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EFFECT OF TEMPERATURE ON TEA RED SPIDER MITE (*OLIGONYCHUS COFFEAE* NIETNER) AND ITS MANAGEMENT USING CYFLUMETOFEN 20 SC

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ABSTRACT

Developmental stages of Tea Red Spider mite (TRSM), *Oligonychus coffeae*, Nietner (Acari: Tetranychidae) was studied at the laboratory of Department of Agricultural Entomology, BCKV. It was seen that in descending order, the, pre-ovipositional (2.20±0.04 to 1.12±0.03), ovipositional (16.06±0.05 to 10.83±0.18) and post evaporation (76.52±0.14 to 52.30±0.11) period decreased with the increase in temperature. The field trial was conducted at the Sukna Tea Estate,Terai, Darjeeling to evaluate the most effective dose of cyflumetofen 20 SC which at 125 g a.i./ha gave excellent (95 to 100%) reduction and the molecule was found to be soft on natural enemies and all the doses did not produce any phytotoxic symptoms on tea bushes. Further, on contact, it provides good knockdown and long residual activity with excellent plant safety. Maximum average yield of made tea was 621.00 kg m.t./ha in the plots treated with cyflumetofen 20 SC @ 125 g a.i./ha

INTRODUCTION

Tea is a perennial plantation crop grown under monoculture providing favorable conditions for a variety of pests (Gurusubramaniam *et al.,* 2008). This ubiquitous common man's drink in India was introduced by the British to this country from neighbouring China. The tea industry is one of the oldest organized industries in India. Thirty-four countries of Asia, Africa, Latin America, and Oceania, situated between latitudes 41ºN and 16ºS, produce tea and the national economy of many of these countries is largely dependent upon its production (Hazarika *et al.,* 2009). India produces three speciality teas like, Darjeeling, Assam and Nilgiris, which are exported world over. Tea is grown in 13 states and Assam, West Bengal, Tamil Nadu and Kerala are the largest producers. Of the many constraints that affect tea production, insect and mite pests play a major role, causing 11% to 55% loss in yield worth U.S. $500 million to $1 billion (Hazarika *et al.,* 2009). *Oligonychus coffeae* is one of the most destructive pests in all the tea growing regions of North East India (Das, 1959b and 1962) causing considerable crop loss in tea (Muraleedharan *et al.*, 2005). It normally attacks the upper surface of the mature leaves in which the sap is not flowing freely. In severe infestation, particularly under conditions of dry weather, the lower surface and the young leaves are almost equally attacked. The affected leaves turn brown, then became bronzy, and may eventually dry up and fall off. Tea Red Spider Mite (TRSM) has already attained a key pest status on tea crop in N.E India and occurs in all tea growing areas under diverse climatic conditions (Das, 1959a). They remain on the upper surface of the leaves (photo +ve) and remain in the field throughout the year in varying numbers, with increase in population during warmer months. Loss in tea crop due to TRSM attack in India may be as much as 75% (Gurusubramaniam et.al., 2008). Developmental stages include six legged larvae, protonymph and this species multiplies throughout the year in the tea bushes in Terai, and increases with rise in temperature (Das, 1959b). Spherical and reddish eggs with tendril are laid on the upper surface of the mature leaves along the mid ribs and veins. There is a continuous need for development of new acaricides with novel mode of action, but also for optimization of their use in order to delay the evolution of resistance and prolong their life span (Dekeyser, 2005). A major problem in controlling TRSM is their ability to rapidly develop resistance to various acaricides after only a few applications. The resistance problem in spider mites, like that in some insect pests, had become serious as a result of a combination of factors including the spider mites' high reproductive potential, extremely short life cycle and arrhenotokous reproductive system (haplo-diploidy) (Van Nieuwenhuyse *et al.*, 2009). The short life cycle in combination with frequent use of acaricides easily induce resistant strains. Mite populations are normally held in check by predators. An early season reduction in predator abundance, due to application of broad spectrum insecticides, allows increased mite survival and earlier development of economically significant outbreaks (Barma and Jha, 2013 and Kumar *et al.,* 2014). The wide spread acaricide resistance has been a major obstacle in the cost effective integrated mite management programme (Cheon *et al.,* 2007b). Hence, new acaricides can be thought as an alternative and effective against the target pests and compatible with their natural enemies; moreover, these compounds must be safe products with respect to human health, beneficial and non-target organisms and the environment (Chakraborty *et al.,* 2010, Reddy *et al.,* 2014). The test chemistry, cyflumetofen's novel mode of action involves inhibition of the mitochondrial electron transport complex II enzyme within mite cells which halts the production of ATP, rapidly depleting the energy of cell, which leads to paralysis and death of the affected mites. It does not impact on variety of non-target arthropod species, including parasitic wasps, predatory mites, predatory bugs, ladybird beetles, rove beetles and lacewings when the organisms are exposed to fresh residues on inert substrates (Gotoh *et al.,* 2011). Due to its highly selective nature, it will be a good fit in integrated pest management programs, or in programs that release beneficial mites, as it is likely to have little impact on the predatory mite populations. Keeping these views in mind, the present investigation deals with, the effect of temperature on different life stages of mite under laboratory condition and its on-field management through cyflumetofen with safety evaluation against natural enemies and phytotoxic effect on tea bushes.

