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Evaluation of different botanicals for the management of mustard aphid, *Lipaphis erysimi* (Kaltenbach)

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Abstract

A field study was conducted at CCS Haryana Agricultural University, Hisar during 2016-17 to evaluate the bio-efficacy and economics of thirteen botanicals insecticides against mustard aphid, *Lipaphis erysimi* Kalt. of Indian mustard. The per cent aphid reduction over control after seven days of application was found to be maximum (93.2 %) in Dimethoate 30 EC @ 625 ml/ha followed by Azadirachtin 10000 ppm @ 1.0 ml per litre of water (81.6%), Azadirachtin 1500 ppm @ 1.0 ml per litre of water (78.49%), neem oil 3% (76.4%) and neem seed kernel extract (NSKE) 5% (71.4%). The highest BCR (1:7.6) was obtained from treatment Dimethoate 30 EC followed by Azadirachtin 1500 ppm (1:5.4), Azadirachtin 10000 ppm (1:4.1) and NSKE 5% (1:3.1). Therefore, Azadirachtin 1500 ppm @ 1.0 ml per litre of water may be recommended as most economical, and ecofriendly alternative to chemical insecticides for the management of mustard aphid.

Key words: *Azadirachtin, bioefficacy, botanical, dimethoate, Lipaphis erysimi, mustard aphid*

Introduction

Rapeseed-mustard belonging to genus *Brassica* and family Cruciferae, is the second most important edible crop in India after groundnut and accounts for nearly 30 per cent of the total oilseeds production in the country. It is cultivated over an area of 5.75 million ha with production and productivity of 6.80 million tonnes and 1183 Kg/ha respectively in India. Haryana is the third most important rapeseed–mustard producing state in the country with an area of 0.53 million ha, production of 0.90 million tonnes and productivity of 1721 Kg/ha (2015-2016) which is highest in the country (Anonymous, 2017). More than 43 species of insect-pests have been reported to infest rapeseed-mustard crop throughout the growing period in India, out of which about a dozen are considered as major pests (Purwar *et al*., 2004). Among these aphids [*Lipaphis erysimi* Kalt., *Brevicoryne brassicae* L. and *Myzus persicae* Sulzer (Hemiptera: Aphididae)] are the most destructive pests (Desh Raj, 1996; Sarangdevot *et al*., 2006) which causes both qualitative and quantitative yield losses. Among the aphids, mustard aphid, *L. erysimi* is predominant and is a key pest and may cause up to 9-96% yield loss, 31% seed weight loss and 5-6% reduction in oil content (Bakhetia and Sekhon, 1989; Singh and Sharma, 2002; Dhaliwal *et al.,* 2004; Rana, 2005; Shylesha *et al*., 2006 and Parmar *et al*., 2007). Such losses may go up to 100% in certain mustard growing region (Singh and Sachan, 1999). Louse shaped pale greenish colored nymphs as well as adults of mustard aphid, suck the cell sap by congregating in large numbers on the leaves, petioles, tender stems, inflorescence and pods. Continuous desapping by a large population of aphids results in to yellowing, curling and subsequent drying of leaves, which ultimately leads to the formation of weak pods and undersized seeds in the pods. The aphids also secrete honeydews which provide a suitable medium for the development of sooty mould which ultimately hampers the process of photosynthesis (Mandal *et al*., 2012).

The demand for edible oil has been increasing steadily in India. Therefore, to meet the requirements of the ever increasing population, there is need to enhance the productivity of rapeseed-mustard by minimizing the losses due to biotic and abiotic stresses. Amongst various biotic factors, the insect-pests infestation is the key limiting factor in achieving higher productivity. A number of chemical insecticides have been found effective against mustard aphid in different parts of the country (Singh *et al*., 2007; Singh *et al*., 2009). But chemical insecticides are not only toxic to natural enemies of aphid such as *Diaeretiella rapae*, *Chrysoperla zastrowi arabica*, coccinellids and syrphid flies (Singh *et al.,* 2007) but are also responsible for environmental pollution, health hazards to human beings, toxicity to pollinators and residue in oil and cake (Singh and Sharma, 2002). Therefore it is needed to discover ecologically sound and environmentally safe methods for managing mustard aphid.

