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Field response of sucking pests to juvenile hormone analogue, pyriproxyfen in okra ecosystem of West Bengal

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Abstract
The present study was conducted to investigate the response of sucking pests and that of natural enemies in okra ecosystem and soil fauna to pyriproxyfen, under field condition during February-May 2015 and 2016. Four doses of pyriproxyfen 10EC (300, 500, 750 and 1000 mL/ha) along with fenpopathrin 30EC @ 250mL/ha and thiamethoxam 25WG @ 200g/ha as standard checks were imposed as foliar treatments and their subsequent effect was recorded. Pyriproxyfen at higher doses was found to reduce whitefly population to the tune of 68-73% in both the seasons. Similarly, leafhopper and aphid populations were reduced to the tune of 46-60% and 57-76% over two seasons. The test molecule was found to be soft to prevailing natural enemies (coccinellds and spiders) and the highest dose exerted a reduction of only 3.5% of population. It was found moderately toxic to soil fauna (micro-arthopods). Increase in yield was found to be around 53%.

Keywords: pyriproxyfen, fenpopathrin, thiamethoxam sucking pests, natural enemies & soil fauna

1. Introduction
Okra (Ladyfinger or bhendi), *Abelmoschus esculentus* (L.), Moench, is cultivated extensively all over India for its highly nutritive green succulent fruits that are consumed as fresh vegetable as well as in canned, dehydrated or frozen forms [1]. It is an export-oriented crop being exported to neighboring countries of India such as Bangladesh, Malaysia, Singapore, etc [2]. West Bengal ranks second in okra production having an area of 74k ha under cultivation producing 862.1k tones with an average productivity of 11.70 tons/ha [3].

However, the major constraint in achieving optimum productivity is the attack of insect pests and diseases. Out of 72 documented insect pests devouring okra, major sucking insect pests comprises of leafhopper, *Amrasca biguttula biguttula* (Ishida), whitefly, *Bemisia tabaci* (Gennadius) and aphid, *Aphis gossypii* (Glover) [4]. These pests are increasingly becoming difficult to manage due to the impact of climate changes and irrational use of conventional pesticides that exert high selection pressure on these insects leading to resistance development against commonly used insecticides [5]. Sucking pest complex of okra was reported to cause 17.46% yield loss and failure to control them at initial stages lead to about 54% yield loss through direct feeding and transmission of viral diseases (whitefly) like Yellow Vein Mosaic (YVMV) and Enation Leaf Curl (ELCV) [6, 7].

To combat these problems, emphasis on applied agricultural research is being directed towards utilization of lesser amount of insecticides with novel mode of actions that are also safe to prevailing natural enemies and are less persistent vis-à-vis easily biodegradable in nature [8]. Insect growth regulator (IGR), pyriproxyfen [4-(phenoxyphenyl)-(RS)-2-(2-pyridyloxy) ethyl ether], is a juvenile hormone analog with low toxicity to mammals. It suppresses embryogenesis with the insect egg and inhibits metamorphosis and adult emergence of target insects [9].

Further, it has translaminar action, which allows control of hidden pests in the plant canopy and on the underside of the leaves and provides excellent control of OP and pyrethroid resistant pests. It is novel in action and has many environmentally positive attributes that make it compatible with integrated pest management (IPM) programs [10].

Keeping in view, the present study was designed to evaluate the efficacy of pyriproxyfen 10% EC at field level as foliar treatment in different dosages against sucking insect pest complex of okra along with its non-target toxicity to prevailing predatory fauna and also its impact on soil micro-arthopods.

2. Materials and Methods

The present study was conducted in In-check farm of BCKV, Kalyani, Nadia, West Bengal during February to May 2015 and 2016.

2.1 Details of experiment

The experiment was laid out in Randomized Block Design with seven treatments (including one untreated check) having four replications in plot sizes of 3x4m. Seeds of variety 'Samrat' were sown with spacing of 45x45cm during 20.02.2015 in first season and 21.02.2016 in second season. All recommended agronomic practices were followed to raise the crop under irrigated condition.