MATERIALS AND METHODS

The developmental stages of TRSM were studied under laboratory conditions with the ambient weather parameters (laboratory temperature during different months). TRSM adults were collected from Sukna Tea Estate of Terai (Darjeeling) and was maintained in the laboratory followed by *"detached leaf culture"* method (Saikia et.al., 1999). Twenty gravid females were released on a fresh leaf in the petridish and allowed overnight, in order to obtain the eggs. Next morning the mobile stages were carefully lifted with the help of a moistened hairbrush and removed from the leaf surface. The leaves were observed after every 12 hours and the development of various stages of the mite was recorded under stereo zoom binocular (Olympus SZ 40, Japan) microscope (10x magnification). Fifteen such petri-plates were maintained for each generation to study the biology of TRSM. The duration of the developmental stages were recorded for six different generations in 6 months from February to July.

The field effectiveness was conducted at Sukna Tea Estate, Terai region (latitude 26.70^{0}N and longitude 88.40^o E and 120 m above mean sea level), Darjeeling, West Bengal on a 22 years old plantation of Mixed Assam clones dominated by TV-9 in 50 m^2 plot. Such 50 plants per treatment with 1m X 1m spacing were considered in each replication. Two foliar applications @ 500 lt. water/ha at 15 days interval was imposed. The treatments were cyflumetofen @ 100 g a.i./ha (formulated product :500ml/ha) , 125 g a.i./ha (formulated product: 625 ml/ha), 150 g a.i./ha (formulated product: 750 ml/ha), 175 g a.i./ha (formulated product: 875 ml/ha), propargite 57% EC 430 g a.i./ha (formulated product: 750 ml/ha), spiromesifen 22.9% SC 96 g a.i./ha (formulated product: 400 ml/ha), hexythiazox 5.45% EC 20g a.i./ha (formulated product: 400 ml/ha) and one untreated control.

Observations on the number of the motile stages of TRSM were recorded on ten leaves selected at random from each of the ten bushes. Observations on TRSM incidence were taken after 1st, 3rd, 5th, 7th, 10th and 15th day after each application. The data were subjected to transformation before statistical analysis fallowing Gomez and Gomez, (1984) to test the significance of treatment.

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 and RC (central insecticide board and registration committee, Govt.of India) guide lines. Observations on the incidence of available predators, like *Amblyseius longospinosus* and *Agistemus fleshneri* were taken on 15th days after both the applications on 10 leaves selected randomly from 10 plants/treatment. The percentage reduction in mite population were assessed by adopting the following formula (Henderson and Tilton, 1955)-

Percentage reduction = {1 - (Ta X Cb / Tb X Ca)} X 100%

Where-

Ta = mite population in treated plant after treatment.
Tb = mite population in treated plant before treatment.

