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Evaluation of biopesticides against major insect pests on mustard (*Brassica juncea* L.)

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Abstract
Investigations on seasonal incidence of major insect-pests on mustard (*Brassica juncea* L.) "(*Brassica juncea* L.)" were conducted at research farm of Department of Entomology, V.N.M.K.V., Parbhani during Rabi 2022-23. The treatment Thiamethoxam 25%WG showed to be best control over mustard aphids which was statistically at par with Gir Sawaj *Lecanicillium lecanii*1.15% WP, 60 g and *Beauveria bassiana* 40 g., for mustard sawfly Thiamethoxam 25%WG also showed to be best control over mustard sawfly which was statistically at par with *Beauveria bassiana* 40 g, and Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 60 g. Thiamethoxam 25% WG treated plots yielded higher (16 q h^{-1}) Gir Sawaj *Lecanicillium lecanii* 1.15% WP0.0035% treated plots yielded (14.9 qh^{-1}), *Beauveria bassiana* (14.5 q h^{-1}), Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 0.09% (14 q ha^{-1}), Azadirachtin 1500 ppm (13.8q ha^{-1}), *Lecanicillium lecanii* 1.15% WP (Market produce) (13q ha^{-1}), Gir Sawaj *Lecanicillium lecanii* 1.15%WP, 0.0035% (12.7 q ha^{-1}), *Metarhizium anisopliae* (12.5 q ha^{-1}),) and the untreated control was recorded (6.6 q ha^{-1}) yield. When considering the economics of treatments, Thiamethoxam 25%WG (1:12.6) was recorded highest cost benefit ratio which was followed by *Beauveria bassiana* (1:10.8).

Keywords: *Brassica juncea,* sawfly, biopesticides, insecticides

Introduction

Indian mustard (*Brassica juncea* L.) belongs to the family Brassicaceae or Cruciferae originated from Asia or Egypt. Various varieties of mustard and rapeseed are cultivated around the nation. Mohori (Marathi) is a commonly produced oilseed crop in India, also known as Rai or Sarson in Hindi. With a volume of 68.87 million tonnes, mustard is the second-largest oilseed in the world and has grown to be a significant component of the Indian economy, ranking second in terms of acreage after peanuts (Anonymous, 2021) [2]. India made up 13.14 percent of global production with a total area of 6.23 m ha, an output of 8.57 MT, and a productivity of 14.99 q ha^{-1}. Rajasthan contributes 38.07 percent of the country's land and 43.69 percent of its production. Rajasthan, Haryana, Uttar Pradesh, Madhya Pradesh, Gujarat, Assam, West Bengal, Punjab, and Maharashtra are the primary mustard and rapeseed producing states in India (Anonymous, 2019) [1]. About 43 insect species have been recorded infesting this crop (Khan *et al*., 2013) and among these aphids (*Lipaphis erysimi* L.), saw fly (*Athalia lugens proxima* L.), painted bug (*Bagrada cruciferarum* L.), leaf miner (*Chromatomyia horticola* L.), flea beetle (*Phyllotreta Cruciferae* L.), cabbage webber and pod borer (*Crocidolomia binotalis* L.) and cabbage butterfly (*Pieris brassicae* L.) are the important insect pests. Besides, insect pests like Bihar hairy caterpillar, *Spilosoma obliqua* L. Walker (Lepidoptera: Arctiidae), Cabbage head borer: *Hellula undalis* L. Fabricius (Lepidoptera: Crambidae) and Diamondback moth: *Plutella xylostella* L. (Lepidoptera: Plutellidae) also infest the crop sporadically. Recently tobacco caterpillar (*Spodoptera litura* L.) has been reported as the major insect pests of mustard in different locations of Orrisa. However, with increase in cropping intensity and the changing cropping patterns under different agro climatic conditions, the pest complex of the crop has changed (Divya *et al*., 2015) [4]. To manage insect pests on mustard crops, a number of ways have been adjusted; chemical management is one of the most widely used pest control strategies. Certain drawbacks of pesticides include their detrimental effects on natural adversaries and environmental contamination.

