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COMPARISON OF INTEGRATED PEST MANAGEMENT TECHNQUE USED TO CONTROL THE DIAMONDBACK MOTH, *PLUTELLA XYLOSTELLA* ON CAULIFLOWER *BRASSICA OLERACEA*

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Abstracts: The diamondback moth (DBM) *Plutella xylostella* L. is the most significant pest of cruciferous crops worldwide. The present research was conducted to control it on the cauliflower, *Brassica oleracea* L. by 5 Integrated Pest Management (IPM) techniques compared with control (untreated) at Agricultural Research Station Baffa, Mansehra, Pakistan. The Randomize Complete Block Design was used for the experiments with 3 replications. For intercropping, the coriander, *Coriandrum sativum* L.; for chemicals control, the lorsban; for neem seeds extract and oil, *Azadirchata indica* Juss and for biological control, the stingless wasp, *Trichogramma chilonis* Ishii were used. The DBM density increased with increased of temperature, therefore, it was the highest (31.0±0.2 larvae/plant; n=6) at the maximum temperature, i.e., 35 °C in 4th week. No parasitism was found until 2nd week, however, the highest (47%) was during 7th week, moreover, it was 5% at the end of 8th week (n=6). During parasitization, DBM population density was 23.8±2.6, however, mummies and adult parasitoids were 3.1±1.4, moreover, mean parasitism was 13.0±1.7. The actual lowest DBM density was compared, obtained by application of 5 IPM techniques (n=6): *A. indica* seeds extract (T_3): 2.1 larvae/plant in 8th week < chemicals control (T_2): 3.5 larvae/plant in 1st week < biological control (T_5): 4.7 larvae/plant in 5thth week = intercropping (T_1): 4.7 larvae/plant in 8th week < *A. indica* oil (T_4): 6.6 larvae/plant > control (T_0): 35.6 larvae/plant both in 1st week. The lowest yield of *B. oleracea* was obtained in control (2.9 ton/ha), however, the highest was by *A. indica* seeds extract (29.1 tons/ha). Therefore, it is recommended that *A. indica* seeds extract can be used by farmers against DBM in order to get the highest yield and the lowest infestation.

Keywords: *Azadirchata indica* Juss seeds extract, *Azadirchata indica* Juss oil, biological control, *Brassica oleracea*, intercropping, lorsban, *Plutella xylostell*a, *Trichogramma chilonis*.

INTRODUCTION

The cauliflower, *Brassica oleracea* L. is an annual highly nutritive vegetable belong to family Brassicacae reproduces seeds. It originates from northeast Mediterranean and presently cultivated all over the world. In Pakistan, total area under cultivation is 11961 ha with production of 180,272 Hg/ha/annum. In Khyber Pukhtunkhwa, production is 18,338 tons/1,542 ha/annum. It is also an important crop of district Mansehra where production is 1042 tons/154280 ha/annum (Chand and Choudhary, 1997).

The diamondback moth (DBM), *Plutella xylostella* L. is the most destructive insect of cruciferous crops in all over the world and causes more than 1 billion US$ in economic losses per year. It feeds on cruciferous crop such as cabbage, *Brassica variants* L. and cauliflower, *B. oleracea* L.; broccoli, *B. oleracea* L. (Cultivar group: Italica); Chinese cabbage, *Brassica rapa chinensis* L.; mustard, *Brassica campestris* L.; radish, *Raphanus sativus* L. etc (Talekar, 1996). It is small grayish moth. The larvae are fully grown from 10-30 days (He and Pang, 2000). Damage is caused by caterpillars, which in their earlier stages feed upon veins on lower sides of *B. oleracea* leaves and in the later stages expose on leaves (Dan, 1994). It can breed and develop between 10-40 $^{\circ}$C and the adults were active at up to 50 $^{\circ}$C. The young pupae and adults survived for several months, however, the eggs and pupae for 2 and 6 weeks at 0 $^{\circ}$C, respectively (Hardy, 1938).

Integrated Pest Management (IPM) is an approach to keeping pests population below the economic injury level (EIL), through the judicious and compatible use of two or more of several possible control measures, i.e., biological, cultural, biology-based, genetic, physical, mechanical and chemical. Selection of the control measures adopted as part of an IPM package is based on many factors, i.e., available resources, such as money, work force, technical knowhow, skills, agro ecosystem, geographical location; socio-economic situations (Isman, 2006). The IPM program emphasizes the use of reduced spray program developed in the early 1990s based on an efficient scouting system using presence/absence per plant of the major pests, and proven action thresholds for *B. oleracea* (Beck et al., 1992).

The cultural practices involve changing agro-technical and other practices in any of many diverse ways, in order to alter the habitat and make it less favorable for pest reproduction and survival. Effects on the pest direct or indirect, such as by favoring natural enemies or increasing plant tolerance or they can include a combination. Habitat modification can involve manipulation of such parameter as planting, harvesting times, cultivation, plant spacing, irrigation, crop rotation, trap-crops, habitat diversity, fertilizers, pruning, thinning, soil preparation and sanitation (Coaker, 1987).