2.2 Insecticides used

1. Pyriproxyfen: 4-(phenoxyphenyl)-(RS)-2-(2-pyridyloxy) ethyl ether in the formulation of emulsifiable concentrate (10% EC) in four dosages of 300mL/ha, 500mL/ha, 750mL/ha and 1000mL/ha as treatments (T1, T2, T3, and T4) was applied as foliar spray. The source of the chemical was Parijat Industries (India), Delhi.
2. Fenpopathrin: (RS)-a-cyano-3-phenoxybenzy l, 2, 3, 3-tetramethylcyclopropanecarboxylate in the formulation of emulsifiable concentrate (30% EC) @ 250 mL/ha as T5 was applied as foliar spray. The chemical was obtained from Excel crop Care, Mumbai.
3. Thiamethoxam: EZ)-3-(2-chloro-1,3-thiazol-5-ylmethyl)-5-methyl-1,3,5-oxadiazinan-4y lidene (nitro) amine in the formulation of wettable granules (25 WG) @ 200g/ha as T6 was applied as foliar spray. T7-control plot which were sprayed with water. The chemical was obtained from Syngenta Mumbai.

2.3 Relative efficacy of different treatment schedules on sucking pest of okra

A total 3 rounds of sprays at 15 days interval @ 500 litre of water / ha were done coinciding with ETL with a hand operated high volume Knap Sack sprayer with hollow cone nozzle at 15 p.s.i following which the observations were recorded. The target pests were: whitefly (*Bemisia tabaci* Genn., Aleyrodidae: Homoptera), leaf hopper (*Amrasca bigutulla bigutulla* Ishida, Cicadellidae: Homoptera) and aphid (*Aphis gossypii* Glover, Aphididae: Homoptera).

Observations were recorded at one day before and 1, 3, 7 and 10 days after spraying (DAS). The number of sucking pests from three randomly selected plants/plot (3leaves/plant) was counted. The upper and lower leaf surfaces were examined for the presence of and aphid, jassid, and whitefly adult counts were recorded in the field. The percentage reduction in sucking pest population was assessed by adopting the following formula [11].

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

Where-

Ta = pest population in treated plant after treatment.

Tb = pest population in treated plant before treatment.

Ca = pest population in control plants after treatment.

Cb =pest population in control plant before treatment.

2.4 Impact of treatment schedules on natural enemies of okra ecosystem (predators)

Observations on natural enemies (coccinellids and spiders) were recorded from 10 randomly selected plants /plot one day before spraying and 1, 3, 7 and 10 DAS. Mean percentage reduction or increase over control was worked out using formula [12]:

% R = [(No. of insects in the control – No. of insects in the treatment)/ No. of insects in the control] × 100

2.5 Impact of treatment schedules on soil fauna (micro-arthopods)

Soil samples were collected 1, 7, and 14 days after the insecticide-foliar application from a depth of 0- 20 cm under and between plants from each plot, collected in polyethylene bags, and labeled accordingly The samples were further moved to the laboratory where the multifaceted extractor (Berlese Tullgren Funnel) method was adopted which suits best for extracting soil micro-arthropods [13]. The soil micro-arthropods were collected and put into containers with 70% alcohol within 48 hours. All experiments were replicated with three independent sets having 100 g of soil in each replication.

After the organisms (soil micro-arthopods) were extracted and collected, they were immediately sorted under a dissecting binocular microscope with the help of a sucking pipette. Individual species were then placed in separate specimen bottles with 70% alcohol for preservation and were later mounted and used for identification. Permanent slides were prepared as per method to mount the organisms in Canada balsam [14].

Identification [15, 16, 17] of slide mounted specimen were done with the help of experts in the Zoological Survey of India, Kolkata and number and type of soil micro-arthropods extracted from each treatment were recorded, and the data obtained were analyzed.

2.6 Impact of treatment schedules of yield

A total of 16 pickings at an interval of 2 days in both seasons were carried out to record yield, which was further converted to tones /ha. Cost of seed, fertilizer, insecticides, labour and market price of okra was computed for the evaluation of cost benefit ratio (CBR).

Phytotoxicity observation were recorded (as per CIB and RC guideline) at 14 days after spraying on leaf injury on tips and leaf surface, wilting, necrosis, vein clearing, epinasty, hyponasty, etc. using 0-10 phytotoxicity rating scale as follows at standard, 2X and 4X dosages.

2.7 Statistical analysis

The data collected were subjected to transformation before statistical analysis to test the treatment significance [18]. 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 soil micro-arthopods and yield were also transformed ("x+0.5) and subjected to further analysis.