Many undesirable side effects of older insecticides include residue issues, environmental risks, destruction of non-targeted insects such as parasites and predators as bio-control agents and honeybees as pollinators, and the growth of insecticide resistance. There is a need to adopt ecofriendly management stratergies to control insect-pests of mustard. In sustainable crop management, entomopathogenic fungi are regarded as useful bio-control agents since they are naturally occurring adversaries of a variety of pests (Deka *et al*., 2017) [3]. Entomopathogenic fungi, which are often host-specific, do not pose a significant hazard to mammals or the environment. As an additional biological control strategy against aphids in an integrated pest management (IPM) programme, *Lecanicillium lecanii* L. is advised. *Azadirachtin*, the main pesticidal ingredient in neem extracts, has the ability to repel, poison, disrupt growth, and prevent aphid feeding (Khanal *et al*., 2020) [6]. In addition to biopesticides, botanicals are better for the environment.

Materials and Methods

The present experiment was conducted evaluation of biopesticides against major insect pests on mustard. The field experiment was performed at Department of Entomology Research Farm, VNMKV, Parbhani, Maharashtra, during rabi 2022-23, Sowing was done on 01-12-2022 at research field. Variety Kranti was used for sowing. The sowing was done by dibbling method at spacing of 45 x 20 cm. the Nine treatment and three replication with RBD design used for this experiment.

Table 1: Treatment details of the experiment on effect of different biopesticides against major insect-pests on mustard

Sr. No.	Treatment	Dose/10 Lit. of water
1	Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 0.0035%	30 g
2	Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 0.07%	60 g
3	Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 0.009%	80 g
4	Azadirachtin 0.15% EC0.006% (1500 ppm)	10 ml
5	*Lecanicillium lecanii* L. 1.15% WP (Market produce)	50 g
6	*Beauveria bassiana*	40 g
7	*Metarhizium anisopliae*	40 g
8	Thiamethoxam 25% WG	1 g
9	Untreated	-

Recording of observation: 10 plants from each treatment were selected and tagged to record observations. Number of Aphids: No. of aphids were recorded on each plant at top, bottom and from 10 randomly selected plants per replicate in each plot on 0 (Pre count), 3, 5, 7 and 10 days after each application. Mustard aphid sit in an overlapping manner and hence, it is difficult to record aphid on numerical basis. Hence, aphid index was given for determining aphid population as described by Patel *et al*., (1995).

The observation on aphid index were worked out by the following formula. The avg. aphid index was analysed by using following formula,

Avg. Aphid Index = 0N+1N+2N+3N+4N+5N/Total No. of plants observed

Where, 0, 1, 2, 3, 4, 5 are the aphid index.

N= No. of plant representing aphid index.

3. Result and Discussion

Effect of different biopesticides against mustard aphid

Data presented in Table No 1, The pre-treatment data on mustard aphid population showed uniform distribution in all the treatment plots ranging from (39.60 to 40.67 aphids 10-1 cm) twig. there were no significant differences in the aphid population. At 3DAT Thiamethoxam 25%WG showed to be best control over aphids as it was observed least (16.40 aphids/10 cm twig) which was statistically at par with Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 60 g (20.43 aphids/10 cm twig.), B*eauveria bassiana* 40 g (24.80 aphids/10 cm twig) Next effective treatments were Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 80 g (28.43 aphids/10 cm twig), Azadirachtin 0.15% EC (1500 ppm) 50 g (34.13 aphids/10 cm twig), *Lecanicillium lecanii* 1.15% WP, (Market produce) 50 g (35.33 aphids/10 cm twig), *Metarhizium* (37.47 aphids/10 cm twig), Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (38.20 aphids/10 cm twig). The highest aphid population was recorded in untreated control plots in the range of 40.93 aphids/10 cm twig.

On 5th and 7 th DAT, among all treatments Thiamethoxam 25%WG (12.60 and 9.60 aphids/10 cm twig) recorded as most superior treatment which was statistically at par with Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 60 g (16.40 and 12.20 aphids/10 cm twig), Beauveria bassiana 40 g (18.20 and 15.40 aphids/10 cm twig) Next effective treatments were *Gir Sawaj Lecanicillium lecanii* 1.15% WP, 80 g (22.27 and 18.67 aphids/10 cm twig), Azadirachtin 0.15% EC (1500 ppm) 50 g (28.87 and 26.67 aphids/10 cm twig), *Lecanicillium lecanii* 1.15% WP, (Market produce) 50 g (32.67 and 31.60 aphids/10 cm twig), *Metarhizium* (35.47 and 33.80 aphids/10 cm twig), Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (36.47 and 32.27 aphids/10 cm twig). The highest aphid population was recorded in untreated control plots in the range of 42.07 and 44.13 aphids/10 cm twig. The observation recorded at 10^{th} DAT after 1st spray clearly indicated that aphid population was raised in all treated plots due to less viability of applied treatments over long duration of time with minimum counts of Thiamethoxam 25%WG (12.67 aphids/10 cm twig) to maximum counts of Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (35.33 aphids/10 cm twig).