Ca = mite population in control plants after treatment.
Cb = mite population in control plant before treatment.

The data were then subjected to Analysis of Variance (ANOVA) after making angular transformation by $\sin^{-1}$ p (where p is % mortality / 100).

The data on the incidence of predators were then subjected to analysis of variance after transformation wherever needed. Yield of tea green leaf in different treatments were recorded and subsequently they were converted to made tea kg /ha (m.t. kg/ha) by multiplying green leaf yield kg/ha by a factor of 0.22 (Rattan, 1994).

RESULTS AND DISCUSSION

Effect of temperature on life stages of tea red spider mite:

The period of different developmental stages of TRSM was longer in the colder months. Life cycle was of short duration in June (6.90±0.09 days) where as in February it took the longest time (14.47±0.25 days) (Table 1). Incubation period was recorded highest in the month of February (7.01 ± 0.04 days) when the room temperature was 22.75ºC followed by 25.50ºC in March (6.03 ±0.16 days). It was lowest during the month of June (3.00 ±0.06 days) when the temperature was 32.00ºC. The mean duration of different developmental stages has been depicted in Table 1. Likewise, longest duration of larval period was recorded in the month of February (2.73±0.02 days), where as lowest duration was observed during June (1.38±0.02 days). It can further be seen that, longest protonymphal period was found during the month of February (2.48±0.01 days) and lowest in June (1.20±0.06 days). Likewise, deutonymphal period was highest in the

Table 1: The mean duration (in days) of different bio-stages of TRSM, *Oligonychus coffeae* infesting tea

Months	Different developmental stages {Mean ± Standard Error } (in days) Incubation period	Larval period	Proto-nymphal period	Deuto-nymphal period	Total	Mean laboratory temperature (°C)
February	7.01±0.04	2.73±0.02	2.48±0.01	2.25±0.06	14.47±0.25	22.75
March	6.03±0.16	2.45±0.07	2.37±0.05	2.52±0.06	13.37±0.21	25.50
April	5.08±0.05	1.93±0.06	1.87±0.02	2.02±0.02	10.9±0.17	29.10
May	3.82±0.03	1.56±0.01	1.45±0.01	1.46±0.02	8.29±0.13 3	31.25
June	3.00±0.06	1.38±0.02	1.20±0.06	1.32±0.01	6.90±0.09	32.00
July	3.65±0.04	1.50±0.03	1.39±0.02	1.38±0.02	7.92±0.16	31.90
R (temperature)	-0.980*	0.994**	-0.969**	-0.894*	-0.978**	

Table 2: Fecundity, pre-oviposition, oviposition and post- oviposition period of TRSM, *Oligonychus coffeae* in Tea at Sukna Tea Estate, Terai, Darjeeling

Month	Pre-oviposition (days)	Oviposition (days)	Post-oviposition (days)	Fecundity /female	Mean laboratory temperature(°C)
February	2.00±0.04	16.06±0.05	1.83±0.03 7	76.52±0.14	22.75
March	1.63±0.01	15.78±0.04	1.73±0.01	68.19±0.05	25.50
April	1.42±0.02 1	14.38±0.11	1.59±0.01	63.25±0.05	29.10
May	1.15±0.01	12.57±0.08	1.53±0.02	58.06±0.04	31.25
June	1.00±0.08	10.83±0.18	1.23±0.09	52.30±0.11	32.00
July	1.12±0.03 1	12.26±0.06	1.48±0.02	57.9±0.06	31.90
r (temp)	-0.987**	-0.931**	-0.891*	-0.971**	

month of March (2.52±0.06 days) followed by February (2.25±0.06 days) and April (2.02±0.02 days).