The biological control is relatively permanent safe, host specific, economic and environmental friendly. The action is of parasite, parasitoid, predators and pathogens to keep pests population below EIL. Efficient natural enemies often continue to have an effect year after year with little or no assistance from man. *Trichogramma sp* gained wide spread in many countries as India, Iran, China, Canada, USA, Germany, Pakistan. Its 18 species can parasitize a wide range of insect pests, but it particularly Lepidoptera (Roy et al., 1996). They are being mass reared to control pests on sugarcane, *Saccharum arundinaceum* L.; rice, *Oryza sativa* L.; cotton, *Gossypium hirsutum* L.; apple, *Malus domestica* Borkh; soybean, *Glycine max* (L.) vegetables and different fruits etc. on about 18,00000 ha in 16 countries (Hassan, 1992). The 5 species of *Trichogramma* (Trichogrammatoidae; prasitoids) have been found to attack DBM eggs at an ecological farm where non chemical control measures as *Bacillus thurongiensis* (Bt) L. and pheromone traps have been used (Dan, 1994).

The botanical pesticides, e.g., plant extract are being advantages over synthetic chemical by now very well-documented and well-known. Most of them are safe to prepare, apply, humans, non-target organisms, beneficial insects and environment. They leave no residues, hence, cause neither contamination nor pollution. They are often cheaper and effective as the synthetics pesticides. In most cases, their bioactive compounds are fairly complex groups, thereby, making it more difficult for the pest to develop resistance. It affects the growth and development in different ways, resulting in distorted pupae, pupal death, partial emergence of adults and deformed adults. The neem, *Azadiracha indica* L. formulation will be used for controlling DBM. It also repels the adult females from laying eggs, thereby, reducing DBM population in next generation (Facknath, 1996).

The intercropping is an ancient and traditional agronomic practice, which, if utilized correctly, can contribute significantly to reduce pest problems. Several field trials have been conducted using different intercrops such as tomato, *Solanum lycopersicum* L., garlic, *Allium sativum* L., carrot *Daucus carota* (Hoffin.) and Coriander, *Coriandrum sativum* L. They were grown in alternate rows with *B. oleracea* and their influence on DBM population was estimated (Buranday and Raros, 1973; Sivapragasam et al., 1982). *Coriandrum sativum* repelled aphids, *Aphis gossypii* Glover; spider, *Parasteatoda tepidariorum* L.; mite *Lorryia formosa* (Tydeidae) and Colorado potato beetle, *Leptinotarsa decemlineata* Say in potato, *Solanum tuberosum* L. and DBM in *B. oleracea* (Dube and Chand, 1977).

The chemical control is also part of IPM. Practically all the available methods and pest control technologies have been tried at some time or another for the management of DBM. In Mauritius, development of pesticide resistance by DBM has progressed rapidly from Lannate (methomyl) to Rogor (dimethoate) to Tamaron (methamidophos) to Decis (deltamethrin) to Selecron (profenofos) to Tokuthion (prothiofos) (MANR, 1995). Keeping in mind the concern problem, the present study was carried out to compare the population trend of DBM on *B. oleracea* during applying 5 different techniques of IPM.

MATERIAL AND METHODS

The experiments were conducted against the diamond back moth (DBM), *Plutella xylostella* L. on the cauliflower, *Brassica oleracea* L. at the Agriculture Research Station (ARS), Baffa, Manshera, Pakistan to compare the effects of Integrated Pests Management (IPM) techniques.
Firstly, *B. oleracea* nursery was raised using the Cauliflower Cultivar Taxila (CCT), Taxila, Pakistan. The 4 week old seedlings were transplanted to the field already prepared for this purpose. The plant-plant and row-row distances were kept as 30 and 75 cm, respectively. The experiment was laid out in Randomize Complete Block Design (RCBD) with 5 IPM techniques and one control (no treatment) were arranged in 3 rows with different sequence in 3 replications. The size of each sub-plot was 15 m² whereas total experimental area was 270 m² (Tables 1 and 2; Saljoqi and Yu-rong, 2003).

In order to find prevalence and population trend of the DBM, number of larvae per leaf were counted and converted into %infestation/plot. Data were recorded from 6 randomly selected tagged plants, avoiding border rows. Number of DBM was counted on 3 leaves on top, middle and lower region of the selected plants. Observations were repeated at weekly intervals until to reach maturity of *B. oleracea*. Data of humidity and temperature were also recorded (Tables 1 and 2).

The experiments consisted of 5 treatments used as IPM tools with a control (T_0) for comparison. For intercropping (T_1), the coriander seeds, *Coriandrum sativum* L. were sown 20 days after transplantation of *B. oleracea* in 3 alternate rows, which played role of repellent for DBM. For chemical treatment (T_2), lorsban®, Dow AgroSciences, Karachi, Pakistan was used. For neem, *Azadirchata indica* Juss seeds extract (T_3), 2 kg of *A. indica* seeds were grinded, raped then put into 98 L of water (d-H_2O), heated up to 80 °C then 2 tea spoon of the biological reagent detergent, octylphenol ethylene oxide [$C_{14}H_{22}O(C_2H_4O)n$ (n=9-10)], Triton X-100, Sigma-Aldrich Corporation, Missouri, USA was added and kept for overnight. For *A. indica* oil (fatty acids) (T_4), was purchased from Hallar Hunain Enterprizes, Karachi, Pakistan. Preliminary test have performed to select the doses for applying by sprayer (Tables 1 and 2).

