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Effectiveness of biopesticides against oat aphid, *Rhopalosiphum padi* L.

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Abstract

The present experiment was carried out on efficacy of microbial and botanical pesticides against aphid (*Rhopalosiphum padi* L.) and conducted during *Rabi* season of 2019-20 on Oat crop at the field of All India Coordinated Research Project on Forage Crops and Utilization at MPKV, Rahuri Dist-Ahmednagar, Maharashtra. Oats crops are heavily attacked by aphid. Three entomopathogenic fungi were tested for their efficacy at different concentrations and compared with neem based biopesticide, with a view to find out most effective treatment (s) against oat aphid. Among the biopesticide and their different concentration the treatment of *Lecanicillium lecanii* fb *L. lecanii* 2×10^8 cfu/gm @5gm/lit gave effective aphid control. Whereas *L. lecanii* fb *M. anisopliae* 2×10^8 cfu/gm @5gm/lit and *M. anisopliae* fb *M. anisopliae* 2×10^8 cfu/gm @5gm/lit next proved to be effective in controlling aphids.

Keywords: Oat, aphid, *Rhopalosiphum padi*, biopesticides

Introduction

Oat (*Avena sativa* L.) belongs to gramineae family is one of the important cosmopolitan forage crops in the world agriculture ecosystem. Oat ranks sixth in the world cereal production following wheat, maize, rice, barley and sorghum. Oat is multipurpose cereal used primarily for animal feed, human food and industrial purpose. It is cultivated all over the world and major producing countries are Russia, Canada, Poland and USA. The average annual production is around 23 million tonnes per year. Oat is most important winter cereal fodder crop grown in North as well as Central India and is now extending to eastern region. It has excellent growth habit, quick recovery after cutting and good quality herbage. It is palatable, succulent and nutritious forme crop. The protein quality of oat is excellent. Oat requires long and cool season for its growth; therefore, it is successfully grown in the plains and hilly areas of the country. Oat is a seasonal crop and can be sown either in autumn (for late summer harvest) or in the spring (for early autumn harvest). It is known locally as "jau". Entomopathogenic fungi are component within integrated pest management systems and have great capacity as biological control agents against insects. Hyphomycete fungi are inexpensive for mass production, easy to store and efficient over an extensive range of temperature and humidity. For the control of large number of agricultural pests entomopathogenic fungi are being developed throughout the world (Ferron, 1985) [5] and some are already available commercially for the control of various species of thrips and aphids (Goettel, 2011) [6]. Entomopathogenic fungi that attack insects are important agents for biocontrol and play vital part in promoting integrated pest management. Up till now, a variety of strains of entomopathogenic fungi such as *Lecanicillium lecanii*, *Beauveria bassiana* and *Metarrhizium anisopliae* (Devi et al., 2003) [3] have been used for the management of aphids and many other pests.

Materials and Methods

The present investigation entitled, "Population Dynamics and Non Chemical Management of Oat Aphid (*Rhopalosiphum padi* L.) on forage oat (*Avena sativa* L.)" was carried out during *Rabi* season of 2019-20 under field condition at the All India Coordinated Research Project on Forage Crops & Utilization at MPKV, Rahuri Dist-Ahmednagar, Maharashtra. Oat variety Kent was sown with recommended agronomic practices in at 25 cm spacing as line sowing in 3 x 4 m plot size with. Aphid population was counted from five leaves each from top, middle and bottom and their average was taken.

For the aphid management, a trial was laid out in the randomized block design with ten treatments, three replications and each replication has five rows. Variety "Kent" was used and three biopesticides and botanical formulations were tested. Observations on the aphid population from the selected plants were recorded before and after 5 and 7 days of spray. The crop was harvested for taking green fodder after 55-60 days of sowing and then the crop was left for re-growth and regeneration. Data thus obtained were analyzed statistically and the efficacy and green forage yield worked out. The details of experiment are given below.