It can further be seen from the table, that, with the increase in temperature, developmental rate increased and the duration of developmental stages decreased i.e.; an inverse relationship existed between the developmental rate and duration of different life stages. Fecundity, pre-oviposition, oviposition and post-oviposition periods has been shown in Table 2. The pre-oviposition period lasted for a period of 1.00±0.08 days in June and in February (2.00±0.04 days). Now, in case of ovipositional and post- ovipositional period, highest and lowest days were recorded in February and June respectively in every case. Highest fecundity was recorded during February (76.52 ±0.14 eggs). It was seen that pre-ovipositional, ovipositional and post-ovipositional period decreased with the increase in temperature. The results of the present study are in agreement with the findings of Northcraft and Watson, (1987), Deciyanto *et al.* (1989), Tsai *et al.* (1989), Yasuda (1982), Congdon and Logan (1983), Praslicka and Huszar, (2004), Kasap, (2009), Abou-Awad *et al.* (2011) and Karami-Jamour and Shishehbor (2012) who reported temperature to have a profound influence on the developmental biology of different spider mites. In this experiment it was found that developmental rate was highest in June followed by May.

Bio-effectiveness of cyflumetofen 20% SC on tea red spider mite

Before application, TRSM population ranged between 4.85 to 6.25 and leaf in different treatments, including control and the population did not differ significantly. One day after treatment, cyflumetofen @ 125,150 and 175 g a.i/ha recorded cent percent reduction of TRSM over control, but, the above treatments were significantly superior than the check spiromesifen 22.9% SC @ 96 g a.i./ha and hexythiazox 5.45% EC @ 20 g a.i./ha, except propargite 57% EC @ 430 g a.i/ha (Table 3).Three, five and seven days after treatment also cyflumetofen 20%SC @ 125 g a.i./ha and its higher doses recorded 99 to 100% TRSM population reduction over control and the above treatments were also significantly superior to check miticides propargite, spiromesifen and hexythiazox. Ten and fifteen days after treatment, cyflumetofen 20%SC @ 125 g a.i/ha and its higher doses recorded 95 to 99% reduction of TRSM population and all the above treatments were at par with spiromesifen 22.9% SC and hexythiazox 5.45% EC (Table 3).From the results, it can be concluded that cyflumetofen @ 125 g a.i/ha is the optimum dose for effective management of TRSM, which recorded 96 to 100% reduction of TRSM population at different time intervals. These findings are in parity with the findings of Cheon et.al., (2007b) and Singh *et al.* (2014). No phytotoxic symptom like epinasty, hyponasty, leaf tip injury, leaf surface injury, wilting, vein clearing, etc., were recorded in any of the treated plots, indicating that all the doses of cyflumetofen 20% SC were safe for tea bushes.

Bio-effectiveness of cyflumetofen 20% SC on predatory mites

The bio-effectiveness of cyflumetofen 20% SC on two most common predatory arachnids found wandering in the canopy of the plucking table, namely, *Amblyseius longispinosus* & *Agistemus fleshneri* were also evaluated. The pre-treatment population of *Amblyseius longispinosus* varied between 1.00 to 2.00/leaf where as post-treatment population oscillated between 1.00 to 2.00 in different treatments, including control and they did not differed significantly. The pre-treatment population of phytoseiid predators *Amblyseius longispinosus* and stigmaeid predators *Agistemus fleshneri* ranged from 0.60 to 2.00 and from 1.00 to 2.10/leaf in different post-treatment sections during 2011 and 1.53 to 2.43/leaf and 1.25 to 2.00/ leaf during 2012 respectively. Fifteen days after application record on the prevalence of predatory mites on different treatments revealed that, there existed no marked change in the population distribution pattern in different treatments as the population did not differ significantly in both the years 1.00 and 2.10/leaf during 2011 and 1.25 to 2.00/leaf during 2012 respectively. So from the findings by the present author

Table 3: Effect of different treatment schedules of cyflumetofen20 EC on TRSM, *O.coffeae* of tea during 2011and 2012 at Sukna Tea Estate, Terai, Darjeeling

