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Full Research Article

Evaluation of Petroleum Spray Oil Against Turnip Aphid, *Lipaphis erysimi* (Kaltenbach) Infesting Oilseed Brassica

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Abstract

Petroleum spray oil was evaluated against turnip aphid, *Lipaphis erysimi* (Kaltenbach) on *Brassica juncea* cv. PBR 210 at Punjab Agricultural University, Ludhiana during 2009-10 and 2010-11 crop seasons. Different treatments of petroleum spray oil included: 0.50, 0.75, 1.00, 1.25, 1.50 and 1.75% along with dimethoate 30 EC @ 1 lt ha^{-1} and untreated control. All the treatments resulted in significant reduction in the aphid population after 3 days of spray except petroleum spray oil (0.5%) and remained effective for up-to 10 days. Though, the chemical insecticide dimethoate was the most effective, petroleum spray oil @ 1.75% was statistically at par with it with 82.2-86.9% reduction in the aphid population and consistently remained effective for up to 10 days after application. Further, petroleum spray oil at either of the concentrations did not result in any toxic effect on *Coccinella septempunctata* and honey bees. The seed yield in the case of petroleum spray oil at all the concentrations, except at 0.5%, was statistically at par with the chemical insecticide dimethoate (1 lt ha^{-1}) in 2009-10, however, in 2010-11, the yield differences were non-significant due to low aphid population. Keeping in view its efficacy, petroleum spray oil has the potential to be used as an alternative to chemical insecticides for the management of turnip aphid.

1. Introduction

The members of the family Brassicaceae are cultivated throughout world for food, oil and feed purposes. Among these, oilseed brassicas are important source of oil and protein and India is one of the largest producers of rapeseed-mustard including China and Canada (FAOSTAT, 2009). *Brassica juncea* is the major winter season oilseed crop cultivated in India, while other species like *B. napus* and *B. rapa* are grown to a limited extent. Among the biotic stresses that confront these crops, the damage caused by mustard/turnip aphid, *Lipaphis erysimi* (Kaltenbach) (Hemiptera: Aphididae) is the major constraint in realization of full yield potential of the crop (Kumar et al., 2011; Atri et al., 2012). The damage caused by this key pest of mustard ranges from 35.0 to 91.0% in different agro-climatic conditions of the country (Singh and Sachan, 1994) and results in complete crop failure in the event of lack of control measures.

Because of the increasing public and scientific concerns about the known adverse effects of toxic insecticidal chemicals and risks associated with their use, the need of alternative methods of pest management is always sought which highlights the importance of this study. Among the alternatives of insect pest management, petroleum spray oils are considered as potential control agents against many insects. They are currently regarded as more environmental friendly than synthetic pesticides and are finding place in Integrated Pest Management (IPM) programs (Beattie and Smith, 1990), and degrade relatively quickly in the environment (Davidson et al., 1991; Beattie et al., 1995b) and have never been associated with resistance or outbreaks of secondary pests (Beattie, 1989, 1990). Keeping these in view, the present study was carried out with the objective to evaluate petroleum spray oil against mustard aphid infesting Indian mustard, *Brassica juncea.*

2. Materials and Methods

2.1. Study site

The study was carried out at Oilseeds Research Farm, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, (30.9° N and 75.85° E, 244 m above msl), India during 2009-10 and 2010-11 crop seasons.

2.2. Treatments and plant material

Brassica juncea cv. PBR 210 was sown in plots of size 4.2×3.0 m^2 with row to row and plant to plant spacing of

30 and 15 cm, respectively. The experiment was laid out in Randomized Complete Block Design with eight treatments and three replications. All the recommended package of practices was followed for raising a good crop except for spray of insecticides (PAU, 2009).