Table 1: Experimental details

1	Design	Randomized block design
2	Replications	3
3	Treatments	10
4	Plot size	Gross-3.40 X 4.40 m ² (net - 3.0 X 4.0 m ²)
5	Variety	Kent
6	Seed rate	100 kg /ha
7	Fertilizer	100:50:40 Kg NPK /ha
8	Sowing date	5 th December, 2019
9	Method of sowing	Line sowing (spacing 22.5 cm Row to Row)

Table 2: Treatments details: Sequential spray 10 days after 1st spray

1 st treatment				2 nd treatment 10 days after 1 st spray			
SN	Treatments	Dose		SN	Treatments	Dose	
1	<i>Lecanicillium lecanii</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	fb	1	<i>Lecanicillium lecanii</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	
2	<i>Metarrhizium anisopliae</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	fb	2	<i>Metarrhizium anisopliae</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	
3	<i>Beauveria bassiana</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	fb	3	<i>Beauveria bassiana</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	
4	<i>Lecanicillium lecanii</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	fb	4	<i>Metarrhizium anisopliae</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	
5	<i>Metarrhizium anisopliae</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	fb	5	<i>Beauveria bassiana</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	
6	<i>Lecanicillium lecanii</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	fb	6	Azadirachtin 10000 ppm	2 ml/lit	
7	<i>Metarrhizium anisopliae</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	fb	7	Azadirachtin 10000 ppm	2 ml/lit	
8	<i>Beauveria bassiana</i> 2 X 10 ⁸ cfu/gm	5 gm/lit	fb	8	Azadirachtin 10000 ppm	2 ml/lit	
9	Azadirachtin 10000 ppm	2 ml/lit	fb	9	Azadirachtin 10000 ppm	2 ml/lit	
10	Untreated control	--	fb	10	Untreated control	--	

Method of application

The biopesticidal spray was applied with the help of a knapsack sprayer in the morning. All the thirty plots were treated at a time avoiding the drift of spray fluid on neighboring plots. While spraying of biopesticides on a plot, sprayed individually on a plot, taking care of contamination. Care was taken to wash the spray pump with water thoroughly well before using other biopesticides.

Observations of oat aphid

Biopesticide spray was given as soon as infestation of oat aphid appeared on crop. Pre and post treatment count of oat aphid were taken on 3 randomly selected tiller/plot at 5 and 7 days after treatment.

Observation on coccinellid predators and natural enemies

Pre and post treatment count of lady bird beetles grub and *chrysoperla* were taken on randomly selected tiller/plots at 5 and 7 days after treatment.

Statistical analysis

The generated data on survival of oat aphid and their natural enemies were transformed into $\sqrt{n+1}$ value where 'n' is number of insects and subjected to statistical analysis.

Results and Discussions

Effectiveness of biopesticides on oat aphid of forage oat

With a view to study the effectiveness of biopesticides and plant product for control of oat aphid on forage oat, the experiments were conducted on farm of All India Coordinated Research Project on Forage Crops and Utilization, M.P.K.V., Rahuri during October, 2019 to March, 2020.

With a view to find out the effective biopesticides for control of oat aphids sequential spraying was done on 21st January, 2020 and 1st February, 2020. Statistical analysis was done in Randomized Block Design to assess the effect of biopesticides against the oat aphid. The results in respect of effectiveness of different biopesticides and against *R. padi* at 5 and 7 days after spraying on forage oat are presented in Tables 4 to 6.

First spray

The precount of average number of aphids/tiller was found statistically non-significant, while all the biopesticides treatments were found superior over untreated control at 5 and 7 days after spraying for the management of oat aphids on forage oat. Untreated control treatment showed 33.30, 37.77 and 47.09 survival aphid population before treatment, 5 and 7 days after treatment, respectively. At 5 days after 1st spray.

At 5 days after 1st spray

All the biopesticides were found superior in suppressing the aphid population as compared to untreated control at five days after spraying. Among the all treatments, foliar application of *L. lecanii* 2x10⁸ cfu/gm @5gm/lit was statistically found to be the most effective treatment in controlling aphids, it was recorded significantly lower (21.80 aphids/ tiller) number of aphids as compared to other treatments except *L. lecanii* 2x10⁸ cfu/gm @5gm/lit (T₆) and *L. lecanii* 2x10⁸ cfu/gm @5gm/lit (T₄). These treatments were at par with it and recorded 21.89 and 22.87 aphids per tiller on oat. The next performing treatments in order to their merits were *M. anisopliae* 2x10⁸ cfu/gm @5gm/lit (T₄), *M. anisopliae* 2x10⁸ cfu/gm @5gm/lit (T₅), *M. anisopliae* 2x10⁸ cfu/gm @5gm/lit (T₂), *B. bassiana* 2x10⁸ cfu/gm @5gm/lit (T₃), *B. bassiana* 2x10⁸ cfu/gm @5gm/lit (T₈) and *Azadirachtin* 10000 ppm @2ml/lit (T₉), which were recorded 24.57, 24.99, 25.52, 28.20, 28.94 and 30.27 aphids per tiller, respectively.

