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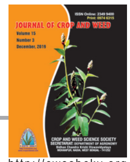

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Evaluation of pre-mix insecticide: teflubenzuron+ alpha cypermethrin as a tool for the management of *Scirtothrips dorsalis* Hood, *Helicoverpa armigera* (Hubner) and *Spodoptera litura* (Fabricius) infesting chilli in red and lateritic zones of West Bengal

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ABSTRACT

The bioefficacy of pre-mix formulation of teflubenzuron 75% + alpha cypermethrin 75% SC @ 30, 45, 60 and 75 g a.i. ha^{-1} along with few conventional insecticides were evaluated against Scirtothrips dorsalis Hood*, Helicoverpa armigera* (Hubner) *and Spodoptera litura* (Fabricius) *infesting chilli under red and lateritic zone of West Bengal. Among all the concentrations of the test chemical, teflubenzuron 75% + alpha cypermethrin 75% SC @ 60 g a.i. ha^{-1} gave optimum results with good per cent reduction in the population of Spodoptera litura (78.82), Helicoverpa armigera (76.54) and Scirtothrips dorsalis (74.35) considering its bioefficacy against target pests, effect on the natural enemies and yield of the crop (46.17 % increase over control).*

***Keywords*:** Alpha cypermethrin, chilli, *Helicoverpa armigera*, *Scirtothrips dorsalis*, *Spodoptera litura*, teflubenzuron

The common name 'chilli' has been derived from the Latin word '*Capsa*' that literally deciphers as 'hollow pod'. The origin of chilli has been traced to the Latin American region. The great explorer Christopher Columbus is often credited for the dissemination of chilli seeds to Spain and the rest of Europe in 1493. Presently, *Capsicum frutescens* L. and *Capsicum annuum* L. are widely cultivated along tropics and subtropics with optimum temperature of 20 to 25°C (Saini *et al.*, 2017). However, the vast geographical diversity of India has enabled us to domesticate five species of chilli viz., *Capsicum annuum*, *C. frutescens*, *C. chinense*, *C. pubescens* and *C. baccatum* (Chandrakar *et al.*, 2019). The pigment 'capsanthin' is responsible for the vibrant colour of chilli fruits while the vigorous pungency is primarily attributed to the concentration of 'capsaicin' along the placenta of fruits. *Capsicum annuum* is the prime cultivated species of chilli in India and is used as a major spice and food flavouring agent (Bokkisam *et al.,* 2010). However, chilli has recently been used as an ingredient in the preparation of beverages and medicines (Kumar and Lekeshmanaswamy, 2016). Chilli is cultivated in almost all the states of India, among which Andhra Pradesh leads the production by solely contributing 49 per cent to the total national output (Mahalingappa *et al*., 2008). Collectively, Andhra Pradesh, Karnataka, Maharashtra, Orissa and Tamil Nadu account for more than 75% of the area and total production of chilli (Sial *et al.,* 2016). Although, West Bengal shares a mere 5 per cent of the national production, chilli still finds a place as a valuable vegetable and spice crop of West Bengal (Datta and Chakraborty, 2013).

A plethora of pests comprising about 51 distinct species of insect and mite belonging to 31 genera within 27 families of 9 orders have been recorded on chilli by Reddy and Puttaswamy (1984). However, two species viz., yellow thrips, *Scirtothrips dorsalis* Hood and chilli mite, *Polyphagotarsonemus latus* Banks have attained the status of major pests and causes drastic economic losses in the chilli growing southern districts of West Bengal (Sarkar *et al.,* 2008). The infestation of aphids (*Aphis gossypii* Glover and *Myzus persicae* Sulzer) and fruit borer complex including *Helicoverpa armigera* (Hubner) and *Spodoptera litura* (Fabricius) may also be problematic in future.The overall yield loss in chilli attributed to the infestation by *Scirtothrips dorsalis* Hood has been reported to the magnitude of 30 to 50 per cent by Bhede *et al.* (2008) while *Helicoverpa armigera* (Hubner) is reported to cause 20-30 per cent damage to chilli fruits (Shivaramu and Kulkarni, 2001). To combat the menace of thrips and mite infestation especially during the early stage of chilli crop, farmers primarily rely on the use of huge amount of broad spectrum pesticide applications. Hence, in the recent past, development of resistance to pesticides, pesticide induced pest resurgence, outbreak of secondary pests and contamination of food and ecosystem are problems incurred due to pesticide mismanagement (Rai and

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Sarkar, 2018). Rational choice of chemicals for pest management needs to be advocated. Alpha-cypermethrin belongs to the insecticide group synthetic pyrethroid and is being widely used in controlling an array of pests in public health, animal husbandry and agriculture considering its relatively lower toxicity to mammals and lesser persistence in the environment. Synthetic Pyrethroids slow down the inactivation of Voltage Gated Sodium Channel (VGSC), which subsequently leads to hyper-excitation of the central nervous system. However, sodium channels of mammals are less sensitive to cypermethrin than those of insects (Singh *et al.*, 2012). On the other hand, Teflubenzuron belongs to Benzo Phenyl Urea (BPU) group that acts as a growth regulator by inhibiting the synthesis of chitin in the insects, thereby disrupting the moulting and development of the larva into an adult. As higher animals and plants do not have chitin in their body structure, BPUs are relatively safe (Ganguly *et al.*, 2020). In the pursuit of a safer alternative, this research experiment is an endeavour to find a suitable management strategy utilising an insecticidal combination product targeting both the major pests of chilli at once.

