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Population dynamics of natural enemies and insect pest in different *Brassica oleracea* (cabbage) growing seasons with different production systems

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Abstract
The present study was designed to investigate the abundance of insect pests and their natural enemies in different plant protection/production systems. Twenty-five day-old *B. oleracea* seedlings were transplanted in the plot of 10×15 ft area with plant-to-plant 10 inches spacing and row-to-row 2ft spacing. Five different treatments (IPM, Reduced risk pesticides, black mulch, grower standard and control) was evaluated on the population dynamics of insect pests and their natural enemies. The research was conducted under Randomized Complete Block Design (RCBD) and data regarding the population dynamics was recorded at every seven days' intervals till maturity and harvesting of the crop. Maximum population of army worm, vegetable weevil, *B. oleracea* butterfly, diamondback moth and aphid was observed on control (8.33), black mulch (5.66), control (4.66), reduced risk pesticides (3.66) and control (22.67) respectively. Minimum population was observed on IPM and black mulch. Maximum average population of yellow wasps, ants, ladybird beetle, crysopid and syrphid fly was observed on control (3.67), (4.33), (4.67), (2.00) and (3.00) respectively and minimum population was observed on IPM. Therefore, the IPM treatment seems to be more suited for the farmers to manage the insect pests of *B. oleracea* and get healthy *B. oleracea* crop.

Keywords: *B. oleracea*, population, dynamics, IPM, pesticides, production systems, natural enemies.

1. Introduction

B. oleracea (cabbage) is the most popular winter vegetables grown throughout the world [1] which contains water (93ml), protein (15g), fat (0.2g), carbohydrates (4g), fiber (0.8g), calcium (40mg), riboflavin (0.05mg) and ascorbic acid (40mg). It has also traditionally been used for its medicinal properties like anti-inflammatory property and contains chemical which can prevent cancer [2].

There are certain limiting factors for its quantitative and qualitative production and among these insect pests are of paramount importance and sometimes cause complete failure of the crop. Among insects the most notorious were diamond back moth (DMB) (*Plutella xylostella*), *B. oleracea* aphids (*Brevicoryne brassicae*) and *B. oleracea* white butterfly (*Pieris brassicae*) which cause leaf damage up to 31% [3]. The *B. oleracea* crop is also attacked by *B. oleracea* semi-looper (*Thysanoplusia orichalcea*), tobacco caterpillar (*Spodoptera litura*), *B. oleracea* leaf Webber (*Crocodolomia binotalis*) and *B. oleracea* flea beetle (*Phyllotreta cruciferae*) [4].

Major natural enemies of *B. oleracea* pests include *Crysoperla carnia* and coccinellid beetles which are predaceous, as both larvae and adults, feed chiefly on aphids [5, 6]. Polyethylene mulches increase crop growth and increase yield of many field grown vegetable crops, especially in winter as it generates particular microenvironment for the plants and attract or repel insect pest and their predators [7, 8].

The problems of injudicious use of insecticides have increased the interest in adoption of biologically based IPM systems, an essential step towards reducing risks associated with the use of highly toxic pesticides. The IPM treatments not only decreased pest populations but also improved yield to a considerable extent than the chemical control. New generation pesticides are much more selective, less disruptive and more environmentally benign and introduce new modes of action to overcome established resistance problems and also more compatible with the existing IPM programs [9, 10].

The present research work was conducted to achieve some objectives in first was to evaluate the incidence of insect pest population dynamics on *B. oleracea* in different seasons.in second objective was evaluation of the best production system against insect pests in *B. oleracea*.

Third objective was to evaluate the population of natural enemies in different *B. oleracea* growing seasons with different production systems.

2. Materials and Methods

The experiment was carried out in Entomological Research Area Young wala Department of Entomology, University of Agriculture Faisalabad first season from September to November (2014) and second season from December to March (2015). Experiment was laid out in randomized complete block design (RCBD) with three replications and five treatments. Twenty-five day-old *B. oleracea* seedlings were transplanted in the plot of 10×15ft area with plant-to-plant 10 inches or 0.83ft spacing and row-to-row 2ft spacing during mid of September and end of November. Recommended management practices except plant protection measures were adopted for raising the crop. Weekly observations were taken after one week of transplanting till maturity and harvesting of the crop.

