International Journal of Agriculture, Environment and Biotechnology
Citation: IJAEB: 9(5): 877-885, October 2016
DOI: 10.5958/2230-732X.2016.00113.3

ENTOMOLOGY

Cost-effective and eco-friendly management of *Oligonychus coffeae*, *Calacarus carinatus* and *Acaphylla theae* on tea with a pyridazinone molecule fenpyroximate 5% EC

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Paper No. 516 Received: 4-1-2016 Accepted: 12-9-2016

Abstract

The hazardous environmental effect, non-selectivity with non-target toxicity and longer residual persistence of conventional synthetic pesticides leads to resistance development and secondary pest outbreak opened the new modern era of bio-rational eco-friendly chemicals having novel mode of action with higher bio-efficacy on insects and mites control as an approach of integrated pest management. Field bio-effectiveness of a METI acaricide fenpyroximate 5% EC along with traditional acaricides as foliar spray against tea red spider mite, purple mite and pink mite was undertaken at Sukna Tea Estate and Kamalpur Tea Estate, West Bengal respectively with a 20+ years old plantation (TV-29) during 2013-2014 and 2014-2015. The treatments at higher dosages (30 and 60 g a.i. ha^{-1}) were superior over standard checks propargite 57% EC and fenazaquin 10% EC. Mean percent reduction of red spider mite, purple mite and pink mite was minimum in treatments with higher dosages with mean value ranging from 73.83%-81.17%, 83.87%-91.66% and 83.90%-90.15% respectively. The test chemistry was relatively safe to important predatory fauna like *Cheilomenes sexmaculata and Amblyseius ovalis*. Highest yield was obtained in case of higher dosages (637.9 and 648.3 kg made tea ha^{-1}), but fenpyroximate 5% EC at 30 g a.i. ha^{-1} (600 ml ha^{-1}) proved most economic with the cost: benefit ratio of 1: 18.22, in the management of different mite pests infesting tea.

Highlights

- The molecule has rarely been tasted against tea mites including Eriophyids.
- Results obtained were highly significant in pest management with negligible non-target toxicity and enhance the yield.

Keywords: Fenpyroximate 5% EC, tea red spider mite, purple mite, pink mite, predators, economic yield

Tea, *Camellia sinensis* (L.) O. Kuntze (Family: Theaceae) is one of the most important cash crops grown over 2.71 million hectares in more than 34 countries to produce 3.22 million metric tonnes of tea annually (Hazzrika *et al*., 2009); cultivated in large and small scale plantations at Sub- Himalayan West Bengal. India is the largest producer of black tea as well as the largest consumer of tea in the world with 23% of total world production and 21% of total world consumption (Basu *et al*., 2010). Though a number of pests have been reported, however, insects and mites pose a greater threat causes 5-55% yield loss (Kumari *et al*., 2012). Among non-insect arthropods, the mite pest complex viz. red spider mite, *Oligonychus coffeae* Nietner (Acari: Tetranychidae), purple mite, *Calacarus carinatus* Green (Acari: Eriophyidae) and pink mite, *Acaphylla theae* Watt (Acari: Eriophyidae) has pivotal role in yield and quality reduction by causing 50-75% economic loss of total crop yield (Gurusubramanian *et al*., 2005; Subaharan and Regupathy, 2006). Sub-Himalayan *Terai* and the Dooars regions located in the foot hills of Darjeeling Himalaya and plains of North Bengal also faced their severity in recent past (Mukhopadhyay and Roy, 2009). High agricultural inputs in various ways are being used in tea cultivation which is detrimental for non-target organisms as well as human being also (Nath *et al*., 2013). Indiscriminate use of pesticides by the tea growers to mitigate these pests leads to resistance, resurgence and environmental problems. Recent reports indicate that insecticides and acaricides consumption has increased in *Terai* as well as in Dooars tea plantations where most of the acaricides (85%) being used between the month of January and June (Sannigrahi and Talukder, 2003). Many workers have reported that management of *Oligonychus coffeae* in tea became a challenge apparently due to higher tolerance to pesticides (Sahoo *et al*., 2003 and Roy *et al*., 2008).

Hence, there is a continual need for application of new acaricides with novel biochemical modes of action, but their use to be optimized in order to prevent or delay the evolution of resistance and prolong their life span (Dekeyser, 2005) with negligible non-target toxicity. Pyridazinone acaricide fenpyroximate is such a compound that acts as mitochondrial electron transport inhibitors (METI) at complex I (Hamedi *et al*., 2010), able to control of larvae, nymphs and adults of tetranychid, tenuipalpid, tarsonemid and eriophyid mites (Tomlin, 2000). Therefore, the present experiment was conducted to evaluate the field efficacy of a novel acaricide molecule, fenpyroximate, in comparison to traditional acaricides to manage major acarine pests of tea followed by their effect on prevailing natural enemies along with estimation of yield and economics.