Table 1. Layout of the experimental field with respects to Integrated Pests Management (IPM) techniques for control of the diamond back moth (DBM), *Plutella xylostella* L. on the cauliflower, *Brassica oleracea* L. at Agricultural Research Station (ARS), Baffa, Manshera, Pakistan.

SNo	**Replications***	**IPM techniques applied***					
1.	1	T_1	T_2	T_3	T_4	T_5	T_0
2.	2	T_5	T_4	T_1	T_0	T_2	T_3
3.	3	T_2	T_3	T_5	T_1	T_0	T_4

*Experiment design: Randomize Complete Block Design (RCBD); Rows: 6 IPM techniques were arranged in 3 rows with different sequence in 3 replications; columns: represent 6 IPM techniques, i.e., T_0: control (no treatment); T_1: intercropping (coriander, *Coriandrum sativum* L.); T_2: chemicals control by lorsban; T_3: neem, *Azadirchata indica* Juss seeds extract; T_4: *A. indica* oil; T_5: biological control by the stingless wasp (parasitoid), *Trichogramma chilonis* Ishii; size of each sub-plot: 15 m²; total experimental area: 270 m²; observations: repeated at weekly intervals until to maturity of *B. oleracea*.

For biological control (T_5), pupae cards of the stingless wasp (parasitoid), *Trichogramma chilonis* Ishii provided by Pakistan Tobacco Company, Mansehra, Pakistan were released in experimental plots. They were stapled with leaves of *B. oleracea* and covered with sheet of cloth (6 m height) to prevent the flight of *T. chilonis* into adjacent sub-plot and interference to other treatments. For determination of parasitism%, pupae of DBM were placed on a piece of *B. oleraced* leaf upside down on a thick layer of circular disc of wet cotton inside petri dishes, which covered and secured with masking tape to avoid the escape of any emerging adults. They were placed in a still tray on working table at 25 °C. The emerged *T. chilonis* were collected with an aspirator, placed in a separate vial. They were mounted for proper identification and population count (Tables 1 and 2). The following formula was used for calculating parasitism% = No of mummies+adult parasitoids emerged×100/total No of DBM. Data were analyzed by MSTATC and Duncan's multiple range tests (Tables 1 and 2; Perveen and Hussain, 2012).

Table 2. Detail of the experiment with respects to Integrated Pests Management (IPM) techniques to control of the diamond back moth (DBM), *Plutella xylostella* L. on the cauliflower, *Brassica oleracea* L. at Agricultural Research Station (ARS), Baffa, Manshera, Pakistan.

SNo	Treatments*	Acronyms	Biological/chemicals used	Conc/No*	Dose /plot*	No of application*
1.	Control	T_0		-	-	no treatment
2.	Intercropping	T_1	coriander, *Coriandrum sativum* L.	½ kg	-	once
3.	Chemicals	T_2	lorsban	2%	16 ml/8 L of d-H_2O	3 times
4.	Neem seeds extract	T_3	*Azadirchata indica* Juss	2%	16 ml/8 L of d-H_2O	3 times
5.	Naeem oil	T_4	*A. indica*	2%	16 ml/8 L of d-H_2O	3 times
6.	Biological control	T_5	stingless wasp, *Trichogramma chilonis* Ishii	100 pupae/card	-	3 times

*Experiment design: randomize complete block design (RCBD); Rows: 6 IPM techniques were arranged in 3 rows with different sequence in 3 replications; columns: represent 6 IPM techniques; Acronyms: abbreviation used for convenience of techniques; Conc/No: concentration of solution/numbers; size of each sub-plot: 15 m²; total experimental area: 270 m²; observations: repeated at weekly intervals until to reach maturity of *B. oleracea*.

RESULTS

The population density of DBM correlated with surrounding temperature, i.e., it gradually increased with increased of temperature. The population density was 1.5±0.2 larvae/plant (n=6) at 21 °C after 1st week. It was recoded as 11.5±0.1 larvae/plant (n=6) at 29 °C after 3rd week. When temperature reached at the maximum 35 °C after 4th week, population increased about 3-fold (31.0±0.2) larvae/plant (n=6). There was no or little effect of humidity on population density (Table 3).

Table 3. Effects of temperature and humidity on population density of the diamond back moth (DBM), *Plutella xylostella* L. in the cauliflower, *Brassica oleracea* L. at Agricultural Research Station (ARS), Baffa, Manshera, Pakistan.