Different treatments were applied when the mustard aphid population reached economic threshold level of 50-60 aphids/plant (PAU, 2009). During 2009-10, two sprays were applied while in 2010-11 only one spray could be applied owing to low aphid population. The treatments included mustard spray oil from Hindustan Petroleum @ 0.5, 0.75, 1.00, 1.25, 1.50 and 1.75% along with dimethoate 30 EC @ 1 lt ha^{-1} and untreated control.

Under laboratory conditions, toxicity of different treatments to coccinellid beetles was evaluated. For this, treated leaves were collected from the field which harboured aphid colonies on their lower surface and placed in Petri plates slightly overlapping one over the other to facilitate contact to the treated surface. Five adults of *Coccinella septempuncata* were released in each Petri plate. The experiment was laid out in Completely Randomized Design with three replications per treatment. The leaves along with aphids were changed every alternate day.

2.3. Data collection and statistical analysis

Data on the aphid population/plant were recorded from top 10 cm central twig of plant before, 1, 3, 5, 7, 10 and 14 days after treatment from 10 plants selected at random from each plot. In 2010-11, the population of mustard aphid was very low, hence, data on the aphid population were recorded from tagged infested plants in the field. In addition, data on the number of bee visits plant^{-1} minute^{-1} were also recorded. Data on number of grubs and adults of coccinellids plant^{-1} were also recorded from 10 plants selected at random from each plot. Yield data were recorded at harvest of the crop. Data of the two years were not pooled due to non-significant differences in yield among different treatments in the year 2010-11. In the laboratory experiment, mortality data of *C. septempunctata* were recorded every 24 hours for five days after their release. The field data on mustard aphid population, honey bees activity, coccinellid population and yield data were subjected to analysis of variance following randomized complete block design while the laboratory data on mortality of coccinellid beetles were subjected to analysis of variance following completely randomized design using the statistical software OPSTAT (OPSTAT, 2009). Means were separated by least significant difference (LSD) at 5% level of significance.

3. Results and Discussion

All the treatments resulted in reduction in aphid population and provided protection from mustard aphid for 10 days. After one day of treatment, there was significant decline in aphid population over control in all the treatments except HP mustard spray oil @ 0.50% (Table 1). In the year 2009-10, the minimum population of 12.3 aphids plant^{-1} was recorded in dimethoate 30 EC @ 1 lt ha^{-1} followed by HP mustard spray oil @ 1.75 and 1.50% (14.7 aphids plant^{-1} each). After 3 days of treatment, aphid population in all the treatments was significantly lower than that in the control. The minimum aphid population was observed in the chemical insecticide dimethoate @ 1 lt ha^{-1} (6.6 aphids plant^{-1}). The aphid population in the HP mustard spray oil treatment 1.75% and 1.50% (12.5 and 14.3 aphids plant^{-1}, respectively) was at par with the chemical insecticide dimethoate @ 1 lt ha^{-1} (6.6 aphids/plant) and significantly lower than the remaining treatments of HP mustard spray oil. Almost similar trend was observed after 5, 7 and 10 days of treatment. The spray oil at 1.50 and 1.75% remained as effective as chemical insecticide for up-to 10 days after treatment. The second spray was done after 15 days of first spray. Almost similar trend as observed after first spray was observed after second spray with respect to efficacy of different treatments after 1 day of second spray. However, due to light thunderstorms, there was a sudden decline in the aphid population which did not develop further.

The trend in the efficacy of different treatments in 2010-11 crop was almost similar to that observed in 2009-10. After 1 day of treatment, the minimum aphid population of 10.2 aphids plant^{-1} was recorded in the case of dimethoate (Table 1). It was followed by petroleum oil @ 1.75 and 1.50% (13.5 and 15.0 aphids plant^{-1}, respectively) which were at par with chemical insecticide. After 3 days of treatment, aphid population in all the treatments was significantly lower than control. The minimum aphid population was observed in dimethoate (4.8 aphids plant^{-1}). It was followed by petroleum spray oil @ 1.75 and 1.50% (11.8 and 12.3 aphids plant^{-1}, respectively). Almost similar trend was observed after 5, 7 and 10 days of treatment. The spray oil at 1.75% remained as effective as chemical insecticide in reducing aphid population for up-to 10 days after application. Since the aphid population started declining after 10 days of first spray, second spray could not be applied. As the population of mustard aphid was very low and only a few plants in a plot were found infested, therefore, yield differences among treatments were non-significant.

