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Efficacy of Coragen 20 SC against Lepidopteran Pest in Greengram and Its Compatibility with *Bacillus thuringiensis* Isolates

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ABSTRACT

Background: Green gram, [*Vigna radiata* (L.) R. Wilczek] is third most important pulse crop cultivated in India. The two key insect pest *viz*., pod borer, *Helicoverpa armigera* Hubner and Tobacco leaf caterpillar, *Spodoptera litura* Fabricius inflicts heavy yield loss in greengram. As these are polyphagous insect pest and the crop is a short duration crop, immediate management strategy such as chemical control is very much essential to check its yield loss. The current study reports the efficacy of novel insecticide *i.e.* Coragen® 20 SC against above cited two insect pest in greengram. Further its effect on non-target insects and its influence on growth and survival of *Bacillus thuringiensis* were evaluated.

Methods: Field experiments were conducted to evaluate the efficacy of Coragen® 20 SC (at four doses *viz*., 75 ml ha^{-1}, 100 ml ha^{-1}, 125 ml ha^{-1} 150 ml ha^{-1}), chlorpyriphos 20 EC @ 2.5 l ha^{-1} and emamectin benzoate 5 SG @ 220 g ha^{-1} against *H. armigera* and *S. litura* during *kharif* 2018 and 2019. Based on larval load per plant, the percent reduction in larval counts was estimated based on Henderson and Tilton method. The benefit cost ratio (BCR) was worked out for each respective year based on seed yield and net returns.

Result: Coragen® 20 SC at 125 ml ha^{-1} and 150 ml ha^{-1} had resulted in highest percent reduction in larval population over control. Simultaneously, the highest BCR during *kharif* 2018 (6.29, 4.21) and 2019 (5.95, 5.64) were recorded from above 2 treatments. Further, Coragen® 20 SC showed compatibility with 5 *Bt* isolates evaluated, *i.e. Bt* growth didn't inhibited in nutrient agar containing field dose of Coragen 20 SC.

Key words: Bio-intensive IPM, *Bt* compatibility, Chlorantraniliprolle, Efficacy, Mungbean, Rynaxypyr.

INTRODUCTION

Greengram, [*Vigna radiata* (L.) Wilczek] is the third most important grain legume cultivated in *kharif*, *rabi* and summer seasons in India. Globally, India is a leading producer (2.41 million tonnes) of greengram with an area of 4.25 million ha during 2018-19 (Anonymous, 2019). The yield of greengram in Uttar Pradesh (536 kg ha^{-1}) is lower than the national average (567 kg ha^{-1}). The insect pests are one of the major biotic constraints for reduced yield of greengram in U.P. About 17 insect pests which are regarded as key pests are reported to cause significant yield losses in greengram (Cheema *et al*. 2017). Pod borer, *Helicoverpa armigera* (Hubner), is a key pest found to cause pod damage up to 27.49% (Joshi *et al*. 2019). Its infestation starts from pre-flowering and prevails upto crop maturity. As it is a polyphagous insect pest wild crop relatives may impart some degree of pod borer tolerance for example, *Cajanus scaraboides* in case of pigeonpea (Sujayanand *et al*. 2019). Whereas in case of greengram sources of heritable pod borer resistance is very scanty (Cheema *et al*. 2017). Hence the farmers are mostly relying on synthetic insecticides for its control in short time. Many pyrethroid insecticides have lost their efficacy against this insect due to development of insecticide resistance (Walsh *et al*. 2018). Hence there is an urgent need for newer molecule with novel mode of action for managing this pest. Coragen belongs to anthranilic diamide group and activates the ryanodine receptors in insect muscle cells indicating a novel mode of action. The treated insects are characterized by immediate feeding cessation, paralysis, lethargy and regurgitation (Cordova *et al*. 2006). In the present study, we evaluated the efficacy of Coragen 20 SC against *H. armigera* and *S. litura* in greengram. The compatibility of Coragen 20 SC with native *Bt* isolates was also tested in the present experiment to assess its effect on colonization of *Bt* isolates.