Botanical insecticides can play an important role in IPM programs as they are naturally available plant materials which are comparatively less expensive, less toxic, less hazardous, biodegradable and also safe to beneficial organisms (Ahamed, 1984). Over 2000 plant species belonging to about 170 families are known to have insecticidal properties (Delvin and Zettel, 1999). Therefore, indigenously available plant and leaf extracts/ oils containing insecticidal properties can be used for managing mustard aphids as they not only help in maintaining biological diversity of beneficial organisms (Buss and Park, 2002) but also reduce environmental contamination and human health hazards. Moreover, botanical pesticides can be produced easily by farmers and small industries (Radhakrishanan and Muraleedharan, 1993). Therefore, the present investigation was carried out to evaluate the efficacy of various indigenously available botanicals for mustard aphid management.

Materials and Methods

The present investigation was carried out at Research Area of Oilseeds Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during *Rabi* season during 2016-17 on mustard cultivar RH 0749. Experiment was conducted in a completely randomized block design with fifteen treatments including control and replicated thrice with plot size of 1.8x3m. The crop was sown during fourth week of November with row to row and plant to plant spacing as 30cm and 10cm respectively and all the standard agronomic practices were followed to raise the good crop. Fifteen treatments including control weretaken including T1= *Millettia pinnata* oil (*Pongamia pinnata*) @ 1.5%; T2= *Millettia pinnata* seed kernel extract @ 5%; T3= Eucalyptus oil 5% ; T4= Eucalyptus leaf extract @ 10% ; T5= *Aloe vera* leaf extract @ 10% ; T6= *Calotropis procera* leaf extract @ 1% ; T7= *Nicotiana tabacum* leaf extract @ 10% ; T8= Neem leaf extracts 5%; T9= Neem seed kernel extract (NSKE) 5%; T10= Neem oil 3%; T11= Azadirachtin 1500 ppm @ 1.0 ml per litre of water; T12= Azadirachtin 10000 ppm @ 1.0 ml per litre of water; T13= Dimethoate 30 EC @ 625 ml/ha ; T14= Water spray and T15 contro without spray.

Preparation of Botanicals

i. ***Millettia pinnata/Pongamia pinnata*** **oil:** 75 ml of *Pongamia pinnata* oil purchased from the local market was added slowly with continuous steering in 5 litre of water along with 2.5 ml of teepol (acts as sticker/ spreader) to make 1.5 % *Pongamia pinnata* oil. It was used immediately using a knapsack sprayer before the oil droplets start floating.

ii. **Neem Seed Kernel Extract and *Millettia pinnata* seed kernel extract:** Fifty gram each of neem seed kernel and pongam seed kernel were sun dried and crushed into powder gently in such a way that no oil comes out and soaked in 500 ml of clean and fresh water for overnight. The extract was filtered through a fine clean muslin cloth to extract the contents completely. 100 ml of decanted solution was added in two litre of water to make 5 % solution. To the one litre of extract 1 ml teepol powder was added as emulsifier. The emulsifier helps the extract to spread well on the leaf surface.

iii. **Eucalyptus oil:** To make 5% eucalyptus oil first 5 ml of teepol (acts as sticker/spreader) was added to 5 liters of water. To this 250 ml of eucalyptus oil purchased from the local market was added slowly along with continuous steering. It was used immediately using a knapsack sprayer before the oil droplets start floating.

iv. Neem Leaf Extract: Two hundred fifty grams of green neem leaves were soaked overnight in 1 liter of water. Next day a thin paste of soaked leaves was made by pulverizing them using pestle and mortar and crude extract was filtered with a fine mesh of cotton cloth. The final volume was made to 5 liters by adding water to the filtrate and 5 ml of teepol was also added as a surfactant.

v. **Neem Oil:** To make 3 % neem oil, 2.5 ml of teepol (acts as sticker/spreader) was added to 2.5 liter of water. To this 75 ml of neem oil purchased from the local market was added slowly along with continuous steering. It was used immediately using a knapsack sprayer before the oil droplets start floating.