3. Results and Discussion

The insecticidal activity of pyriproxyfen 10%EC at different dosages along with standard checks of fenpopathrin 30%EC and thiamethoxam 25%WG applied as foliar treatments against sucking pests (whitefly, jassid and aphid) on okra were evaluated under field conditions over two seasons respectively.

3.1 Effect of treatment schedules on whitefly population

The obtained data are summarized and represented in Table 1 (pooled analysis of three sprayings). Observations recorded on number of whiteflies before treatment showed a uniform distribution on all treatment plots ranging from 7.20-8.60/3 leaves in first season and 11.40-13.60/ 3 leaves in second

season. Post-treatment results revealed that all the treatments significantly reduced the population of whitefly over untreated control. Pyriproxyfen 10%EC @ 750 mL/ha and 1000 mL/ha was most effective in both seasons having a mean percentage reduction of 71.36 and 73.30% in first season and 65.25 and 70.88% in second season. Reduction was in close proximity with standard check thiamethoxam 25WG which also registered a mean reduction of 67.49 and 68.18% over two seasons. Pyriproxyfen 10EC @ 500mL/ha was statistically at par with pyriproxyfen 10EC @750mL/ha giving a mean reduction of 68.33 and 63.73% over two seasons. Pyriproxyfen 10EC@ 300mL/ha was found to be the least effective with mean population reduction below 50%. Fenpopathrin 30EC was found to give a mean reduction of 54.70 and 61.58% respectively over two seasons.

The present study results are similar to the findings of Kumar and Singh (2016) [19], Dey *et al.* (2006) [20] and Kumar *et al.* (2016) [21] who reported that pyriproxyfen 10 EC was effective in management of whitefly.

3.2 Effect of treatment schedules on leaf hopper population

The data are summarized and represented in Table 2 (pooled analysis of three sprayings). Pre-treatment observations show uniform distribution of leaf hopper population in all treatment plots to the tune of 14.40-16.00/leaf and 6.20-11.00/leaf over two seasons respectively. It is understood from the computed post treatment data that all the treatments were effective in reducing leaf hopper populations over untreated check in both seasons. Pyriproxyfen 10EC @ 500 mL/ha, 750mL/ha and 1000 mL/ha all were found prominent in keeping population of leafhopper in below ETL up to 10 days and they were statistically at par having mean reduction of 46.48%, 45.73% and 47.50% in first season and 57.25%, 59.18% and 60.45% in second season respectively. These results exhibited no significant difference from that of standard checks fenpopathrin 30EC and thiamethoxam 25WG with a mean reduction of 44.24% and 49.84% in first season and 57.56% and 57.30% in the second season.

The results of the present study are in parity with that of the results reported by Kumar and Singh (2016) [19].

3.3 Effect of treatment schedules on aphid population

The data are summarized and represented in Table 3 (pooled analysis of three sprayings).Observation recorded on number of aphids before spraying indicates uniform distribution of aphids in all the treatments, which ranged from 11.4-16.00 /leaf in first season and 17.00-28.40/ leaf in second season. After imposition of treatments, the results reveal that all the treatments successfully reduced aphid population upto 10 days. Pyriproxyfen 10EC @1000mL/ha was found to be the most effective giving 75.53 and 76.50 % reduction over two seasons followed by thiamethoxam 25WG which had an initial knockdown effect and mean reduction was 70.94 and 71.26% respectively over two seasons. This was further followed by pyriproxyfen 10EC @ 750 mL and fenpopathrin 30EC, which were statistically at par and gave mean reductions of 68.30% and 68.69% in first year and 71.43% and 71.26% in second year respectively. Pyriproxyfen 10EC@ 300mL and 500 mL/ha was found to be moderately effective in reducing aphid population.

Similar results were reported by Richardson and Doris (2007) [22] Sadeghi *et al.* (2009) [23] and Khan *et al.* (2017) [24] all of which states that pyriproxyfen is effective in bringing down the population of aphid in different crops in field as well as under laboratory conditions.