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MATERIALS AND METHODS

Field efficacy of Coragen® 20 SC

Field experiments were conducted in greengram cultivar "*Samrat*" to assess the efficacy of Coragen® 20 SC against pod borer, *H. armigera* and tobacco caterpillar, *Spodoptera*

litura Fabricius during *kharif* 2018 and 2019 at New Research Campus (NRC) of ICAR-Indian Institute of Pulses Research, Kanpur. The crop was sown on 29th Standard Meteorological week (SMW) and 30th SMW during *kharif* 2018 and 2019, respectively in randomized block design. All agronomic practices were adopted to raise the crop except plant protection measures. The experiment consisted seven treatments *viz*., 4 different doses (15/20/25/30 g a.i. ha^{-1}) of Chlorantraniliprolle (Coragen® 20 SC, Dupont India limited), a CIBRC recommended dose of Emamectin benzoate 5 SG (Em1®, Dhanuka agritech limited) and Chlorpyriphos 20 EC (Lethal®, Insecticides (India) limited) each and untreated control. Each treatment was replicated thrice in a plot size of 6 m × 5 m. Each treatment was sprayed at 15 days interval during the podding stage of crop. Five plants were randomly selected and tagged in each replication to record the larval counts of *H. armigera* and *S. litura*. The larval counts were taken at a day before spraying followed by 1, 3 and 7 days after spraying. The percent reduction in larval population over untreated control was calculated (Henderson and Tilton, 1955) as given below,

$$\text{Per cent efficacy} = 1 - [(Ta/Tb) \times (Cb/Ca)]] \times 100$$

Where,

Ta- population of the treated plot after spray, Tb- population of the treated plot before spray, Ca - population of the control plot after spray, Cb - population of the control plot before spray.

Yield and benefit cost ratio

The greengram seed yield from each plot was recorded as g m^{-2} and subsequently mean was calculated for each treatment then converted as Q ha^{-1}. Based on this increased yield over control was calculated by Pradhan (1964):

$$\text{Increase in yield} = \frac{\text{Yield in treatment-Yield in control}}{\text{Yield in control}}$$

The gross returns and cost involved in each treatment was calculated for each year based on the Minimum support price (MSP) for the respective years. The net profit was calculated by detecting the total cost of protection from the gross returns of that treatment and then Benefit Cost Ratio (BCR) was calculated as follows:

$$\text{BCR} = \frac{\text{Net profit for the treatment (Rs } ha^{-1})}{\text{Total cost of the treatment (Rs } ha^{-1})}$$

Impact of Coragen® 20 SC on non-target insects

The natural enemies and pollinators' presence were also noticed before and after the spray. The crop was harvested and yield data was recorded treatment wise for each replication and then converted to quintals per hectare.

Compatibility of Coragen® 20 SC with Bt

The compatibility of Coragen® 20 SC with *Bacillus thuringiensis*, a microbial bio-control agent was tested by inoculating the five *Bt* isolates *viz*., Ak2.IIPR, F8.IIPR, F5.IIPR, F6.IIPR and *Bt kurstaki* HD-1 in nutrient agar (NA) containing four different doses of Coragen® 20 SC (100 to 300 µl L^{-1}) along with chlorpyriphos 20 EC and Emamectin benzoate 5 SG. All the treatments were replicated thrice and their colony growth was recorded from NA plates after incubating at 25°C for 24 hrs.

Statistical analysis

The larval count and yield data were analysed with SAS 9.2 PROC GLM procedure (SAS, 2006) while the percent reduction over control was analysed with OPSTAT (one factor analysis) by using angular transformation. The growth parameters of *Bt* isolates in NA medium were subjected to square root transformation and analysed in OPSTAT software (Sheoran *et al*., 1998).

RESULTS AND DISCUSSION

Field efficacy of Coragen® 20 SC against *H. armigera*

***kharif* 2018**

The pre-treatment larval population of *H. armigera* was varied from 6.6 to 8.4 larvae per plant. One day after first spraying the lowest (2.8/plant) larval population was recorded from Coragen® 20 SC @ 150 ml/ha followed by Coragen® 20 SC @ 125ml/ha (3.4/plant). Similar trend of lowest larval count (0 larvae/plant) was recorded on both the above treatments at 3rd and 7th days after spraying. The per cent reduction over untreated control was also lowest for Coragen® 20 SC @ 150ml/ha followed by Coragen® 20 SC @ 125 ml/ha during 1st (59.5 and 57.3), 3rd (100 and 100) and 7th (100 and 100) days after spraying (Table 1). The pretreatment larval population of *H. armigera* during 2nd spray varied from 5.8 to 6.4 larvae per plant. The lowest larval population on 1st day after spraying was recorded from Coragen® 20 SC @ 150 ml/ha (2.47 larvae/plant) followed by Chlorpyriphos 20 EC @ 2500ml/ha (3.06 larvae/plant) and Coragen® 20 SC @ 125 ml/ha (3.40 larvae/plant). The percent reduction over control was lowest for Coragen® 20 SC @ 150 ml/ha and Coragen 20 SC @ 125 ml/ha for 3rd (100 and 100) and 7th (100 and 100) days after spraying (Table 1).