vi. ***Aloe vera*** **leaf extract,** ***Nicotiana tabacum*** **leaf extract, Eucalyptus leaf extract:** Botanical formulations of *Aloe vera* leaf extract, *Nicotiana tabacum* leaf extract, Eucalyptus leaf extract were made as per methodology given by Sarwar (2013). Five hundred gram leaves of each plant were weighed separately and a thin paste was made by crushing in pestle and mortar. Five hundred gram of the leaves paste was mixed with 1 liter of water and kept for 10 hours and thereafter by means of a fine mesh of cotton cloth, the crude extract was filtered. The spray formulation of each plant product was made by adding 5 liters of water to the filtrate, and as a surfactant 50 ml of teepol was added to each sample.

vii. ***Calotropis procera*** **leaf extract:** *Calotropis procera* leaves were collected from various localities in Hisar. The leaves were shade dried and grounded in a mechanical

grinder to get them in a powder form and finally passed through a 30 mesh sieve. Using 200 grams of the powdered material of test plants in 500 ml of petroleum ether (40-60 ÚC); crude extract was prepared in a soxlet apparatus. 50 ml of extract was mixed in 5 L of water to make 1 % solution.

The population of aphids was recorded in the field on the ten randomly selected plants from each plot at one day before spray and 3, 5 and 7 days after spray of botanical insecticides. The numbers of aphids/plant were converted into % reduction of aphid population over the control by the formula given below.

$$\text{Percent reduction over control} = \frac{\text{Population recorded in control (untreated)} - \text{Population recorded after spray}}{\text{Population recorded in control (untreated)}}$$

The seed yield/plot in different treatments was recorded after harvest. The incremental cost benefit ratio (ICBR) was calculated by prevailing market price of mustard seed, cost of insecticides and labour used with the following formulae:

Incremental Cost Benefit Ratio = Additional Profit over the control – Cost of Treatment

Results and Discussion

The first spray was applied at full bloom stage, when the mustard aphid population reached the Economic Threshold (ET). Before treatment, mean aphid population ranged from 24.00 to 42.33 aphids/10 cm main apical shoot and was found to be non-significant which indicate that the aphid population was uniformly distributed throughout the experimental field. Data recorded on 3rd day after first application revealed that aphid population was decreased in every treatment except untreated plot. Among different treatments tested, dimethoate 30EC @ 625 ml/ha was found most effective in reducing aphid population (13.33 aphids/10 cm main apical shoot) against (37 aphids/10 cm main apical shoot) in control and it differ significantly from all the botanical treatments used. Among botanicals, azadirachtin 10000 ppm @ 1.0 ml per litre of water was found most effective treatment followed by azadirachtin 1500 ppm @ 1.0 ml per litre of water and neem oil 3% having 18.3, 20.0 and 21.0 aphids/10 cm main apical shoot, respectively. All these treatments were found at par with each other. NSKE 5% was the next most effective treatment with 23.1 aphids/10 cm main apical shoot and was found statistically at par with Neem leaf extracts 5% and *Nicotiana tabacum* leaf extract @ 10% with mean aphid population of 24 and 27 aphids/10 cm main apical shoot respectively. *Millettia pinnata* oil @ 1.5%, *Millettia pinnata* seed kernel extract @ 5%, Eucalyptus oil 5% and Eucalayptus leaf extract @10% treatments with mean aphid population of 28.7, 29, 31.7 and 32 aphids/10 cm main apical shoot respectively, were at par with each other in managing mustard aphid. Whereas, *Calotropis procera* leaf extract @ 1% and *Aloe vera* leaf extract @10% were least effective having a mustard aphid population of 37.3 and 35.6 aphids/10 cm main apical shoot respectively (Table 1).

Data recorded on 5th and 7th day after application also showed the similar trend of effectiveness of different treatments. There was general trend of decrease in aphid population in all the treatments up to 7th days contrary to increase in aphid population in control plot.