Materials and Methods

Details of field experiment

The experiment was carried out at Kamalpur Tea Estate region for tea red spider mite and at Sukna Tea Estate for pink and purple mite of *Terai*, Darjeeling district, West Bengal, India, on a 20+ years old plantation (TV 29) with single hedge planting of four replications for each treatment in Randomized Block Design under both the experimental sites during December to April of 2013-2014 and 2014-2015.

Treatment details and data recording

Two foliar applications @ 500 liter water per hectare at 15 days interval was imposed. The treatments were: (i) fenpyroximate 5% EC (PYROMITE manufactured by Excel Crop Care Ltd., Mumbai) @ 300 ml ha^{-1} (15 g ai. ha^{-1}), (ii) @ 600 ml ha^{-1} (30 g ai. ha^{-1}), (iii) @ 1200 ml ha^{-1} (60 g ai. ha^{-1}), (iv) propargite 57% EC (OMITE manufactured by Dhanuka Agritech Ltd., Gurgaon) @ 1000 ml ha^{-1} (570 g ai. ha^{-1}), (v) fenazaquin 10% EC (MAGISTER manufactured by DUPONT Crop Protection, Gurgaon) @ 1000 ml ha^{-1} (100 g ai. ha^{-1}) with untreated control plots. Observations on the number of the motile stages of mites were recorded on ten leaves selected at random from each of the ten bushes. Observations on mite incidence were taken on 3rd, 7th and 10th day after each imposition.

The percentage reduction in mite population was assessed by adopting the following formula (Henderson and Tilton, 1955): Percentage reduction = $\{1 - (T_a \times C_b / T_b \times C_a)\} \times 100$ %, [where, Ta= mite population in treated plant after treatments, Tb= mite population in treated plant before treatments, Ca= mite population in control plants after treatments and Cb= mite population in control plants before treatments]. Observations on the incidence of available predators, like *Cheilomenes sexmaculata and Amblyseius ovalis* were taken on 15th day after both the applications on 10 leaves selected randomly from 10 bushes treatment^{-1}.

To record the phytotoxicity, visual observations were recorded in each treatment for epinasty, hyponasty, leaf tip injury, leaf surface injury, wilting, vein clearing, etc., on 0-10 scale as per CIB & RC (Central Insecticide Board and Registration Committee, Govt. of India) guide lines.

Statistical interpretation

All data were then subjected to Analysis of Variance (ANOVA) after making necessary transformation [$\sqrt{x+0.5}$ or by $\sin^{-1}$ p (where p is % mortality / 100)] wherever necessary. Yield of tea green leaf in different treatments were recorded and subsequently they were converted to made tea kg ha^{-1} (m.t. kg ha^{-1}) by multiplying green leaf yield kg ha^{-1} by a factor of 0.22 (Rattan, 1994).

Results and Discussion

Efficacy against red spider mite, *O. coffeae*

Table 1 represents the population data of tea red spider mite in different treatments varied from 5.69 to 7.53 per cm^2 leaf surface before spray. Though, all the treated plots gave significant reduction of population over control, it can be said that maximum reduction in population was recorded at 3 days after spraying after which population gradually started to build up but still proving significant reduction of pest population till 10 days after spraying.

Satisfactory results were obtained in plots treated with fenpyroximate 5 % EC @ 15 and 30 g a.i. per hectare as it recorded 71.29 and 74.70 percent and 75.18 and 77.05 percent mean reduction in population over control respectively after first and second spray during the first season which were statistically at par and provided more effective control of population than the standard checks. Although, higher dose of fenpyroximate 5 % EC @ 60 g a.i. per hectare gave the best result in terms of reduction of red spider mite population over control at 10 days after spraying, in terms of safety evaluation, the test acaricide in the highest dose found moderately toxic towards predatory population.

Similar results were also encountered in the second season also. 100 % mortality of nymphs and adults with no hatching of eggs of tea red spider mites at 24 hours after application of fenpyroximate was observed by Babu *et al*. (2009). Field effectiveness of the same molecule against *O. coffeae* was also investigated by Biswas *et al*. (2009) and Radhakrishnan *et al*. (2015).

Efficacy against purple mite, *C. carinatus*

Table 2 revealed the population data of purple mites where, similar trend in population control was observed here also. Fenpyroximate 5 % EC @ 15 and 30 g a.i. per hectare recorded 80.50 to 84.72 percent and 83.87 to 86.28 percent mean reduction of population over control respectively during both the seasons but were preceded by the higher dose of 60 g a.i. per hectare (86.91 to 91.66 percent mean population reduction). The test molecule performed better than the standard checks at 30 g a.i. per hectare even after 10 days of spraying during 2013-2014 and 2014-2015.