***kharif* 2019**

The *H. armigera* larval population varied from 9.33 to 10.40 larvae per plant during first spray of *kharif 2019*. One day after spraying the lowest (2.87/plant) larval population was recorded from Coragen® 20 SC @ 150 ml/ha followed by Coragen® 20 SC @ 125 ml/ha (3.13 larvae/plant). On 3rd and 7th day after spraying, lowest (0.00 larvae/plant) larval population was recorded in above said treatments. The per cent reduction over untreated control was also lowest for Coragen® 20 SC @ 150 ml/ha followed by Coragen® 20 SC @ 125 ml/ha during 1st (71.28 and 70.27), 3rd (100 and 99.22) and 7th (100 and 100) days after spraying (Table 2) wherein they were superior to all other treatments. The pretreatment larval population of *H. armigera* during 2nd spray varied from 6.67 to 6.93 larvae per plant. The lowest larval population on 1st day after spraying was recorded from Coragen® 20 SC @ 150 ml/ha (2.33 larvae/plant) followed by Coragen® 20 SC @ 125 ml/ha (2.73 larvae/plant). The per cent reduction over control was lowest for Coragen® 20 SC

Table 1: Efficacy of Coragen® 20 SC on *Helicoverpa armigera* larva in greengram during *kharif* 2018.

Treatments (g or ml per ha)	Larva/plant								% Reduction over control						Non target insects recorded after spraying
	I[st] Spray				II[nd] Spray				I[st] Spray			II[nd] Spray			
	Pre-treatment	1 DAS	3 DAS	7 DAS	Pre-treatment	1 DAS	3 DAS	7 DAS	1 DAS	3 DAS	7 DAS	1 DAS	3 DAS	7 DAS	
Coragen 20SC @75	7.0[c]	4.4[b]	1.4[b]	1.0[b]	6.13[d]	3.93[b]	1.8[b]	0.9[b]	40.00 (39.09)	84.15 (67.61)	86.96 (68.80)	46.47 (42.94)	78.16 (62.11)	89.18 (70.80)	Dragonfly, spider, mud wasp, coccinellid
Coragen 20SC @100	7.0[c]	4.0[c]	1.4[b]	1.0[b]	6.07[d]	3.80[b]	1.47[c]	0.8[b]	45.45 (42.42)	84.15 (67.61)	86.96 (68.80)	47.71 (43.66)	82.01 (64.90)	90.62 (72.22)	Dragonfly, spider, mud wasp, spring beetle, coccinellid
Coragen 20SC @125	7.6[b]	3.4[d]	0.0[d]	0.0[c]	6.2[c,d]	3.40[c]	0.00[f]	0.00[d]	57.30 (49.03)	100.00 (90.00)	100.00 (90.00)	54.22 (47.41)	100.00 (90.00)	100.00 (90.00)	Dragonfly, spider, mud wasp, sphecid wasp, coccinellid
Coragen 20SC @150	6.6[b]	2.8[e]	0.0[d]	0.0[c]	6.67[a]	2.47[e]	0.00[f]	0.00[d]	59.50 (50.50)	100.00 (90.00)	100.00 (90.00)	69.11 (56.19)	100.00 (90.00)	100.00 (90.00)	Dragonfly, spider, mud wasp, coccinellid and spring beetle
Chlorpyriphos 20EC @ 2500	6.8[c]	4.4[b]	1.6[b]	1.0[b]	5.8[e]	3.06[d]	0.93[d]	0.73[b]	38.24 (38.17)	81.35 (63.04)	89.26 (71.03)	55.86 (48.33)	88.02 (69.76)	91.01 (72.54)	Mud wasp
Emamectin benzoate 5SG @ 220	7.0[c]	4.0[c]	1.0[c]	0.2[c]	6.47[a,b]	3.66[c]	0.27[e]	0.33[c]	45.45 (42.16)	88.68 (70.10)	97.39 (80.70)	56.97 (49.00)	96.93 (80.07)	96.33 (79.05)	Dragonfly, spider, mud wasp, coccinellids and spring beetle
Untreated Control	8.4[a]	8.8[a]	10.6[a]	9.2[a]	6.40[b,c]	7.67[a]	8.6[a]	9.0[a]	-	-	-	-	-	-	Dragonfly, spider, mud wasp, spring beetle, coccinellid
Sem±	0.13	0.41	0.77	0.69	0.06	0.35	0.63	0.67	1.121	1.25	0.83	0.59	0.81	0.79	
SE (d)	0.20	0.36	0.33	0.36	0.10	0.10	0.10	0.13	1.585	1.76	1.17	0.84	1.14	1.11	
CV (%)	3.48	4.19	7.14	10.92	1.91	3.16	6.75	9.33	4.458	2.90	1.84	2.14	1.84	1.72	