The per cent reduction in aphid population over control at seven days after first spray was also found to be maximum (91.3 %) in dimethoate 30 EC @ 625 ml/ha followed by azadirachtin 10000 ppm @ 1.0 ml per litre of water (81.0%), azadirachtin 1500 ppm @ 1.0 ml per litre of water (77.9%), neem oil 3% (74.2%), NSKE 5% (67.9%) and Neem leaf extract 5% (64.5%). The remaining less effective treatments in reducing mustard aphid over control were *Millettia pinnata* oil @ 1.5% (62.9), *Millettia pinnata* seed kernel extract @ 5% (62.3%), *Nicotiana tabacum* leaf extract @ 10% (60.3%), Eucalayptus leaf extract @10% (58.5%) and Eucalyptus oil 5% (57.4%). Minimum reduction in aphid population over control after seven days of application was recorded in water spray (3.3%) followed by *Aloe vera* leaf extract @10% (41.6%) and *Calotropis procera* leaf extract @ 1% (42.9%) (Table 1).

The second spray was applied at full pod formation stage of the crop when aphid population again reached the ET. The general aphid population during one day before second spray varied significantly between 29.0 (dimethoate 30 EC @ 625 ml/ha) to 72.0 (control) aphids/ 10 cm main apical shoot. Data recorded on 3rd day after second spray, showed that all the treatments were significantly effective in reducing the population of mustard aphid. Similar to first spray application with dimethoate 30 EC @ 625 ml/ha recorded significantly the lowest aphid population of 7.1 aphids/ 10 cm main apical shoot, followed by azadirachtin 10000 ppm @ 1.0 ml per litre (19.9 aphids/10 cm main apical shoot) and it was statistically at par with azadirachtin 1500 ppm @ 1.0 ml per litre of water (22.5 aphids/ 10 cm main apical shoot). NSKE 5% was the next subsequent most effective botanical and statistically at par with *Millettia pinnata* seed kernel extract @ 5%, Neem leaf extracts 5%, Eucalyptus oil 5%, *Millettia pinnata* oil @ 1.5%, *Nicotiana tabacum* leaf extract @ 10%, Eucalyptus leaf extract @10% and Neem oil 3% in managing mustard aphid having 26.6, 27.3, 27.5, 28.0, 28.3, 28.7, 29.0 and 29.33 aphids/10 cm main apical shoot, respectively

Table 1: Efficacy of botanicals against mustard aphid, *Lipaphis erysimi* during *Rabi* 2016-17 at Hisar