The experiment was conducted at the College of Agriculture (extended campus of B.C.K.V.), Susunia, Bankura, West Bengal in a Randomized Block Design (RBD) during *kharif* season of 2017. Healthy seedlings of chilli variety 'VNR-26-13' aged 28 days were transplanted in 15 m^2 plots maintaining a 75 x 45 cm spacing. Nine insecticidal treatments including the untreated control were replicated thrice and evaluated for their bio-effectiveness against chilli thrips, *Scirtothrips dorsalis* Hood and chilli fruit borers {*Helicoverpa armigera* (Hubner); *Spodoptera litura* (Fabricius)}. The detail of the treatments are as follows:

	Treatment details	Dosage (g a.i. ha^{-1})
T_1	Teflubenzuron 75 % + Alpha cypermethrin 75 % SC	30
T_2	Teflubenzuron 75 % + Alpha cypermethrin 75 % SC	45
T_3	Teflubenzuron 75 % + Alpha cypermethrin 75 % SC	60
T_4	Teflubenzuron 75 % + Alpha cypermethrin 75 % SC	75
T_5	Teflubenzuron 150 % SC	30
T_6	Alpha cypermethrin 10% SC	30
T_7	Emamectin Benzoate 5% SG	10
T_8	Acetamiprid 20% SP	20
T_9	Untreated Control (UTC)	-

Two applications of insecticidal treatment were done at 15 days interval at the rate of 500 litres of spray solution per hectare utilizing high volume Knap sack sprayer fitted with a cone nozzle for observations on thrips population, both the nymphs and adults were counted in situ from half to fully opened young top leaves from three shoots on ten randomly selected plants in each plot with the help of 10X hand lens and the data collected were expressed as number of thrips per leaf. For observations on fruit borer population, the number of larva was recorded on 5 randomly selected plants per plot and data were expressed as number of larvae per plant. The population of natural enemies encountered in the field, particularly coccinellids and spiders, was counted in situ and expressed in population per plant. Observations on pest and natural enemies were recorded one day before the treatment followed by 1, 3, 5, 7 and 10 days after treatment. The data recorded were then subjected to square root transformation and subsequently analysed using appropriate statistical procedures.

a) Bio-efficacy of teflubenzuron and alpha cypermethrin against Scirtothrips dorsalis Hood

Table 1 represents the population of *Scirtothrips dorsalis* Hood in the experimental field. It is pretty evident that all the treatments effectively reduced the population of the target pest compared to untreated control. Before the first spray, pre-treatment count of thrips varied between 7.40 to 8.91 thrips per leaf in different treatments. At 1 day after spraying (DAS), it was observed that T_4 (Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 75 g a.i. ha^{-1}) recorded lowest number of thrips (3.91) which was statistically on par with T_8 (acetamiprid 20% SP @ 20 g a.i. ha^{-1}) recording 4.44 number of thrips followed by T_3 (Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 60 g a.i. ha^{-1}) (4.82). T_1 and T_2 (Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 30 and 45 g a.i. ha^{-1} respectively) were statistically on par with each other and recorded 6.93 and 6.49 thrips respectively while untreated control recorded the highest number of thrips (7.87). At 5 DAS, T_4 and T_3 continued to perform well recording 2.22 and 2.47 number of thrips which were on par with T_8 (2.29) and T_7 (2.56). Similar trends in bio-efficacy of treatments were observed at 7 DAS. However at 10 DAS, T_4 and T_3 were observed to be the best treatments recording least number of thrips (1.67 and 1.80 respectively) and were statistically on par with T_7 (1.73) and T_8 (1.80). Although, T_1 recorded 2.53 number of thrips, it was statistically on par with T_5 (teflubenzuron 150 SC @ 30 g a.i. ha^{-1}) (2.49) and T_6 (alpha cypermethrin 10% SC @ 30 g a.i. ha^{-1}) (2.62). Untreated control recorded the highest number of thrips (9.27). Among all the treatments, T_4 recorded the highest percent reduction over control (84.92%) followed by T_7 (84.50), T_3 (83.25) and T_8 (82.24).

Table 1 : Bioefficacy of Teflubenzuron 75 % + Alpha cypermethrin 75 % SC against *Scirtothrips dorsalis* Hood infesting chilli at Chhatna, Bankura, West Bengal during *Kharif* season, 2017