()- values in parenthesis are angular transformed. In a column means followed by same letter are not significantly different from each other ($P > 0.05$).

Table 2: Efficacy of Coragen® 20 SC on *Helicoverpa armigera* larva in greengram during *kharif* 2019.

Treatments (g or ml per ha)	Larva /plant								% reduction over control						Non target insects recorded after spraying
	Ist Spray				IInd Spray				Ist Spray			IInd Spray			
	Pre-treatment	1 DAS	3 DAS	7 DAS	Pre-treatment	1 DAS	3 DAS	7 DAS	1 DAS	3 DAS	7 DAS	1 DAS	3 DAS	7 DAS	
Coragen 20SC @75	9.33^{a}	4.67^{b}	1.60^{c}	0.80^{c}	6.80^{a}	3.67^{b,c}	1.40^{c,d}	0.87^{c,d}	53.92 (60.29)^{b}	82.82 (62.95)^{b,c}	90.54 (61.62)^{b}	51.59 (58.91)^{b}	83.56 (60.52)^{b}	89.90 (64.04)^{b}	Ant, Dragonfly, spider, mud wasp, coccinellid, Indian bee and megachilid
Coragen 20SC @100	9.47^{a}	4.13^{b,c}	1.40^{c}	0.67^{c}	6.80^{a}	3.40^{c}	1.27^{d}	0.73^{d}	59.16 (62.37)^{b}	84.76 (67.93)^{b}	92.37 (61.34)^{b}	55.25 (61.07)^{b}	85.07 (63.35)^{b}	91.48 (63.95)^{b,c}	Dragonfly, spider, mud wasp, spring beetle, coccinellid
Coragen 20SC @125	9.80^{a}	3.13^{c,d}	0.07^{d}	0.00^{d}	6.67^{a}	2.73^{d}	0.00^{e}	0.00^{e}	70.27 (75.17)^{a}	99.22 (78.86)^{a}	100.00 (79.99)^{a}	63.34 (76.00)^{a}	100.00 (77.32)^{a}	100.00 (79.49)^{a}	Ant, Dragonfly, spider, mud wasp, sphecid wasp, coccinellid
Coragen 20SC @150	9.33^{a}	2.87^{d}	0.00^{d}	0.00^{d}	6.93^{a}	2.33^{d}	0.00^{e}	0.00^{e}	71.28 (79.59)^{a}	100.00 (80.18)^{a}	100.00 (77.86)^{a}	69.83 (77.73)^{a}	100.00 (78.60)^{a}	100.00 (80.42)^{a}	Dragonfly, spider, mud wasp, megachilid, Indian bee, coccinellid and spring beetle.
Chlorpyriphos 20EC @ 2500	9.60^{a}	5.00^{b}	2.4^{b}	1.67^{b}	6.87^{a}	4.07^{b}	2.20^{b}	1.4^{b}	52.07 (58.16)^{b}	74.85 (57.35)^{c,d}	80.44 (54.37)^{b}	46.89 (56.07)^{b}	74.20 (59.20)^{b}	83.80 (53.90)^{d}	Mud wasp
Em amectin benzoate 5SG @ 220	10.33^{a}	4.40^{b}	1.93^{b,c}	1.47^{b}	6.80^{a}	3.67^{b,c}	1.87^{b,c}	1.13^{b,c}	61.41 (60.29)^{b}	81.49 (59.89)^{b,c,d}	84.18 (62.54)^{b}	51.71 (58.20)^{b}	78.16 (60.81)^{b}	86.81 (57.86)^{b,c,d}	Dragonfly, spider, mud wasp, coccinellids, indian bee and spring beetle.
Untreated control	10.40^{a}	11.33^{a}	10.47^{a}	9.33^{a}	6.87^{a}	7.67^{a}	8.60^{a}	8.67^{a}	-	-	-	-	-	-	Dragonfly, spider, mud wasp, spring beetle, coccinellid
Sem±	0.22	0.62	0.76	0.71	0.09	0.39	0.63	0.65	2.63	2.80	3.44	2.96	2.68	2.64	
SE (d)	0.87	0.49	0.29	0.19	0.14	0.29	0.25	0.12	3.72	3.95	4.87	4.19	3.79	3.74	
CV(%)	10.98	11.76	13.82	11.60	2.56	7.67	13.90	8.33	6.90	7.14	8.99	7.93	6.96	6.87	