SNo	week	n*	Humidity* (M±SD)%	Temperature* (M±SD) °C	DBM larvae/plant (M±SD)*
1.	1st	6	67.5±12.0	21.0 ± 1.6^{a}	1.5 ± 0.2^{a}
2.	2nd	6	67.0±12.7	23.0 ± 1.4^{b}	5.2 ± 0.3^{b}
3.	3rd	6	75.5±6.4	29.0 ± 8.5^{c}	11.5 ± 0.1^{c}
4.	4th	6	77.0±7.1	35.0 ± 1.4^{c}	31.0 ± 0.2^{d}

*n: no of plant observed; (M±SD)%: mean humidity percentage of observing day ± standard deviation; (M±SD) °C: mean temperature of observing day in centigrade ± standard deviation; data were analyzed by Duncan's multiple range tests in MSTATC at p<0.05 level; values with different superscript letters show significantly different at 5% level.

For biological control, the parasitism% of *T. chilonis* for DBM were observed on *B. oleracea* during the period of 8 weeks and 6 plants per week. There was no activity until 2nd week and very few parasitoid in 3rd week, i.e., only 2%. The highest parasitism 47% was during 7th week followed by 30% parasitism was found at the end of 6th week. It was 5% at the end of 8th week of observation (Figure 1).

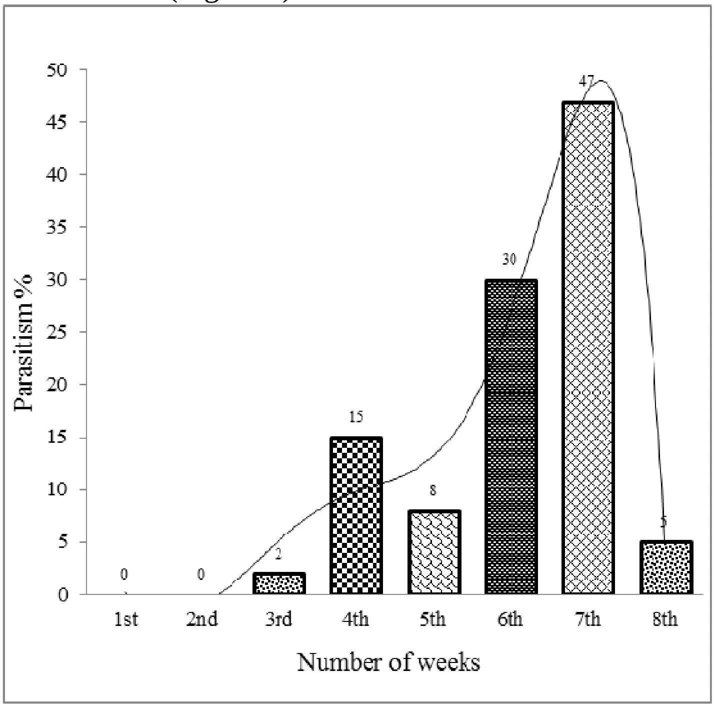

Figure 1 Parasitism% of the stingless wasp (parasitoid), *Trichogramma chilonis* Ishii on the diamond back moth (DBM), *Plutella xylostella* L. on the cauliflower, *Brassica oleracea* L. at Agricultural Research Station (ARS), Baffa, Manshera, Pakistan; n=8(6): experiments were conducted in consecutive 8 weeks and 6 plants were observed per week; trend line: polynomial; data were analyzed by Duncan's multiple range tests in MSTATC at p<0.05 (5%).

During the parasitization by *T. chilonis* on *B. oleracea*, DBM was 23.8±2.6, mummies and adult parasitoids were 3.1±1.4, and average parasitism% was 13.0±1.7 (Table 4).

Table 4. Parasitism% by the stingless wasp (parasitoid), *Trichogramma chilonis* Ishii on the diamond back moth (DBM), *Plutella xylostella* L. per plant of the cauliflower, *Brassica oleracea* L. at Agricultural Research Station (ARS), Baffa, Manshera, Pakistan.

SNo	Nature of DBM population	n*	No of plants/week	Number of DBM/plant (M±SD)*
1.	Population of DBM	8	6	23.8±2.6
2.	Mummies and adult parasitoids	8	6	3.1±1.4
3.	Parasitism%	8	6	13.0(%)±1.7

*n: Experiments have been conducted in number of weeks; M±SD: mean ± standard deviation;

parasitoid: *T.* chilonis; data were analyzed by Duncan's multiple range tests in MSTATC at $p<0.05$ (5%).

For control (T_0), no treatment was applied throughout the experimental period, i.e., 8 weeks duration. In 1st and 8th week of observation, the lowest and the highest population of DBM was found 35.6 and 97.1 larvae/plant, respectively. During the days of observation, the humidity and temperature were 71.5±0.7, 29.0±8.5, and 56.0±14.1, 26.0±8.5, at the same weeks, respectively. Therefore, IPM techniques can be compared with the control with respect to population density (Table 5).

For intercropping (T_1), *C. sativum* seeds were sown 20 days later than plantation of *B. oleracea*. In 8th and 5th week of observation, by intercropping, the lowest and the highest population of DBM was found 4.7 and 23.7 larvae/plant, respectively. During the days of observation, the humidity and temperature were 56.0±14.1, 26.0±8.5 and 72.5±3.52, 7.5±10.6, at the same weeks, respectively. This treatment was found no significantly effective when compared with control (Table 5).