2.1 Data collection of insect pests

The population of different insect pests on *B. oleracea* was counted to evaluate the abundance of insect pests in both sowing season. The data was taken on weekly base. Five plants were selected from each treatment and the larvae of diamond back moth, *B. oleracea* butterfly, semi lopper and other chewing insect pests will be counted. The population of aphid and other sucking insects was recorded from two leaves per plant covering three regions per leaf using one square inch template made of card board. The population of vegetable weevil was counted on the base of damaged plants per treatments

2.2 Treatments and their application

In case of integrated pest management, cultural control (complete eradication of weeds were maintained by hoeing, throughout the experiment period). In mechanical control (yellow sticky traps, light traps and pitfall traps were installed till maturity of crop). For chemical control in IPM, (new chemistry insecticides recommended for chewing or sucking insect pests were applied by knapsack sprayer whenever any of chewing or sucking insect pests reached ETL). In case of reduced risk insecticides, IGRs, recommended for chewing insects (lufenuron) and sucking insects (Buprofezin, Pyriproxyfen) were used alternatively when any of the chewing or sucking insect pests reached ETL. In case of grower standard insecticide recommended for chewing insects (lambda cayhalothrin) and sucking insect (imidacloprid) were used alternatively when any of the chewing or sucking insect pests reached ETL. In third treatment black mulch was used. In standard grower treatment lambda cayhalothrin was applied at 0.75ml/1.5 liter of water and was sprayed with hand operated sprayer. In control treatment no control measures were applied (Table 1).

2.3 Experiment 1

The number of natural enemies (predators and parasitoids) such as spiders, coccinellids, lacewing and minute pirate bug and parasitoids such as *Diaeretiella rapae, Aphidius colemani* chalcid wasps and *ichneumonid* wasps were counted. Population of natural enemies was recorded by using sweep net method and visual count. For sweep net method, about 20 strokes of sweeping was made. After each five strokes, the predators caught in the net were counted. For visual method 5 plants were randomly observed. The predators on the plants were counted. This was done for each treatment separately.

Table 1: Treatments used in Experimentation

Treatment No.	Treatment Name	Details
T1	Integrated pest management (IPM)	Yellow sticky traps Eradication of weeds Chlorpyrifos 2.5ml/1.5L Thiacloprid 1.5ml/1.5L
T2	Reduced risk pesticide	Buprofezin 2.5ml/1.5L Pyriproxyfen 2.5ml/1.5L
T3	Black mulch	Only black mulch was used
T4	Growers standard	lambda cayhalothrin1 25ml/1.5L Imidacloprid 0.75ml/1.5L
T5	Control	Control/ no control measures was applied

2.4 Experiment 2

Assessment of production system for both season to manage insect pest and their population was counted on all the treatments. The comparison was done on the bases of population of insect pests on each treatment. The treatments were also evaluated on the bases of yield in each treatment.

3. Results

After first week of nursery transplantation only army worm and vegetable weevil infestation was observed. The maximum infestation of army worm was observed in grower standard plot (1.48) and minimum was in IPM plot (1.00). Similarly, vegetable weevil infestation was high in reduced risk pesticides plot (1.85) and minimum in IPM plot (1.20). While for yellow wasps and ant's maximum population (2.33) for both was observed in grower standard plot. After second week of nursery transplantation the maximum infestation of army worm was observed in control (3.08) and minimum was in IPM plot (2.50). Similarly, vegetable weevil infestation was high in grower standard plot (2.00) and minimum in IPM plot (1.95). The maximum population of *B. oleracea* butterfly was observed in reduced risk pesticides plot (1.50) and minimum was in IPM plot (1.10). While for yellow wasps and ants' maximum population (3.00) and (3.33) was observed in control. After third week of nursery transplantation maximum infestation of army worm was observed in control (8.33) and minimum was in IPM plot (6.33). Similarly, vegetable weevil infestation was high in black mulch plot (5.67) and minimum in IPM plot (4.00). The maximum population of *B. oleracea* butterfly was observed in control (4.66) and minimum was in IPM plot (3.33). Maximum population of diamondback moth was observed in reduced risk pesticides plot (3.66) and minimum was in IPM plot (2.33) (Table 2).

