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ENTOMOLOGY

Efficacy of some Medicinal Plant Oils against Cabbage Aphid, *Brevicoryne brassicae* L. On Cabbage

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ABSTRACT

Field experiments were carried out at Vegetable Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi U.P. during the year 2016-17 to control the *Bravicoryne brassicae* in cabbage variety Golden acre. result revealed that Among the all the essential medicinal plant oils the maximum reduction of aphid population over control was observed in plots treated with Citronella oil (85.25%) followed by *Pogostemon cablin* oil (80.21%). Whereas, Mentha oil (58.48%) was found least effective in reducing the aphid population over control. The tested plant essential oils and insecticide on the basis of field efficacy in reducing aphid population are found in order of Citronella oil > Patchouli oil > *O. basilicum* var. saumya > Palmarosa oil > *O. basilicum* var. Surabhi > *O. basilicum* × *O. tenuiflorum* > Asataf > Turmeric oil > Mentha oil. The effect of different essential oils on cabbage yield was also studied under investigation; and maximum yield of cabbage heads was obtained in the plots treated with Citronella oil (233.89 qha^{-1}) and Minimum yield obtained menthe oil (217.22 qha^{-1}) Over the control and then The highest B/C ratio was found in the treatment of *Cymbopogon martinii* 0.05%(31.27:1) whereas, the lowest B:C ratio of 17.70:1 was obtained in Mentha oil treated plot followed by *Curcuma longa* 0.1% (22.82:1). Though the maximum yield was obtained from plots treated with *Cymbopogon citrates* oil. However, the highest B/C ratio was obtained from the plots treated with *Cymbopogon martinii* oil. This is so, because of differences in cost of essential oils.

Highlights

- Testing of eight medicinal plant oils and one insecticide against *Bravicoryne brassicae* L
- The result obtained was highly significant in the pest management and also ecofriendly in nature.

Keywords: Cabbage crop, medicinal plant oil, *Bravicoryne brassicae* L., Efficacy, yield, B/C Ratio

Cabbage, *Brassica oleracea* L. var. *capitata* (Brassicaceae), is of Cyprus and Mediterranean origin. Cabbage is an introduced vegetable crop in India, but it has adapted itself well and is grown all over the country. In India it is cultivated in 3.86 lakh hectares with the total production of 85.85 lakh Metric tonnes and average productivity of 22.2 Metric tonnes/ha Anonymous (2014-15). The Cabbage crop has got huge domestic demand but a number of limiting factors have been attributed for its low productivity and one of the chief constraint in the production of cabbage is damage caused by insect pests complex right from germination till harvesting. A total of 37 insect pests have been reported to feed on cabbage in India (Lal, 1975). Under present investigation we have dealt with cabbage aphid management with essential oils. Cabbage aphid, *Brevicoryne brassicae* L. belongs to order Hemiptera and family Aphididae and feeds on cabbage, mustard, cauliflower, kohlrabi and turnip. Cabbage aphid can cause 35-75% reduction in yield. The cabbage aphid, *Brevicoryne brassicae* L. (Homoptera: Aphididae), is found on brassica crops with worldwide distribution and severe damage

and outbreaks. This aphid was identified for the first time in Europe and later on it has been reported worldwide in most countries with a temperate climate (Ellis and Singh 1993). The cabbage aphid only thrives on cruciferous plants. Cabbage aphid cause significant yield losses in many crops in the family Brassicaceae. Continued feeding by aphids causes yellowing, wilting and stunting of plants. Severely infested plants become covered with a mass of small sticky aphids, which can eventually lead to leaf death and decay. Cabbage aphids feed on the underside of the leaves and on the center of the cabbage head .They prefer feeding on young leaves and often go deep into the heads of Brussels sprouts and cabbage. Under severe infestation conditions colonies of aphids are found on upper and lower leaf surfaces, in leaf folds, along the leafstalk, and near leaf axils. It also secretes honey dew while feeding on leaves over which sooty mould also develops that reduces the quality of cabbage. Cabbage aphid populations, if not controlled, often build high densities so, heavily infested plants acquire a grayish appearance due to the mass of aphid bodies on the foliage. Controlling cabbage aphid is not an easy practice although synthetic chemicals are apparently available for use. Effective pest control is no longer a matter of heavy application of limited insecticides, because continuous use of chemicals lead to several ill effects i.e. toxic residual hazard, development of pesticide resistance in the target pests, pest resurgence, emergence of secondary pests, affects non-target insects species, affects the environment and human health. Plant essential oils and their constituents are primarily lipophilic compounds that act as toxins, feeding deterrents, repellent, oviposition deterrents and even attractant to a large number of insect pests. Essential oils degrade rapidly in air so less persistence in the environment and reduced risks to non-target organisms. Plant oils are generally considered broad-spectrum and safe for the human beings and their environment.