* Values inside parenthesis () are arcsine transformed. In a column means followed by same letter are not significantly different from each other ($P > 0.05$).

Table 3: Efficacy of Coragen® 20 SC on *Spodoptera litura* larva in green gram during *kharif* 2019.

Treatment (g or ml per ha)	Larva/plant								% Reduction over control					
	I[st] Spray				II[nd] Spray				I[st] Spray			II[nd] Spray		
	Pre-treatment	1 DAS	3 DAS	7 DAS	Pre-treatment	1 DAS	3 DAS	7 DAS	1 DAS	3 DAS	7 DAS	1 DAS	3 DAS	7 DAS
Coragen 20SC @75	5.87^{a}	2.27^{c,d}	1.13^{b,c}	0.53^{c,d}	4.47^{a}	1.33^{c}	1.00^{b,c}	0.53^{c}	60.16 (63.85)^{b,c}	81.71 (62.09)^{b}	90.42 (61.68)^{c}	69.80 (67.98)^{b,c}	75.38 (55.81)^{b}	88.56 (64.43)^{b,c}
Coragen 20SC @100	5.73^{a}	1.60^{d,e}	0.73^{c}	0.27^{c,d}	4.53^{a}	1.2^{c,d}	0.93^{c}	0.33^{c}	73.22 (66.80)^{b}	83.38 (66.81)^{b}	94.98 (73.09)^{b}	74.80 (72.87)^{b}	78.15 (60.24)^{b}	92.75 (64.50)^{b}
Coragen 20SC @125	5.20^{a}	1.13^{e,f}	0.00^{d}	0.00^{d}	4.40^{a}	0.73^{c,d}	0.00^{d}	0.00^{d}	78.96 (79.78)^{a}	100.00 (79.56)^{a}	100.00 (83.78)^{a}	83.27 (84.14)^{a}	100.00 (80.28)^{a}	100.00 (81.76)^{a}
Coragen 20SC @150	5.40^{a}	0.67^{f}	0.00^{d}	0.00^{d}	4.27^{a}	0.60^{d}	0.00^{d}	0.00^{d}	87.51 (82.95)^{a}	100.00 (82.29)^{a}	100.00 (84.14)^{a}	85.38 (84.27)^{a}	100.00 (79.76)^{a}	100.00 (84.13)^{a}
Chlorpyriphos 20EC @ 2500	5.40^{a}	3.00^{b}	1.73^{b}	1.33^{b}	4.53^{a}	2.27^{b}	1.53^{b}	1.20^{b}	42.61 (54.14)^{d}	69.62 (51.44)^{c}	73.86 (50.94)^{e}	50.16 (54.07)^{d}	64.14 (52.52)^{b}	74.15 (51.21)^{d}
Emamectin benzoate 5SG @ 220	5.27^{a}	2.53^{b,c}	1.33^{b,c}	0.93^{b,c}	4.67^{a}	2.00^{b}	1.2^{b,c}	0.93^{b}	49.75 (59.37)^{b,c,d}	75.90 (54.86)^{b,c}	81.12 (55.50)^{d}	57.18 (60.27)^{d}	72.27 (54.55)^{b}	79.93 (56.22)^{c,d}
Untreated control	5.40^{a}	5.27^{a}	5.73^{a}	5.20^{a}	4.73^{a}	4.73^{a}	4.47^{a}	4.80^{a}	-	-	-	-	-	-
Sem±	0.08	0.35	0.43	0.40	0.08	0.31	0.33	0.36	2.49	2.45	1.76	2.29	4.27	2.64
SE (d)	0.28	0.32	0.31	0.35	0.33	0.28	0.24	0.14	3.52	3.47	2.49	3.24	6.04	3.74
CV(%)	6.23	16.50	24.75	35.92	9.07	18.77	22.27	15.67	6.36	6.43	4.47	5.62	11.58	6.83

* Values inside parenthesis () are arcsine transformed. In a column means followed by same letter are not significantly different from each other (P>0.05).