Maximum population reduction in percentage after the 7 days of 1st spray in 1st season of army worm (72.67%), *B. oleracea* butterfly (62.00%), diamondback moth (69.67%), vegetable weevil (75.00%), ants (62.33%) was observed in IPM. This indicated that population reeducation parentage in IPM treatment was 10 times for army worm, *B. oleracea* butterfly, diamondback moth, 11 times for ants and 12 times for vegetable weevil higher in IPM, reduce risk pesticides, grower standard and black mulch respectively as compared to control. Maximum population reduction percentage of after 7 days of 2nd spray on 1st season army worm (68.33%) *B. oleracea* butterfly (79.33%), diamondback moth (89.00%), vegetable weevil (72.33%), yellow wasps (71.33%) and for ants () was observed in IPM. This indicated that population reeducation parentage in IPM treatment was 13 times for army worm, *B. oleracea* butterfly, 14 times for diamondback moth, 12 times for yellow wasps and 19 times for vegetable weevil higher in IPM, reduce risk pesticides, grower standard and black mulch respectively as compared to control (Table3).

After first week of second season nursery transplantation only aphid infestation was observed. Maximum infestation of aphid was observed in grower standard plot (9.33) (Table 4) and minimum population was in IPM plot (5.00). After second week maximum infestation of aphid was in control plot (22.67) and minimum in IPM plot (15.33).

Maximum population reduction percentage of aphid after 7 days of 1stsprayon 2ndseason crop was observed on IPM (72.33%) followed by reduce risk pesticides (59.00%), grower standard (50.00%), black mulch (32.33%) and control (3.00%). After 7 days of 2ndspraymaximum population reduction percentage of aphid was observed on IPM (59.00%) followed by reduce risk pesticides (34.00%), grower standard (25.00%), black mulch (12.33%) and control (3.00%). While after 7 days of 3rdspray maximum population reduction percentage of aphid was observed on IPM (83.67 %) followed by reduce risk pesticides (57.33%), grower standard (43.67%), black mulch (25.67%) and control (5.67%). This indicated that population reeducation parentage in IPM treatment was 24, 20, 16 and 10 for 1st spray, 19, 10, 8 and 4 times for 2nd spray and 14, 10, 7 and 5 time for 3rd spray was higher in IPM; reduce risk pesticides, grower standard and black mulch respectively as compared to control (Table 4).

After first week of second season crop nursery transplantation maximum population of ladybird beetle was observed in grower standard plot (2.33) and minimum was in IPM plot (0.67). Similarly, syrphid fly population was high in control plot (2.00) and minimum in IPM plot (0.33).

After second week of second season crop nursery transplantation maximum population of ladybird beetle was observed in grower standard plot (2.67) and minimum was in IPM plot (1.67). Similarly, syrphid fly population was high in control plot (3.00) and minimum in IPM plot (1.33). Maximum population of crysopid was observed in control plot (2.00) and minimum was in IPM plot (0.33) (Table 5, 6, 7).

Maximum population reduction percentage after 7 days of 1st spray in 2nd season of crysopid (68.33%), ladybird beetle (63.33%) and syrphid fly (72.33%) was observed on IPM. This indicated that population reeducation parentage in IPM treatment was 10, 6, 8 and 5 times for crysopid, 21, 10, 14 and 6 times for ladybird beetle, 24, 9, 13 and 5 times for syrphid fly higher in IPM, reduce risk pesticides, grower standard and black mulch respectively as compared to control (Table 5,6,7).

Maximum population reduction percentage after 7 days of 2ndsprayon 2ndseason of crysopid (65.33%), ladybird beetle (65.00%) and syrphid fly (69.00%) was observed on IPM. This indicated that population reeducation parentage in IPM treatment was 13, 6, 8 and 3 times for crysopid, 16, 6, 10 and 4 times for ladybird beetle, 15, 8, 11 and 4 times for syrphid fly higher in IPM, reduce risk pesticides, grower standard and black mulch respectively as compared to control (Table 5,6,7).