MATERIALS AND METHODS

The experiment was conducted to study bioefficacy of essential oils from some medicinal plants against cabbage aphid (*Brevicoryne brassicae*) on cabbage during *rabi* season of year 2016-17. Seedlings of cabbage variety "Golden Acre" were procured from local market of Varanasi and were used to raise the crop. The transplanting of seedlings was done in the 3rd week of November on the bunds, furrows were opened with manually operated hand driven spade with row to row spacing of 60cm and plant to plant spacing of 45cm . The field experiment was laid out in simple randomized block design (RBD) with ten treatments with eight plant essential oils, One insecticide and one untreated control, *ocimum basilicum* Var. *saumya* oil, citronella oil, *Cymbopogon martinii* oil, *Pogostemon cablin* oil, *Curcuma longa* oil, *Ocimum basilicum* Var. *surabhi* oil, *Ocimum basilicum* × *O. tenuiflorum* oil, Mentha oil and Acephate 75SP (As a check) were selected and applied at above mentioned concentration and sprayed by using a hand sprayer, each replicated four times. The plot size was kept 3 × 4.5 m^2 to accommodate the 50 plants in each plot. Along with one main irrigation channel of 1m width and three sub-irrigation channels were also prepared. Each plot was separated by a trench of 0.25 m, so that drifting of different insecticides during spraying was minimized. Normal tap water and shampoo as emulsifier were used to dilute the essential oils to their recommended field concentration and untreated of control plots were sprayed with normal tap water. The total spray volume was taken @ 500l/ha. Hand sprayer was used for spraying of different treatments i.e. essential oils and insecticide, on the crop. The data on aphids population were recorded from randomly selected five plants in each plot. All the leaves of each selected plant were observed to record the aphid population. Pre-treatment counts of aphids were taken one day prior to the application of essential oils and insecticide in all the plots. Post-treatment counts of aphids were taken after 1st, 3rd and 7th day of application of treatments. Instatistical analysis data was transformed by log (x+1). Similar observations were continued till the harvesting of crop. The percent increase in yield over control in various treatments was calculated by using the following formula:

$$\text{Increase in yield (\%)} = \frac{\text{Yield in treatment} - \text{Yield in control}}{\text{Yield in control}} \times 100$$

The benefit cost ratio (B/C) of each treatment was also calculated from the value of additional yield

received over control as well as the cost incurred over the treatment. The cost of treatment included the material cost of the particular treatment and also labour cost for its application.

RESULTS AND DISCUSSION

Present experiment efficacy of different treatments against cabbage aphid observations on aphid population were recorded one day before spraying and one, three and seven days after spraying of different treatments. The data contained in Table 1 clearly demonstrate that average aphid population in all plots allocated to different treatments ranges from 48.1 to 74.9 aphids per plant before application of treatments as on 6th February 2017. On 7th February 2017 different treatments were applied to each plot according to our layout plan. Observations on aphid population after treatment were recorded on 8th February, 10th February and 14th February. Data on average aphid population after treatment are presented in Table 1 and per cent reduction in aphid population over control were computed and presented in Table 2. The data contained in Table 1, shows that after one day of

Table 1: Effect of various treatments over population of *Brevicoryne brassicae* on Cabbage during *rabi* season 2016-17