Sl. No.	Treatment	Dose/ha		Pre-application count		% reduction of mite population over control at various days								Mean % reduction				after application**	
						1st		3rd		5th		7th		10th		15th			
		g a.i.	ml	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
1	Cyflumetofen 20 EC	100	500	3.83	6.75	84.6	60.2	85.1	64.5	82.17	75.2	80.53	77.17	73.7	65.6	65.81	59.53	78.7	67.2
				-2.2	-2.78	-66.1	-51.2	-67.2	-52.5	-65.2	-59.5	-63.9	-61.5	-59.2	-54.1	-54.2	-50.5		
2	Cyflumetofen 20 EC	125	625	4.1	5.5	100	100	100	100	100	100	98.15	99.07	97.53	98.23	95.33	96.3	98.5	98.9
				-2.26	-2.55	-86	-86	-86	-86	-86	-86	-82.3	-83.6	-81.3	-82.5	-78.5	-79.7		
3	Cyflumetofen 20 EC	150	750	2.96	6	100	100	100	100	100	100	98.58	99.69	96.79	97.52	96.15	95	98.6	98.7
				-1.99	-2.65	-86	-86	-86	-86	-86	-86	-83.7	-85.6	-80.4	-81.8	-79.4	-78.1		
4	Cyflumetofen 20 EC	175	875	3.23	5.1	100	100	100	100	100	100	100	100	99.26	99.08	97.32	98.58	99.4	99.6
				-2.06	-2.47	-86	-86	-86	-86	-86	-86	-86	-86	-84.6	-84.2	-81.1	-83.4		
5	Propargite57% EC	430	750	4.13	6.25	97.85	96.16	89.94	88	84.7	84.65	74.4	77.94	64.69	66.88	61.96	62.25	78.9	79.3
				-2.26	-2.69	-82.1	-80	-71.7	-69.8	-67.1	-67.1	-59.7	-62	-53.6	-54.9	-51.9	-52.1		
6	Spiromesifen 22.9%SC	96	400	3.6	4.85	43.89	49.18	76.78	71.11	78.75	82.57	97.72	97.29	100	100	99.65	99.01	82.8	83.4
				-2.14	-2.42	-41.5	-44.5	-61.3	-57.5	-62.6	-65.7	-81.6	-80.9	-86	-86	-84.8	-84		
7	Hexythiazox 5.45%EC	20	400	4.33	5	31.85	54.64	65.94	66.67	81.28	79.83	100	91.49	99.63	100	97.32	98.83	79.3	81.9
				-2.31	-2.45	-4.13	-47.7	-54.4	-54.8	-64.5	-63.5	-86	-73.2	-85.7	-86	-81	-83.6		
8	(Untreated Control)	-	-	4.90	6.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				(2.43)	-2.75														
C.D. at 5%				(N.S.)	(N.S.)	-4.33	-5.32	-4.31	-3.08	-4.01	-5.6	-4.88	-4.68	-4.86	-4.44	-6.73	-6.75		

N.S. = Not significant; *Figures in parentheses are transformed to square root transformed values **Figures in parentheses are angular transformed values

Table 4: Effect of different treatment schedules of cyflumetofen 20 EC on predatory mites encountered in association with TRSM during 2011 and 2012 at Sukna Tea Estate,Terai, Darjeeling, West Bengal.