For chemicals control (T_2), the first spray of lorsban was applied in 1st week of treatment. Which gave 3.5 larvae/plant was the lowest population density, the same was found in 8th week as well. During the days of observation, the humidity and temperature were 71.5±0.7, 29.0±8.5 and 56.0±14.1, 26.0±8.5 at the same weeks, respectively. In 5th week of observation, by lorsban, the highest population of DBM was found 16.1 larvae/plant, respectively. During the days of observation, the humidity and temperature were 72.5±3.5 and 27.5±10.6 at the same weeks, respectively. This treatment was also found significantly effective when compared when control.

For *A. indica* seeds extract (T_3), the first spray was applied in 1st week of observation but in 8th and 3th week, the lowest and the highest population of DBM was found 2.1 and 12.9 larvae/plant, respectively. During these days of observation, the humidity and temperature were 56.0±14.1, 26.0±8.5 and 69.0±1.4, 27.5±9.2, at the same weeks, respectively. This treatment was also found significantly effective when compared with control (Table 5).

For neem oil (T_4), the first spray was applied in 1st week of observation, which gave the lowest population of 6.6 larvae/plant. During the day of observation, the humidity and temperature were 71.5±0.7 and 29.0±8.5 at the same weeks, respectively. In 6th week of observation, the highest population was 24.3 larvae/plant. During the day of observation, the humidity and temperature were 71.0±15.6 and 27.5±12.0 at the same weeks, respectively. This treatment was found not significantly effective when compared with control.

For biological control (T_5), the 1st pupae card of parasitoid of was stapled in 1st week of observation, which gave the lowest population of 3.5 larvae/plant. During the day of observation, the humidity and temperature were 71.5±0.7 and 29.0±8.5 at the same weeks, respectively. In 5th week of observation, the highest population was 23.7 larvae/plant. During the day of observation, the humidity and temperature were 72.5±3.5 and 27.5±10.6 at the same weeks, respectively. This treatment was found significantly effective when compared with control (Table 5).

Table 5. Comparison of **e**ffect of different IPM techniques (T_0-T_5) on the diamond back moth (DBM), *Plutella xylostella* L. population attacked on the cauliflower, *Brassica oleracea* L. at Agricultural Research Station (ARS), Baffa, Manshera, Pakistan.

SNo	W	n	DBM population density (larvae/plant)						Humidity (M±SD)	Temp. (M±SD)
			T_0	T_1	T_2	T_3	T_4	T_5		
1.	1st	6	35.6^{ji}	4.7^{xy}	3.5^{yz}	2.6^{yz}	6.6^{wx}	4.7^{xy}	71.5±0.7	29.0±8.5
2.	2nd	6	47.4^{g}	10.6^{st}	9.8^{uv}	7.8^{vw}	13.5^{rs}	11.7^{stu}	75.5±6.4	27.0±5.7
3.	3rd	6	53.4^{f}	16.2^{pq}	14.2^{qr}	12.9^{rst}	13.1^{rs}	16.2^{pq}	69.0±1.4	27.5±9.2
4.	4th	6	65.1^{e}	19.3^{no}	6.4^{wx}	3.9^{yz}	17.8^{m}	19.3^{no}	74.0±2.8	28.0±9.9
5.	5th	6	75.9^{d}	23.7^{m}	16.1^{pq}	8.0^{vw}	17.9^{m}	23.7^{m}	72.5±3.5	27.5±10.6
6.	6th	6	84.4^{c}	20.2^{n}	11.7^{stu}	5.1^{uv}	24.3^{l}	20.2^{n}	71.0±15.6	27.5±12.0
7.	7th	6	91.0^{b}	17.4^{op}	11.1^{tu}	4.5^{uv}	23.6^{l}	17.4^{op}	77.0±4.2	24.0±4.2
8.	8th	6	97.1^{a}	6.4^{wx}	3.5^{yz}	2.1^{z}	16.0^{pq}	3.5^{wx}	56.0±14.1	26.0±8.5

[1]Experiment design: randomize complete block design (RCBD) and size of each sub-plot: 15 m²; total experimental area: 270 m²;
[2]5 IPM techniques: T_0: control (no treatment); T_1: intercropping (coriander, *Coriandrum sativum* L.); T_2: chemicals control by lorsban; T_3: neem, *Azadirchata indica* Juss seeds extract; T_4: *A. indica* oil; T_5: biological control by the stingless wasp (parasitoid), *Trichogramma chilonis* Ishii; 3 replications were set for each treatment
[3]W: duration of observation in week (1-8) until to maturity of *B. oleracea* for each treatment
[4]n: no of plant observed 6 for each treatment
[5]Temp (M±SD) °C: mean temperature of observing day in centigrade ± standard deviation; Humidity (M±SD)%: mean humidity of observing day in % ± standard deviation
[6]Data were analyzed by Duncan's multiple range tests in MSTATC; values in columns with different superscript letters shows significantly different at $p<0.05$ (5%); LSD for period of observations: 1.179; LSD for treatments (T_1-T_6): 0.769; LSD for interaction (period of observations × treatments): 2.178.