Sl. No.	Treatments	Dose	*Average no. of Aphids /plant before spraying	*Average no. of aphids per plant at different days after spraying			
				1st	3rd	7th	Mean
1	*Ocimum basilicum* Var. Saumya oil	0.1%	69.2 (1.75)	47.35 (1.6)	7.25 (0.81)	3.6 (0.56)	19.40 (0.99)
2	*Cymbopogon citrates* oil	0.05%	74.35 (1.82)	22.7 (1.32)	8 (0.91)	2.2 (0.42)	10.97 (0.88)
3	*Cymbopogon martinii* oil	0.05%	50.7 (1.63)	27.5 (1.36)	11.75 (1.03)	4.05 (0.59)	14.43 (1.00)
4	*Pogostemon cablin* oil	0.05%	48.1 (1.66)	17.9 (1.24)	7.9 (0.93)	2.75 (0.51)	9.52 (0.89)
5	*Curcuma longa* oil	0.1%	52.75 (1.66)	38.2 (1.51)	18.4 (1.18)	4 (0.62)	20.20 (1.11)
6	*Ocimum basilicum* Var. Surabhi oil	0.1%	58.1 (1.7)	34.25 (1.51)	15.5 (1.19)	3.7 (0.58)	17.82 (1.09)
7	*O. basilicum* × *O. tenuiflorum* oil	0.1%	48.1 (1.62)	29.25 (1.43)	13.55 (1.13)	5.95 (0.74)	16.25 (1.10)
8	Mentha oil	0.1%	68.8 (1.73)	52.25 (1.59)	25.1 (1.3)	8.35 (0.83)	28.57 (1.24)
9	Acephate 75 SP	500gm a.i/ha	50.9 (1.66)	30.95 (1.47)	12.6 (1.1)	11.5 (1.02)	18.35 (1.20)
10	Control	—	74.9 (1.82)	81.6 (1.86)	84.6 (1.87)	58.2 (1.67)	74.80 (1.80)
	C.D. at 5%	—		0.26	0.23	0.25	0.23

**Average of four replication and there were 5 plants in each plot.*

Figures in parenthesis are (log (X+1)) transformed values.

Table 2: Average per cent reduction in aphid population due to various treatments

Sl. No.	Treatments	Dose	Per cent reduction in aphid population after different days of application			Mean
			1 DAS*	3 DAS	7 DAS	
1	*Ocimum basilicum* var. Saumya oil	0.1%	31.58	89.52	94.80	71.97
2	*Cymbopogon citrates* oil	0.05%	69.47	89.24	97.04	85.25
3	*Cymbopogon martinii* oil	0.05%	45.76	76.82	92.01	71.53
4	*Pogostemon cablin* oil	0.05%	62.79	83.58	94.28	80.21
5	*Curcuma longa* oil	0.1%	27.58	65.12	92.42	61.71
6	*Ocimum basilicum* var. Surabhi oil	0.1%	41.05	73.32	93.63	69.33
7	*O. basilicum* × *O. tenuiflorum* oil	0.1%	39.19	71.83	87.63	66.22
8	*Mentha piperita* oil	0.1%	24.06	63.52	87.86	58.48
9	Acephate 75 SP	500gm a.i/ha	39.19	75.25	77.41	63.95
10	Control	—	+8.95	+12.95	22.30	0.13
	CD at 5%		15.54	8.79	12.20	9.21

**DAS: Days after spraying*

spraying, all the treatments proved statistically superior over untreated control in reducing the aphid population except the treatment of *Ocimum basilicum* var. Saumya oil which was found statistically at par with untreated control. Thus the aphid population recorded from the plots treated with *Ocimum basilicum* var.. Saumya oil was less than the population recorded from untreated control plots yet the difference in aphid population of these two treatments was statistically not significant. However, the efficacy of *O. basilicum* var. saumya oil was also found at par with the efficacy of Mentha oil, *curcuma longa* oil, *O. basilicum var surabhi* oil, Acephate, *O. basilicum* × *O. tenuiflorum* oil and *Cymbopogon martinii* oil.

The rest of the treatments were performed statistically better than *O. basilicum* var. saumya oil. Efficacy of different treatments on 1st day after spraying were found in order of *Pogostemon cablin* oil > *Cymbopogon citrates* oil > *Cymbopogon martinii* oil > *O. basilicum* × *O. tenuiflorum* oil > Acephate > *O. basilicum* var. surabhi oil > *Curcuma longa* oil > *O. basilicum* var. Saumya oil > Mentha oil > control with an average aphid population of 17.9, 22.7, 27.5, 29.25, 30.95, 34.25, 38.2, 47.35, 52.25, and 81.6 per plant respectively. After one day of application of different treatments the plants treated with *Pogostemon cablin* oil harbour minimum aphid population but was found statistically at par with the effect of *Cymbopogon citrates* oil, *Cymbopogon martinii* oil, *O. basilicum* × *O. tenuiflorum* oil and Acephate with an average aphid population of 17.9, 22.7, 27.5, 29.25 and 30.95 respectively. Similarly, the effect of *Cymbopogon citrates* oil was found statistically superior over Mentha oil and *O. basilicum* var. saumya oil. The difference in aphid population observed in other treatments were not differ significantly among themselves.