Treatments	(First Spray)							(Second Spray)							
	Population of *Scirtothrips dorsalis*/ leaf @							Population of *Scirtothrips dorsalis*/ leaf @							
	PT	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	PROC	PT	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	PROC	APR
T_1	8.02	6.93 (2.63)*	5.29 (2.30)	3.56 (1.88)	3.13 (1.76)	2.53 (1.59)	74.82	4.60	4.42 (2.10)	4.13 (2.03)	3.80 (1.94)	3.40 (1.84)	3.11 (1.76)	58.26	66.54
T_2	8.64	6.49 (2.54)	5.27 (2.29)	3.53 (1.87)	3.09 (1.75)	2.22 (1.48)	79.49	4.51	4.40 (2.09)	3.91 (1.97)	3.60 (1.89)	3.29 (1.81)	3.02 (1.73)	58.66	69.07
T_3	8.58	4.82 (2.19)	3.29 (1.81)	2.47 (1.57)	2.20 (1.48)	1.80 (1.34)	83.25	4.29	4.09 (2.02)	3.78 (1.94)	3.40 (1.84)	2.84 (1.68)	2.40 (1.54)	65.46	74.35
T_4	8.84	3.91 (1.97)	3.13 (1.76)	2.22 (1.48)	1.93 (1.38)	1.67 (1.29)	84.92	4.89	4.00 (2.00)	3.60 (1.89)	3.22 (179)	2.73 (1.65)	2.38 (1.54)	69.95	77.43
T_5	8.62	5.27 (2.29)	3.87 (1.96)	2.67 (1.63)	2.58 (1.60)	2.49 (1.57)	76.94	4.58	4.38 (2.09)	3.87 (1.96)	3.58 (1.89)	3.20 (1.78)	2.87 (1.69)	61.32	69.13
T_6	7.91	6.40 (2.52)	5.02 (2.24)	3.69 (1.92)	3.13 (1.76)	2.62 (1.61)	73.56	4.67	4.58 (2.14)	4.11 (2.02)	3.80 (1.94)	3.38 (1.83)	3.00 (1.73)	60.34	66.95
T_7	8.91	5.44 (2.33)	3.76 (1.93)	2.56 (1.60)	2.04 (1.42)	1.73 (1.31)	84.50	4.80	4.29 (2.07)	3.71 (1.92)	3.36 (1.83)	2.87 (1.69)	2.40 (1.54)	69.13	76.81
T_8	8.09	4.44 (2.10)	3.62 (1.90)	2.29 (1.51)	2.07 (1.43)	1.80 (1.34)	82.24	4.73	4.20 (2.04)	3.80 (1.94)	3.27 (1.80)	2.91 (1.70)	2.42 (1.55)	68.42	75.33
T_9	7.40	7.87 (2.80)	8.11 (2.80)	8.40 (2.89)	8.80 (2.96)	9.27 (3.04)	-	4.42	5.00 (2.23)	5.24 (2.28)	5.78 (2.40)	6.20 (2.48)	7.16 (2.67)	-	-
SEm (±)	**-**	**0.20**	**0.15**	**0.12**	**0.07**	**0.06**	**-**	**-**	**0.08**	**0.07**	**0.05**	**0.06**	**0.04**	**-**	**-**
LSD (0.05)	**NS**	**0.62**	**0.46**	**0.37**	**0.21**	**0.19**	**-**	**NS**	**0.26**	**0.21**	**0.17**	**0.18**	**0.13**	**-**	**-**

Note: T_1:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 30g a.i.ha^{-1};T_2:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 45g a.i.ha^{-1};T_3:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 60g a.i.ha^{-1};T_4:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 75g a.i.ha^{-1};T_5:Teflubenzuron 150 SC @ 30g a.i.ha^{-1};T_6:Alpha Cypermethrin 10% SC @ 30g a.i.ha^{-1}; T_7:Emamectin Benzoate 5% SG @ 10g a.i.ha^{-1};T_8:Acetamiprid 20% SP @ 20g a.i.ha^{-1}; T_9: Untreated control

**Figures in parenthesis are square root transformed values*

PROC: Percent reduction over control, APR: Average percent reduction over control, PT:Pretreatment count, DAS: Days after spraying

Table 2 : Bioefficacy of Teflubenzuron 75 % + Alpha cypermethrin 75 % SC against *Helicoverpa armigera*Hubn. infesting chilli at Chhatna, Bankura, West Bengal during *Kharif* season, 2017