When average temperature and humidity were 27.1±1.5 and 70.8±6.5, respectively, the total effects of IPM techniques was determined. The lowest population of DBM was found by *A. indica* seeds extract, i.e., 5.9±3.6 larvae/plant and the highest was 16.6±5.8 larvae/plant by *A. indica* oil, however, the order of efficacy of IPM techniques was: *A. indica* seeds extract (T_3): 5.9±3.6 < chemical treatment (T_2): 9.5±4.7 < biological control (T_5): 14.6±6.8 < intercropping (T_1): 14.8±7.3 < *A. indica* oil (T_4): 16.6±5.8 < control (no treatment: T_0): 68.7±22.0 (Figure 2).

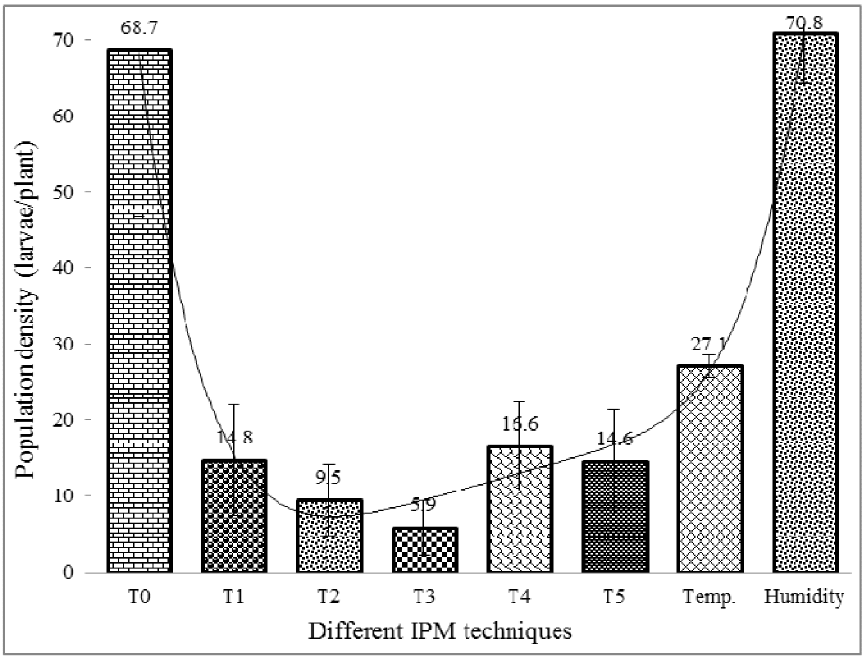

Figure 2 Comparison of effect of different IPM techniques (T_1-T_5) on the population of the diamond back moth (DBM), *Plutella xylostella* L. attacked on cauliflower, *Brassica oleracea* L. at Agricultural Research Station (ARS), Baffa, Manshera, Pakistan; experiment design: randomize complete block design (RCBD); size of each sub-plot: 15 m²; total experimental area: 270 m²; 5 IPM techniques: T_0: control (no treatment); T_1: intercropping (coriander, *Coriandrum sativum* L.); T_2: chemicals control by lorsban; T_3: neem, *Azadirchata indica* Juss seeds extract; T_4: *A. indica* oil; T_5: biological control by the stingless wasp (parasitoid), *Trichogramma chilonis* Ishii; 3 replications were set for each treatment; n=8(6): duration of observation in week (1-8) until to maturity of *B. oleracea* 6 plants observed for each treatment; Temp.: mean temperature of the day of observation (°C); Humidity: mean humidity of the day of observation (%); data were analyzed by Duncan's multiple range tests in MSTATC at $p<0.05$ (5%).; SD: vertical bars on columns indicate standard deviation; trend line: polynomial.

The highest yield of *B. oleracea* was obtained by *A. indica* seeds extract which was 29.1 tons/ha. However, the lowest yield was obtained by control, which was 2.9 tons/ha. The yields were not significantly different [5% ($p<0.05$)] firstly, when *A. indica* seeds extract and lorsban were applied, secondly, intercropping and *A. indica* oil were applied on *B. oleracea*. The order of efficacy of IPM techniques in production of *B. oleracea* was: *A. indica* seeds extract (T_3): 29.11a > chemical treatment (T_2): 28.1a > biological control (T_5): 19.55b > intercropping (T_1): 14.1c > *A. indica* oil (T_4): 9.9c > control (no treatment: T_0): 2.9d measured in tons/ha (Figure 3).