Maximum population reduction percentage after 7 days of 3rdsprayon 2ndseason of crysopid (71.33%), ladybird beetle (65.33%) and syrphid fly (63.00%) was observed on IPM. This indicated that population reeducation parentage in IPM treatment was 13, 6, 9 and 4 times for crysopid, 11, 7, 5 and 2 times for ladybird beetle, 9, 3, 6 and 2 times for syrphid fly higher in IPM, reduce risk pesticides, grower standard and black mulch respectively as compared to control (Table 5,7).

Table 2: Mean comparison of natural enemies and insect pest population of on 1st, 2nd and 3rdweek before spray1st season crop from September to November

	1st week					
Treatments	**Army worm**	**Vegetable weevil**	***B.oleracea* butterfly**	**Diamondback moth**	**Yellow wasps**	**Ants**
IPM	1.00±0.12^{B}	1.20±0.09^{B}			0.67±0.13^{B}	0.67±0.05^{B}
Reduced Risk Pesticides	1.45±0.06^{A}	1.85±0.15^{A}			1.67±0.05^{AB}	1.67±0.12^{AB}
Grower Standard	1.48±0.11^{A}	1.80±0.11^{A}			2.33±0.11^{A}	2.33±0.14^{A}
Black Mulch	1.13±0.17^{AB}	1.40±0.19^{AB}			1.33±0.09^{AB}	1.00±0.05^{AB}
Control	1.47±0.04^{A}	1.79±0.13^{A}			2.33±0.17^{A}	2.00±0.07^{AB}
	2nd week					
IPM	2.00±0.13^{B}	1.95± 0.12^{B}	1.10±0.12^{B}		1.67±0.04^{B}	1.33±0.11^{B}
Reduced Risk Pesticides	3.06±0.11^{A}	2.90± 0.05^{A}	1.50±0.07^{A}		3.00±0.14^{A}	3.33±0.15^{A}
Grower Standard	3.06±0.09^{A}	2.97± 0.09^{A}	1.44±0.11^{A}		2.33±0.19^{A}	3.00±0.09^{A}
Black Mulch	2.50±0.05^{AB}	2.50± 0.15^{AB}	1.25±0.08^{AB}		2.00±0.10^{AB}	2.33±0.12^{AB}
Control	3.08 ±0.16^{A}	2.92±0.06^{A}	1.46±0.15^{A}		3.00±0.12^{A}	3.33±0.14^{A}
	3rd week					
IPM	6.33±0.16^{B}	4.00± 0.07^{B}	3.33± 0.26^{B}	2.33± 0.13^{B}	2.33±0.13^{B}	2.00±0.17^{B}
Reduced Risk Pesticides	8.33±0.21^{A}	5.00± 0.13^{A}	4.33± 0.11^{A}	3.66± 0.11^{A}	3.33±0.16^{AB}	3.67±0.05^{A}
Grower Standard	8.00±0.23^{A}	5.33± 0.12^{A}	4.66± 0.08^{A}	3.33± 0.18^{A}	3.67±0.18^{A}	4.00±0.08A
Black Mulch	7.67±0.19^{AB}	5.67± 0.19^{AB}	4.00± 0.18^{AB}	3.00± 0.08^{AB}	3.00±0.11^{AB}	3.00±0.18^{AB}
Control	8.33 ±0.19^{A}	5.33± 0.14^{A}	4.66± 0.19^{A}	3.33± 0.07^{A}	3.67±0.10^{A}	4.33±0.10^{A}

Table 3: Mean comparison of population reduction percentage of natural enemies and insect pest in different treatments after 7 days of sprays1^{st} season crop from September to November