Efficacy against pink mite, *A. theae*

Fenpyroximate 5 % EC @ 15 and 30 g a.i. per hectare recorded 81.90 to 85.43 and 83.90 to 86.99 percent mean reduction of pink mite population over control respectively during both the seasons has depicted in table 3. The test molecule performed better than the standard checks at both the dosage even after 10 days of spraying.

Non-target toxicity of fenpyroximate 5% EC

Table 4 represents the population data pertaining to the natural enemies (primarily predators) encountered in the different treatment schedules. It is clear from the table that the population of *Cheilomenes sexmaculata* varied from 6.86 to 7.91 in different treatments, while that of *Amblysius ovalis* varied from 19.14 to 23.66 per 10 leaves before application of the test molecule. A slight decline in population of natural enemies was recorded after application of fenpyroximate 5% EC at different dosages.

However, fenpyroximate 5 % EC @ 15 and 30 g a.i. per hectare recorded minimum reduction to the tune of 5.04 to 5.96 and 7.87 to 9.03 percent of *Cheilomenes sexmaculata* and 7.14 to 8.50 and 9.18 to 10.93 percent of *Amblysius ovalis* respectively over untreated control, performing better than the standard checks. Khan, (2009) investigated and reported negligible toxicity of fenpyroximate against coccinellid predators. Present findings are also in parity with Park *et al*. (2011), regarding the safety evaluation of fenpyroximate against predatory mite population. Highest number of both the natural enemies were recorded in untreated control plots while highest reduction was encountered in tea bushes treated with propargite 57% EC.

Yield and economics

Regarding the yield parameter, fenpyroximate 5 % EC @ 60 g a.i. per hectare provided highest yield (648.3 kg made tea ha^{-1}) followed by 30 and 15 g a.i. per hectare (637.9 and 605.8 kg made tea ha^{-1}) have depicted on table 5. But, fenpyroximate 5% EC at 30 g a.i. per hectare found most economic dose with highest cost: benefit ratio (1: 18.22). 561.6 and

Table 1: Bio-efficacy of fenpyroximate 5 % EC against Red Spider mite, *Oligonychus coffeae* Nietner on Tea at Kamalpur Tea Estate, Terai, Darjeeling during 2013-2014 and 2014-2015

Sl. No.	Treatments	Dose (g a.i. ha^{-1})	2013-2014										2014-2015									
			1st spray					2nd spray					1st spray					2nd spray				
			Pre-application count (No. of motile stages sq.cm^{-1} leaf surface)	Mite population on different DAS (No. of motile stages sq.cm^{-1} leaf surface)			Mean % reduction of mite population over untreated control	Pre-application count (No. of motile stages sq.cm^{-1} leaf surface)	Mite population on different DAS (No. of motile stages sq.cm^{-1} leaf surface)			Mean % reduction of mite population over untreated control	Pre-application count (No. of motile stages sq.cm^{-1} leaf surface)	Mite population on different DAS (No. of motile stages sq.cm^{-1} leaf surface)			Mean % reduction of mite population over untreated control	Pre-application count (No. of motile stages sq.cm^{-1} leaf surface)	Mite population on different DAS (No. of motile stages sq.cm^{-1} leaf surface)			Mean % reduction of mite population over untreated control
				3rd	7th	10th			3rd	7th	10th			3rd	7th	10th			3rd	7th	10th	
1	Fenpyroximate 5 % EC	15	6.27	1.82 (1.52)$^{\#}$	2.38 (1.70)$^{\#}$	3.13 (1.91)$^{\#}$	71.29 (57.60)*	6.21	1.30 (1.34)	1.96 (1.57)	2.71 (1.79)	75.18 (60.12)	7.23	1.79 (1.51)	2.41 (1.71)	3.14 (2.06)	69.90 (56.73)	6.47	1.41 (1.38)	1.86 (1.54)	2.35 (1.69)	76.68 (61.12)
2	Fenpyroximate 5 % EC	30	7.53	1.54 (1.43)	2.11 (1.62)	2.80 (1.82)	74.70 (59.80)	5.87	1.22 (1.31)	1.73 (1.49)	2.56 (1.75)	77.05 (61.38)	6.59	1.56 (1.44)	2.07 (1.60)	2.77 (1.81)	73.83 (59.23)	6.31	1.23 (1.32)	1.66 (1.47)	2.08 (1.61)	79.30 (62.94)
3	Fenpyroximate 5 % EC	60	7.16	1.36 (1.36)	1.89 (1.55)	2.74 (1.80)	76.58 (61.06)	5.69	1.17 (1.29)	1.68 (1.48)	2.12 (1.62)	79.30 (62.94)	6.54	1.23 (1.32)	1.73 (1.49)	2.25 (1.66)	78.62 (62.46)	5.88	1.12 (1.27)	1.53 (1.42)	1.87 (1.54)	81.17 (64.28)
4	Propargite 57% EC	500	6.88	1.94 (1.56)	2.44 (1.71)	3.31 (1.95)	69.88 (56.71)	6.13	1.41 (1.38)	2.04 (1.59)	2.80 (1.82)	74.06 (59.38)	7.18	1.82 (1.52)	2.50 (1.73)	3.29 (1.95)	68.79 (56.04)	5.90	1.54 (1.43)	1.90 (1.55)	2.40 (1.70)	75.68 (60.45)
5	Fenazaquin 10 % EC	100	6.24	1.67 (1.47)	2.19 (1.64)	2.85 (1.83)	73.64 (59.11)	6.05	1.38 (1.37)	1.97 (1.57)	2.77 (1.81)	74.56 (59.71)	7.13	1.80 (1.52)	2.47 (1.72)	3.20 (1.92)	69.41 (56.42)	6.34	1.49 (1.41)	1.85 (1.53)	2.33 (1.68)	76.43 (60.96)
6	Untreated Control	—	6.50	7.55 (2.84)	8.27 (2.96)	9.68 (3.19)	—	6.42	7.12 (2.76)	7.93 (2.90)	9.01 (3.08)	—	6.68	7.22 (2.78)	8.13 (2.94)	9.08 (3.09)	—	6.52	7.23 (2.78)	7.97 (2.90)	8.85 (3.06)	—
	CV (%)		NS	0.33	0.29	3.34	—	NS	3.41	0.53	2.95	—	NS	3.27	3.14	0.77	—	NS	3.65	2.89	3.47	—
	SEm		NS	0.02	0.01	0.21	—	NS	0.16	0.03	0.18	—	NS	0.17	0.18	0.05	—	NS	0.18	0.21	0.13	—
	C.D.at 5%		NS	0.05	0.05	0.63	—	NS	0.49	0.09	0.53	—	NS	0.50	0.53	0.15	—	NS	0.55	0.36	0.44	—