Data on the toxicity of different treatments to honeybees are presented in (Table 2). Although slight reduction in bees' activity was recorded in all the treatments following spray including the chemical insecticide dimethoate during both the years, but statistically it was non-significant when compared with untreated control. Almost similar trend was observed with respect to toxicity of different treatments to natural enemies during both the years i.e. the treatments were statistically

Table 1: Efficacy of petroleum spray oil against mustard aphid under field conditions during 2009-10 and 2010-11

Sr. no.	Treatment	Aphid population plant^{-1} (Mean±SE)																Yield (kg ha^{-1})	
		2009-10									2010-11								
		BS*	1DAS†	3 DAS	5 DAS	7 DAS	10DAS	14DAS	1 DAS	3 DAS	BS	1 DAS	3 DAS	5 DAS	7 DAS	10DAS	14DAS	2009-10	2010-11
1.	Petroleum spray oil @ 0.50%	42.0±1.7	30.2±7.8	28.2±2.5	35.5±13.0	48.7±10.9	53.3±1.6	35.7±1.7	27.2±4.7	0.0±0.0	46.8±3.2	24.3±1.3	30.7±2.4	35.8±6.5	29.7±2.6	18.2±1.9	0.0±0.0	1430.56±87.01	1405.83 ±68.05
2.	Petroleum spray oil @ 0.75%	48.3±1.8	16.0±1.2	23.7±6.3	21.7±4.5	29.3±1.9	35.8±2.2	27.5±7.0	17.5±1.3	0.0±0.0	45.5±5.5	18.0±1.6	24.5±2.7	19.2±1.7	20.5±2.8	16.7±2.8	0.0±0.0	1534.72±66.24	1487.50± 79.38
3.	Petroleum spray oil @ 1.00%	39.7±2.1	18.8±2.0	22.7±6.7	17.7±2.6	16.0±1.3	21.8±1.8	32.7±7.2	16.8±3.7	0.0±0.0	49.8±3.1	17.7±1.4	22.3±1.5	16.5±1.1	15.7±2.6	15.5±2.4	0.0±0.0	1541.67±24.05	1491.67± 168.85
4.	Petroleum spray oil @ 1.25%	43.1±1.5	16.8±2.8	22.0±1.7	11.7±2.2	12.8±1.7	23.7±6.0	29.3±12.4	15.3±6.6	0.0±0.0	49.3±1.9	18.2±1.7	20.3±1.2	11.0±2.1	10.5±2.4	9.0±4.6	5.3±3.5	1580.56±21.69	1418.06± 67.19
5.	Petroleum spray oil @ 1.50%	49.0±3.3	14.7±1.1	14.3±3.9	11.0±1.6	9.7±0.1	18.3±3.0	36.2±5.7	14.0±0.7	0.0±0.0	47.0±5.2	15.0±0.2	12.3±2.6	10.0±1.8	7.3±0.7	12.2±3.2	0.0±0.0	1598.61±18.68	1463.89± 189.19
6.	Petroleum spray oil @ 1.75%	49.0±3.3	14.7±1.8	12.5±0.2	8.7±0.4	7.8±1.3	18.8±2.0	30.0±1.0	11.8±1.9	0.0±0.0	44.5±3.6	13.5±1.0	11.8±1.9	9.5±1.0	7.3±1.4	5.8±1.0	5.0±5.0	1611.11±60.54	1508.33± 156.86
7.	Dimethoate 30 EC @ 1 lt ha^{-1}	49.3±0.8	12.3±2.8	6.6±6.4	6.2±1.1	6.0± 0.7	8.8±1.0	31.0±5.5	9.2±2.6	0.0±0.0	45.5±4.9	10.2±0.4	4.8±0.4	4.5±0.2	4.7±2.4	1.7±1.6	0.0±0.0	1625.00±72.16	1488.89± 69.11
8.	Control	46.2±2.6	37.2±2.6	43.2±2.4	57.8±3.0	48.5±3.9	53.7±5.2	43.5±7.5	37.0±5.0	0.4±0.1	51.5±3.5	47.8±2.0	46.7±2.2	51.2±3.0	47.5±1.8	23.2±4.8	8.8±1.9	1347.22±13.89	1486.11± 13.89
	CD (p=0.05)	NS	10.6	13.9	15.8	13.4	10.9	NS	11.9		NS	4.33	5.36	8.54	7.28	9.16	NS	167.00	NS