Effect of biopesticides against mustard aphid (Lipaphis erysimi L.)

After second spray Data presented in Table No.2, reveals that, before second spray there were non significant differences between aphid populations (13.53 to 70.07 aphids/10cm twig). At 3DAT Thiamethoxam 25%WG showed to be best control over aphids as it was observed least (10.00 aphids/10 cm twig) which was statistically at par with Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 60 g (12.00 aphids/10 cm twig.), *Beauveria bassiana* 40 g (15.00 aphids/10 cm twig) Next effective treatments were Gir

Sawaj *Lecanicillium lecanii* 1.15% WP, 80 g (17.40 aphids/10 cm twig), *Azadirachtin* 0.15% EC (1500 ppm) 50 g (20.80 aphids/10 cm twig), *Lecanicillium lecanii* 1.15% WP, (Market produce) 50 g (22.67 aphids/10 cm twig), *Metarhizium* (28.20 aphids/10 cm twig), Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (32.33 aphids/10 cm twig). The highest aphid population was recorded in untreated control plots in the range of 70.07 aphids/10 cm twig. On 5th and 7 th DAT, among all treatments Thiamethoxam 25%WG (6.03 and 5.60 aphids/10 cm twig) recorded as most superior treatment which was statistically at par with Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 60 g (8.87 and 6.73 aphids/10 cm twig), *Beauveria bassiana* 40 g (8.60 and 7.23 aphids/10 cm twig) Next effective treatments were Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 80 g (15.33 and 8.33 aphids/10 cm twig), *Azadirachtin* 0.15% EC (1500 ppm) 50 g (20.21 and 11.37 aphids/10 cm twig), *Lecanicillium lecanii* 1.15% WP, (Market produce) 50 g (22.33 and 12.20 aphids/10 cm twig), Metarhizium (24.33 and 12.47 aphids/10 cm twig), Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (26.60 and 18.33 aphids/10 cm twig). The highest aphid population was recorded in untreated control plots in the range of 82.67 and 87.33 aphids/10 cm twig. The observation recorded at 10th DAT after 2nd spray clearly indicated that aphid population was decreased in all treated plots with minimum counts of Thiamethoxam 25%WG (4.67 aphids/10 cm twig) to maximum counts of Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (16.67 aphids/10 cm twig). Ghadage (2012) reported that Verticillium lecanii (Zimm.) Viegas @1.0 kg/ha + imidacloprid 0.0025 percent, *Beauveria bassiana* (Bals.) Vuill @ 1.25 kg/ha + imidacloprid 0.0025 percent, V. lecanii 1.0 kg/ha + acetamiprid 0.002 percent and B. bassiana 1.25 kg/ha + acetamiprid 0.002 percent were found reasonably viable against mustard aphid, respectively. Sajid and Zia (2017) [7] documented that M. anisopliae was observed to be the most successful biopesticide towards mustard aphid, accompanied by *B. bassiana and B. thuringiensis*. Sharma *et al*., (2017) [8] reported that dimethoate was observed as being the most successful in lowering the aphid population (95.33%), led by V. lecanii @ 108 CS/ml + NSKE @ 5% (88.52%), NSKE @ 5% + Clipping of infested twigs (87.77%), and B. bassiana @ 108 CS/ml + NSKE @ 5% (86.91%).