Sl.No.	Treatment	Dose / ha		Pre-application count of motile stage/leaf (No.)				Post-application count after 15 days (No.)			
		a.i.	ml	*Amblyseius longispinosus.*		*Agistemus fleshneri*		*Amblyseius longispinosus*		*Agistemus fleshneri*	
				2011	2012	2011	2012	2011	2012	2011	2012
1.	Cyflumetofen 20 EC	100	500	1.80 (1.67)	1.53 (1.59)	0.60 (1.26)	1.83 (1.68)	1.10 (1.45)	1.25 (1.50)	1.90 (1.70)	1.70 (1.64)
2.	Cyflumetofen 20 EC	125	625	1.90 (1.70)	2.26 (1.81)	1.60 (1.61)	1.70 (1.64)	1.60 (1.61)	2.00 (1.74)	2.10 (1.76)	1.30 (1.51)
3.	Cyflumetofen 20 EC	150	750	2.00 (1.73)	2.16 (1.78)	1.90 (1.70)	2.10 (1.76)	1.00 (1.41)	1.76 (1.66)	1.68 (1.64)	2.00 (1.73)
4.	Cyflumetofen 20 EC	175	875	1.60 (1.61)	1.83 (1.68)	1.70 (1.64)	1.83 (1.68)	2.00 (1.73)	1.86 (1.68)	1.10 (1.45)	2.00 (1.73)
5.	Propargite 57% EC	430	750	1.00 (1.41)	2.03 (1.74)	1.80 (1.67)	2.43 (1.85)	1.20 (1.48)	1.56 (1.60)	1.00 (1.41)	1.85 (1.68)
6.	Spiromesifen 22.9%SC	96	400	1.90 (1.70)	1.90 (1.70)	1.90 (1.70)	2.16 (1.78)	1.00 (1.41)	1.35 (1.53)	1.90 (1.70)	1.50 (1.58)
7.	Hexythiazox 5.45%EC	20	400	1.70 (1.64)	2.40 (1.84)	1.80 (1.67)	1.93 (1.71)	1.00 (1.41)	2.00 (1.73)	1.60 (1.61)	2.00 (1.73)
8.	Control (Untreated Check)	-	-	1.80 (1.67)	1.66 (1.63)	1.00 (1.41)	2.23 (1.80)	1.20 (1.48)	1.89 (1.70)	1.53 (1.59)	1.53 (1.58)
C.D. at 5%				(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)

NS = Non significant, Figures in parentheses are square root transformed values.

Table 5: Effect of different treatment schedules of cyflumetofen 20 EC on yield of Tea during 2011 and 2012 at Terai, Darjeeling, West Bengal.

Sl.No.	Treatment	Dose / ha	Yield of m.t. (kg /ha)				
		a.i.	ml	2011	2012	Mean	Percent increase in yield over untreated control
1.	Cyflumetofen 20 EC	100	500	534	601	567.50	33.21
2.	Cyflumetofen 20 EC	125	625	600	625	612.50	38.13
3.	Cyflumetofen 20 EC	150	750	621	633	627.00	39.56
4.	Cyflumetofen 20 EC	175	875	623	642	632.50	40.07
5.	Propargite 57% EC	430	750	525	517	521.00	27.26
6.	Spiromesifen 22.9%SC	96	400	500	485	492.50	23.04
7.	Hexythiazox 5.45%EC	20	400	530	589	559.50	32.18
8.	Control (Untreated Check)		-	337(NS)	421(NS)	379.00	....
C.D. at 5%							

NS = Nonsignificant, m.t = Made tea (kg/ha)

it can be concluded that the test miticide chemistry was absolutely safe for the naturally occurring predatory arachnids. (Table 4). Singh et.al., (2014) found cyflumetofen as an effective acaricide in successful management of spider mite (*T. urticae*) in Okra in the presence of the predators (insects, mites and spiders) because of their lower and negligible side effect on these natural enemies. This finding is in conformity with the finding of the present author and lends further support.

D] yield

Yield of made tea (kg m.t./ha) during 2011 and 2012 in different treatments were evaluated and presented in the table: 5. It can be seen from the table, that, maximum average yield (632.50 kg m.t./ha) was recorded in the section treated with cyflumetofen 20% SC @ 175 g a.i./ha followed by 150 and 125 g a.i/ha (627.00 and 621.00 kg m.t./ha) respectively. But, they were statistically on par. It can also been seen from the table that, highest percent increase in yield over untreated control was recorded in 175 g a.i/ha (40.07 % increase) followed by 750 and 125 g a.i/ha (39.56 and 38.96 % increase) respectively.

Hence, it is evident from the present investigation, that, cyflumetofen 20% SC @ 125 g a.i/ha is the optimum dose for the effective control of TRSM, as this dose was equally same in effectiveness with that of higher doses and also showed significant effectiveness after 1, 3, 5 and 7 days after treatment in comparison to check followed by commendable yield. The test acaricide was also found to safe to the prevailing predatory mites in tea plucking tables and non phytotoxic to tea canopy. So the miticide with diverse mode of action has great potential as an effective, environmentally friendly component of management of TRSM in tea.

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