3.4 Effect of treatment schedules on natural enemy population (predators)

Different coleopteran predators' viz.; *Coccinella* spp**.,** *Coccinella transversalis***,** *Chielomenes sexmaculata* and *Micraspis discolor* and also spiders were found to be prevalent in okra eco-system. Attempts were made to observe the relative toxicity of pyriproxyfen 10% EC against these natural enemies. The results are presented in Table 4. The initial observation recorded indicated that natural enemy population varied from 4.00-4.5/plant in first season and 3.34-5.67/plant in second season. Post-treatment data revealed that all the treatments were soft on prevailing predatory fauna and pyriproxyfen at low doses of 300mL/ha and 500mL/ha almost showed no mortality upto 10 days. Standard check thiamethoxam 25WG also showed low reduction of natural enemy population in comparison to fenpopathrin 30EC which reduced natural enemy population up to about 5%.

The results obtained from the present study were found to be similar to that of Kumar *et al.* (2015) [25] and Kumar *et al.* (2016) [19] who reported that the pyriproxyfen was safe to prevailing natural enemies in tomato ecosystem in Punjab and in cotton ecosystem of Rajasthan. However, the results of the present study are contradictory to that of Mendel *et al.* (1994) [26] who reported to have found detrimental effects of pyriproxyfen on parasitoids of scale insects and also Tong and Stansly (1997) [27] who reported pyriproxyfen to have toxic effects on pupae of *Encarsia* sp.

3.5 Effect of treatment schedules on soil fauna

The mean number of soil micro-arthropods sampled from a depth of 0-20cm pre and post foliar treatments have been represented in Table 5. The most abundant was Acarina (having soil mites from orders Oribatida, Gamasida and Actinedida) followed by Psocoptera and Collembola. All dosages of pyriproxyfen 10EC was found to be moderately soft on prevailing Acarina and only highest dosage (1000mL/ha) gave a mean reduction of about 31.00%. Fenpopathrin 30EC was found to be more toxic to acarina giving a mean population reduction of 51.05% within 10 days of treatment. Thiamethoxam 25WG was found to be moderately toxic to soil mites giving a mean reduction of 29.90%. Pyriproxyfen 10EC at all dosages was found to be toxic to both Psocoptera and Collembola populations at initial stages giving a mean reduction of 35.49-57.41% and 47.07-71.91% within 10 days of treatment. However, in comparison to fenpopathrin 30EC it was less toxic which gave a mean reduction of 60.32% of Psocoptera population and 77.03% reduction in Collembola population. Thiamethoxam 25WG was not found to be significantly different from pyriproxyfen and had a mean reduction of 40.56% and 65.17% of Psocoptera and Collembola population.

The results of the present study are similar to the findings of El-Naggar and Zidan (2013) [28] and that of Carbera *et al.* (2004) [12] who reported pyriproxyfen to have a little or no mortality to soil dwelling predatory mites under greenhouse conditions and have high initial toxicity to Collembola and moderately toxic to soil dwelling predatory mites.

Table 1: Relative efficacy of different treatment schedules of Pyriproxyfen 10% EC against white fly infesting Okra at In-check farm, Kalyani, BCKV (Mean of three sprayings) during February-May, 2015 and 2016

No	Treatment	Dosages (mL/ g /ha)	2015						2016					
			Pre-treatment count (Mean population /3 leaves)	% Reduction/ increase (+) in population after different days of treatment					Pre-treatment count (Mean population /3 leaves)	% Reduction / increase (+) in population after different days of treatment				
				1	3	7	10	Mean % reduction / increase (+)		1	3	7	10	Mean % reduction / increase (+)
1	Pyriproxyfen 10% EC	300	8.20	38.75 (38.47) *	38.50 (38.34)	60.18 (50.96)	45.50 (42.41)	45.73	12.00	25.75 (30.49) *	26.00 (30.65)	30.75 (33.67)	20.90 (27.20)	25.85
2	Pyriproxyfen 10% EC	500	8.60	61.86 (51.86)	57.75 (49.46)	86.35 (68.45)	67.35 (55.26)	68.33	13.20	56.75 (48.87)	62.35 (52.15)	70.50 (57.10)	65.32 (53.92)	63.73
5	Pyriproxyfen 10% EC	750	8.00	65.00 (53.74)	62.75 (52.47)	88.03 (69.79)	69.65 (56.57)	71.36	12.40	58.25 (49.74)	61.75 (51.79)	72.50 (58.37)	68.50 (55.86)	65.25
3	Pyriproxyfen 10% EC	1000	7.60	65.15 (53.86)	66.25 (54.50)	90.31 (71.90)	71.50 (57.81)	73.30	13.00	59.00 (50.18)	65.30 (53.93)	85.70 (67.78)	73.50 (59.01)	70.88
4	Fenpropathrin 30% EC	250	7.20	56.75 (48.88)	40.25 (39.33)	74.35 (59.59)	47.45 (43.53)	54.70	13.60	55.30 (48.04)	60.75 (51.20)	73.00 (58.69)	57.25 (49.06)	61.58
6	Thiamethoxam 25% WG	200	8.40	70.15 (56.92)	75.29 (60.34)	65.25 (53.93)	59.25 (50.34)	67.49	11.60	65.50 (54.02)	73.20 (58.82)	70.50 (57.10)	63.50 (52.83)	68.18
7	UTC (Control)	-	7.40	+12.32 (00.00)	+10.32 (00.00)	+ 15.50 (00.00)	+9.32 (00.00)	(+)11.87	11.40	+4.30 (00.00)	+5.12 (00.00)	+ 2.20 (00.00)	+11.30 (00.00)	(+)5.73
8	CD (p=0.05)		NS	(6.40)	(5.29)	(4.67)	(5.00)		NS	(3.50)	(4.19)	(3.50)	(3.96)	