*BS: Before spray; †DAS: Days after spray

Table 2: Toxicity of petroleum spray oil to honey bees under field conditions during 2009-10 and 2010-11

Sr. no.	Treatment	Number of bee visits plot^{-1} minute^{-1}													
		2009-10							2010-11						
		BS*	1 DAS†	3 DAS	5 DAS	7 DAS	10 DAS	14 DAS	BS	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	14 DAS
1.	Petroleum spray oil @ 0.50%	2.7±0.3	2.3±0.3	1.7±0.3	2.7±0.3	3.3±0.3	1.0±0.0	0.3±0.3	3.0±0.5	1.7±0.3	2.0±1.1	2.3±0.8	1.3±0.6	1.3±0.6	1.0±0.5
2.	Petroleum spray oil @ 0.75%	2.7±0.6	2.7±0.3	1.0±0.5	1.7±0.3	2.7±0.3	1.3±0.3	0.7±0.6	3.0±1.1	2.7±1.4	2.0±0.5	2.7±1.3	3.3±1.2	0.7±0.6	0.0±0.0
3.	Petroleum spray oil @ 1.00%	2.3±0.6	2.3±0.3	1.0±0.5	1.3±0.3	2.0±0.5	0.7±0.3	0.0±0.0	1.7±0.3	2.0±1.0	2.7±0.3	1.0±0.5	2.7±0.3	1.0±0.0	0.7±0.6
4.	Petroleum spray oil @ 1.25%	3.0±0.5	2.3±1.4	1.7±0.3	2.0±0.0	2.0±0.5	0.7±0.6	0.3±0.3	2.7±0.8	2.0±1.0	2.0±0.5	2.3±0.3	1.7±1.2	2.3±0.6	0.7±0.6
5.	Petroleum spray oil @ 1.50%	2.0±0.5	1.3±0.6	2.0±0.5	1.7±0.8	1.0±0.5	1.0±0.0	0.0±0.0	1.7±1.2	1.7±1.2	2.0±1.0	4.0±0.5	2.3±0.3	2.0±0.0	0.3±0.3
6.	Petroleum spray oil @ 1.75%	1.7±0.8	2.0±0.5	2.3±0.6	2.7±0.3	1.3±0.8	1.0±0.5	0.3±0.3	2.7±0.6	1.7±1.2	1.7±1.2	2.3±0.8	1.7±0.8	2.0±1.1	1.0±0.5
7.	Dimethoate 30 EC @ 1 lt ha^{-1}	2.7±0.8	1.0±0.5	1.3±0.3	3.0±0.5	1.7±0.3	0.7±0.6	1.0±0.5	1.3± 0.8	1.3±0.6	1.0±0.5	2.3±1.2	2.0±1.1	1.7±0.8	1.3±0.8
8.	Control	2.3±0.8	4.7±0.6	2.3±0.8	2.7±0.8	2.0±0.5	0.3±0.3	0.0±0.0	3.0±0.5	4.3±0.6	2.0±0.5	3.0±0.5	2.3±0.8	1.3±0.8	0.3±0.3
	CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*BS: Before spray; †DAS: Days after spray

non-significant (Table 3). Although, larvae of *Chrysoperla carnea* and *syrphid fly* were observed in the later part of the season, but the population was in traces and too low to draw valid conclusions. Therefore, the data for coccinellid beetles only are presented. There were non significant differences in the population of coccinellid beetles in different treatments (Table 3).