At 7 days after 1st spray

The results in respect of survival of aphid population at 7 days after first spraying revealed that the similar trend of the result was obtained as resulted in 5 DAS. The treatment with *L. lecanii* @5gm/lit recorded significantly lower number of aphid (12.29 aphids/tiller), which proved to be significantly superior over other biopesticides. However, it was at par with *L. lecanii* @5gm/lit (T₆) (12.62 aphids/tiller) and *L. lecanii* @5gm/lit (T₄) (9.12 aphids/tiller). Neem based insecticides showed increasing population of aphids at 7 days after treatment.

Performance of the remaining treatments in order to their merits were *M. anisopliae* @5gm/lit (T₂), *M. anisopliae* @5gm/lit (T₇), *M. anisopliae* @5gm/lit (T₅), *B. bassiana* @5gm/lit (T₃), *B. bassiana* @5gm/lit (T₈) and *Azadirachtin* 10000 ppm @2ml/lit (T₉). These treatments were recorded 16.25, 16.83, 16.97, 21.78, 22.14 and 34.63 aphids per tiller, respectively.

Second spray

After the first spray, the sequential spray of biopesticides was taken 10 days after 1st spray and results of the same are presented in Table 5. The precount of the average number of aphids per tiller was found statistically significant due to the earlier effect of the biopesticidal spray. All the treatments were showed their superiority over untreated control at 5 and 7 days after spraying against oat aphids on forage oat. In untreated control, the survival population of aphids after second spray was 53.87, 60.62 and 68.79 at before spray, 5 and 7 days after spray treatment, respectively.

Precount

Precount of second spray was found significant due the effect of biopesticides applied in first spray. Treatments of *L. lecanii* @5gm/lit were applied during the first spray showed significantly lowest population of aphids on oat as compared to other treatments. These treatments were T₁ (16.87 aphids/tiller), T₄ (17.62 aphids/tiller) and T₆ (17.88 aphids/tiller).

At 5 days after 2nd spray

At five days after second spray, all the biopesticides were proved to be effective against oat aphid. The treatment of *L. lecanii* @5gm/lit showed significant lesser population (9.28 aphids/ tiller) of oat aphids as compared to other biopesticidal treatments except *M. anisopliae* @5gm/lit (10.94 aphids/tiller). These treatments were at par with each other. The next performing treatments against aphids in order to their merits were, *M. anisopliae* @5gm/lit (T₂), *Azadirachtin* 10000 ppm @ 2ml/lit (T₆), *B. bassiana* @5gm/lit (T₅), *Azadirachtin* 10000 ppm @2ml/lit (T₇), *B. bassiana* @5gm/lit (T₃), *Azadirachtin* 10000 ppm @2ml/lit (T₈) and *Azadirachtin* 10000 ppm @2ml/lit (T₉), which were recorded 12.18, 15.85, 17.15, 20.19, 21.42, 23.79 and 34.42 aphids per tiller, respectively.

At 7 days after 2nd spray

All the entomopathogenic fungi proved to be effective against oat aphid at 7 days after treatment. However, neem based insecticides were found moderately effective at 5 and 7 days after treatment. The results of survived aphid population at 7 days after second spray revealed that the treatment with *L. lecanii* @5gm/lit recorded significantly lower number of survived aphid population (4.77 aphids/tiller). None of the treatments were found at par with it. The next promising treatments in order to their merits were *M. anisopliae* (T₄), *M. anisopliae* (T₂), *B. bassiana* (T₅), *Azadirachtin* (T₆), *B. bassiana* (T₃), *Azadirachtin* (T₇), *Azadirachtin* (T₈) and *Azadirachtin* (T₉). These treatments were recorded 8.16, 8.18, 13.52, 18.17, 18.81, 22.80, 26.22 and 36.43 aphids/tiller, respectively.

Average of sequential sprays

The data on mean value of survived aphid population recorded during sequential spray of 1st and 2nd sprays are presented in Table 6. Precount of aphids before initiation of spray treatment was in the range of 24.19 to 43.59. The precount of sequential

spray was found significant due to the effect of 1st and 2nd sprays of biopesticides against oat aphids.