Table 2: Effect of biopesticides against mustard aphid (*Lipaphis erysimi* L.) First spray and Second spray

Tr. No.	Treatment	Dose g/10 L	PTC Spray	No. of aphids/10cm.central twig for First spray				No. of aphids/10cm.central twig for Second spray				
				3rd	5th	7th	10th	PTC Spray	3rd	5th	7th	10th
T_1	Gir Sawaj *Lecanicillium Lecanii* 1.15% WP	30 g	39.60 (6.33)	38.20 (6.22)	36.47 (6.08)	32.27 (5.76)	35.33 (5.94)	35.40 (5.99)	32.33 (5.73)	26.60 (5.21)	18.33 (4.34)	16.67 (4.14)
T_2	Gir Sawaj *Lecanicillium lecanii*1.15% WP	60 g	36.07 (6.05)	20.43 (4.58)	16.40 (4.11)	12.20 (3.56)	13.33 (3.72)	13.53 (3.75)	12.00 (3.54)	8.87 (3.04)	6.73 (2.63)	6.67 (2.65)
T_3	Gir Sawaj *Lecanicillium Lecanii* 1.15% WP	80 g	39.80 (6.35)	28.43 (5.38)	22.27 (4.77)	18.67 (4.34)	20.00 (4.52)	20.27 (4.56)	17.40 (4.23)	15.33 (3.98)	8.33 (2.97)	7.33 (2.79)
T_4	Azadirachtin 0.15% EC (1500ppm)	2.5 ml	39.20 (6.30)	34.13 (5.88)	28.87 (5.39)	26.67 (5.21)	28.00 (5.33)	28.60 (5.39)	20.80 (4.61)	20.21 (4.55)	11.37 (3.43)	11.33 (3.44)
T_5	*Lecanicillium lecanii* 1.15% WP (Market produce)	50 g	37.17 (6.13)	35.33 (5.98)	32.67 (5.69)	31.60 (5.66)	32.00 (5.70)	34.00 (5.87)	22.67 (4.64)	22.33 (4.78)	12.20 (3.56)	12.00 (3.54)
T_6	*Beauveria bassiana*	40 g	38.43 (6.24)	24.80 (3.75)	18.20 (4.32)	15.40 (3.87)	17.33 (4.22)	17.60 (4.25)	15.00 (3.94)	8.60 (2.95)	7.23 (2.77)	6.27 (2.60)
T_7	*Metarhizium anisopliae*	40 g	39.60 (6.33)	37.47 (6.16)	35.47 (5.99)	33.80 (5.86)	34.67 (5.93)	35.33 (5.98)	28.20 (5.36)	24.33 (4.98)	12.47 (3.59)	12.00 (3.50)
T_8	Thiamethoxam 25% WG	1 g	40.00 (6.36)	16.40 (3.94)	12.60 (3.54)	9.60 (3.10)	12.67 (3.63)	14.07 (3.79)	10.00 (3.24)	6.03 (2.48)	5.60 (2.45)	4.67 (2.26)
T_9	Untreated control	-	40.67 (6.29)	40.93 (6.44)	42.07 (6.52)	44.13 (6.68)	44.67 (6.66)	70.07 (8.39)	76.00 (5.36)	82.67 (9.12)	87.33 (9.37)	56.67 (7.56)
CD5%			0.92	0.87	0.93	0.80	0.86	0.50	0.98	0.70	0.55	0.52
CV			8.56	9.42	10.52	9.51	9.79	5.43	11.58	8.91	8.20	8.37

*(Figures in parentheses are $\sqrt{x+0.5}$ transformed values) PTC-Pre-Treatment Count

Table 3: Effect of biopesticides against mustard sawfly (*Athalia proxima lugens* L.) after first spray and second spray