Treatments	(First Spray) Population of *Helicoverpa armigera* / plant @							(Second Spray) Population of *Helicoverpa armigera* / plant @							
PT	1 DAS	3 DAS	5 DAS	7 DAS	10DAS	PROC	PT	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	PROC	APR	
T_1	2.65	2.48	2.32	1.92	1.40	1.26	67.01	1.58	1.46	1.32	1.14	0.98	0.87	69.21	68.11
		(1.57)*	(1.52)	(1.38)	(1.18)	(1.12)			(1.20)	(1.14)	(1.06)	(0.98)	(0.93)		
T_2	2.37	2.21	2.08	1.68	1.16	1.03	69.84	1.46	1.35	1.19	1.00	0.88	0.75	71.27	70.55
		(1.48)	(1.44)	(1.29)	(1.07)	(1.01)			(1.16)	(1.09)	(1.00)	(0.93)	(0.86)		
T_3	2.67	2.31	2.00	1.64	1.04	0.89	76.87	1.67	1.51	1.29	1.02	0.86	0.71	76.22	76.54
		(1.51)	(1.41)	(1.28)	(1.01)	(0.94)			(1.22)	(1.13)	(1.00)	(0.92)	(0.84)		
T_4	2.75	2.21	1.95	1.46	0.83	0.64	83.85	1.54	1.30	1.12	0.86	0.68	0.49	82.21	83.03
		(1.48)	(1.39)	(1.20)	(0.91)	(0.80)			(1.14)	(1.05)	(0.92)	(0.82)	(0.70)		
T_5	2.55	2.38	2.24	1.84	1.38	1.22	66.80	1.62	1.50	1.35	1.23	1.05	0.93	67.89	67.34
		(1.54)	(1.49)	(1.35)	(1.17)	(1.10)			(1.22)	(1.16)	(1.10)	(1.02)	(0.96)		
T_6	2.78	2.62	2.48	2.00	1.35	1.19	70.30	1.69	1.58	1.46	1.34	1.18	1.05	65.25	67.77
		(1.61)	(1.57)	(1.41)	(1.16)	(1.09)			(1.25)	(1.20)	(1.15)	(1.08)	(1.02)		
T_7	2.62	2.45	2.15	1.71	1.21	1.01	73.25	1.48	1.30	1.11	1.00	0.81	0.65	75.44	74.34
		(1.56)	(1.46)	(1.30)	(1.10)	(1.00)			(1.14)	(1.05)	(1.00)	(0.90)	(0.80)		
T_8	2.81	2.43	2.10	1.65	1.02	0.86	78.76	1.71	1.52	1.30	0.98	0.79	0.60	80.38	79.57
		(1.55)	(1.44)	(1.28)	(1.00)	(0.92)			(1.23)	(1.14)	(0.98)	(0.88)	(0.77)		
T_9	2.38	2.53	2.71	2.89	3.11	3.43	-	1.51	1.64	1.87	2.09	2.33	2.70	-	-
		(1.59)	(1.64)	(1.70)	(1.76)	(1.85)			(1.28)	(1.36)	(1.44)	(1.52)	(1.64)		
SEm (±)	**-**	**0.15**	**0.13**	**0.10**	**0.08**	**0.05**	**-**	**-**	**0.09**	**0.08**	**0.06**	**0.06**	**0.04**	**-**	**-**
LSD (0.05)	**NS**	**0.46**	**0.39**	**0.31**	**0.25**	**0.15**	**-**	**NS**	**0.28**	**0.24**	**0.19**	**0.18**	**0.12**	**-**	**-**

Note: T_1:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 30g a.i.ha^{-1};T_2:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 45g a.i.ha^{-1};T_3:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 60g a.i.ha^{-1};T_4:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 75g a.i.ha^{-1};T_5:Teflubenzuron 150 SC @ 30g a.i.ha^{-1};T_6:Alpha Cypermethrin 10% SC @ 30g a.i.ha^{-1}; T_7:Emamectin Benzoate 5% SG @ 10g a.i.ha^{-1};T_8:Acetamiprid 20% SP @ 20g a.i.ha^{-1}; T_9: Untreated control

** Figures in parenthesis are square root transformed values*

PROC: Percent reduction over control, APR: Average percent reduction over control, PT: Pretreatment count, DAS: Days after spraying

Table 3 : Bioefficacy of Teflubenzuron 75 % + Alpha cypermethrin 75 % SC against *Spodoptera litura* Fab. infesting chilli at Chhatna, Bankura, West Bengal during *Kharif* season, 2017

Treatments	(First Spray)							(Second Spray)							
		Population of *Spodoptera litura* / plant @							Population of *Spodoptera litura* / plant @						
	PT	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	PROC	PT	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	PROC	APR
T_1	1.27	1.16 (1.07)*	1.07 (1.03)	0.99 (0.99)	0.90 (0.94)	0.83 (0.91)	67.08	1.17	1.09 (1.04)	1.01 (1.00)	0.87 (0.93)	0.72 (0.84)	0.63 (0.79)	72.83	69.95
T_2	1.40	1.25 (1.11)	1.12 (1.05)	0.98 (0.98)	0.87 (0.93)	0.78 (0.88)	71.93	1.14	1.04 (1.01)	0.95 (0.97)	0.79 (0.88)	0.64 (0.80)	0.55 (0.74)	75.66	73.79
T_3	1.36	1.21 (1.10)	1.06 (1.02)	0.91 (0.95)	0.77 (0.87)	0.65 (0.80)	75.92	1.16	1.02 (1.00)	0.89 (0.94)	0.72 (0.84)	0.54 (0.73)	0.42 (0.64)	81.73	78.82
T_4	1.35	1.17 (1.08)	1.01 (1.00)	0.84 (0.91)	0.66 (0.81)	0.54 (0.73)	79.85	1.13	0.98 (0.98)	0.82 (0.90)	0.62 (0.78)	0.41 (0.64)	0.26 (0.50)	88.39	84.12
T_5	1.28	1.19 (1.09)	1.11 (1.05)	1.02 (1.00)	0.94 (0.96)	0.89 (0.94)	64.97	1.22	1.14 (1.06)	1.06 (1.02)	0.93 (0.96)	0.79 (0.88)	0.71 (0.84)	70.64	67.80
T_6	1.32	1.23 (1.10)	1.15 (1.07)	1.07 (1.03)	0.98 (0.98)	0.91 (0.95)	65.27	1.14	1.07 (1.03)	1.00 (1.00)	0.89 (0.94)	0.75 (0.86)	0.66 (0.81)	70.79	68.03
T_7	1.36	1.24 (1.11)	1.09 (1.04)	1.00 (1.00)	0.89 (0.94)	0.80 (0.89)	70.37	1.19	1.09 (1.04)	1.00 (1.00)	0.85 (0.92)	0.69 (0.83)	0.59 (0.76)	74.99	72.68
T_8	1.38	1.22 (1.10)	1.07 (1.03)	0.95 (0.97)	0.80 (0.89)	0.70 (0.83)	74.45	1.17	1.04 (1.01)	0.91 (0.95)	0.74 (0.86)	0.56 (0.74)	0.43 (0.65)	81.46	77.95
T_9	1.34	1.51 (1.22)	1.73 (1.31)	1.96 (1.40)	2.32 (1.52)	2.66 ()	-	1.12	1.27 (1.12)	1.43 (1.19)	1.70 (1.30)	2.05 (1.43)	2.22 (1.48)	-	-
SEm (±)	**-**	**0.07**	**0.06**	**0.04**	**0.04**	**0.03**	**-**	**-**	**0.07**	**0.07**	**0.05**	**0.04**	**0.03**	**-**	**-**
LSD (0.05)	**NS**	**0.21**	**0.18**	**0.12**	**0.12**	**0.15**	**-**	**NS**	**0.21**	**0.21**	**0.16**	**0.12**	**0.10**	**-**	**-**