Table 4: Compatibility of Coragen® 20 SC with *Bacillus thuringiensis* strains.

	F6.IIPR		F5.IIPR		Ak2.IIPR		F8.IIPR		*Bt kurstaki* HD1	
Bt strain Treatment	Mean Width (cm)	Mean Length (cm)	Mean Width (cm)	Mean Length (cm)	Mean Width (cm)	Mean Length (cm)	Mean Width (cm)	Mean Length (cm)	Mean Width (cm)	Mean Length (cm)
Coragen 150 µl/l	3.00	6.50	2.70	6.85	1.45	5.75	1.65	5.25	1.90	5.75
	(1.99)^{a}	(2.74)^{a}	(1.92)^{b}	(2.80)^{a}	(1.56)^{b,c}	(2.60)^{a,b,c}	(1.63)^{a,b}	(2.50)^{c}	(1.70)^{a}	(2.60)^{a,b}
Coragen 200 µl/l	3.00	6.50	3.10	6.35	2.25	6.20	2.25	6.50	2.25	5.25
	(1.99)^{a}	(2.74)^{a}	(2.02)^{a}	(2.71)^{b}	(1.79)^{a,b}	(2.68)^{a,b}	(1.80)^{a}	(2.74)^{a}	(1.80)^{a}	(2.50)^{b,c}
Coragen 250 µl/l	2.15	6.15	2.75	6.45	1.10	6.35	2.25	5.75	2.25	6.25
	(1.77)^{b}	(2.67)^{a}	(1.94)^{a,b}	(2.73)^{b}	(1.45)^{c}	(2.71)^{a}	(1.80)^{a}	(2.60)^{a,b,c}	(1.80)^{a}	(2.69)^{a}
Coragen 300 µl/l	2.50	6.00	1.05	4.55	2.75	6.00	1.75	6.25	2.00	5.00
	(1.87)^{a,b}	(2.65)^{a}	(1.43)^{c}	(2.36)^{c}	(1.94)^{a}	(2.65)^{a,b,c}	(1.65)^{a,b}	(2.69)^{a,b}	(1.73)^{a}	(2.45)^{c}
Chlropyriphos 2.5 ml/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(1.00)^{d}	(1.00)^{c}	(1.00)^{e}	(1.00)^{e}	(1.00)^{d}	(1.00)^{d}	(1.00)^{d}	(1.00)^{e}	(1.00)^{b}	(1.00)^{d}
Emamectin benzoate	1.00	1.75	0.60	1.25	0.00	0.00	0.75	1.90	0.00	0.00
0.44g/l	(1.41)^{c}	(1.66)^{b}	(1.26)^{d}	(1.50)^{d}	(1.00)^{d}	(1.00)^{d}	(1.32)^{c}	(1.70)^{d}	(1.00)^{b}	(1.00)^{d}
C.D.	0.149	0.101	0.088	0.066	0.229	0.112	0.198	0.158	0.130	0.137
SE(m)	0.048	0.032	0.028	0.021	0.074	0.036	0.064	0.051	0.042	0.044
SE(d)	0.068	0.046	0.040	0.030	0.104	0.051	0.090	0.072	0.059	0.062
C.V. (%)	4.942	2.505	3.052	1.674	8.748	2.944	7.191	3.993	4.811	3.729

()- values in parenthesis are square root transformed. In a column means followed by same letter are not significantly different from each other (P>0.05).

@ 150 ml/ha and Coragen® 20 SC @ 125 ml/ha for 3rd (100 and 100) and 7th (100 and 100) days after spraying (Table 2). Thus Coragen® 20 SC @ 125 ml/ha and 150ml/ha was superior in managing *H. armigera* than Chlorpyriphos and Emamectin benzoate. The present result corroborates with that of Mahalakshmi *et al*. (2013) wherein they had reported lowest spotted pod borer, *Maruca vitrata* larva incidence in Coragen 20 SC at 30 ml a.i./ha treated blackgram plots.