Tr. No.	Treatment	Doseg/10 L	PTC Spray	No.of sawfly larvae/plant for first spray				PTC Spray	No.of sawfly larvae/plant for second spray			
				3rd	5th	7th	10th		3rd	5th	7th	10th
T_1	Gir Sawaj *Lecanicillium lecanii* 1.15% WP	30 g	3.00 (1.87)	2.93 (1.82)	2.83 (1.83)	2.60 (1.76)	2.67 (1.78)	3.73 (2.05)	3.67 (2.04)	2.40 (1.70)	2.33 (1.68)	2.07 (1.60)
T_2	Gir Sawaj *Lecanicillium lecanii* 1.15% WP	60 g	2.60 (1.76)	2.07 (1.60)	2.00 (1.58)	1.33 (1.29)	1.87 (1.54)	2.60 (1.76)	2.40 (1.70)	1.40 (1.38)	1.33 (1.34)	1.27 (1.33)
T_3	Gir Sawaj *Lecanicillium lecanii* 1.15% WP	80 g	2.80 (1.81)	2.60 (1.76)	2.53 (1.74)	2.00 (1.58)	2.13 (1.62)	3.27 (1.94)	3.00 (1.86)	2.13 (1.62)	2.07 (1.59)	1.87 (1.54)
T_4	Azadirachtin 0.15% EC (1500 ppm)	2.5 ml	2.87 (1.83)	2.67 (1.78)	2.60 (1.76)	2.03 (1.59)	2.20 (1.64)	3.53 (2.00)	3.47 (1.99)	2.20 (1.64)	2.00 (1.58)	1.67 (1.47)
T_5	*Lecanicillium lecanii* 1.15% WP (Market produce)	50 g	2.93 (1.85)	2.73 (1.80)	2.67 (1.78)	2.10 (1.61)	2.33 (1.68)	3.60 (2.02)	3.53 (2.00)	2.27 (1.66)	2.20 (1.64)	1.80 (1.52)
T_6	*Beauveriabassiana*	40 g	2.80 (1.82)	2.00 (1.58)	1.80 (1.52)	1.33 (1.35)	1.40 (1.38)	2.40 (1.70)	2.20 (1.64)	1.37 (1.36)	1.20 (1.25)	1.07 (1.25)

T_7	*Metarhiziumanisopliae*	40 g	2.93 (1.85)	2.87 (1.83)	2.73 (1.80)	2.40 (1.70)	2.53 (1.74)	3.67 (2.04)	3.60 (2.02)	2.33 (1.68)	2.27 (1.66)	2.00 (1.58)
T_8	Thiamethoxam 25% WG	1 g	2.60 (1.76)	1.33 (1.29)	1.07 (1.20)	0.67 (1.00)	1.33 (1.29)	2.20 (1.64)	2.00 (1.58)	1.33 (1.29)	1.03 (1.24)	1.00 (1.22)
T_9	Untreated control	-	3.07 (1.89)	3.60 (2.02)	4.27 (2.14)	4.33 (2.18)	4.67 (2.26)	4.73 (2.28)	5.27 (2.4)	7.47 (2.82)	7.60 (2.81)	7.47 (2.82)
CD5%			0.11	0.37	0.34	0.34	0.34	0.26	0.26	0.32	0.33	0.24
CV			3.56	12.57	11.71	12.62	11.84	8.02	7.99	11.03	11.62	8.76

*(Figures in parentheses are $\sqrt{x+0.5}$ transformed values) PTC-Pre-Treatment Count

Effect of biopesticides against mustard sawfly (*Athalia proxima lugens* L.)

After first spray The data on number of sawfly larvae/plant presented in Table No.3, The pre-treatment data on mustard sawfly larval population showed uniform distribution in all the treatment plots ranging from 2.60 to 3.07 larvae/plant. At 3DAT Thiamethoxam 25%WG showed to be best control over mustard sawfly as it was observed least (1.33 larvae/plant) which was statistically at par with *Beauveria bassiana* 40 g (2.00 larvae/plant), Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 60 g (2.07 larvae/plant. Next effective treatments were Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 80 g (2.60 larvae/plant), *Azadirachtin* 0.15% EC (1500 ppm) 50 g (2.67 larvae/plant), *Lecanicillium lecanii* 1.15% WP, (Market produce) 50 g (2.73 larvae/plant), *Metarhizium* (2.87 larvae/plant), Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (2.93 larvae/plant). The highest aphid population was recorded in untreated control plots in the range of 3.60 larvae/plant.

On 5th and 7 th DAT, among all treatments Thiamethoxam 25%WG (1.07 and 0.67 larvae/plant) recorded as most superior treatment which was statistically at par with *Beauveria bassiana* 40 g(1.80 and 1.33 larvae/plant) and Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 60 g (2.00 and 1.33 larvae/plant), Next effective treatments were Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 80 g (2.53 and 2.00 larvae/plant), *Azadirachtin* 0.15% EC (1500 ppm) 50 g (2.60 and 2.03 larvae/plant), *Lecanicillium lecanii* 1.15% WP, (Market produce) 50 g (2.67 and 2.10 larvae/plant), *Metarhizium* (2.73 and 2.40 larvae/plant), Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (2.83 and 2.60 larvae/plant). The highest aphid population was recorded in untreated control plots in the range of 4.27 and 4.33 larvae/plant. The observation recorded at 10^{th} DAT after 1st spray clearly indicated that mustard sawfly larvae population was raised in all treated plots due to less viability of applied treatments over long duration of time with minimum counts of Thiamethoxam 25%WG (1.33 larvae/plant) to maximum counts of Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (2.67 larvae/plant)

Effect of biopesticides against mustard sawfly (*Athalia proxima lugens* L.)