Under the laboratory conditions, HP mustard spray oil did not result in significant mortality of coccinellid beetles compared to control for up-to 120 hours after treatment (Table 4). However, more than 60 and 80% mortality was observed in dimethoate in 2009-10 and 2010-11, respectively, which was significantly higher than that in the control.

In the year 2009-10, the seed yield in all the treatments was significantly higher than that in the control (1347.2 k ha^{-1}) except in petroleum spray oil @ 0.5% (1430.56 k ha^{-1}) (Table 1). The maximum seed yield of 1625.00 k ha^{-1} was recorded in the case of dimethoate. It was followed by petroleum spray oil @ 1.75% (1611.11 k ha^{-1}), 1.50% (1598.61 k ha^{-1}), 1.25% (1580.56 k ha^{-1}), 1.00% (1541.67 k ha^{-1}) and 0.75% (1534.72 k ha^{-1}) which were at par with each other. However, in the year 2010-11, the population of mustard aphid was very low and hence, the yield differences among the treatments were non-significant. Thus, it can be concluded from the study that petroleum spray oil @ 1.75% resulted in significant reduction in aphid population for up-to 10 days of treatment in both the years and was at par with chemical insecticide dimethoate @ 1 ml ha^{-1}. Further, it did not result in any significant adverse effect on both coccinellid predators as well as honey bees.

Petroleum spray oils are very effective in controlling a range of insect-pests such as aphids, scale insects, mites etc. (Davidson et al., 1991; Lawson and Weires, 1991). In the present study,

Table 3: Toxicity of petroleum spray oil to coccinellids under field conditions during 2009-10 and 2010-11

Sr. no.	Treatment	Number of Coccinellid beetles plant^{-1}															
		2009-10									2010-11						
		BS*	1 DAS†	3 DAS	5 DAS	7 DAS	10 DAS	14 DAS	1 DAS	3 DAS	BS	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	14 DAS
1.	Petroleum spray oil @ 0.50%	0.17±0.17	0.00±0.00	0.10±0.10	0.07±0.07	0.10±0.05	0.73±0.21	1.17±0.20	1.03±0.20	1.13±0.17	0.00±0.00	0.00±0.00	0.00±0.00	0.20±0.11	0.33±0.06	0.20±0.11	0.13±0.07
2.	Petroleum spray oil @ 0.75%	0.00±0.00	0.07±0.00	0.07±0.33	0.10±0.10	0.07±0.03	0.47±0.08	1.07±0.14	0.87±0.12	0.77±0.17	0.20±0.20	0.13±0.13	0.20±0.11	0.33±0.17	0.47±0.27	0.40±0.20	0.00±0.00
3.	Petroleum spray oil @ 1.00%	0.03±0.03	0.03±0.03	0.07±0.07	0.07±0.07	0.10±0.00	0.50±0.15	1.03±0.14	1.60±0.32	0.70±0.15	0.00±0.00	0.00±0.00	0.07±0.07	0.00±0.00	0.13±0.13	0.07±0.07	0.00±0.00
4.	Petroleum spray oil @ 1.25%	0.00±0.00	0.00±0.00	0.03±0.03	0.03±0.03	0.13±0.08	1.00±0.11	1.33±0.27	1.23±0.33	1.47±0.29	0.00±0.00	0.07±0.07	0.07±0.07	0.40±0.20	0.27±0.07	0.20±0.11	0.00±0.00
5.	Petroleum spray oil @ 1.50%	0.07±0.07	0.00±0.00	0.00±0.00	0.10±0.05	0.13±0.03	1.07±0.23	1.37±0.20	1.83±0.63	0.90±0.15	0.00±0.00	0.00±0.07	0.00±0.00	0.07±0.07	0.20±0.11	0.13±0.07	0.20±0.20
6.	Petroleum spray oil @1.75%	0.10±0.10	0.07±0.07	0.03±0.03	0.07±0.07	0.23±0.08	0.83±0.08	1.00±0.11	1.53±0.26	0.70±0.26	0.07±0.07	0.07±0.07	0.20±0.11	0.33±0.07	0.27±0.17	0.27±0.06	0.07±0.07
7.	Dimethoate 30 EC @ 1 lt ha^{-1}	0.00±0.00	0.00±0.00	0.07±0.07	0.03±0.03	0.27±0.13	0.63±0.08	1.20±0.11	2.27±0.89	1.03±0.43	0.00±0.00	0.00±0.00	0.00±0.00	0.13±0.13	0.07±0.07	0.13±0.13	0.00±0.00
8.	Control	0.00±0.00	0.00±0.00	0.03±0.03	0.07±0.07	0.20±0.05	1.17±0.20	1.30±0.17	2.30±0.32	0.93±0.23	0.27±0.27	0.33±0.24	0.27±0.17	0.53±0.07	0.60±0.11	0.47±0.07	0.13±0.07
	CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*BS: Before spray; †DAS: Days after spray