*Data in parentheses are angular transformed values.
Data were arc-sin transformed and then analyzed by one-way ANOVA.
UTC – Un-treated control.

Table 2: Relative efficacy of different treatment schedules of Pyriproxyfen 10% EC against leaf hopper infesting Okra at In check farm, Kalyani, BCKV (Mean of three sprayings) during February-May, 2015 and 2016.

No	Treatment	Dosages (mL/ g /ha)	2015						2016					
			Pre-treatment count (Mean population / leaf)	% Reduction / increase (+) in population after different days of treatment					Pre-treatment count (Mean population /leaf)	% Reduction / increase (+) in population after different days of treatment				
				1	3	7	10	Mean % reduction / increase (+)		1	3	7	10	Mean % reduction / increase (+)
1	Pyriproxyfen 10% EC	300	15.20	28.39 (32.03)	44.65 (41.92)	40.25 (39.36)	32.15 (34.48)	36.36	9.40	30.50 (32.03) *	32.00 (41.92)	34.50 (39.36)	26.50 (34.48)	30.88
2	Pyriproxyfen 10% EC	500	15.00	44.50 (41.84)	50.55 (45.32)	55.39 (48.10)	35.49 (36.55)	46.48	10.60	52.25 (46.28)	60.75 (51.20)	63.50 (52.83)	52.50 (46.43)	57.25
5	Pyriproxyfen 10% EC	750	16.00	47.60 (43.62)	50.55 (45.32)	47.39 (43.50)	37.39 (37.68)	45.73	10.40	56.50 (48.73)	62.50 (52.23)	65.00 (53.72)	52.75 (46.57)	59.18
3	Pyriproxyfen 10% EC	1000	14.60	38.25 (38.19)	56.15 (34.15)	52.35 (31.56)	43.26 (25.63)	47.50	6.20	52.50 (34.75)	66.50 (41.68)	63.50 (39.42)	59.30 (36.37)	60.45
4	Fenpropathrin 30% EC	250	15.00	44.65 (41.93)	50.15 (45.09)	47.15 (43.36)	35.00 (36.24)	44.24	11.00	53.50 (47.00)	61.50 (51.64)	62.00 (51.94)	53.25 (46.86)	57.56

6	Thiamethoxam 25% WG	200	14.60	56.00 (48.45)	55.36 (48.10)	45.53 (42.42)	42.46 (40.66)	49.84	10.80	62.20 (52.23)	67.00 (54.93)	55.75 (48.30)	44.25 (41.69)	57.30
7	UTC (Control)	-	14.40	+13.36 (00.00)	+11.73 (00.00)	+10.65 (00.00)	+16.35 (00.00)	(+)13.02	9.60	+10.36 (00.00)	+5.46 (00.00)	+7.25 (00.00)	+3.25 (00.00)	(+)6.58
8	CD (p=0.05)		NS	(4.00)	(5.13)	(3.96)	(3.40)	-	NS	(3.59)	(4.00)	(4.01)	(3.69)	-

*Data in parentheses are angular transformed values.
Data were arc-sin transformed and then analysed by one-way ANOVA.
UTC – Un-treated control.