Treatments	Mean number of aphids/10 cmmain apical shoot				Percent reduction over control	Mean number of aphids/10 cmmain apical shoot				Percent reduction over control	Mean Yield Kg	Increased in yield over control
	After first spray					After second spray						
	BS	3 DAS	5 DAS	7 DAS	7 DAS	BS	3 DAS	5 DAS	7 DAS	7 DAS	/ha	(%)
T1:*Millettia pinnata* oil (*Pongamia pinnata*) @ 1.5%	36.0 (6.1)	28.7 (5.4)	23.0 (4.9)	22.7 (4.9)	62.9	32.3 (5.8)	28.3 (5.4)	23.0 (4.9)	27.0 (5.3)	68.7	1673	6.7
T2: *Millettia pinnata* seed kernel extract @ 5%	38.7 (6.3)	29.0 (5.5)	25.7 (5.2)	23.0 (4.9)	62.3	31.0 (5.7)	27.3 (5.3)	21.7 (4.8)	23.0 (4.9)	73.4	1659	5.8
T3: Eucalyptus oil 5%	35.7 (6.0)	31.7 (5.7)	27.3 (5.3)	26.00 (5.2)	57.4	40.0 (6.4)	28.0 (5.4)	25.0 (5.1)	28.0 (5.4)	67.5	1633	4.2
T4: Eucalyptus leaf extract @10%	35.0 (6.0)	32.0 (5.7)	26.7 (5.3)	25.33 (5.1)	58.5	41.3 (6.5)	29.0 (5.5)	30.0 (5.6)	28.7 (5.4)	66.9	1620	3.3
T5: *Aloe vera* leaf extract @10%	37.3 (6.2)	35.6 (6.0)	34.0 (5.9)	35.7 (6.0)	41.6	45.7 (6.8)	33.0 (5.8)	40.0 (6.4)	37.0 (6.2)	57.5	1601	2.1
T6:*Calotropis procera* leaf extract @ 1%	42.3 (6.6)	37.3 (6.2)	33.0 (5.8)	34.90 (6.0)	42.9	41.7 (6.5)	35.7 (6.1)	38.7 (6.3)	35.3 (6.0)	59.4	1608	2.6
T7:*Nicotiana tabacum* leaf extract @ 10%	30.7 (5.6)	27.0 (5.3)	25.0 (5.1)	24.20 (5.0)	60.3	36.3 (6.1)	28.7 (5.4)	25.7(5.2)	22.0 (4.8)	74.5	1639	4.5
T8: Neem leaf extracts 5%	29.0 (5.5)	24.0 (5.0)	22.4 (4.8)	21.63 (4.8)	64.5	32.0 (5.7)	27.5 (5.3)	23.0 (4.9)	25.3 (5.1)	70.7	1689	7.7
T9: Neem seed kernel extract (NSKE) 5%	26.3 (5.2)	23.1 (4.9)	22.7 (4.9)	19.60 (4.5)	67.9	31.0 (5.7)	26.6 (5.3)	22.0 (4.8)	21.7 (4.8)	75.0	1780	13.5
T10: Neem oil 3%	24.0 (5.0)	21.0 (4.7)	17.7 (4.3)	15.8 (4.1)	74.2	31.7 (5.7)	29.3 (5.5)	19.0 (4.5)	18.3 (4.4)	78.7	1793	14.4
T11:Azadirachtin 1500 ppm @ 1.0 ml/ litre of water	39.7 (6.3)	20.0 (4.6)	16.0 (4.1)	13.5 (3.8)	77.9	33.0 (5.8)	22.5 (4.9)	21.3 (4.7)	18.0 (4.4)	79.1	1874	19.5
T12:Azadirachtin 10000 ppm @ 1.0 ml/litre of water	34.0 (5.9)	18.3 (4.4)	14.0 (3.9)	11.6 (3.6)	81.0	31.7 (5.7)	19.9 (4.6)	17.7 (4.3)	15.3 (4.0)	82.2	1906	21.6
T13: Dimethoate 30 EC @ 625 ml/ha	38.0 (6.2)	13.3 (3.8)	7.0 (2.8)	5.3 (2.5)	91.3	29.0 (5.5)	7.1 (2.8)	5.7 (2.6)	4.2 (2.3)	95.2	1971	25.7
T14: Water spray	28.0 (5.4)	34.7 (6.0)	48.9 (7.1)	59.0 (7.8)	3.3	71.3 (8.5)	77.7 (8.9)	94.3 (9.8)	84.3 (9.2)	2.7	1579	0.7
T15:Control (No spray)	31.0 (5.6)	37.0 (6.2)	49.0 (7.1)	61.0 (7.9)	-	72.0 (8.5)	82.9 (9.2)	95.7 (9.8)	86.7 (9.4)	-	1568	-
C.D. (P = 0.05)	(NS)	(0.47)	(0.4)	(0.39)	-	(0.75)	(0.51)	(0.41)	(0.45)	-	0.23	-

Figures in parentheses are square root transformations; DAS = Days after spray

Whereas *Calotropis procera* leaf extract @ 1% and *Aloe vera* leaf extract @10% were least effective having a mustard aphid population of 35.7 and 33.0 aphids/ 10 cm main apical shoot respectively and were found at par with each other (Table 1).

Similar trend was observed on fifth and seventh days after second spray with dimethoate 30 EC @ 625 ml/ha continued to be the best treatment followed by azadirachtin 10000 ppm @ 1.0 ml per litre, azadirachtin 1500 ppm @ 1.0 ml per litre of water and neem oil 3%.

The per cent reduction in aphid population over control at seven days after second spray at full pod formation stage was found to be maximum (95.2 %) in dimethoate 30 EC @ 625 ml/ha followed by azadirachtin 10000 ppm @ 1.0 ml per litre of water (82.2%), azadirachtin 1500 ppm @ 1.0 ml per litre of water (79.1%) and neem oil 3% (78.7%). Minimum reduction in aphid population over control after seven days of application was recorded in water spray (2.68%) followed by *Aloe vera* leaf extract @10% (57.5%) and *Calotropis procera* leaf extract @ 1% (59.4%) (Table 2).