*DAS-Days After Spraying. *Figures in parentheses are angular transformed values; #Figures in parentheses are square root transformed values*

Table 2: Bio-efficacy of fenpyroximate 5 % EC against Purple mite, *Calacarus carinatus* on Tea at Sukna Tea Estate, Bagdogra, Darjeeling during 2013-2014 and 2014-2015

Sl. No.	Treatments	Dose (g a.i. ha^{-1})	2013-2014										2014-2015									
			1st spray					2nd spray					1st spray					2nd spray				
			Pre treatment count (No. of motile stages 10 leaves^{-1})	Mite population on different DAS (No. of motile stages 10 leaves^{-1})			Mean % reduction of mite population over untreated control	Pre treatment count (No. of motile stages 10 leaves^{-1})	Mite population on different DAS (No. of motile stages 10 leaves^{-1})			Mean % reduction of mite population over untreated control	Pre treatment count (No. of motile stages 10 leaves^{-1})	Mite population on different DAS (No. of motile stages 10 leaves^{-1})			Mean % reduction of mite population over untreated control	Pre treatment count (No. of motile stages 10 leaves^{-1})	Mite population on different DAS (No. of motile stages 10 leaves^{-1})			Mean % reduction of mite population over untreated control
				3rd	7th	10th			3rd	7th	10th			3rd	7th	10th			3rd	7th	10th	
1	Fenpyroximate 5 % EC	15	2.24	0.43 (0.96)#	0.92 (1.19)#	1.31 (1.35)#	84.72 (66.99)*	2.13	0.41 (0.95)	0.58 (1.04)	0.89 (1.18)	81.52 (64.54)	2.56	0.39 (0.94)	0.83 (1.15)	1.23 (1.32)	81.44 (64.48)	2.12	0.42 (0.96)	0.71 (1.10)	0.98 (1.22)	80.50 (63.79)
2	Fenpyroximate 5 % EC	30	2.28	0.37 (0.93)	0.84 (1.16)	1.15 (1.28)	86.28 (68.26)	2.05	0.36 (0.93)	0.49 (0.99)	0.81 (1.14)	83.87 (66.32)	2.78	0.32 (0.91)	0.77 (1.13)	1.02 (1.23)	84.16 (66.55)	2.00	0.36 (0.93)	0.53 (1.01)	0.80 (1.14)	84.40 (63.74)
3	Fenpyroximate 5 % EC	60	3.00	0.28 (0.88)	0.48 (0.99)	0.68 (1.09)	91.66 (73.21)	2.56	0.28 (0.88)	0.35 (0.92)	0.63 (1.06)	87.68 (69.45)	2.61	0.28 (0.88)	0.59 (1.04)	0.80 (1.14)	87.33 (69.15)	2.56	0.28 (0.88)	0.49 (0.99)	0.65 (1.07)	86.91 (68.79)
4	Propargite 57% EC	500	2.11	0.48 (0.99)	1.00 (1.22)	1.40 (1.38)	83.33 (65.90)	2.78	0.50 (1.00)	0.86 (1.16)	1.18 (1.30)	75.07 (60.05)	3.01	0.46 (0.98)	0.94 (1.20)	1.37 (1.37)	79.18 (62.85)	2.47	0.45 (0.97)	0.78 (1.13)	1.09 (1.26)	78.55 (62.41)
5	Fenazaquin 10 % EC	100	2.43	0.42 (0.96)	0.96 (1.21)	1.27 (1.33)	84.72 (66.99)	2.34	0.47 (0.98)	0.73 (1.11)	1.05 (1.24)	78.00 (62.03)	3.07	0.42 (0.96)	0.90 (1.18)	1.31 (1.34)	80.09 (63.50)	2.36	0.44 (0.97)	0.72 (1.10)	1.11 (1.27)	78.83 (62.61)
6	Untreated Control	—	2.00	4.88 (2.32)	5.67 (2.48)	6.73 (2.69)	—	2.19	2.93 (1.85)	3.28 (1.94)	4.03 (2.13)	—	2.95	3.11 (1.90)	4.87 (2.32)	5.29 (2.41)	—	2.65	2.99 (1.87)	3.46 (1.99)	4.31 (2.19)	—
	CV %		NS	2.52	3.15	0.59	—	NS	3.25	2.74	3.42	—	NS	1.54	3.11	0.87	—	NS	2.42	0.89	2.68	—
	SEm		NS	0.12	0.78	0.12	—	NS	0.12	0.51	0.15	—	NS	0.33	0.25	0.19	—	NS	0.22	0.10	0.15	—
	C.D.at 5%		NS	0.37	0.89	0.36	—	NS	0.35	0.68	0.57	—	NS	0.65	0.78	0.54	—	NS	0.61	0.41	0.34	—