After three days of spraying the average aphid population was recorded in order of control > Mentha oil > Curcuma longa oil > *O. basilicum* var. surabhi > O. basilicum × *O. tenuiflorum* oil > Acephate > *Cymbopogon martinii* oil. > *Cymbopogon citrates* oil > *Pogostemon cablin* oil> *O. basilicum* var. Saumya oil with 84.6, 25.1, 18.4, 15.5, 13.55, 12.6, 11.75, 8, 7.9 and 7.25 aphids per plant respectively.

It is evident from Table 3 that all the treatments were statistically superior over untreated control. The minimum aphid population was recorded in plots treated with *O. basilicum* var. Saumya oil and proved most effective treatment. However the effect of *O. basilicum* var. Saumya oil was found at par with the effect of *Cymbopogon citrates* oil, *Pogostemon cablin* oil and *Cymbopogon martinii* oil and superior over rest of the treatments. Second best treatment was *Cymbopogon citrates* oil which was statistically at par with *Pogostemon cablin* oil, *Cymbopogon martinii*, Acephate and O. basilicum × *O. tenuiflorum* oil and superior from rest of the treatments.

The average aphid population observed in different treatments after seven days of application was found in order of Control > Acephate > Mentha oil > O. basilicum × *O. tenuiflorum* oil > *Cymbopogon martinii* oil > Curcuma longa oil > *O. basilicum* var. surabhi oil > *O. basilicum* var. Saumya oil > *Pogostemon cablin* oil > *Cymbopogon citrates* with 58.2, 11.5, 8.35, 5.95, 4.05, 4, 3.7, 3.6, 2.75 and 2.2 aphids per plant, respectively. It is also evident from the data contained in Table 3 that the minimum aphid population (2.2 per plant) on 7th day after spraying was observed in the plots treated with *Cymbopogon citrates* oil but this treatment did not differ significantly with the aphid population observed in plots treated with *Pogostemon cablin* oil (2.75), *O. basilicum* var. Saumya oil (3.6), *O. basilicum* var. surabhi oil (3.7), *Curcuma longa* oil (4) and *Cymbopogon martinii* oil (4.05) and these were statistically superior to rest of the treatments. Overall average aphid population in different treatments after spraying was found in order of control > Mentha oil > Curcuma longa oil > *O. basilicum* var. Saumya oil > Acephate > *O. basilicum* var. surabhi oil > O. basilicum × *O. tenuiflorum* oil > *Cymbopogon martinii* oil > *Cymbopogon citrates* > *Pogostemon cablin* oil. This clearly indicate that the plots treated with *Pogostemon cablin* oil harbour minimum aphid population after spraying and untreated control plots harbour maximum aphid population.

Under present investigation attempts were also made to study the per cent reduction in aphid population due to different treatments. The data computed on per cent reduction in aphid population at different days after spraying were presented in Table 2. The data contained in Table 2 revealed that the per cent reduction in aphid population in all the treatments were statistically more than untreated control. Whereas in untreated control plots the aphid population have increasing trend upto 3rd after treatment (i.e. 10 Feb, 2017) thereafter on 7th day of spraying the reduction in aphid population was also observed under untreated plots with slower rate. It is also evident from the Table 2 that on 1st and 7th days after treatment maximum per cent reduction in aphid population was observed from plots treated with *Cymbopogon citrates* oil and found statistically superior over rest of the treatments. Whereas, on 3rd day after spraying *O. basilicum* var. saumya oil was found highly effective. On the 1st day after spraying reduction in aphid population was found in order of *Cymbopogon citrates* oil > *Pogostemon cablin* oil > *Cymbopogon martinii* oil > *O. basilicum* var. surabhi oil > Acephate = O. basilicum × *O. tenuiflorum* oil > *O. basilicum* var. Saumya oil > *Curcuma longa* oil > Mentha oil > control. Maximum reduction in aphid population over control was found with *Cymbopogon citrates* oil (69.47%) followed by *Pogostemon cablin* oil (62.79%). These treatments were statistically at par with each other in their efficacy and significantly superior to rest of the treatments. Further, it was also observed that per cent reduction in aphid population under *Cymbopogon martinii* oil (45.76%). *O. basilicum* var. surabhi oil (41.05%), Acephate (39.19%), *O. basilicum* × *O. tenuiflorum* oil (39.19%)