Note: T_1:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 30g a.i.ha^{-1};T_2:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 45g a.i.ha^{-1};T_3:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 60g a.i.ha^{-1};T_4:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 75g a.i.ha^{-1};T_5:Teflubenzuron 150 SC @ 30g a.i.ha^{-1};T_6:Alpha Cypermethrin 10% SC @ 30g a.i.ha^{-1}; T_7:Emamectin Benzoate 5% SG @ 10g a.i.ha^{-1};T_8:Acetamiprid 20% SP @ 20g a.i.ha^{-1}; T_9: Untreated control

**Figures in parenthesis are square root transformed values*

PROC: Percent reduction over control, APR: Average percent reduction over control, PT:Pre treatment count, DAS: Days after spraying

Table 4 : Bioefficacy of Teflubenzuron 75 % + Alpha cypermethrin 75 % SC against important natural enemies encountered in chilli field at Chhatna, Bankura, West Bengal during *Kharif* season, 2017 (First Spray)

Treatments	**Population of Coccinellids / plant @						**Population of Spiders / plant @					
	PT	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	PT	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS
T_1	6.23	6.16 (2.48)*	6.08 (2.46)	6.04 (2.45)	7.16 (2.67)	8.14 (2.85)	3.96	3.51 (1.87)	2.95 (1.71)	2.44 (1.56)	3.48 (1.86)	4.36 (2.08)
T_2	6.45	6.35 (2.51)	6.27 (2.50)	6.20 (2.48)	6.99 (2.64)	7.77 (2.78)	4.03	3.49 (1.86)	2.89 (1.70)	2.31 (1.51)	3.23 (1.79)	4.06 (2.01)
T_3	6.44	6.32 (2.51)	6.24 (2.49)	6.16 (2.48)	6.68 (2.58)	7.31 (2.70)	4.59	4.01 (2.00)	3.35 (1.83)	2.75 (1.65)	3.61 (1.90)	4.40 (2.09)
T_4	6.12	5.96 (2.44)	5.84 (2.41)	5.76 (2.40)	5.98 (2.44)	6.63 (2.57)	4.20	3.49 (1.86)	2.76 (1.66)	1.94 (1.39)	2.42 (1.55)	3.12 (1.76)
T_5	5.87	5.78 (2.40)	5.70 (2.38)	5.63 (2.37)	6.71 (2.59)	7.54 (2.74)	4.15	3.67 (1.91)	3.01 (1.73)	2.46 (1.56)	3.46 (1.86)	4.38 (2.09)
T_6	6.65	6.54 (2.55)	6.44 (2.53)	6.36 (2.52)	6.47 (2.54)	7.22 (2.68)	3.91	3.41 (1.84)	2.86 (1.69)	2.28 (1.50)	3.14 (1.77)	4.00 (2.00)
T_7	6.32	6.23 (2.49)	6.15 (2.47)	6.12 (2.47)	6.23 (2.49)	7.01 (2.64)	4.36	3.91 (1.97)	3.40 (1.84)	2.89 (1.70)	3.81 (1.95)	4.69 (2.16)
T_8	6.41	6.33 (2.51)	6.26 (2.50)	6.20 (2.48)	6.61 (2.57)	7.21 (2.68)	4.53	4.10 (2.02)	3.42 (1.84)	2.79 (1.67)	3.62 (1.90)	4.43 (2.01)
T_9	6.36	6.66 (2.58)	6.80 (2.60)	7.48 (2.73)	8.76 (2.96)	9.93 (3.15)	4.11	4.46 (2.11)	5.09 (2.25)	5.66 (2.37)	6.83 (2.61)	7.80 (2.79)
SEm (±)	**-**	**0.12**	**0.13**	**0.14**	**0.19**	**0.21**	**-**	**0.10**	**0.08**	**0.08**	**0.11**	**0.13**
LSD (0.05)	**NS**	**0.31**	**0.40**	**0.43**	**0.56**	**0.63**	**NS**	**0.28**	**0.25**	**0.24**	**0.30**	**0.36**