After second spray The data on number of sawfly larvae/plant presented in Table No.3, The pre-treatment data on mustard sawfly larval population showed uniform distribution in all the treatment plots ranging from 2.20 to 4.73 larvae/plant. At 3DAT Thiamethoxam 25%WG showed to be best control over mustard sawfly as it was observed least (2.00 larvae/plant) which was statistically at par with *Beauveria bassiana* 40 g (2.20 larvae/plant), Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 60 g (2.40 larvae/plant. Next effective treatments were Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 80 g (3.00 larvae/plant), *Azadirachtin* 0.15% EC (1500 ppm) 50 g (3.47 larvae/plant), *Lecanicillium lecanii* 1.15% WP, (Market produce) 50 g (3.53 larvae/plant), Metarhizium (3.60 larvae/plant), Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (3.67 larvae/plant). The highest aphid population was recorded in untreated control plots in the range of 4.73 larvae/plant. On 5th and 7 th DAT, among all treatments Thiamethoxam 25%WG (1.33 and 1.03 larvae/plant) recorded as most superior treatment which was statistically at par with *Beauveria bassiana* 40 g (1.37 and 1.20 larvae/plant) and Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 60 g (1.40 and 1.33 larvae/plant), Next effective treatments were Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 80 g (2.13 and 2.07 larvae/plant), *Azadirachtin* 0.15% EC (1500 ppm) 50 g (2.20 and 2.00 larvae/plant), *Lecanicillium lecanii* 1.15% WP, (Market produce) 50 g (2.27 and 2.20 larvae/plant), *Metarhizium* (2.33 and 2.27 larvae/plant), Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (2.40 and 2.33 larvae/plant). The highest aphid population was recorded in untreated control plots in the range of 7.47 and 7.60 larvae/plant.The observation recorded at 10th DAT after 2nd spray clearly indicated that mustard sawfly larvae population was decreased in all treated plots with minimum counts of Thiamethoxam 25%WG (1.00 larvae/plant) to maximum counts of Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g (2.07 larvae/plant). Lipsa Dash and A. Konar (2019) concluded that after the first round spray it was found that the highest (94.68%) mortality was observed in the plots treated with Dimethoate 30% EC followed by Thiamethoxam 25%WG (84.45%), Chloropyriphos 20%EC @ 600ml/ha (77.81%), Chloropyriphos 20%EC @ 500ml/ha (68.04%), Chloropyriphos 20%EC @ 500ml/ha, market sample (60.36%) and Chloropyriphos 20%EC @ 400ml/ha (55.97%) over control. However, after the second round spray with the same treatments, it was observed that Dimethoate 30% EC showed highest (80.04%) mortality followed by Thiamethoxam 25%WG (68.39%), Chloropyriphos 20%EC @600ml/ha 62.93%), Chloroyriphos 20%EC @ 500ml/ha (53.76%), Chloropyriphos 20%EC @ 500ml/ha market sample (45.96%) and Chloropyriphos 20%EC @ 400ml/ha (44.18%) over the control. Vinyas *et al*., (2022) concluded that average larval population depicted that *Beauveria bassiana* had the better control (0.44 larvae/plant), followed by *Lecanicillium lecanii* (0.59 larvae/plant), *Azadirachtin* 10000 ppm (0.61 larvae/plant). These finding are in conformity with the current research.