Table 3: Impact of various treatments on cabbage yield during *rabi* season 2016-17

Sl. No.	Treatments	Dose	Average yield Kg/ plot	Yield in Kg/ha	Yield in Qt/ha	Per cent increase in yield over control
1	*Ocimum basilicum* var. Saumya oil	0.1%	30.85	22851.85	228.52	22.06
2	*Cymbopogon citrates* oil	0.05%	31.58	23388.89	233.89	24.93
3	*Cymbopogon martinii* oil	0.05%	31.18	23092.59	230.93	23.34
4	*Pogostemon cablin* oil	0.05%	30.93	22907.41	229.07	22.35
5	*Curcuma longa* oil	0.1%	30.50	22592.59	225.93	20.67
6	*Ocimum basilicum var*. Surabhi oil	0.1%	30.78	22796.30	227.96	21.76
7	*O. basilicum* × *O. tenuiflorum oil*	0.1%	30.80	22814.81	228.15	21.86
8	*Mentha piperita* oil	0.1%	29.33	21722.22	217.22	16.02
9	Acephate 75 SP	500gm a.i/ha	30.40	22518.52	225.19	20.28
10	Control	—	25.28	18722.22	187.22	—

CD at 5%- 3.37

Table 4: Benefit /Cost ratio

Treatments	Yield (q ha^{-1})	Total increase in yield over control (q ha^{-1})	Per cent increase in yield over control	Return of increased yield (₹)*	Total cost/ expenditure (₹)**	Net profit (₹ ha^{-1})	B:C Ratio
Ocimum basilicum var. Saumya oil	228.52	41.3	22.06	49560	1850	47710	25.78
Cymbopogon citrates oil	233.89	46.67	24.93	56004	1875	54129	28.86
Cymbopogon martinii oil	230.93	43.71	23.34	52452	1625	50827	31.27
Pogostemon cablin oil	229.07	41.85	22.35	50220	1750	48470	27.69
Curcuma longa oil	225.93	38.71	20.67	46452	1950	44502	22.82
Ocimum basilicum var. Surabhi oil	227.96	40.74	21.76	48888	1850	47038	25.42
O. basilicum × *O. tenuiflorum* oil	228.15	40.93	21.86	49116	1850	47266	25.54
Mentha piperita oil	217.22	30	16.02	36000	1925	34075	17.70
Acephate 75 SP	225.19	37.97	20.28	45564	1750	43814	25.03
Control	187.22	—	—	—	—	—	—

Note: Price of cabbage ₹ 12/kg Labour charges = ₹ 250/ man day To spray 1 ha total man days required = 5 man days

** Cost of cabbage during current season ₹ 1200/- q-1*

*** It includes cost of insecticides and labour charge*

and *O. basilicum* var. Saumya oil (31.58%) treated plots were statistically at par. Though, the minimum reduction in aphid population over control on 1st day after spraying was observed in Mentha oil (24.06%) and *Curcuma longa* oil (27.58%), which were statistically at par with each other but superior to the untreated control.

The efficacy of different treatments after three days of spraying was found in order of *O. basilicum* var. Saumya oil > *Cymbopogon citrates* oil > *Pogostemon cablin* oil > *Cymbopogon martinii* oil > Acephate > *O. basilicum* Var. surabhi oil > O. basilicum × *O. tenuiflorum* oil >*Curcuma longa* oil > Mentha oil > control. Maximum reduction in aphid population over control was observed in *O. basilicum* var. saumya oil (89.52%) which was found statistically at par with *Cymbopogon citrates* oil (89.24%), and *Pogostemon cablin* oil (83.58%). The next effective treatments were *Cymbopogon martinii* oil (76.82%), Acephate (75.25%), *O. basilicum* var. Surabhi oil (73.32%) and *O. basilicum* × *O. tenuiflorum* (71.83%), these were comparable and statistically at par with each other. The Mentha oil (63.52%) was found least effective as compared to other treatments followed by *Curcuma longa* oil (65.12%), these treatments were statistically at par with each other but far superior to the untreated control plots.