*DAS-Days After Spraying. *Figures in parentheses are angular transformed values, # Figures in parentheses are square root transformed values*

Table 3: Bio-efficacy of fenpyroximate 5 % EC against Pink mite, *Acaphylla theae* on Tea at Sukhna Tea Estate, Bagdogra, Darjeeling during 2013-2014 and 2014-2015

Sl. No.	Treatments	Dose (g a.i. ha^{-1})	2013-2014										2014-2015									
			1st spray					2nd spray					1st spray					2nd spray				
			Pre treatment count (No. of motile stages 10 leaves^{-1})	Mite population on different DAS (No. of motile stages 10 leaves^{-1})			Mean % reduction of mite population over untreated control	Pre treatment count (No. of motile stages 10 leaves^{-1})	Mite population on different DAS (No. of motile stages 10 leaves^{-1})			Mean % reduction of mite population over untreated control	Pre treatment count (No. of motile stages 10 leaves^{-1})	Mite population on different DAS (No. of motile stages 10 leaves^{-1})			Mean % reduction of mite population over untreated control	Pre treatment count (No. of motile stages 10 leaves^{-1})	Mite population on different DAS (No. of motile stages 10 leaves^{-1})			Mean % reduction of mite population over untreated control
				3rd	7th	10th			3rd	7th	10th			3rd	7th	10th			3rd	7th	10th	
1	Fenpyroximate 5 % EC	15	3.11	0.66 (1.08)#	1.17 (1.29)#	1.47 (1.40)#	83.07 (65.70)*	2.93	0.68 (1.09)	1.09 (1.26)	1.38 (1.37)	82.02 (64.91)	3.13	0.69 (1.10)	0.95 (1.20)	1.27 (1.13)	81.90 (64.82)	2.92	0.57 (1.03)	0.71 (1.10)	0.96 (1.21)	85.43 (65.56)
2	Fenpyroximate 5 % EC	30	2.95	0.62 (1.06)	1.09 (1.26)	1.33 (1.35)	84.46 (66.78)	3.03	0.59 (1.04)	0.98 (1.22)	1.26 (1.33)	83.90 (66.34)	2.79	0.58 (1.04)	0.88 (1.17)	1.08 (1.26)	84.14 (66.53)	2.75	0.48 (0.99)	0.66 (1.08)	0.87 (1.17)	86.99 (68.86)
3	Fenpyroximate 5 % EC	60	3.16	0.41 (0.95)	0.62 (1.06)	0.88 (1.17)	90.15 (71.71)	2.32	0.40 (0.95)	0.75 (1.12)	1.02 (1.23)	87.67 (69.44)	2.96	0.36 (0.93)	0.65 (1.07)	0.87 (1.17)	88.24 (69.94)	2.56	0.36 (0.93)	0.54 (1.02)	0.70 (1.10)	89.70 (71.28)
4	Propargite 57% EC	500	3.00	0.75 (1.12)	1.20 (1.30)	1.51 (1.42)	82.30 (65.12)	2.87	0.75 (1.12)	1.11 (1.27)	1.59 (1.45)	80.30 (63.65)	3.17	0.85 (1.16)	1.17 (1.29)	1.49 (1.41)	78.17 (62.15)	3.04	0.79 (1.14)	1.06 (1.25)	1.35 (1.36)	79.41 (63.01)
5	Fenazaquin 10 % EC	100	2.65	0.72 (1.10)	1.16 (1.29)	1.44 (1.39)	82.92 (65.59)	2.91	0.69 (1.09)	1.14 (1.28)	1.47 (1.40)	81.16 (64.28)	2.36	0.73 (1.11)	1.10 (1.26)	1.34 (1.36)	80.22 (63.60)	2.79	0.72 (1.10)	0.98 (1.22)	1.16 (1.29)	81.55 (64.56)
6	Untreated Control	—	3.05	5.33 (2.41)	6.40 (2.63)	7.78 (2.8)	—	3.14	4.96 (2.34)	5.68 (2.49)	6.89 (2.72)	—	3.08	4.21 (2.17)	5.41 (2.43)	6.47 (2.64)	—	3.73	4.29 (2.19)	5.10 (2.37)	6.05 (2.56)	—
	CV %		NS	3.77	5.09	2.52	—	NS	3.15	2.63	2.72	—	NS	4.19	3.41	2.11	—	NS	2.12	3.34	1.58	—
	SEm		NS	0.33	0.23	0.48	—	NS	0.18	0.38	0.22	—	NS	0.55	0.34	0.56	—	NS	0.18	0.56	0.16	—
	C.D.at 5%		NS	1.02	0.68	1.19	—	NS	0.96	1.05	0.78	—	NS	1.03	0.98	1.19	—	NS	0.78	1.01	0.57	—