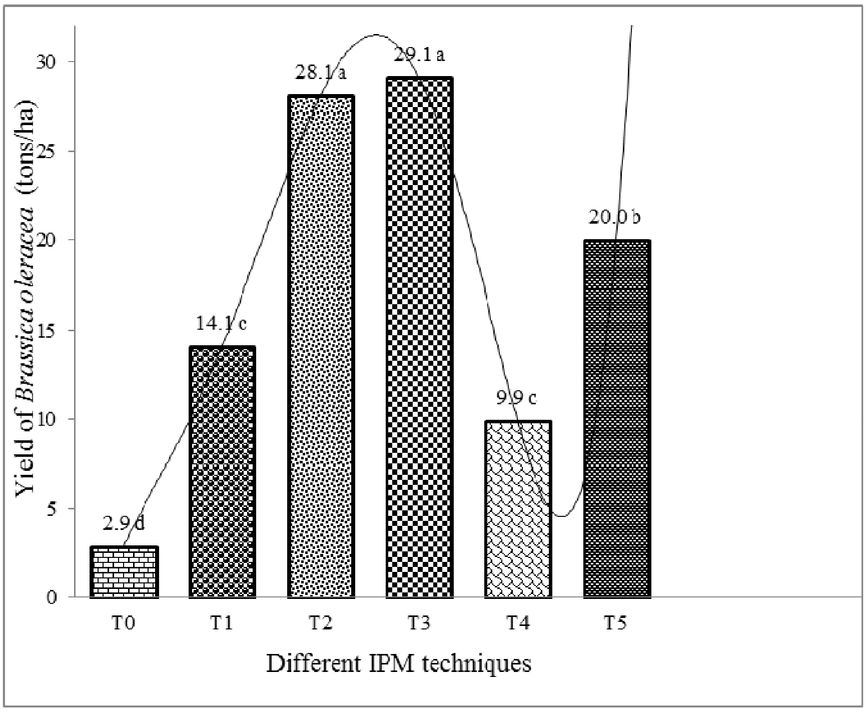

Figure 3 Effect of different treatments [used for controlling of the diamond back moth (DBM), *Plutella xylostella* L.] on yield of the cauliflower, *Brassica oleracea* L. during experimental period at Agricultural Research Station (ARS), Baffa, Manshera, Pakistan; experiment design: randomize complete block design (RCBD); size of each sub-plot: 15 m²; total experimental area: 270 m²; 5 IPM techniques: T_0: control (no treatment); T_1: intercropping (coriander, *Coriandrum sativum* L.); T_2: chemicals control by lorsban; T_3: neem, *Azadirchata indica* Juss seeds extract; T_4: *A. indica* oil; T_5: biological control by the stingless wasp (parasitoid), *Trichogramma chilonis* Ishii; 3 replications were set for each treatment; n=8(6): duration of observation in week (1-8) until to maturity of *B. oleracea* 6 plants observed for each treatment; [6]Data were analyzed by Duncan's multiple range tests in MSTATC; values in columns with different superscript letters shows significantly different at $p<0.05$ (5%); LSD for period of observations: 5.52; LSD for treatments (T_1-T_6): 0.05; CV: 17.66%; trend line: polynomial.

DISCUSSION

The diamondback (DBM), *plutella xylostella* (L.) is considered the major pest of cauliflower, *Brassica oleracea* L., which causes colossal losses, if proper controlled measured not performed. In the present research, the population density increased (31 larvae/plant) with the increase of temperature (34 °C). Singh and Jalai (1993) explained that cruciferous vegetable were grown all the year-round, which provides an easily accessible food source for DBM as well as other pests, whose population increases up to 10-30 larvae/plant along with increase of temperature 25-30 °C. By comparing both results, it is concluded that with increase of temperature 25-32 °C, population density increased upto 11-30 larvae/plant.

During the present research, the application of NES 2% (16 ml/8 L of H_2O) was found the best treatment against DBM reducing population up to 2.1 larvae/plant. Charleston et al. (2006) reported that effect of 3 different doses of botanical insecticides derived from the chinaberry tree, *Melia azedarch* L. and the neem tree. *Azadirchata indica* Juss were used against DBM had a great effect on larval stages and decreased 2-5 larvae/plant. Hanhong (2004) used products of *A. indica* extracted from leaves, seeds or other parts and reported that they were the most promising among many kind of botanical insecticides. Naqvi and Perveen (1991) that the residual effect after 4 days of treatment caused 54% mortality in the red flour beetle, *Tribolium castaneum* (Herbst.) by 11.0 µl/cm^2 of the Indian Oleander, *Nerium indicum* Mill leaves extract. Perveen and Shah (2012) reported that the reduction in *T. castaneum* fertility was 33.2±6.4, 39.7±3.7, 45.7±2.9, 58.0±4.4 and 66.3±5.1% by 7.86, 9.43, 11.01, 12.58 and 14.15 µL/cm^2 doses of *N. indicum* leaves extract. Naqvi and Perveen (1993) reported that adults of the graham bean weevil, *Callosobruchus analis* (F.) were treated with 5 different doses of methanolic extract of 3 plants viz. the apple of Sodom, *Calotropis procera* (Aiton), Karonda, *Carissa carandass* L. and *N. indicum*. Mortality in each case was checked after 24 h and LD_{50} were calculated as 14.8 µl/cm^2 for *C. procera*, 119.9 µl/cm^2 for *Ca. carandass* and 22 µl/cm^2 for *N. indicum*. Perveen et al. (2010) reported that toxicity and residual effects of yellow-berried nightshade, *Solanum surrattense* Burm. leaves extract were determined against adults of *T. castaneum*. The highest mortality 92% was observed at the maximum 11.1 µl/cm^2 after 24 h. Akbar et al. (2010a) reported that azadirachtin based neem insecticides are environment friendly. Inspite of having diverse pests control properties their use is limited due to the instability, which needs its application at short time intervals. Akbar et al. (2010b) reported that the 59.77% reduction in the aphid, *Myzus persicae* (Sulzer) population was obtained when biosal 10EC (*A. indica* formulation) was sprayed on *B. oleracea* at economic threshold level (ETL). Facknath, (1997) explained that mentioned insecticides are unique in their properties, they acts as broad spectrum repellent, insect growth regulator (caused deformities in immature stages) and pests poison. It discouraged feeding by making plants unpalatable to insects pests, therefore, suppressed the insects appetite (ant-feedant effect), it interrupted in moulting and reduced fertility. Therefore, it is conclude by comparing the present and other researches that the plant origin bio-pesticides are more effective against DBM and other insect pests.