	1^{st} spray					
Treatments	**Army worm**	**Vegetable weevil**	***B. oleracea* butterfly**	**Diamondback moth**	**Yellow wasps**	**Ants**
IPM	72.67±1.07^{A}	75.00± 2.90^{A}	62.00± 3.31^{A}	69.67± 2.98^{A}	72.333 ± 1.07^{A}	66.33± 1.91^{A}
Reduced Risk Pesticides	54.00± 1.78^{B}	46.00± 0.45^{AB}	55.66± 2.42^{B}	57.67± 1.86^{AB}	50.00± 0.78^{B}	49.33± 0.57^{B}
Grower Standard	43.33± 2.43^{C}	42.66± 1.69^{B}	34.00± 5.60^{C}	50.00± 3.92^{B}	28.00± 2.08^{C}	31.00± 1.22^{C}
Black Mulch	33.00± 2.08^{D}	18.00± 0.46^{C}	21.33± 1.60^{D}	33.00± 6.86^{C}	16.33± 0.43^{CD}	12.00± 0.98^{CD}
Control	7.00 ± 1.54 ^{E}	6.01 ±2.42^{D}	6.00 ±0.72^{E}	7.00 ± 2.34^{D}	5.333± 1.54^{D}	4.667± 1.66^{D}
	2^{nd}Spray					
IPM	68.33± 1.42^{A}	72.33± 1.46 ^{A}	79.33± 1.47^{A}	89.00± 0.37 ^{A}	62.33± 1.81^{A}	71.33± 2.81^{A}
Reduced Risk Pesticides	54.33± 0.33^{B}	55.67± 1.95 ^{B}	54.67± 1.69^{B}	66.67± 0.87 ^{B}	40.00± 2.48^{B}	46.33± 2.48^{B}
Grower Standard	49.67± 1.89^{C}	44.33± 0.54 ^{C}	47.33± 0.49^{C}	50.00± 0.26 ^{C}	21.67± 0.55^{C}	30.00± 1.55^{C}
Black Mulch	26.67± 2.94^{D}	11.00± 1.99 ^{D}	26.00± 2.26^{D}	11.00± 1.28^{CD}	14.67± 0.93^{BC}	14.67± 0.93^{D}
Control	5.07 ±1.64^{E}	3.67 ± 0.43 ^{E}	6.00 ± 1.27^{E}	6.00 ± 0.98 ^{D}	5.67± 1.77^{D}	6.00± 1.77^{E}

Table 4: Mean comparison of population of aphid on 2^{nd}season crop from December to March

	Before		**After**		
Treatments	**1^{st}week**	**2^{nd}week**	**1^{st} Spray**	**2^{nd}Spray**	**3^{rd}Spray**
IPM	5.00±0.16^{C}	15.33±0.15^{C}	72.33± 1.40^{A}	59.00± 0.81^{A}	83.67 ± 1.66^{A}
Reduced Risk Pesticides	8.67±0.19^{A}	19.00±0.22^{A}	59.00± 1.38^{AB}	34.00± 0.49^{B}	57.33 ± 0.73^{B}
Grower Standard	9.33±0.21^{A}	19.67±0.19^{A}	50.00± 0.98^{B}	25.00± 0.99^{C}	43.67± 0.98^{BC}
Black Mulch	6.00±0.20^{B}	17.00±0.21^{B}	32.33± 0.65^{C}	12.33± 1.71^{D}	25.67± 1.20^{C}
Control	8.67±0.14^{A}	22.67±0.29^{A}	3.00 ± 0.76^{D}	3.00±0.59^{E}	5.67 ± 0.40^{D}

Table 5: Mean comparison of population of Lady bird beetle on 2^{nd}season crop from December to March

	Before		**After**		
Treatments	**1^{st}week**	**2^{nd}week**	**1^{st} Spray**	**2^{nd}Spray**	**3^{rd}Spray**
IPM	0.67±0.03^{C}	1.67±0.02^{B}	63.33± 2.74^{A}	65.00± 1.07^{A}	65.33± 3.31^{A}
Reduced Risk Pesticides	2.00±0.06^{A}	2.67±0.05^{A}	44.33± 2.84^{B}	39.00± 1.78^{B}	46.33± 2.42^{B}
Grower Standard	2.33±0.11^{A}	2.67±0.17^{A}	30.33±1.43^{C}	27.67± 2.08^{C}	24.33± 5.60^{C}
Black Mulch	1.33±0.07^{B}	1.67±0.11^{B}	19.33± 0.21^{D}	15.67 ± 2.43^{D}	14.67± 1.60^{BC}
Control	2.33±0.04^{A}	2.67±0.08^{A}	3.00± 1.61^{E}	4.00± 1.54^{E}	6.33±0.72^{D}