*DAS-Days After Spraying. * Figures in parentheses are angular transformed values, #Figures in parentheses are square root transformed values*

Table 4: Effect of different treatment schedules of fenpyroximate 5 % EC on the predominant natural enemies of tea ecosystem during 2013-2014 and 2014-2015

Sl. No.	Treatments	Dose (g a.i. ha^{-1})	Mean number of Predators* per 10 leaves															
			2013-2014								2014-2015							
			1st spray				2nd spray				1st spray				2nd spray			
			Before application		% reduction/ increase (+) at 15 days after application		Before application		% reduction/ increase (+) at 15 days after application		Before application		% reduction/ increase (+) at 15 days after application		Before application		% reduction/ increase (+) at 15 days after application	
			Cheilomenes sexmaculata	*Amblysius ovalis*	*Cheilomenes sexmaculata*	*Amblysius ovalis*	*Cheilomenes sexmaculata*	*Amblysius ovalis*	*Cheilomenes sexmaculata*	*Amblysius ovalis*	*Cheilomenes sexmaculata*	*Amblysius ovalis*	*Cheilomenes sexmaculata*	*Amblysius ovalis*	*Cheilomenes sexmaculata*	*Amblysius ovalis*	*Cheilomenes sexmaculata*	*Amblysius ovalis*
1	Fenpyroximate 5 % EC	15	7.89	19.47	5.96 (14.13) #	8.06 (16.49)	7.21	19.87	5.25 (13.25)	7.32 (15.70)	6.42	20.26	5.04 (12.97)	7.14 (15.50)	6.35	20.32	5.41 (13.45)	8.50 (16.95)
2	Fenpyroximate 5 % EC	30	6.88	21.51	8.71 (17.16)	10.93 (19.31)	6.54	19.54	9.03 (17.49)	9.18 (17.64)	6.85	22.15	7.87 (16.29)	9.73 (18.18)	6.54	19.56	8.12 (16.56)	10.00 (18.43)
3	Fenpyroximate 5 % EC	60	7.91	23.66	13.28 (21.37)	14.24 (22.17)	6.87	20.30	12.88 (21.03)	15.77 (23.40)	7.32	19.57	11.32 (19.66)	13.62 (21.66)	6.78	19.98	12.70 (20.88)	14.75 (22.58)
4	Propargite 57% EC	500	7.16	19.14	18.57 (25.53)	19.96 (26.54)	7.13	20.16	17.71 (24.89)	22.95 (28.62)	7.25	23.74	15.29 (23.02)	16.81 (24.21)	7.15	20.47	16.65 (24.08)	16.60 (24.04)
5	Fenazaquin 10 % EC	100	6.94	22.32	14.30 (22.22)	16.81 (24.21)	6.91	20.71	15.92 (23.52)	17.10 (24.43)	6.84	21.78	13.11 (21.23)	13.59 (21.63)	7.58	20.75	14.71 (22.55)	15.25 (22.99)
6	Untreated Control	—	6.86	19.28	+6.62 (0.00)	+18.52 (0.00)	7.11	19.85	+7.32 (0.00)	+20.12 (0.00)	7.63	19.69	+6.61 (0.00)	+17.16 (0.00)	6.49	19.50	+ 6.55 (0.00)	+20.23 (0.00)
	CV %		NS	NS	3.53	2.09	NS	NS	2.81	1.56	NS	NS	3.31	2.29	NS	NS	2.28	3.18
	SEm		NS	NS	1.77	1.13	NS	NS	1.15	0.48	NS	NS	1.26	1.05	NS	NS	1.34	1.44
	C.D.at 5%		NS	NS	5.35	3.42	NS	NS	3.44	1.76	NS	NS	1.82	3.11	NS	NS	3.29	3.02