After 7th day of spraying per cent reduction in aphid population was found in order of *Cymbopogon citrates* oil > *O. basilicum* var. saumya oil > *Pogostemon cablin* oil > O basilicum var. surabhi > *Curcuma longa* oil > Cymbopogon martinii > Mentha oil > O. basilicum × O. tenuiflorum oil > Acephate > control with per cent reduction of 97.04%, 94.80%, 94.28%, 93.63%, 92.42%, 92.01%, 87.86%, 87.63%, 77.41% and 22.30%, respectively. On 7th day after treatment *Cymbopogon citrates* oil showed the maximum reduction of aphid population over control followed by *O. basilicum* var. saumya oil, *Pogostemon cablin* oil , O. basilicum var. surabhi, *Curcuma longa* oil and Cymbopogon martinii. These were statistically at par with each other in their efficacy in reducing the aphid population. The next effective treatments in reducing the aphid population over control were Mentha oil and *O. basilicum* × *O. tenuiflorum* oil and these were statistically at par with each other. The minimum reduction of aphid population after seven days of spraying was observed in Acephate , although it was far superior than the control plots. On 7th day after spraying a reduction in aphid

population was also observed in control plots. Mean of per cent reduction in aphid population was also computed in Table 2. It clearly shows that among all treatments, *Cymbopogon citrates* (85.25%) was found most effective and which was statistically at par with *Pogostemon cablin* oil (80.21%). The next effective treatments were *O. basilicum* var. saumya (71.97%) and *Cymbopogon martinii* (71.53%) followed by *O. basilicum* var. Surabhi (69.33%) and *O. basilcum* × *O. tenuiflorum* (66.22%). They were statistically at par with each other. The least effective treatment was Mentha oil (58.48%) followed by *Curcuma longa* oil (61.71%) and Acephate (63.95%), these were statistically at par with each other but significantly different with untreated control. The effectiveness of Citronella oil was also studied by Gorski *et al*. (2010) on Foxglove aphid, *Aulacorthum solani* and they reported that 100 % mortality of foxglove aphid (*A. solani*) was recorded at 72 h after treatment of citronella oil at a concentration of 0.05% which is in conformity of present findings. Similarly Shiberu *et al.* (2016) reported that under field conditions *Cymbopogon citrates* gave 52.50 at one location and 62.72% mortality at another location in Ethiopia, against cabbage aphids, *Brevicoryne brassicae* (L.) after 3rd day observation in first spray. However, under present investigation the Citronella oil gave 89.24% aphid mortality after three days of spraying. The differences in per cent mortality may be due to difference in agro-climatic conditions of the locations where experiments were conducted. Further, Choi *et al.* (2003) and Park *et al.* (2008) tested the effect of Citronella oil against *Trialeurodes vaporariorum* adults and larvae of *Lycoriella ingenua* and found 100% @ 2.3 × 10^{-3} µl/ml air and 90% mortality @ 30 × 10^{-3} mg/l air, respectively. Under present investigation patchouli, *Pogostemon cablin* oil (0.05%) showed second highest mortality (80.21%) after Citronella oil. Whereas, Gorski *et al.* (2010) observed that the use of patchouli oil at a concentration 0.10% caused 100% mortality of foxglove aphid (*A. solani*) after 72 h of treatment. The differences observed in per cent mortality is due to difference in concentration used also may be due to difference of insect species. Patchouli, *Pogostenmon heyneanus* (Solanaceae) essential oil showed insecticidal activity against *Sitophilus oryzae* (Coleoptera: Curculionidae), *Stegobium paniceum* (Coleoptera: Anobiidae), *Tribolium castaneum* (Coleoptera: Tenebrionidae) and *Bruchus chinensis* (Coleoptera: Bruchidae) (Deshpande *et al*. 1974; Deshpande and Tipnis, 1977). Under present investigation basil oils [*Ocimum basilicum* var. saumya (71.97%), *O. basilicum* var. surabhi (69.33 %), *O. basilicum* × *O. tenuiflorum* (66.22%)] were proved comparatively less effective in reducing the aphid population in the field. The effectiveness of basil oils was also studied by Digilio *et al.* (2008), they found high mortality of pea aphid (*Acyrthosiphon pisum* Harris) and green peach aphid (*Myzus persicae* Sulzer) following the application of oil produced from basil (*Ocimum basilicum* L.). They also reported that basil (*Ocimum basilicum*) oil caused 100% mortality in Pea aphid, *A. pisum* at a dose of 1.0 µl/l and 2.0 µl/l. Under present investigation the other essential oils shown the varying toxic effects against cabbage aphid and found statistically superior over control Salvatore *et al.* (2004). Govindaraddi (2005), Walia (2005), Chang *et al.* (2009) and Gorski *et al*. (2010) have also carried out the experiments at different places against different pests to study the toxicity of different essential oils (selected under present investigation) and observed that all the essential oils provide toxic effects against insect pest.