Table 6: Mean comparison of population of Syrphid on 2^{nd}season crop from December to March

	Before		**After**		
Treatments	**1^{st}week**	**2^{nd}week**	**1^{st} Spray**	**2^{nd}Spray**	**3^{rd}Spray**
IPM	0.33±0.02^{C}	1.33±0.02^{B}	72.33± 1.98^{A}	69.00± 1.64^{A}	63.00± 2.79^{A}
Reduced Risk Pesticides	1.33±0.06^{A}	2.33±0.07^{A}	41.67± 3.44^{B}	49.33± 2.98^{B}	38.00± 2.07^{B}
Grower Standard	1.67±0.04^{A}	2.67±0.11^{A}	27.33± 3.13^{C}	33.67± 0.54^{C}	21.67± 2.98^{B}
Black Mulch	1.00±0.01^{B}	1.33±0.09^{B}	15.67± 0.42^{CD}	18.67± 0.32^{D}	14.67± 1.73^{C}
Control	2.00±0.11^{A}	3.00±0.12^{A}	3.00± 3.76^{D}	4.33 ± 1.76^{E}	6.67 ± 1.95^{D}

Table 7: Mean comparison of population of Crysopid on 2^{nd}season crop from December to March

	Before		**After**		
Treatments	**1^{st}week**	**2^{nd}week**	**1^{st} Spray**	**2^{nd}Spray**	**3^{rd}Spray**
IPM		0.33±0.06^{C}	68.33± 1.07^{A}	65.33± 3.74^{A}	71.33± 2.64^{A}
Reduced Risk Pesticides		1.67±0.11^{A}	43.00± 0.08^{B}	44.00± 4.44^{B}	52.67 ± 1.29^{B}
Grower Standard		1.67±0.12^{A}	31.00± 0.78^{C}	32.33± 0.31^{BC}	36.00± 3.54^{C}
Black Mulch		1.00±0.07^{B}	14.33 ± 0.43^{BC}	18.00± 2.99^{C}	19.67± 2.42^{BC}
Control		2.00±0.04^{A}	4.67 ± 1.54^{D}	5.33± 2.54^{D}	5.66 ± 0.76^{D}

4. Discussion

The present research work was conducted to investigate seasonal population dynamics of *B. oleracea* insect pests and their natural enemies in different production/protection systems. The treatments including IPM (Yellow sticky traps, Eradication of weeds, Chlorpyrifos and Thiacloprid), reduce risk pesticides (Buprofezin and Pyriproxyfen), black mulch and grower standard (lambda cayhalothrin and Imidacloprid) was used against the insect pests of *B. oleracea.* All treatments had significant impact on infestation of aphid, *B. oleracea* butterfly, diamondback moth, vegetable weevil, army worm and their natural enemies like ladybird beetle, *crysoperla carnia*, syrphid fly yellow wasps and ants after 7 days of treatments. Among all these treatments IPM and reduce risk pesticide showed the best control against all insects infested *B. oleracea* crop.

The IPM treatments reduced pest populations and damage, resulting in a better yield than the other treatments. The use of integrated pest management was also environment friendly and low cost. The average maximum infestation per plant of army worm (6.33), *B. oleracea* butterfly (3.33), diamondback moth (2.33), vegetable weevil (4.00) and aphid (15.33) was observed in IPM treated plot which was in accordance with the findings of Hanchinal [11] and Gahukar [12]. The incorporation of these two insecticides (Chlorpyrifos and Thiacloprid) in IPM is evidenced in the previous work done against different insect pests of *B. oleracea* [13, 14, 15, 16, 17, 18]. The results indicated that IPM was found to be most effective for *B. oleracea* production/protection as observed by Musser [19] who found IPM practices best for the management of *B. oleracea* insect pests. The minimum average population was observed at the early stage of crop. The population also reduced by the feeding of these natural enemies.