Table 3: Relative efficacy of different treatment schedules of Pyriproxyfen 10% EC against aphid infesting Okra at In check farm, Kalyani, BCKV (Mean of three sprayings) during February-May, 2015 and 2016

No	Treatment	Dosages (mL/ g /ha)	2015						2016					
			Pre-treatment count (Mean population / leaf)	% Reduction / increase (+) in population after different days of treatment					Pre-treatment count (Mean population /leaf)	% Reduction / increase (+) in population after different days of treatment				
				1	3	7	10	Mean % reduction / increase (+)		1	3	7	10	Mean % reduction / increase (+)
1	Pyriproxyfen 10% EC	300	15.20	52.75 (46.59)*	55.15 (47.97)	64.20 (53.27)	50.00 (45.00)	55.53	17.00	46.50 (42.99)*	50.25 (45.14)	57.00 (49.02)	46.75 (43.13)	50.13
2	Pyriproxyfen 10% EC	500	16.00	50.25 (45.14)	56.50 (48.75)	67.50 (55.26)	57.50 (49.34)	57.94	27.60	63.75 (52.98)	56.50 (48.73)	63.25 (52.68)	55.50 (48.16)	59.75
5	Pyriproxyfen 10% EC	750	11.40	55.50 (48.17)	68.20 (55.76)	88.00 (69.96)	61.50 (51.69)	68.30	28.40	62.75 (52.38)	71.35 (57.63)	82.35 (65.15)	69.25 (56.32)	71.43
3	Pyriproxyfen 10% EC	1000	12.80	70.75 (57.01)	75.40 (60.37)	90.50 (72.72)	65.50 (54.09)	75.53	22.60	75.00 (60.00)	78.25 (62.20)	83.75 (66.23)	69.00 (56.17)	76.50
4	Fenpropathrin 30% EC	250	15.00	58.25 (49.77)	70.50 (57.18)	86.50 (68.54)	59.50 (50.50)	68.69	19.00	68.50 (55.85)	72.50 (58.37)	76.50 (61.00)	65.20 (53.84)	70.68
6	Thiamethoxam 25% WG	200	12.00	75.75 (60.59)	80.00 (63.57)	70.50 (57.13)	57.50 (57.83)	70.94	18.60	73.00 (58.69)	78.25 (62.20)	71.50 (57.74)	62.35 (52.15)	71.26
7	UTC (Control)	-	16.00	+12.25 (0.00)	+17.75 (0.00)	+ 15.00 (0.00)	+25.75 (0.00)	(+)17.69	24.40	+7.15 (0.00)	+4.25 (0.00)	+ 6.50 (0.00)	+8.50 (0.00)	(+) 6.60
8	CD (p=0.05)		NS	(4.81)	(5.32)	(5.05)	(5.61)	-	NS	(3.94)	(4.12)	(3.98)	(4.01)	-

*Data in parentheses are angular transformed values.
Data were arc-sin transformed and then analysed by one-way ANOVA.
UTC – Un-treated control.

Table 4: Effect of different treatment schedules of Pyriproxyfen 10% EC against against prevailing natural enemies (predatory complex) in Okra ecosystem at In check farm, Kalyani, BCKV (Mean of three sprayings) during February-May, 2015 and 2016