Field efficacy of Coragen® 20 SC against *Spodoptera litura*

The tobacco caterpillar, *Spodoptera litura* Fabricius larval population recorded before spraying were on par with all the treatments and it varied between 5.20 to 5.87 larvae per plant during *kharif* 2019. The per cent reduction over control was highest from Coragen® 20 SC @ 150 ml/ha (87.51) and Coragen® 20 SC @ 125 ml/ha (78.96) followed by Coragen® 20 SC @ 100 ml/ha (73.22) (Table 3). The Coragen® 20 SC @ 150 ml/ha and 125 ml/ha has resulted in 100 per cent reduction over control on 3rd and 7th day after spraying. The pretreatment larvae per plant during second spraying varied from 4.40 to 4.73 during 2nd spray. The percent reduction over control on 1st day after spraying was highest for Coragen® 20 SC @ 150 ml/ha (85.38) that is on par with Coragen® 20 SC @ 125 ml/ha (83.27). The 3rd and 7th day after spraying has recorded the highest per cent reduction over control (100). Thus Coragen® 20 SC at 150 ml/ha and 125 ml/ha seems to be superior to Chlorpyriphos and Emamectin benzoate in managing *S. litura* larva.

Yield and benefit cost ratio

The highest marketable yield during *kharif* 2018 was obtained from the treatment Coragen® 20 SC @ 125 ml/ha (2216.7 g/30 m^2) that was on par with Coragen® 20 SC @ 150 ml/ha (2168.3 g/30 m^2) followed by Emamectin benzoate 5 SG @ 220 g/ha (1866.7/30 m^2) this was on par with Coragen® 20 SC @ 100 ml/ha (1850 g/30 m^2) (Fig 1). The highest benefit cost ratio (BCR) was recorded from the Coragen® 20 SC @ 125 ml/ha (6.29) followed by Coragen® 20 SC @ 150 ml/ha (5.95).

The highest marketable yield during *kharif* 2019 was obtained from the treatment having Coragen® 20 SC @ 150 ml/ha (1741.7 g/30 m^2 or 5.81 q/ha) that is statistically on par with Coragen® 20 SC @ 125ml/ha (1541.7 g/30 m^2 or 5.14 q/ha) (Fig 1). The highest BCR is recorded from Coragen® 20 SC @ 150ml/ha (5.64) followed by Coragen® 20 SC @ 125 ml/ha (4.21). Thus these two treatments have highest BCR than remaining all other treatments.

Impact of Coragen® 20 SC on non-target insects

Many odonata (dragon fly), hymenopterans (sphecid wasps, ants, mudwasp, *Xylocopa sp*, honey bees), dipterous (Syrphids, Tachinids) and Coleopterans (Coccinellids, Ellateridae) insect activity along with Spider (*Clubsiona sp, Lynx sp*) were recorded during flowering and podding. Interestingly no ants or syrphids or dragonfly or coccinellids were harmed by spraying Coragen® 20 SC during *kharif* 2018 and 2019 (Table 1 and 2). The present results are in agreement with Depalo *et al*. (2017) demographic analysis demonstrated that chlorantraniliprole and spirotetramat caused sub-lethal effects.