Chielomenes sexmacculata and Amblyseius ovalis; #Figures in parentheses are angular transformed values

Table 5: Yield of green tea leaves and economics following spray of fenpyroximate 5% EC on the crop to control Tea Red Spider Mite, Purple Mite and Pink Mite at Kamalpur Tea Estate and Sukna Tea Estate, Darjeeling during 2013-2014 and 2014-2015.

Sl. No.	Treatments	Dose (g a.i. ha^{-1})	Yield of made tea (kg ha^{-1}) 2013-2014: Yield of made tea against Tea Red Spider Mite	Yield of made tea (kg ha^{-1}) 2013-2014: Yield of made tea against Pink Mite and Purple Mite	Yield of made tea (kg ha^{-1}) 2014-2015: Yield of made tea against Tea Red Spider Mite	Yield of made tea (kg ha^{-1}) 2014-2015: Yield of made tea against Pink Mite and Purple Mite	Mean yield of made tea against Tea Red Spider Mite (Season I and II) (kg ha^{-1})	% increase in yield over control	Mean yield of made tea against Pink Mite and Purple Mite (Season I and II) (kg ha^{-1})	% increase in yield over control	Overall mean yield of made tea against pink, purple and Tea Red Spider Mite (kg ha^{-1})	Cost of treatment including labour charges (₹. ha^{-1})	Gross realization (₹ ha^{-1})	Net realization (₹ ha^{-1})	Net profit (₹ ha^{-1})	ICBR
1	Fenpyroximate 5 % EC	15	590.4	604.0	610.2	618.4	600.3	42.31	611.2	41.84	605.8	6156.00	121160.00	115004.00	108848.00	1: 17.68
2	Fenpyroximate 5 % EC	30	621.2	633.5	636.5	660.1	628.9	44.94	646.8	45.04	637.9	6311.00	127580.00	121269.00	114958.00	1: 18.22
3	Fenpyroximate 5 % EC	60	627.8	648.1	652.8	664.5	640.3	45.92	656.3	45.83	648.3	6624.00	129660.00	123136.00	116412.00	1: 17.57
4	Propargite 57% EC	500	515.4	517.9	520.7	523.0	518.1	33.16	520.5	31.70	519.3	5711.00	103860.00	98149.00	92438.00	1: 16.18
5	Fenazaquin 10 % EC	100	530.5	565.6	570.4	579.7	550.5	37.10	572.7	37.93	561.6	6053.00	112320.00	106267.00	100214.00	1: 16.55
6	Untreated Control	—	337.3	349.4	355.3	361.6	346.3	—	355.5	—	350.9	4600.00	70180.00	65580.00	60980.00	1: 13.25

ICBR- Cost Benefit Ratio. Market price of fresh tea leaves: ₹ 200.00 per kg made tea. Labour charges (skilled): ₹ 193.00 per day as per Govt. of West Bengal Labour Commission Circular, 2013.

519.3 kg made tea per hectare were obtained from fenazaquin and propargite treated plots with cost: benefit ratio of 1: 16.55 and 1: 16.18 respectively.

Phytotoxicity

No phytotoxic symptom was observed in any of the treated plots with fenpyroximate 5 % EC at higher dosages i.e. at 120 and 240 g a.i. per hectare even up to 15th day of observation.

Conclusion

Hence, from the present investigation it can be concluded that fenpyroximate 5% EC at 30 g a.i. per hectare (600 ml ha^{-1}) proved most suitable concentration to combat the major mite pests of tea with least toxicity against prevailing potential defenders and a sustainable option under tea ecosystem of North Bengal from entomological, eco-toxicological and economic point of view in near future.