the spray oil at 1.75% concentration consistently remained as effective as chemical insecticide for up-to 10 days after application in both the years. The major tenet of IPM is the reduced use of pesticides and the use of alternative pest management options least disruptive to the environment. It is a well known fact that oils can result in insect mortality by physically interfering with their respiration as well as by chemical action (Martin and Woodcock, 1983). Mineral oils are being used for insect pest management for over two centuries (Miller, 1983; Agnello, 2002) and continue to play an important role in insect pest management in fruit trees in the United States (Riehl, 1981), Australia (Furness and Maelzer, 1981), Israel (Neubauer, 1981), Japan (Ohkubo, 1981) and Canada (Anonymous, 1991). However, there is scanty information about their use on mustard crop and the present work attempts to fill this gap.

Phytotoxicity is a major limitation of petroleum oils as crop protectants. But in the present study, no phytotoxicity was observed even at the highest concentration of 1.75%. Petroleum spray oil is a refined petroleum product that is distilled to

Table 4: Toxicity of petroleum spray oil to *Coccinella septempunctata* under laboratory conditions

Sr. no.	Treatment	% Cumulative mortality (Hrs. after treatment)									
		2009-10					2010-11				
		24	48	72	96	120	24	48	72	96	120
1.	Petroleum spray oil @ 0.50%	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)
2.	Petroleum spray oil @ 0.75%	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)
3.	Petroleum spray oil @ 1.00%	0.0 (0.0±0.00)	6.7 (8.8±8.85)	6.7 (8.8±8.85)	6.7 (8.8±8.85)	6.7 (8.8±8.85)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)
4.	Petroleum spray oil @ 1.25%	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)
5.	Petroleum spray oil @ 1.50%	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)
6.	Petroleum spray oil @ 1.75%	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	13.3 (13.07±13.07)	13.3 (13.07±13.07)	13.3 (13.07±13.07)	13.3 (13.07±13.07)
7.	Dimethoate 30 EC @ 1lt ha^{-1}	60.0 (51.1±6.98)	66.7 (54.9±4.22)	66.7 (54.9±4.22)	66.7 (54.9±4.22)	66.7 (54.9±4.22)	66.7 (54.97±4.22)	80.0 (68.05±11.56)	80.0 (68.05±11.56)	80.0 (68.05±11.56)	80.0 (68.05±11.56)
8.	Control	6.7 (8.8±8.85)	6.7 (8.8±8.85)	6.7 (8.8±8.85)	6.7 (8.8±8.85)	6.7 (8.8±8.85)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)	0.0 (0.0±0.00)
CD (p=0.05)		(12.05)	(14.12)	(14.12)	(14.12)	(14.12)	(4.51)	(18.66)	(18.66)	(18.66)	(18.66)