Precount

The precount was found significant due to the effect of 1st spray treatments against oat aphid. Among the all biopesticidal treatments, *L. lecanii* fb *L. lecanii* @5gm/lit recorded significantly lesser number of aphids on oat. However it was at par with *L. lecanii* fb *M. anisopliae*, *L. lecanii* fb *Azadirachtin*, *M. anisopliae* fb *B. bassiana* and *M. anisopliae* fb *Azadirachtin*, which recorded 25.90, 26.89, 27.03 and 28.19 aphids/tiller, respectively.

At 5 days after spraying

On the basis of average of two sequential sprays against oat aphids at 5 days after spray showed that all the entomopathogenic fungi proved to be effective in suppressing the aphid population on forage oat. The treatment with *L. lecanii* fb *L. lecanii* @5gm/lit recorded significantly lowest (15.54) number of aphids per tiller than other biopesticides. None of the treatments were found at par with it. Next performing treatments in order to their merits were *L. lecanii* fb *M. anisopliae* @5gm/lit (16.91 aphids /tiller), *M. anisopliae* fb *M. anisopliae* @5gm/lit (18.85 aphids/tiller), *L. lecanii* fb *Azadirachtin* @2ml/lit (18.87 aphids/tiller), *M. anisopliae* fb *B. bassiana* @5gm/lit (21.07 aphids/tiller), *M. anisopliae* @5gm/lit fb *Azadirachtin* @2ml/lit (22.38 aphids/tiller), *B. bassiana* fb *B. bassiana* @5gm/lit (24.81 aphids/tiller), *B. bassiana* @5gm/lit fb *Azadirachtin* 10000 ppm @2ml/lit (26.37 aphids/tiller) and *Azadirachtin* @2ml/lit (32.34 aphids/tiller). All the entomopathogenic fungi treatments showed their pathogenicity on oat aphids and maintained their superiority in suppressing the aphid population on oat.

At 7 days after spraying

All evaluated entomopathogenic fungi proved to be highly pathogenic to aphids and they maintained their superiority against aphids at 7 days after spray. Similar trend of the results was noticed as observed at 5 days after spray. The treatment with *L. lecanii* fb *L. lecanii* @5gm/lit recorded significantly lowest (8.53) number of aphids per tiller than other biopesticides. None of the treatments were found at par with it. Next performing treatments in order to their merits were *L. lecanii* fb *M. anisopliae* @5gm/lit (10.48 aphids/tiller), *M. anisopliae* fb *M. anisopliae* @5gm/lit (12.21 aphids/tiller), *M. anisopliae* fb *B. bassiana* @5gm/lit (15.25 aphids/tiller), *L. lecanii* fb *Azadirachtin* @2ml/lit (15.40 aphids/tiller), *M. anisopliae* @5gm/lit fb *Azadirachtin* @2ml/lit (19.81 aphids/tiller), *B. bassiana* fb *B. bassiana* @5gm/lit (20.30 aphids/tiller), *B. bassiana* @5gm/lit fb *Azadirachtin* @2ml/lit (24.18 aphids/tiller) and *Azadirachtin* @2ml/lit (35.53 aphids/tiller). All the entomopathogenic fungi treatments showed their pathogenicity on oat aphids and maintained their superiority in suppressing the aphid population on oat. However, neem based insecticides showed moderate effect on oat aphids.

Overall results indicated that all entomopathogenic fungi showed their pathogenicity on oat aphids due to the thick plant population of oat, it maintained micro climate which help to fungi for fast multiplication on target pests. Forage oat is green forage crop which is highly nutritious as animal feed. It is therefore, necessary to avoid chemical pesticides which can be harm to animal and human being through milk/meat consumption also. Entomopathogenic fungi are the most

important solution to avoid toxicity of chemical insecticides and safer to natural enemies for their survival.

Results of entomopathogenic fungi, neem based insecticides indicated that, neem based insecticide proved to be their moderate effectiveness against aphids upto 5 days after spray treatment during present investigation. Gour and Pareek (2003) [7] reported that NSE as least effective against mustard aphids on mustard. Salunkhe (2003) [10] reported moderate effect of econeem and neem seed extract on cowpea aphids on cowpea. Verma and Chaman Lal (2006) [11] reported that *Azadirachta indica* was effective statistically but provided only moderate level of control of mustard aphids.