Note: T_1:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 30g a.i.ha^{-1};T_2:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 45g a.i.ha^{-1};T_3:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 60g a.i.ha^{-1};T_4:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 75g a.i.ha^{-1};T_5:Teflubenzuron 150 SC @ 30g a.i.ha^{-1};T_6:Alpha Cypermethrin 10% SC @ 30g a.i.ha^{-1}; T_7:Emamectin Benzoate 5% SG @ 10g a.i.ha^{-1};T_8:Acetamiprid 20% SP @ 20g a.i.ha^{-1}; T_9: Untreated control

** Figures in parenthesis are square root transformed values PROC: Percent reduction over control, PT: Pre treatment count, DAS: Days after spraying*

***Coccinellids encountered in the field were Coccinellaseptempunctata, C. transversalis and Chielomenessexmaculata. Spiders encountered were Oxyopessp, Thomisussp and Telamoniadimidiata*

Table 5 : Bioefficacy of Teflubenzuron 75 % + Alpha cypermethrin 75 % SC against important natural enemies encountered in chilli field at Chhatna, Bankura, West Bengal during *Kharif* season, 2017 (Second Spray)

Treatments	**Population of Coccinellids / plant @						**Population of Spiders / plant @					
	PT	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	PT	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS
T_1	7.84	7.43 (2.72)	6.81 (2.60)	6.58 (2.56)	7.52 (2.74)	8.78 (2.96)	4.82	4.46 (2.11)	4.08 (2.01)	3.44 (1.85)	4.16 (2.03)	5.39 (2.32)
T_2	8.12	7.62 (2.76)	6.90 (2.62)	6.55 (2.55)	7.79 (2.79)	8.84 (2.97)	4.95	4.57 (2.13)	4.16 (2.03)	3.45 (1.85)	4.13 (2.03)	5.09 (2.25)
T_3	7.91	7.36 (2.71)	6.61 (2.57)	6.23 (2.49)	7.13 (2.67)	8.11 (2.84)	5.09	4.69 (2.16)	4.24 (2.05)	3.49 (1.86)	4.14 (2.03)	4.96 (2.22)
T_4	8.13	7.46 (2.73)	6.62 (2.57)	6.11 (2.47)	6.54 (2.55)	7.29 (2.70)	5.12	4.60 (2.14)	4.00 (2.00)	3.14 (1.77)	3.10 (1.76)	3.74 (1.93)
T_5	8.04	7.56 (2.74)	6.90 (2.62)	6.61 (2.57)	7.31 (2.70)	8.45 (2.90)	4.85	4.53 (2.12)	4.18 (2.04)	3.59 (1.89)	4.24 (2.06)	5.26 (2.29)
T_6	7.78	7.16 (2.67)	6.47 (2.54)	6.09 (2.46)	6.71 (2.59)	7.61 (2.75)	4.77	4.42 (2.10)	4.07 (2.01)	3.49 (1.86)	4.01 (2.00)	4.96 (2.22)
T_7	7.96	7.48 (2.73)	6.79 (2.60)	6.45 (2.53)	7.17 (2.67)	8.15 (2.85)	4.92	4.62 (2.14)	4.31 (2.07)	3.78 (1.94)	4.36 (2.08)	5.42 (2.32)
T_8	8.00	7.54 (2.74)	6.84 (2.61)	6.40 (2.52)	7.21 (2.68)	8.19 (2.86)	4.96	4.60 (2.14)	4.17 (2.04)	3.44 (1.85)	4.02 (2.00)	4.70 (2.16)
T_9	7.93	8.01 (2.83)	8.45 (2.90)	8.93 (2.98)	9.85 (3.13)	10.88 (3.29)	4.78	4.96 (2.22)	5.63 (2.37)	6.11 (2.47)	6.87 (2.62)	8.05 (2.83)
SEm (±)	**-**	**0.18**	**0.17**	**0.17**	**0.18**	**0.19**	**-**	**0.11**	**0.10**	**0.09**	**0.09**	**0.10**
LSD (0.05)	**NS**	**0.54**	**0.52**	**0.52**	**0.56**	**0.58**	**NS**	**0.33**	**0.31**	**0.28**	**0.29**	**0.30**

Note: T_1:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 30g a.i.ha^{-1};T_2:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 45g a.i.ha^{-1};T_3:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 60g a.i.ha^{-1};T_4:Teflubenzuron 75 % + Alpha cypermethrin 75 % SC @ 75g a.i.ha^{-1};T_5:Teflubenzuron 150 SC @ 30g a.i.ha^{-1};T_6:Alpha Cypermethrin 10% SC @ 30g a.i.ha^{-1}; T_7:Emamectin Benzoate 5% SG @ 10g a.i.ha^{-1};T_8:Acetamiprid 20% SP @ 20g a.i.ha^{-1}; T_9: Untreated control

** Figures in parenthesis are square root transformed values PROC: Percent reduction over control, PT: Pre treatment count, DAS: Days after spraying*

***Coccinellids encountered in the field were Coccinellaseptempunctata, C. transversalis and Chielomenessexmaculata. Spiders encountered were Oxyopessp, Thomisussp and Telamoniadimidiata*