No	Treatment	Dosages (mL/ g /ha)	2015						2016					
			Pre-treatment count (Mean population / plant)	% Reduction (-) / increase (+)in population of predatory complex after different days of treatment					Pre-treatment count (Mean population /plant)	% Reduction (-) / increase (+)in population of predatory complex after different days of treatment				
				1	3	7	10	Mean % reduction / increase (+)		1	3	7	10	Mean % reduction / increase (+)
1	Pyriproxyfen 10% EC	300	4.25	N.M (0.00)	1.25 (6.35)	2.00 (8.09)	N.M (0.00)	0.81	4.67	N.M (0.00)	N.M (0.00)	N.M (0.00)	N.M (0.00)	NM
2	Pyriproxyfen 10% EC	500	4.50	1.70 (7.48)	1.50 (6.96)	2.80 (9.59)	1.00 (5.64)	1.75	5.67	2.01 (8.15)	1.25 (6.41)	0.85 (5.28)	N.M (0.00)	1.03
3	Pyriproxyfen 10% EC	750	4.08	2.20 (8.47)	3.00 (9.96)	2.75 (9.51)	1.20 (6.25)	2.29	3.34	2.25 (8.62)	3.00 (9.97)	1.25 (6.41)	0.50 (4.05)	1.75
4	Pyriproxyfen 10% EC	1000	4.08	3.20 (10.28)	4.00 (11.42)	3.75 (11.14)	2.00 (8.00)	3.24	2.67	4.25 (11.89)	4.50 (12.24)	3.00 (9.97)	2.25 (8.62)	3.50
5	Fenpropathrin 30% EC	250	4.50	4.45 (12.11)	6.00 (14.11)	3.50 (10.74)	2.00 (7.99)	3.99	3.67	4.50 (11.89)	5.25 (13.24)	5.00 (12.92)	3.50 (10.78)	4.56
6	Thiamethoxam 25% WG	200	4.00	2.35 (8.78)	3.50 (10.68)	2.75 (9.50)	1.25 (6.40)	2.46	4.34	3.50 (10.78)	4.75 (12.58)	2.00 (8.13)	1.02 (6.28)	2.82
7	UTC (Control)	-	4.15	+ 6.35 (0.00)	+ 3.25 (0.00)	+2.75 (0.00)	+2.20 (0.00)	(+)3.64	3.34	+ 2.25 (0.00)	+ 1.75 (0.00)	+1.00 (0.00)	+2.25 (0.00)	(+)1.81
8	CD (p=0.05)		N.S.	(1.46)	(2.17)	(1.56)	(1.74)		N.S.	(1.46)	(2.17)	(1.56)	(1.74)	

Data in parentheses are angular transformed values.

Data were arcsine transformed and then analyzed by one-way ANOVA.

UTC – Un-treated control.NM- No mortality

**Predatory complex consisted with: *Coccinella septempunctata*; *Coccinellatransversalis*; *Cheilomenes sexmaculata and Micraspis discolor* and Spiders

Table 5: Effect of different treatment schedules of Pyriproxyfen 10% EC applied as foliar treatments on some beneficial soil fauna during February-May, 2015 and 2016 (Pooled of two seasons)

No	Treatment	Dosages (mL/ g /ha)	Mean number of individuals/100 gm soil at a depth of 0-20cm at different intervals pre and post application of treatments															
			Psocoptera						Collembola						Acarina					
			Pre-treatment count	Days after treatment			Mean	% reduction or (+) increase from UTC	Pre-treatment count	Days after treatment			Mean	% reduction or (+) increase from UTC	Pre treatment count	Days after treatment			Mean	% reduction or (+) increase from UTC
				1	7	14				1	7	14				1	7	14		
1	Pyriproxyfen 10% EC	300	3.42 (1.98)	3.18 (1.92)	2.58 (1.75)	2.69 (1.79)	2.82	35.49	1.67 (1.47)	1.54 (1.43)	1.32 (1.35)	1.38 (1.37)	1.41	47.07	26.2 (5.17)	22.45 (4.79)	20.10 (4.54)	21.09 (4.65)	21.21	17.65
2	Pyriproxyfen 10% EC	500	1.98 (1.57)	1.92 (1.56)	1.73 (1.49)	1.76 (1.50)	1.80	52.29	1.52 (1.42)	1.39 (1.37)	0.84 (1.16)	0.9 (1.18)	1.04	60.92	22.38 (4.78)	21.59 (4.70)	19.43 (4.46)	19.59 (4.48)	20.20	21.57
5	Pyriproxyfen 10% EC	750	2.85 (1.83)	2.07 (1.60)	1.3 (1.34)	1.82 (1.52)	1.73	54.23	1.04 (1.24)	0.98 (1.22)	0.74 (1.11)	0.79 (1.14)	0.84	68.66	24.84 (5.03)	22.77 (4.82)	17.92 (4.29)	17.98 (4.30)	19.56	24.08
3	Pyriproxyfen 10% EC	1000	1.65 (1.47)	1.63 (1.46)	1.59 (1.45)	1.61 (1.45)	1.61	57.41	1.04 (1.24)	0.84 (1.16)	0.67 (1.08)	0.74 (1.11)	0.75	71.91	19.26 (4.45)	18.97 (4.41)	16.45 (4.12)	17.9 (4.29)	17.77	31.00
4	Fenpropathrin 30% EC	250	2.04 (1.59)	1.42 (1.39)	1.46 (1.40)	1.62 (1.46)	1.50	60.32	1.14 (1.28)	0.85 (1.16)	0.48 (0.99)	0.51 (1.00)	0.61	77.03	18.9 (4.40)	14.05 (3.81)	11.58 (3.48)	12.2 (3.56)	12.61	51.05
6	Thiamethoxam 25% WG	200	2.78 (1.81)	2.15 (1.63)	2.02 (1.59)	2.57 (1.75)	2.25	40.56	1.34 (1.36)	1.2 (1.30)	0.78 (1.13)	0.81 (1.14)	0.93	65.17	20.6 (4.59)	19.09 (4.43)	17.28 (4.22)	17.8 (4.28)	18.06	29.90
7	UTC (Control)	-	3.32 (1.95)	3.35 (1.96)	4.33 (2.20)	3.66 (2.04)	3.78	0.00	1.41 (1.38)	1.4 (1.38)	2.95 (1.86)	3.67 (2.04)	2.67	0.00	25.55 (5.10)	22.34 (4.78)	28.68 (5.40)	26.25 (5.17)	25.76	0.00
8	CD (p=0.05)		NS	0.29	0.48	1.03			NS	0.03	0.15	0.23			NS	1.25	1.48	2.43		