At the present, chemical control by lorsban (2% concentration; 16 ml/8 L of H_2O) was reduced DBM population 3.5 larvae/plant of *B. oleracea*. Akbar et al, (2010b) reported that *B. oleracea* was sprayed with imidacloprid 25WP, endosulfan 35EC and profenofos 500EC when *M. persicae* population reached at ETL. All the 3 insecticides were found effective against *M. persicae*. The order of efficacy was found as imidacloprid > endosulfan > profenophos showing 90.41, 77.01, and 69.84% reduction in *M. persicae*, respectively. Mani and Krishnamoorthy (1984) reported that crops required frequent application to produce marketable heads/curds. The attempts were made to assess the effects of some insecticide on natural enemies of DBM, therefore, the safer insecticides could be recommended.

Coriandrum sativum as intercropping in the present research was not effective in controlling DBM (10 larvae/plant). Facknath (1969) reported that it was an ancient and traditional agronomic practice, which if utilized correctly, could have contributed significantly to reduce pests problem in *B. oleracea*. By comparing both results, it can be said that weather and climatic differences have affected the results.

Randhawa (1993) reported that neem oil has long been produced in Asia in an industrial scale and used in soaps, cosmetics, pharmaceuticals and pests control, therefore, in the present research, it (2%: 16 ml/8 L of H_2O) was used but it was not found significance mean of control against DBM.

Results of the present studies, on biological control (100 pupae of *T. chilonis*/1 card) of DBM on *B. oleracea* (6.36 larvae/plant) was placed on 3rd in controlling the DBM population. When the grain moth, *Sitotroga cereallela* (Olivier) and rice meal moth, *Corcyra cephalonica* (Stainton) were control by *T. chilonis*. It was found that parasitism% and adult longevity of *T. chilonis* were the highest on *S. cereallela* as compared to *C. cephalonica* eggs. It means *S. cereallela* was more affected than *C. cephalonica* (Perveen and Sultan, 2012). Maximum parasitism and adult emergence of *T. chilonis* were observed on *S. cereallela* and *C. cephalonica* at 28 °C, respectively. Maximum female longevity was 4.0 d on 2 h fresh eggs *C. cephalonica*, while minimum was 3.0 d on 24–48 h old *S. cereallela* eggs. The results showed that *T. chilonis* preferred young eggs when offered older eggs, simultaneously (Perveen et al., 2012). He et al. (2000) explained on the base of the natural population life tables of two continuous generations of DBM the control effectiveness of *T. chilonis*, *Oomyzus sokolowskii* and *Costesia plutellae* on DBM were simulated and evaluated using the state-space equation and the addition analysis method of population control. Miura (2003) studied the effectiveness of an egg parasitoid *T. chilonis* Ishii, in reducing number of DBM, he performed three experiment to observe effect of *T. chilonis* in laboratory and green house. The more parasitoid released more parasitoid occur in multiple regression analysis showed 80% parasitism. The release of 60 parasitoid are required per plant is needed. The experiments reveal reducing effect on DBM density. By comparing the results of present research with scientist cited above, it was noted that as biological control showed the best control but less than NSE and lorsban for controlling DBM population density may be due to weather and improper handling.

CONCLUSION

When temperature was increased, the DBM population density was also increased, however, humidity has no effect on it. When temperature reached at the maximum population increased about 3-folds. The actual highest DBM density was compared, obtained by application of 5 IPM techniques (n=6) in descending order as: *A. indica* seeds extract (T_3): 12.9 larvae/plant in 3rd week < chemicals control (T_2): 16.1 larvae/plant in 5th week < biological control (T_5) = intercropping (T_1): 23.7 larvae/plant in 5th week < *A. indica* oil (T_4): 24.3 larvae/plant in 6th week < control (T_0): 97.1 larvae/plant in 8th week. The results showed that *A. indica* seeds extract was the most efficient controlling IPM technique.

Recommendation

Among other IPM techniques, the *A. indica* seeds extract was found the most significant and the cheapest controlling agent for DBM, therefore, recommended for farmers' community. However, appropriate integrated IPM program can be launched to control DBM population on *B. oleracea* to obtain the highest yield.

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