A significantly higher yield was recorded in all the treatments compared to control except water spray. The highest yield was recorded in treatment dimethoate 30 EC @ 625 ml/ha (1971 Kg/ha) followed by azadirachtin 10000 ppm @ 1.0 ml per litre of water (1906 Kg/ha) and azadirachtin 1500 ppm @ 1.0 ml per litre of water (1874 Kg/ha). The lowest seed yield (1601 Kg/ha) was obtained in treatment with *Aloe vera* leaf extract @10% and *Calotropis procera* leaf extract @ 1% (1608 Kg/ha) whereas, the yield obtained in control was only 1568 Kg/ ha. Similarly, Singh (2007) also reported maximum mean yield in oxydemeton methyl @ 0.025% (1753 Kg/ha) followed by NSKE @ 5% (1627 Kg/ha), neem leaves extract @ 5% (1523 Kg/ha) and while 1122 Kg/ha in untreated check.

From the present findings it is evident that the performance of plant products especially azadirachtin 10000 ppm @ 1.0 ml per litre of water (82.2% aphid reduction) was better as compared to other plant products but was inferior to dimethoate 30 EC @ 625 ml/ha (95.2 aphid reduction). Finally increased in yield over control was highest in dimethoate 30 EC @ 625 ml/ha followed by azadirachtin 10000 ppm @ 1.0 ml per litre of water (25.7% and 21.7%), respectively. The present findings, are in confirmation with Singh *et al*. (2014) who found

Table: 2 Economic analyses of different treatments against mustard aphid during *Rabi*, 2016-17 at Hisar

Treatments	Mean Yield (Kg/ha)	Gross Income *(Rs/ha)	Cost of insecticides (Rs./ha)	Labour charge	Total expenditure on insecticide (Rs/ha)	Net return over control (Rs/ha)	IBCR
T1:*Millettia pinnata* oil (*Pongamia pinnata*) @ 1.5%	1673	61901	750	1520	2270	3885	1 : 1.71
T2: *Millettia pinnata* seed kernel extract @ 5%	1659	61383	900	1520	2420	3367	1 : 1.39
T3: Eucalyptus oil 5%	1633	60421	4000	1520	5520	2405	1 : 0.44
T4: Eucalyptus leaf extract @10%	1620	59940	200	1520	1720	1924	1 : 1.12
T5: *Aloe vera* leaf extract @10%	1601	59237	300	1520	1820	1221	1 : 0.67
T6: *Calotropis procera* leaf extract @ 1%	1608	59496	200	1520	1720	1480	1 : 0.86
T7: *Nicotiana tabacum* leaf extract @ 10%	1639	60643	1000	1520	2520	2627	1 : 1.04
T8: Neem leaf extracts 5%	1689	62493	150	1520	1670	4477	1 : 2.68
T9: Neem seed kernel extract (NSKE) 5%	1780	65860	1000	1520	2520	7844	1 : 3.11
T10: Neem oil 3%	1793	66341	1500	1520	3020	8325	1 : 2.76
T11:Azadirachtin 1500 ppm @ 1.0 ml/litre of water	1874	69338	562	1520	2082	11322	1 : 5.40
T12: Azadirachtin 10000 ppm @ 1.0 ml/litre of water	1906	70522	1562	1520	3082	12506	1 : 4.05
T13: Dimethoate 30 EC @ 625 ml/ha	1971	72927	440	1520	1960	14911	1 : 7.61
T14: Water spray	1579	58423	-	1520	1520	407	1 : 0.27
T15:Control (No spray)	1568	58016	-	-	-	-	-

