the Gujranwala was the resistant. The results herein suggest that the effectiveness of NPV and *A. indica* can be improved by the presence of chlorantraniliprole against the larvae of *H. armigera*.

Chauhan *et al.* (2013) [8] revealed that maximum mean mortality of 9.66,9.33 and 9.00 was obtained in Endosulfan, Indocarb and Fipronil treatments in case of 2nd and 3rd instar larvae of *H. armigera* under laboratory conditions. The order was found to be descending. Repellency test through square dip experiments showed that, the significant difference was recorded amongst the different treatments for mean mortality of *Helicoverpa armigera* larvae. Statistically significant mean mortality was observed from larvae allowed to feed on square dipped in Neem seed extract 2.5-10% followed by *Carica papaya* seed extract-2.5%, while other treatments were not found significant. During larval immersion method *Carica papaya* seed extract (2.5-10%) was again proved to be most significant followed by Acacia bark extract (5-10%) concentrations. However, Endosulphan was found superior than botanicals in both square dip and larval immersion methods. The field spray schedule showed the significant results with the spray of Neem leaf extract (2.5-10%) and Acacia extract (5.0%) concentration in comparison to control experiments. The mortality of *H. armigera* larvae was higher under laboratory conditions. There was a significant difference in the mortality between 2nd and 4th instar larvae both under laboratory and field conditions.

Akbar *et al.* (2014) [3] conducted the leaf dip bioassays to compare the relative effectiveness of the insecticides against larvae after 12, 24, 48 and 72 hours in laboratory. The results revealed that Emamectin benzoate proved to be the best one with significantly higher level of morality 90.8% followed by Lannate (75.8%), Lufenuron (60.0%), Neem (50.6%), Bakain (36.8%) as compared to that of control (14.8%) after 72 hours. The results regarding field experiment showed that all the treatments were significantly different but Emamectin benzoate provided excellent control of larvae and kept larval densities at relatively low level with the mean number of 3.0 larvae plant^{-1} followed by Lannate (4.1), Lufenuron (5.2), Neem (6.0) and Bakain (6.8) larvae plant^{-1}, respectively. The effect of treatments was proved reciprocal to the effect on pest population. Hence, Emamectin benzoate treated plots gave the highest yield (30,533) Kg ha^{-1}followed by Lannate (25, 266), Lufenuron (16,933), Neem (12,733) and Bakain (9,333) compared with the control plots (5,333) Kg ha^{-1}. It was concluded that there is potential to use Emamectin benzoate in combination with the botanical insecticides to maintain the population of this pest below damage level.

Thakur and Sharma (2014) [20] evaluvated against key insect pests of cabbage, aphids (*Brevicorynebrassicae*) wereexposed to seven treatments till 72 hours andtheir mortality was recorded at 24, 48 and 72hours of exposure. Among which neem oil @0.3% resulted in 100% mortality (30.0aphid) followed by 81.1% mortality (24.3aphid) in aqueous extract of Eupatorium@10%. Using eight treatments by leaf diptechnique against neonate larvae of *Pieris brassicae*, *Baccillus thuriengiensis* (16000 IU/mg) gave complete mortality (5.0 larvae) andit was followed by neem oil (0.30 %) with 66.7% mortality (3.3 larvae). Diamondback moth (*Plutella xylostella*) pupae were exposed to eight treatments to assess antijuvenoid effect where neem oil caused 60% reduction (2 pupae emerged out of 5 pupae) compared to 20% reduction in Melia extract. As per controlled conditions neem oil can effectively manage cabbage aphid and DBM while *Bt* can shield cabbage butterfly.

Abbas *et al.* (2015) [1] reported that maximum % mortality, *i.e.* 89.36 and 85.09 of the pest, was observed with Volium Flexy, and Delegate also worked well even after 7 and10 days. Similarly, the results on the basis of damaged fruits and per cent loss of yield pointed out that Chlorantraniliprole, Flubendiamide and Indoxacarb had resulted better as compared with others, although the difference was statistically non-significant. These new chemistry pesticidesare suggested to be used against *Helicoverpa armigera* which are best fitted in the IPM programme for the control of the pest.

Kodandaram *et al.* (2015) [12] carried out an experiment both in laboratory and field condition to evaluate the dose mortality response and bio-efficacy of a new anthranilicdiamide molecule, cyantraniliprole against a serious shoot and fruit borer pest of brinjal. Cyantraniliprole when applied as fruit dip, it was 6543 timesmore toxic compared to cypermethrin. The descending order of toxicity of tested insecticides was cyantraniliprole > chlorantraniliprole > flubendiamide > cypermethrin. Under laboratorybioassays, the third instar larvae were found to be more susceptible to cyantraniliprole @90 ga.i./ha and recorded highest per cent mortality of 91.66 and 99.00 at 24 and 48 hrs after treatment. In field experiment, cyantraniliprole @105 g a.i./ha was significantly most effective and recorded lowest per cent fruit damage of 8.92 and 8.25 with highest marketable fruit yield of 18.46 and 22.40 t ha during year 2010 and 2011, respectively. The present findings indicate that among different diamide insecticides, cyantraniliprole @ 90-105 g a.i./ha proved to be highly effective against brinjal pests. This novel moleculecan be used as a new tool by farmers and new component for strengthening integrated pest management (IPM) and insecticide resistance management (IRM) programme for *L. orbonalis*.

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