All the entomopathogenic fungi showed the pathogenic effect on aphids 5 and 7 days after treatment and it maintained later on due to epizootic nature. Among entomopathogenic fungi, *L. lecanii* fb *L. lecanii* 2×10^8 cfu/gm @5gm/lit proved excellent control of oat aphids on forage oat. All the tested formulations

are oil based formulations which facilitate the spread of fungal spores over the water surface and improves the efficacy of formulated spores against aphids. Bhukari *et al.* (2004) [1] reported that synthetic oil formulation of *L. lecanii*, *M. anisopliae* and *B. bassiana* were easy to work and apply to water surface. It improves persistence of fungal spores after application to the water. Krauss *et al.* (2004) [9] reported that entomopathogens and myco parasites are compatible elements of integrated pest management. Yeo *et al.* (2003) [12] reported that *L. lecanii* is most pathogenic to aphids. Similarly Ekese *et al.* (2002) [4] reported that *B. bassiana* caused 58 to 91 percent mortality in cowpea aphids. Also, Kazda (1994) [8] reported that *L. lecanii* causes 60% mortality in aphids. Similarly, Deng *et al.* (1991) [2] reported that *L. lecanii* causes 30 to 50 percent mortality in aphids. The present results are in agreement with those of above workers.

Table 3: Particulars of biopesticides evaluated against oat aphid infesting oat crop

Sr. No.	Technical name	Bio ingredient	Trade formulation	Manufacturer or source
1	<i>Lecanicillium lecanii</i>	2 x 108cfu/gm	Phule Bugicide (1.15% WP)	Biocontrol Laboratory, Department of Agril. Entomology, MPKV, Rahuri
2	<i>Metarrhizium anisopliae</i>	2 x 108cfu/gm	Phule Metarrhizium (Ma) (1.15% WP)	
3	<i>Beauveria bassiana</i>	2 x 108cfu/gm	Phule Beauveria (Bb) (1.15% WP)	
4	Azadirachtin	Content Azadirachtin	Econeem 10,000 ppm	M/S Margo Biocontrols, Pvt. Ltd. Bangalore-80

Table 4: Effect of biopesticides on survival population of oat aphids (1st Spray)

Sr. No.	Treatments	Dose	Av. No. of aphids/tiller		
			Precount	5 DAT	7 DAT
1	<i>Lecanicillium lecanii</i> 2×10^8 cfu/gm	5 gm/lit	34.18 (5.92)	21.80 (4.77)	12.29 (3.64)
2	<i>Metarrhizium anisopilaie</i> 2×10^8 cfu/gm	5 gm/lit	33.91 (5.90)	25.52 (5.15)	16.25 (4.15)
3	<i>Beauveria bassiana</i> 2×10^8 cfu/gm	5 gm/lit	33.05 (5.83)	28.20 (5.40)	21.78 (4.77)
4	<i>Lecanicillium lecanii</i> 2×10^8 cfu/gm	5 gm/lit	34.20 (5.92)	22.87 (4.88)	12.80 (3.72)
5	<i>Metarrhizium anisopilaie</i> 2×10^8 cfu/gm	5 gm/lit	33.35 (5.86)	24.99 (5.10)	16.97 (4.24)
6	<i>Lecanicillium lecanii</i> 2×10^8 cfu/gm	5 gm/lit	35.89 (6.07)	21.89 (4.78)	12.62 (3.69)
7	<i>Metarrhizium anisopilaie</i> 2×10^8 cfu/gm	5 gm/lit	34.54 (5.96)	24.57 (5.06)	16.83 (4.22)
8	<i>Beauveria bassiana</i> 2×10^8 cfu/gm	5 gm/lit	33.78 (5.90)	28.94 (5.47)	22.14 (4.81)
9	<i>Azadirachtin</i> 10000 ppm	2 ml/lit	34.11 (5.92)	30.27 (5.59)	34.63 (5.97)
10	Untreated control		33.30 (5.85)	37.77 (6.22)	47.09 (6.93)
	SE \pm		0.16	0.08	0.09
	CD at 5%		N.S.	0.22	0.22

Figures in the parentheses are $\sqrt{n+1}$ DAT: Days after treatment

Table 5: Effect of biopesticides on survival population of oat aphids (2nd spray)