Figures in parentheses are arc sin transformed values

remove impurities that can damage plants. Highly refined narrow range petroleum spray oils in particular are IPM-compatible pest control compounds (Beattie, 1991; Nicetic et al., 2001) that are effective against a wide range of pests (Davidson et al., 1991; Lawson and Weires, 1991).

The petroleum spray oils with application rates between 100x and 200x are frequently applied on citrus to control Arrowhead scale, *Unaspis yanonensis* (Kuwama) in Jeju (RDA, 2008). These have also been found to be effective against citrus red mite, *Panonychus citri* (Herron et al., 1995) and citrus leaf miner, *Phyllocnistis citrella* (Beattie et al., 1995a, b). Furthermore, they can also improve integrated pest management systems because petroleum oils do not severely affect populations of beneficial arthropods, although predators and parasites may be killed on contact when sprayed directly (Davidson et al., 1991). Both the direct application as well as the deposits of petroleum spray oil were found to be highly effective in controlling *Aphis gossypii* (Najar-Rodriguez et al., 2007a, b).

Though, anoxia is considered as the most common physical mode of action of these oils that act by blocking the spiracles, accumulating in the tracheae and thus suffocating the insect (Davidson et al., 1991), petroleum spray oils have been suggested to have effects other than suffocation, including desiccation through water loss (Wigglesworth, 1941; Ebeling, 1974), solubilisation of cell membranes (Van Overbeek and Blondeau, 1954) and disruption to the nervous system (Taverner et al., 2001). Direct toxic effects of an nC15 oil to the peripheral nerves of light brown apple moth, *Epiphyas postvittania* Walker have been demonstrated by Taverner et al. (2001). Negative behavioural effects on the feeding and oviposition behaviour of *Helicoverpa* adults (Mensah et al., 1995) and citrus leaf miner, *Phyllocnistis citrella* Stainton (Beattie et al., 1995a) have also been recognized and quantified.

The commercial formulation of the petroleum spray oil was found to be highly effective in controlling the turnip aphid at concentration as low as 0.75%. It did not show any apparent toxic effect on the honeybees as well as ladybird beetles in the field as well as laboratory. Recently, Najar-Rodriguez et al. (2008) have demonstrated that modern petroleum spray oils show their effect on the nervous system of insects. Since petroleum spray oils show their effect on the nerve activity of insects, thus, they could be integrated into resistance management strategies especially for synthetic insecticides that target central nervous system of insects such as pyrethroids and organophosphates. Though these insecticides also act on central nervous system but they kill the insect in different ways than the oils. The oil could be applied in conjunction with such synthetic insecticides to kill the resistant individuals that survive the insecticide application. No case for resistance to petroleum spray oils has ever been documented in more than a century of use (Davidson et al., 1991), which further confirms the suitability of petroleum spray oils as effective components of insecticide resistance management programs. The petroleum spray oils could also be used as a means of increasing the penetration and toxicity of new botanical pesticides or as a tool to deliver the toxins to their site of action, if this includes the central nervous system (Najar-Rodriguez et al., 2008).

4. Conclusion

Petroleum spray oil @ 1.75% can be used as an alternative to chemical insecticides for the management of aphids on rapeseed-mustard. It offers an environment friendly pest management strategy to which no case of resistance by any pest has been reported so far. Thus, a pest control product based on petroleum spray oil could be promising for the control of soft bodied insects such as turnip/mustard aphid and can be incorporated in Integrated Pest Management (IPM) program.

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