Impact on yield of cabbage: The impact of different essential oils on cabbage yield was also studied under investigation; and maximum yield of cabbage heads was obtained in the plots treated with Citronella oil (233.89 qha^{-1}) followed by Palmarosa oil (230.93 q ha^{-1}), Patchouli oil (229.07 q ha^{-1}), *O. basilicum* var. saumya (228.52 q ha^{-1}), *O. basilicum* × *O. tenuiflorum* (228.15 q ha^{-1}), *O. basilicum var. Surabhi* (227.96 q ha^{-1}),*Curcuma longa* (225.93 q ha^{-1}), Acephate (225.19 q ha^{-1}), mentha oil (217.22 q ha^{-1}) and untreated control (187.22 q ha^{-1}). This may be due to their effectiveness against cabbage aphid population, Further, as various literatures demonstrate that these essential oils have toxic effect over other insect- pests hence they might have controlled the other pests of cabbage which gives better results over yield.

Benefit/cost ratio: The economics (B/C ratio) of various treatments applied for management of cabbage aphid were also calculated and presented in Table 4. The figures shows that maximum benefit was incurred from the plots treated with *Cymbopogon citrates* oil 0.05% (54129 ₹/ha) followed by *Cymbopogon martinii*, *Pogostemon cablin*, *O. basilicum* var. saumya, *O. basilicum* × *O. tenuiflorum*,

O. basilicum var. surabhi, *Curcuma longa*, Acephate 75 SP, Mentha oil with net profit of 50827 ₹/ha, 48470 ₹/ha, 47710 ₹/ha, 47266 ₹/ha, 47038 ₹/ha, 44502 ₹/ha, 43814 ₹/ha, 34075 ₹/ha respectively. Whereas, Table 4 clearly demonstrates that B/C ratio of *Cymbopogon martinii* oil treatment was maximum in comparison with other treatments and statistically superior over rest of the treatments. B/C ratio of different treatments was found in order of C*ymbopogon martinii* (31.27:1) > *Cymbopogon citrates* oil (28.86:1) > *Pogostemon cablin* (27.69:1) > *O. basilicum* var. saumya (25.78:1) > *O. basilicum* × *O. tenuiflorum* (25.54:1) > *O. basilicum* var. surabhi (25.42:1)> Acephate (25.03:1)> *Curcuma longa* (22.82:1) > Mentha oil (17.70:1).

CONCLUSION

All treatments showed high efficacy in reducing the aphid population as compared to untreated control. Among the different treatments Citronella oil was most effective against cabbage aphid which was followed by Patchouli oil Whereas, Mentha oil recorded the lowest efficacy compared with rest of treatments but it was also significantly superior over control. The yield data revealed that the effect of different essential oils was quiet good when compared with untreated control. The effect of *Cymbopogon citrates* i.e. Citronella oil on cabbage yield was found superior over rest of the treatments, whereas the performances of *Cymbopogon martinii* oil, *Pogostemon cablin* oil and *O. basilicum* var. saumya oil were also very good like the performance of Citronella oil. The yield from rest of treatments was also found superior over the control plots.present investigation it has also been found that maximum returns in terms of rupees was from plots treated with *Cymbopogon citrates* whereas, the maximum B/C ratio was observed in case of *Cymbopogon martinii*. Usage of Citronella oil and patchouli oil was found most effective which could be utilize against cabbage aphids for effective control and to avoid harmful effects of insecticides on human health and environment. These essential oils may proved a good alternative to the chemical insecticides or could be effectively incorporated for the management of cabbage aphid.

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