In the plot treated with black mulch, the average maximum infestation of vegetable weevil per plant (5.67), was high. It was because of the shelter provided by black mulch. Thus, vegetable weevil was protected from natural enemies and other environment factors. These type of results was also obtained by Newman [20] and Kavallieratos [21] and reported that population of vegetable weevil was high because it attacks at night or evening and black mulch provide shelter during day time. The average minimum infestation was observed at early stage of crop. The average maximum infestation of other insect pest army worm (7.67) followed by *B. oleracea* butterfly (4.00), diamondback moth (3.00) and aphid (17) was low which may be due to the absence of host plants and other weeds. Because the host plants and weed flowers act as a source of food and shelter for different insect pests. These observations were also confirmed in previous study [22]. Maximum population reduction percentage of army worm (33%), *B. oleracea* butterfly (26%), diamondback moth (33%), vegetable weevil (18%) which was low than the other treatments. The yield was also good over control. Black mulch also increases the soil temperature and increase the growth of crop especially in winter [23, 24].

Reduced risk pesticides replacing the conventional toxic chemical because their reduced toxicity to environment and other non-target organisms. Maximum average infestation of aphid (19.00) followed by army worm (8.33), *B. oleracea* butterfly (4.33) diamondback moth (3.66) and vegetable weevil (5.00) was observed in reduce risk pesticide plot which may be due to the emergence of host plants and weed. The flowers act as attractant for the insect pest. Reduce risk pesticides showed better results after IPM. Maximum population reduction percentage of aphid (59.00%), army worm (54.33%), *B. oleracea* butterfly (55.66%), diamondback moth (66.67%) and vegetable weevil (55.67%) was observed when control measures was applied by using Pyriproxyfen, Lufenuron and Buprofezin at ETL. The incorporation of these insecticides (Pyriproxyfen, Lufenuron and Buprofezin) in reduce risk pesticides is evidenced in the previous work done against different insect pests of *B. oleracea* [25, 26, 27, 28, 29]. In current experimentation, it was observed that reduced risk pesticide was less toxic to natural enemies which may be due to their target specific mode of action. It is evidenced in the previous work done [30, 31, 32].

During the observation of natural enemies' population dynamics, maximum average population of ants (3.67) was observed on 3rd week followed by yellow wasps (3.33), ladybird beetle (2.67), syrphid fly (2.33) and crysopids (1.67). Maximum population reduction percentage crysopids (36.00%) followed by syrphid fly (33.67%), yellow wasps (31.00%), ladybird beetle (30.3) and ants (28.00%) was observed.

Grower standard treatment reduces the pest population but the insecticides used were conventional. The pesticides used were Imidacloprid and Lambda cayhalothrin. These are toxic to environment and cause health hazards to human health [32]. Maximum average infestation of *B. oleracea* butterfly (4.66) followed by army worm (8.00), vegetable weevil (5.33), aphid (19.67) and diamondback (3.33) was observed. Maximum population reduction percentage of aphid (50.00%) followed by army worm (49.67%), *B. oleracea* butterfly (47.33%), diamondback moth (50%) and vegetable weevil (44.33%) was observed in grower standard plot by using conventional pesticides i.e., Imidacloprid and Lambda cayhalothrin. These observations were also confirmed in previous studies [34]. The minimum average natural enemies' population per plant was observed at the beginning of crop. The maximum average natural enemies' population was observed on 3rd week after transplantation and found population of ants (4.00) followed by yellow wasps (3.67), ladybird beetle (2.67), syrphid fly (2.67) and crysopids (1.67). Maximum population reduction percentage of crysopids (52.7%) followed by syrphid fly (49.33%), ants (49.33%), and ladybird beetle (49.33%) was observed.

In conclusion Farmer should avoid using these pesticides due to their high toxicity, maximum residues in the crop and development of resistance. The pesticides used in IPM were not target specific and these were harmful to natural enemies. While the reduce risk pesticides was target specific and less harmful to natural enemies. So the use of reduce risk pesticides in IPM program increase the population of natural enemies which is helpful to manage insect pests.

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