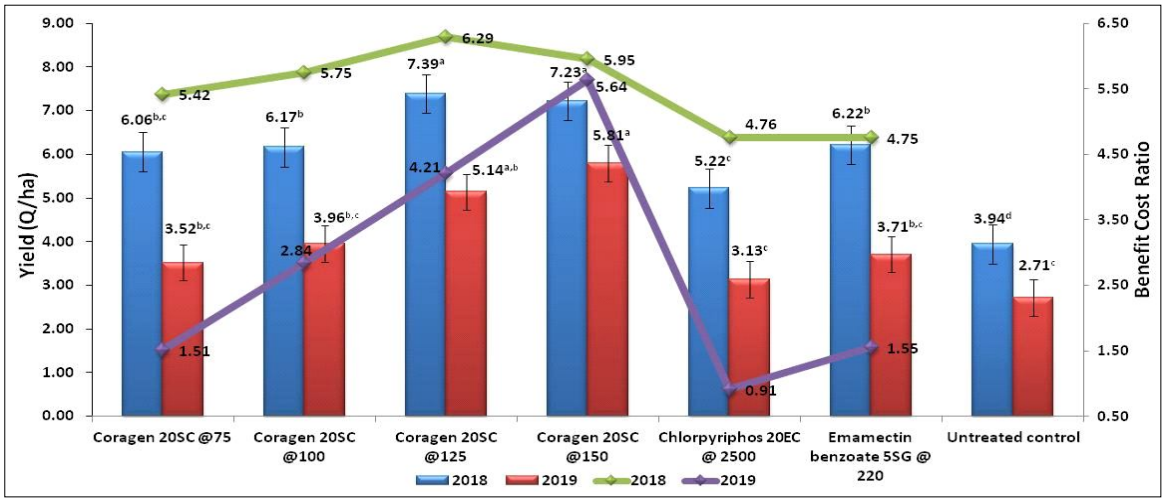

Fig 1: Effect of Coragen® 20 SC on greengram yield and BCR during *kharif* 2018 and 2019.

*In a series means followed by same letter are not significantly different from each other (P>0.05). @ -Calculated based on greengram MSP Rs. 6975/quintal and Rs7050/quintal for 2018 and 2019 respectively. Includes labour cost @ Rs300 and cost of chemical @ Coragen® Rs 997/60 ml; chlorpyriphos 20 EC (Lethal®) Rs 50/100 ml and Emamectin benzoate (Em1®) Rs 112/10 g.

Compatibility of Coragen® 20 SC with Bt isolates

The native *Bt* isolates *viz.*, F8.IIPR, Ak2.IIPR, F6.IIPR, F5.IIPR and the reference strain (*Bt kurstaki* HD 1) recorded highest growth in nutrient agar containing Coragen® 20 SC than Emamectin benzoate 5 SG and Chlorpyriphos 20 EC. None of the *Bt* isolate had recorded growth in the treatment having Chlorpyriphos 20 EC @ 2.5 ml/l while Emamectin benzoate at 0.44 g/l has recorded growth in 3 *Bt* isolates except 2 *Bt* cultures *viz.*, Ak2.IIPR and *Bt kurstaki* HD 1. Interestingly, the table 6 reveals that Coragen® 20 SC is highly compatible with *Bt* than Emamectin benzoate 5 SG (Table 4). The present result supports the findings of Amizadeh *et al*. (2015) wherein they had reported that chlorantraniliprolle is not reducing the colonization of *Bt* and also it is exhibiting synergistic action against *Tuta absoluta*. Further Khalifa *et al*. (2015) has reported that mixture of chlorantraniliprole at $LC_{12.5}$/Bacillus thuringiensis at $LC_{12.5}$ resulted in an additive effect against cotton leaf worm, *Spodoptera littoralis*.

CONCLUSION

The results of bio-efficacy trials conducted during *kharif* 2018 and 2019 indicated that the pod borer, *H. armigera* larval population was lowest from the treatment having Coragen® 20 SC at 150ml/ha and Coragen® 20 SC at 125ml/ha on 1st day after spraying and it is significantly differed from all the treatments tested. Similarly, the percent reduction over untreated control was highest for the same treatments (100%) and it has reached on 3rd day after spraying. The tobacco caterpillar, *S. litura* larval population was also effectively controlled by Coragen® 20SC at 150ml/ha (0.67 and 0.60 larvae/plant) and Coragen® 20SC at 125 ml/ha (1.13 and 0.73 larvae/plant) during 1st spray and 2nd spray respectively. The per cent reduction over control was lowest for the above said treatments during 3rd and 7th day after spraying (100). The highest grain yield and BCR were recorded from Coragen® 20 SC at 150ml/ha followed by Coragen® 20 SC at 125 ml/ha. The natural enemies (spiders, coccinellids, dragon fly, *etc*) and non-targets (pollinators, mud wasp, elaterid beetles, *etc*) insect population were found unaffected by Coragen® 20 SC at 125 and 150ml/ha spray. Similarly, the compatibility tests also revealed that Coragen® 20 SC at 150ml/ha was highly compatible with native *Bt* isolates than emamectin benzoate 5 SG whereas chlorpyriphos 20 EC was found to be incompatible with all *Bt* isolates. Thus this new insecticide can be included as part of bio-intensive IPM module in greengram.

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Authors' contribution

G.K. Sujayanand conceived the experiment. G.K. Sujayanand along with Sonika Pandey recorded the experimental data. G.K. Sujayanand and Sonika Pandey wrote the manuscript. G.K. Sujayanand, Sonika Pandey and Sanjay M. Bandi edited the manuscript.

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