Sr. No.	Treatments	Dose	Av. No. of aphids/tiller		
			Precount	5 DAT	7 DAT
1	<i>L. lecanii</i> 2×10^8 cfu/gm	5 gm/lit	16.87 (4.22)	09.28 (3.20)	4.77 (2.40)
2	<i>M. anisopilaie</i> 2×10^8 cfu/gm	5 gm/lit	20.47 (4.63)	12.18 (3.63)	8.18 (3.03)
3	<i>B. bassiana</i> 2×10^8 cfu/gm	5 gm/lit	26.74 (5.27)	21.42 (4.73)	18.81 (4.45)
4	<i>M. anisopilaie</i> 2×10^8 cfu/gm	5 gm/lit	17.62 (4.31)	10.94 (3.45)	8.16 (3.03)
5	<i>B. bassiana</i> 2×10^8 cfu/gm	5 gm/lit	20.71 (4.66)	17.15 (4.26)	13.52 (3.81)
6	<i>Azadirachtin</i> 10000 ppm	2ml/lit	17.88 (4.34)	15.85 (4.10)	18.17 (4.38)
7	<i>Azadirachtin</i> 10000 ppm	2 ml/lit	21.83 (4.78)	20.19 (4.60)	22.80 (4.88)
8	<i>Azadirachtin</i> 10000 ppm	2 ml/lit	27.38 (5.33)	23.79 (4.98)	26.22 (5.22)
9	<i>Azadirachtin</i> 10000 ppm	2 ml/lit	39.78 (6.38)	34.42 (5.95)	36.43 (6.12)
10	Untreated control		53.87 (7.41)	60.62 (7.85)	68.79 (8.35)
	SE \pm		0.09	0.08	0.07
	CD at 5%		0.25	0.24	0.20

Figures in the parentheses are $\sqrt{n+1}$ DAT: Days after treatment

Table 6: Effect of biopesticides on survival population of oat aphids (Av. of 2 sequential sprays)

Sr. No.	Treatments	Dose	Av. No. of aphids/tiller		
			Precount	5 DAT	7 DAT
1	<i>Lecanicillium lecanii</i> fb <i>L. lecanii</i> 2×10^8 cfu/gm	5 gm/lit	25.52 (5.11)	15.54 (3.99)	8.53 (3.02)
2	<i>Metarrhizium anisopilaie</i> fb <i>M. anisopilaie</i> 2×10^8 cfu/gm	5 gm/lit	27.19 (5.27)	18.85 (4.39)	12.21 (3.59)

3	<i>Beauveria bassiana</i> fb <i>B. bassiana</i> 2x10 ⁸ cfu/gm	5 gm/lit	29.90 (5.55)	24.81 (5.07)	20.30 (4.61)
4	<i>Lecanicillium lecanii</i> fb <i>M. anisopiliae</i> 2x10 ⁸ cfu/gm	5 gm/lit	25.91 (5.12)	16.91 (4.17)	10.48 (3.37)
5	<i>Metarrhizium anisopiliae</i> fb <i>B. bassiana</i> 2x10 ⁸ cfu/gm	5 gm/lit	27.03 (5.26)	21.07 (4.68)	15.25 (4.02)
6	<i>Lecanicillium lecanii</i> fb Azadirachtin 10000 ppm	5 gm/lit 2 ml/lit	26.89 (5.20)	18.87 (4.44)	15.40 (4.03)
7	<i>Metarrhizium anisopiliae</i> fb Azadirachtin 10000 ppm	5 gm/lit 2 ml/lit	28.19 (5.37)	22.38 (4.83)	19.81 (4.55)
8	<i>Beauveria bassiana</i> fb Azadirachtin 10000 ppm	5 gm/lit 2 ml/lit	30.58 (5.61)	26.37 (5.22)	24.18 (5.01)
9	Azadirachtin 10000 ppm	2 ml/lit	36.94 (6.15)	32.34 (5.77)	35.53 (6.04)
10	Untreated control	--	43.59 (6.63)	49.20 (7.04)	57.94 (7.64)
	SE ±		0.08	0.06	0.06
	CD at 5%		0.24	0.16	0.17

Figures in the parentheses are $\sqrt{n+1}$ DAT: Days after treatment

Conclusion

Among the entomopathogenic fungal treatments, *L. lecanii* fb *L. lecanii* 2x10⁸ cfu/gm (5gm/lit) gave effective aphid control with highest green forage and dry matter yield of oat. Whereas, *L. lecanii* fb *M. anisopiliae* and *M. anisopiliae* fb *M. anisopiliae* next alternative treatments for management of oat aphids. Neem based insecticide were found moderately effective against aphid. All the entomopathogenic fungal, neem based treatments were found safe to coccinellid, not any treatment showed pathogenic effect on predatory coccinellids at 5 and 7 days after application. Incorporation of entomopathogenic fungus viz., *L. lecanii*, *M. anisopiliae*, *B. bassiana* in IPM programme would be effective and ecofriendly management of oat aphid.

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