Effects of different biopesticides on yield of mustard

The data on effect of different biopesticides application on yield of mustard are presented in the table 4, All the treatments were observed higher yield over untreated control plots. The yield due to different applications were ranged from (12.5 to 16 q ha^{-1}). The superior yield was recorded from Thiamethoxam 25%WG applied plots (16 q ha^{-1}),followed by Gir Sawaj *Lecanicillium lecanii*

1.15%WP,0.07% (14.9 q ha^{-1}), *Beauveria bassiana* (14.5q ha^{-1}) Gir Sawaj *Lecanicillium lecanii* 1.15%WP,0.09% (14 q ha^{-1}),Azadirachtin 1500 ppm (13.8 q ha^{-1}), *Lecanicillium lecanii* 1.15% WP(Market produce) (13 q ha^{-1}), Gir Sawaj *Lecanicillium lecanii* 1.15%WP,0.0035% (12.7 q ha^{-1}), *Metarhizium anisopliae*(12.5 q ha^{-1}),) and the untreated control was recorded (6.6 q ha^{-1}) yield. Sharma *et al.*, (2017) [8], treatment dimethoate 30EC provided the highest seed output (1702 kg/ha), followed by *B. bassiana* @ 108 CS/ml + NSKE @ 5% (1617 kg/ha), *V. lecanii* @ 108 CS/ml + NSKE @ 5% (1635 kg/ha), and NSKE @ 5% + Clipping of infested twigs (1626 kg/ha). Singh *et al.*, (2020) [9], Azadirachtin supported by Lecanicillium leccani was the next most effective treatment after Dimethoate since it had the biggest benefit (1:37.6) in comparison to the other medications. Considering the yield and economics of these biopesticides are the one of the cost effective alternatives to the chemical insecticides. Therefore, were commend theuse of biopesticides as an ecofriendly and economically viable alternative for the management of mustard aphid, *Lipaphis erysimi* in mustard

Table 4: Effects and economics of different biopesticides on management of major insect-pests on mustard (*Brassica juncea* L.)

Tr. No.	Treatments	Dose (q/ha)	Yield (q/ha)	Increase in yield over control (q/ha)	Value of additional yield (Rs/ha)	Total cost of treatment application	Net profit (Rs/ha)	ICBR	Rank
T_1	Gir Sawaj *Lecanicillium lecanii* 1.15% WP 0.0035%	1.5 kg	12.7	6.1	26840	2885	23955	1:8.30	III
T_2	Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 0.07%	3 kg	14.9	8.3	26520	3635	22885	1:6.29	VIII
T_3	Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 0.009%	4 kg	14	7.4	32560	4135	28425	1:6.87	VII
T_4	Azadirachtin 0.15 % EC0.006% (1500ppm)	500 ml	13.8	7.2	31680	3531	28149	1:7.97	VI
T_5	*Lecanicillium lecanii* 1.15% WP (Market produce)	2.5 kg	13	6.4	28160	3135	25025	1:7.98	V
T_6	*Beauveriabassiana*	2 kg	14.5	7.9	34760	2935	31885	1:10.8	II
T_7	*Metarhizium anisopliae*	2 kg	12.5	6.2	27280	2935	24345	1:8.29	IV
T_8	Thiamethoxam 25% WG	100 g	16	9.4	41360	3035	38325	1:12.6	I
T_9	Control	-	6.6	-	-	-	-	-	-

Rates

Gir Sawaj *Lecanicillium lecanii*: 250Rs/kg	Azadirachtin 1500 ppm: 349Rs/250 ml	*Lecanicillium lecanii*: 200Rs/kg (Marketproduce)
Beauveriabassiana: 200Rs/kg	*Metarhizium anisopliae*: 200 Rs/kg	Thiamethoxam: 450Rs/100gm
Labour Charges: 347Rs	Spraying Charges: 200 Rs	Marketable price of mustard:4400 Rs

Summary and conclusions

Thiamethoxam 25%WG showed to be best control over mustard aphids which was statistically at par with Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 60 g and *Beauveria bassiana* 40 g., Next effective treatments were Gir Sawaj *Lecanicillium lecanii* 1.15% WP,80 g, Azadirachtin 0.15% EC (1500 ppm) 50 g, *Lecanicillium lecanii* 1.15% WP, (Market produce) 50 g *Metarhizium anisopliae*, Gir Sawaj *Lecanicillium lecanii* 1.15% WP, 30 g. Thiamethoxam 25% WG also showed to be best control over mustard sawfly which was statistically at par with *Beauveria bassiana* 40 g. All the treatments were observed higher yield over untreated control plots. The yield due to different applications were ranged from (12.5 to 16 q ha^{-1}). The superior yield was recorded from Thiamethoxam 25% WG applied plots (16 q ha^{-1}), followed by Gir Sawaj *Lecanicillium lecanii* 1.15% WP.

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