*Mustard seed @ Rs.3700/q

that the dimethoate 30EC @ 300g a.i. /ha was effective against aphid population causing 91.1, 93.5 and 96.2 per cent reduction after 3, 7 and 10 days of spray respectively. Similarly, Singh (2007) revealed that after four days of spray, oxydemton-methyl @ 0.025% and NSKE were found most effective and reduced aphid population significantly by 64.2 and 57.9 per cent respectively. *Calotropics procera* leaf extract @ 5 % was least effective with only 11.3 per cent reduction in aphid population after 4 days of spray. After 7 days of treatment, among the plant extracts, NSKE @ 5% showed its superiority with 67.8 per cent reduction in aphid population followed by neem leaf extract (49.5%). Similarly, Bathal and Singh (1994) mentioned that treatment of Neemark and Neemguard resulted in 73 % and 83 % mortality of mustard aphid under laboratory conditions. Likewise Bunker *et al.* (2006) reported that neem oil 2% and NSKE 10% treatments reduced the aphid population by 71.5 per cent and 68.5 per cent, respectively as compared to castor oil 2% and Karanj oil 2%.

Contrary to it, Srivastava and Guleria (2003) evaluated thirty four extracts against *L. erysimi* and revealed that all the treatments were sowing insecticidal properties against mustard aphid but the extract from *Chrysanthemum*, *Calotropis procera* gave result at par with *A. indica*. Percent aphid mortality was highest (41.1) in *C. procera* leaf extract and lowest (1.2) in *Amaranthus spinosus*.

On the basis of economics of different treatment maximum net return over control (14911Rs/ha) was obtained in plots treated with dimethoate 30 EC @ 625 ml/ha followed by azadirachtin 10000 ppm @ 1.0 ml per litre of water (12506 Rs/ha) and azadirachtin 1500 ppm @ 1.0 ml per litre of water (11322 Rs/ha). Water spray was found least economical on the basis of net return over control followed by *Aloe vera* leaf extract @10% (1221 Rs/ha) and *Calotropis procera* leaf extract @ 1% (Rs/ha). The highest BCR (1 : 7.61) was obtained from treatment dimethoate 30 EC@ 625 ml/ha followed by azadirachtin 1500 ppm @ 1.0 ml per litre of water (1 : 5.40), azadirachtin 10000 ppm @ 1.0 ml per litre of water (1 : 4.05), NSKE 5% (1 : 3.11), neem oil 3% (1 : 2.76), neem leaf extracts 5% (1 : 2.68) , *Millettia pinnata* oil @ 1.5% (1 : 1.71), *Millettia pinnata* seed kernel extract @ 5% (1 : 1.39), Eucalaptus leaf extract @ 10% (1 : 1.12). The lowest BCR (1:0.27) was obtained from treatment Water spray, followed by Eucalyptus oil 5% (1:0.44), *Aloe vera* leaf extract @10% (1:0.67), *Calotropis procera* leaf extract @ 1% (1:0.86) and *Nicotiana tabacum* leaf extract @ 10% (1:1.04) (Table 2), respectively.

Similarly, Sharma *et al*. (2012) observed that the most favorable incremental cost benefit ratio was obtained under the control (chemical) i.e. dimethoate (1:20.5) followed by azadirachtin 1500 ppm @ 0.1% (1:14.0), green chilly extract 5% (1:8.3), NSKE 5% (1:8.1), *Verticillium lecanii* @ 108 conidia ml/1 (1:4.9), neem oil 1% (1:2.8), neem oil 2% (1:2.0) and karanj oil 1% (1:0.8), respectively. Similar results were reported by Sahoo (2012) that on the basis of Incremental cost benefit ratio, most favourable return was obtained under dimethoate 30 EC (1:20.8 & 1:13.3) followed by oxydemeton-methyl 25 EC (1:16.8 & 1:9.1), while poor incremental cost-benefit ratio was observed in fipronil 5 SC (1:5.8 & 1:2.1) and acephate 75 SP (1:7.1& 1:4.3).

From the present findings it may be concluded that azadirachtin 1500 ppm @ 1.0 ml per litre of water, azadirachtin 10000 ppm @ 1.0 ml per litre of water and Neem seed kernel extract 5% may be recommended as ecofriendly, most economic and effective alternative to chemical insecticides for the management of mustard aphid on Indian mustard.

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