Table 6: Impact of Teflubenzuron 75 % + Alpha cypermethrin 75 % SC on the yield of chilli at Chhatna, Bankura, West Bengal during Kharif season, 2017

Treatment number	Treatment	Dose (g a.i. ha^{-1})	Yield of green chilli (Tons/ha)	% increase in yield over control
T_1	Teflubenzuron 75 % + Alpha cypermethrin 75 % SC	30	8.16	24.77
T_2	Teflubenzuron 75 % + Alpha cypermethrin 75 % SC	45	8.38	28.13
T_3	Teflubenzuron 75 % + Alpha cypermethrin 75 % SC	60	9.56	46.17
T_4	Teflubenzuron 75 % + Alpha cypermethrin 75 % SC	75	9.62	47.09
T_5	Teflubenzuron 150 SC	30	8.08	23.54
T_6	Alpha cypermethrin10% SC	30	8.10	23.85
T_7	Emamectin Benzoate 5% SG	10	9.21	40.82
T_8	Acetamiprid 20% SP	20	9.17	40.21
T_9	Untreated control	-	6.54	-
SEm (±)	-	**2.95**	-	
LSD (0.05)	-	**0.98**	-	

Before the second spray, the pre-treatment count of thrips varied from 4.29 to 4.89 per leaf. At 1 DAS, T_4 and T_3 were observed to be the best treatment recording least number of thrips (4.00 and 4.09 respectively) and both were statistically on par with T_8 (4.20). T_1 and T_2 recorded 4.42 and 4.40 number of thrips and were on par with each other. Highest number of thrips was recorded in untreated control (5.00). However, at 5 DAS, T_3 and T_4 continued to perform well, recording 3.40 and 3.22 thrips, which were statistically on par with T_8 (3.27) and T_7 (3.36). At 10 DA orded 7.16 number of thrips. T_4 was observed to be the most effective treatment against *Scirtothrips dorsalis* providing highest average per cent reduction over control to the magnitude of 77.43, which was closely followed by T_7 (76.81%), T_8 (75.33) and T_3(74.35).

b) Bio-efficacy of teflubenzuron and alpha cypermethrin against Helicoverpa armigera Hubn:

Table 2 represents the population of *Helicoverpa armigera* Hubn in the experimental field. All the treatments were effective in reducing the population of the target pest in comparison with untreated control. Before the first spraying, the pre-treatment count of *Helicoverpa armigera* ranged between 2.37 to 2.81 per plant. At 1 DAS, T_2 and T_4 were found to be the best treatments with lowest number of target pest (2.21). At 5 DAS, T_2, T_3 and T_4 were very effective in reducing the pest population and recorded 1.68, 1.64 and 1.46 *Helicoverpa armigera* per plant, all of these were statistically on par with T_7 (1.71) and T_8 (1.65). It was followed by T_5 (1.84) and T_6 (2.00) which were also on par with each other. However, at 10 DAS, T_4 was found to be the best treatment with 0.64 number of *Helicoverpa armigera* per plant. It was closely followed by T_8 (0.86), T_3 (0.89), T_7 (1.01) and T_2 (1.03) and were statistically on par with each other. The highest percent reduction over control was recorded in T_4 (83.85 %) which was followed by T_8 (78.76 %), T_3 (76.87 %) and T_7 (73.25 %) respectively.

Before the second spraying, pre-treatment count ranged between 1.46 to 1.71 *Helicoverpa armigera* per plant. At 1 DAS, the lowest number of target pest was recorded in $T_4$and T_7 (1.30), followed by T_2 (1.35). At 5 DAS, T_2, T_3 and T_4 recorded 1.00, 1.02 and 0.86 *Helicoverpa armigera* per plant which were on par with T_8 (0.98) and T_7 (1.00). At 10 DAS, T_3 and T_4 were the best treatments recording 0.71 and 0.49 *Helicoverpa armigera* per plant and were on par with T_8 (0.60). The highest average percent reduction over control was recorded in T_4(83.03 %) which was followed by T_8 (79.57 %), T_3 (76.54 %) and T_7 (74.34 %), respectively.

c) Bio-efficacy of teflubenzuron and alpha cypermethrin against Spodoptera litura Fab.

Table 3 represents the population of *Spodoptera litura* in the experimental field. Before the first spray, the pre-treatment count varied between 1.27 to 1.40 in different treatments. At 1 DAS, T_3 and T_4 significantly reduced target pest population (1.21 and 1.17 respectively) and were statistically on par with each other. At 5 DAS, T_4 was found to be the best treatment with 0.84 *Spodoptera litura* per plant. It was closely followed by T_3 (0.91), T_8 (0.95), T_2(0.98) and T_7 (1.00) which were statistically on par with each other. At 10 DAS, T_4 recorded the least number of *Spodoptera litura* per plant (0.54) followed by T_3 (0.65) and were on par. However, T_3 was also found to be on par with T_8 (0.70), T_2 (0.78) and T_7 (0.80). T_4 recorded the highest percent reduction over control (79.85%) followed by T_3 (75.92%), T_8 (74.45%) and T_2 (71.93%).