Data in parentheses are square root transformed values

Table 6: Yield of okra and economics of different treatment schedules of Pyriproxyfen 10% EC against sucking pest complex of okra during February-May, 2015 and 2016 (Pooled of two seasons)

Treatment	Dosage(mL/ g /ha)	OkraYield (t/ha)		Mean Yield (t/ha)	% increase in yield over UTC	Cost of treatments including labour charges(`/ha)	Gross realization (`/ha)	Net realization (`/ha)	Net profit (`/ha)	Cost Benefit Ratio
		Season 1	Season 2							
Pyriproxyfen 10% EC	300	9.90 (3.22)	12.24 (3.57)	11.07	14.60	35600	201650	166050	130450	1:3.66
Pyriproxyfen 10% EC	500	12.20 (3.56)	17.50 (4.24)	14.85	53.73	36200	258950	222750	186550	1:5.15
Pyriproxyfen 10% EC	750	13.40 (3.73)	19.25 (4.44)	16.33	69.05	37200	282075	244875	207675	1:5.58
Pyriproxyfen 10% EC	1000	15.41 (3.45)	18.00 (4.18)	16.70	72.88	38100	288600	250500	212400	1:6.67
Fenpropathrin 30% EC	250	12.10 (3.55)	18.00 (4.30)	15.05	55.80	35800	261550	225750	189950	1:5.31
Thiamethoxam 25% WG	200	12.50 (3.61)	16.00 (4.06)	14.25	47.52	35300	249050	213750	178450	1:5.06
UTC (Control)	-	7.00 (2.74)	4.32 (2.20)	9.66	0.00	34000	178900	144900	110900	1:3.26
CD (p=0.05)		2.79	2.51	-		-	-	-	-	-

Data in parentheses are square root transformed values

Market price of cabbage: 15000.00 per ton (As of 16 March, 2017, Govt. of India. http:// http://agmarknet.nic.in/)

Labour charges (skilled): 222.00 day as per govt. of W.B. Labour Commission Cicular, 2014

3.6 Effect of treatment schedules on yield

Table 6 represents the yield economics of okra under different treatment schedules over two seasons. Plots treated with higher doses of pyriproxyfen 10EC gave significantly higher yield (11.07-16.70tonnes/ha) than that of untreated control (9.66tonnes/ha). The yield increment was promising in the treated plots with pyriproxyfen 10EC at higer doses than that of standard checks fenpopathrin 30EC and thiamethoxam 25WG (15.05 and 14.25tonnes/ha). Highest cost: benefit ratio (1: 6.67) was obtained from pyriproxyfen 10EC at the rate 1000 mL/ha closely followed by pyriproxyfen 10EC at the rate 750 mL/ha (1:5.58) and the least being pyriproxyfen 10EC at the rate 300 mL/ha (1:3.66).

Pyriproxyfen did not exhibit any phytotoxic symptoms even at very high doses.

4. Conclusions

From the present study, pyriproxyfen 10% EC was found quite effective against the sucking pests of okra at 500 mL/ha and 750 mL/ha and was on par in the context of efficacy against target pest with thiamethoxam 25%WG.

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