Acknowledgements

Authors are thankful to the Directorate of Research, BCKV, Kalyani, West Bengal, India for providing infrastructural facilities to carry out the research work.

References

Babu, A., Rahman, V.K.J. and Kumar, A.R. 2009. Efficacy of Fenpyroximate (Sedna) against red spider mite. *Newsletter*. UPASI *Tea Research Foundation* **19**: 4.

Basu, M.A., Bera, B. and Rajan, A. 2010. Tea statistics: Global scenario. *International Journal of Tea Science* **8**: 121-124.

Biswas, K., Mallikarjunappa, S., Bhat, U.G. and Koneripalli, N. 2009. Evauation of novel acaricide, sedan 5% SC (fenpyroximate) against red spider mite of tea, *Oligonychus coffeae* Nietner. *Pestology* **33:** 22-24.

Dekeyser, M.A. 2005. Acaricide mode of action. *Pest Management Science* **61**: 103-10.

Gurusubramanian, G., Borthakur, M., Sarmah, M. and Rahman, A. 2005. Pesticide selection, precautions, regulatory measures and usage. pp. 81-91. In: Plant Protection in Tea: Proc. Plant Protection Workshop, A. Dutta *et al.* (eds.). Tocklai Experimental Station, TRA, Jorhat, Assam, India.

Hamedi, N., Fathipour, Y. and Saber, M. 2010. Sublethal effects of fenpyroximate on life table parameters of the predatory mite *Phytoseius plumifer*. *Bio Control* **55**: 271-278.

Hazzrika, L.K., Bhuyan, M. and Hazarika, B.N. 2009. Insect pests of tea and their management. *Annual Review of Entomology* **54**: 267-286.

Henderson, C.F. and Tilton, E.W. 1955. Tests with acaricides against the brown wheat mite. *Journal of Economic Entomology* **48**: 157-161.

Khan, A.A., 2009. Relative toxicity of pesticides for safety of predatory coccinellids. *Annals of Plant Protection Science* **17**: 307-311.

Kumari, A., Kumar, A., Tweary, D. and Nadda, G. 2012. Field evaluation of bifenazate (acramite 50 WP) for control of tea mites. *Munis Entomology and Zoology* **7**: 780-786.

Mukhopadhyay, A. and Roy, S. 2009. Changing diminutions of IPM in the tea plantations of the north-eastern sub Himalayan region. In: Proc. National Symposium on IPM strategies to Combat Emerging Pests in the Current Scenario of Climate Change, Ramamurthy, V.V. and G.P. Gupta (eds.), January 28-30, 2009. Central Agricultural University, Pasighat, Arunachal Pradesh, India, pp. 290-302.

Nath, R., Sharma, G.D. and Barooah, M. 2013. Screening of endophytic bacterial isolates of tea (*Camellia sinensis* L.) roots for their multiple plant growth promoting activities. *International Journal of Agriculture, Environment & Biotechnology* **6**: 211-215.

Park, J.J., Kim, M.S., Lee, J.H., Shin, K., Lee, S.E., Kim, J.G. and Cho, K.J. 2011. The impact of selected pesticides used in strawberry protection for predatory mite *Amblyseius andersoni* (Chant) survival. *Progressive in Plant Protection* **51**: 900-904.

Radhakrishnan, B., Srikumar, K.K. and Suresh Kumar, B. 2015. Evaluation of Pyridaben 20 WP against red spider mite, *Oligonychus coffeae* Nietener infesting tea in southern India. *Pest Management in Horticultural Ecosystem* **21:** 65-68.

Rattan, P.S. 1994. Red spider mite and crop loss. *Quality Newsletter*- Tea Research Foundation of Central Africa, **115**: 16-22. http://www.cabi.org/isc/FullTextPDF/Pre2000/19951112241.pdf accessed on 07.11.2015.

Roy, S., Mukhopadhyay, A. and Gurusubramanian, G. 2008. A preliminary toxicological study of commonly used acaricides of tea red spider mite (*Oligonychus coffeae* Neitner) of North Bengal, India. *Resistance Pest Management Newsletter* **18**: 5-10.

Sahoo, B., Sahoo, S.K. and Somchaudhury, A.K. 2003. Studies on the toxicity of newer molecules against tea red spider mite. In: Proc. National Symposium on Frontier Areas of Entomological Research, IARI and ESI, New Delhi, India, p. 301.

Sannigrahi, S. and Talukder, T. 2003. Pesticide use patterns in Dooars tea industry. *Two and a Bud* **50**: 35-38.

Subaharan, K. and Regupathy, A. 2006. Effect of neem formulations on the management of purple mite, *Calacarus carinatus* L. infesting tea. *Journal of Plantation Crops* **34**: 435-438.

Tomlin, C. 2000. The pesticide manual. The British Crop Protection Council, Farnham, p. 1250.