Before the second spray, the pre-treatment count of *Spodoptera litura* varied between 1.12 to 1.22 per plant in different treatments. At 5 DAS, T_4 was the best treatment with 0.62 *Spodoptera litura* per plant, followed by T_3 (0.72) and T_8 (0.74) and were statistically on par with each other. At 10 DAS, T_4 continued to be the best treatment recording 0.26 *Spodoptera litura* per plant. It was followed by T_3 (0.42) and T_8 (0.43) respectively which were statistically on par with each other. Here also, $T_4$was the most effective treatment which recorded highest average percent reduction over control (84.12%) followed by T_3 (78.82%), T_8 (77.95%) and T_2 (73.79%).

d) Bio-efficacy of teflubenzuron and alpha cypermethrin against important natural enemies of pests of chilli

Important natural enemies frequently encountered in the experimental field mostly comprised of predators viz., Ladybird beetles (Coccinellidae), Lynx spiders (Oxyopidae), Crab spiders (Thomisidae) and Jumping spiders (Salticidae). The ladybird beetles observed in the field included *Coccinella septempunctata*, *C. transversalis* and *Chielomenes sexmaculata* while the predatory spider species encountered were *Telamonia dimidiata* (Family: Salticidae), *Thomisus* sp (Family: Thomisidae) and *Oxyopes* sp (Family: Oxyopidae).

Table 4 represents the population of some important natural enemies encountered in the experimental field after the first spray. The pretreatment count of coccinellids varied between 5.87 and 6.65 per plant in different treatments. At 10 DAS, T_1, T_2 and T_3 recorded 8.14, 7.77 and 7.31 coccinellids per plant respectively which was satisfactory as compared to the untreated control which recorded the highest number of coccinellids per plant (9.93). All these treatments except T_1 were statistically on par with T_8 (7.21). The pre-treatment count of spiders varied between 3.91 to 4.59 per plant in various treatments. However at 10 DAS, T_1, T_2 and T_3 recorded 4.36, 4.06 and 4.40 spiders per plant respectively and were statistically on par with T_8 (4.43). Highest number of spider per plant was recorded in untreated control (7.80) followed by T_7 (4.69) and T_8 (4.43). T_4 was observed to be the least effective treatment in terms of safety against natural enemies as it recorded the lowest population of coccinellid beetles (6.63) and predatory spiders (3.12).After the second spray (Table 5), the pre-treatment count of coccinellids varied between 7.78 and 8.13 per plant in different treatments. At 10 DAS, it was observed that T_1, T_2 and T_3 recorded 8.78, 8.84 and 8.11 coccinellids per plant, respectively, compared to the untreated control (10.88) and all the treatments were statistically on par with T_8 (8.19). On the other hand, pre-treatment count of spiders varied between 4.77 and 5.12 per plant in various treatments. At 10 DAS, T_1, T_2 and T_3 recorded 5.39, 5.09 and 4.96 spiders per plant, respectively, compared to untreated control (8.05). The lowest population of coccinellid beetles (7.29) and predatory spiders (3.74) were recorded in T_4.

e) Impact of teflubenzuron and alpha cypermethrin on the yield

The impact of different treatments on the yield of chilli has been presented in table 6. It was observed that the highest yield of chilli was recorded from plots treated with T_4 (9.62 t ha^{-1}) making it the best treatment among all which was closely followed by T_3 (9.56 t ha^{-1}), both were statistically on par with T_7 (9.21) and T_8 (9.17). T_1 and T_2 recorded a satisfactory 8.16 and 8.38 tons ha^{-1} yield as compared to untreated control (6.54) which recorded the least yield among all. Highest percentage increase in yield over control was recorded in T_4 (47.09%) followed by T_3 (46.17%) as compared to T_8 (40.21%).

Pre-mix formulation of teflubenzuron and alpha cypermethrin at higher concentrations (@ 60 and 75 g a.i. ha^{-1}) were moreover equally effective as the recommended conventional insecticides viz., emamectin benzoate and acetamiprid against the target pests. Although, very few literature is available on the use of insecticide combination involving teflubenzuron and alpha cypermethrin for pest control in agriculture, the findings of the experiment is partially substantiated by the investigation of Raja Sekhar *et al.* (1995) who reported that teflubenzuron exhibited as high as 100 percent mortality of early instars of *Helicoverpa armigera* in cotton. Similarly, Vivan *et al.* (2017) also reported that teflubenzuron and triflumuron produced 60 per cent mortality of second-instar larvae and lower than 50 percent in older larvae of *Helicoverpa armigera*.

Further, Chakraborti and Chatterjee (2000) and Mead and Khedr (2018) have also reported the larvicidal action of tuflubenzuron against *Helicoverpa armigera* and *Spodoptera littoralis* respectively.

Based on the findings of this research, it can be concluded that premix formulation of teflubenzuron and alpha cypermethrin provided satisfactory reduction in population of *Scirtothrips dorsalis*, *Helicoverpa armigera* and *Spodoptera litura* infesting chilli in comparison to the conventional chemicals. But at the same time, teflubenzuron and alpha cypermethrin @ 75 g a.i. ha^{-1} recorded the lowest number of natural enemies including both coccinellids and spiders. Therefore, teflubenzuron 75 % + alpha cypermethrin 75 % SC @ 60 g a.i. ha^{-1}can be recommended as the optimal dose considering its effectiveness against target pests, impact on crop yield and important natural enemies in the ecosystem.

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