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Bio-efficacy of newer insecticides against lepidopteron pests in castor (*Ricinus communis* L.)

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Abstract
Field experiments were conducted during *Kharif* 2018-19 to evaluate the efficacy of different insecticides against major lepidopteran pests of castor revealed that all the treatments were found significantly superior over untreated control in reducing pest population. The results the newer insecticides were in general, superior over the untreated check in reducing the larval population. Among the tested treatments, efficacy of the treatments *viz.,* chlorantraniliprole 18.5 SC and flubendiamide 480 SC were superior and followed by spinosad 45 SC and indoxacarb 15.80 EC which were found to be effective for all lepidopteran pests of castor. Considering the cost-effectiveness of various treatments, the maximum cost-benefit ratio (1:3.08) was registered in lambda cyhalothrin 2.5 EC with yield of 10.83 q / ha followed by flubendiamide 480 SC with C:B ratio of 1:3.06 and chlorantraniliprole 18.50 SC with C:B ratio of 1:3.05 as well yield of 13.10 q / ha and 13.8 q / ha, respectively.

Keywords: Newer insecticides, lepidopteran pests, castor and C:B ratio

Introduction
Castor (*Ricinus communis* L.) is the most important non-edible oilseed crop of India. Its seed oil has multifarious applications in production of wide industrial products including medicine, cosmetics, lubricants, paints, biopolymers and biodiesel. The global production of castor seed on an average is 13.2 lakh tonnes and of castor oil is 5.5 lakh tonnes with total area of 15.02 m ha. India, China and Brazil are the major castor cultivating countries which accounts for 90 per cent of world's production. The current castor production in the country is 15.4 mt from 10.9 m ha hectares with a productivity of 1512 kg/ha in 2015 (DAC, 2015) [1].

The major problem limiting castor production in India is the damage due to insect pests *viz*., semilooper, *Achaea janata* L. (Lepidoptera: Noctuidae) and capsule borer, *Conogethes* (*Dichocrosis*) *punctiferalis* Guen. (Lepidoptera: Pyralidae). Incidence of *A. janata* is generally noticed from vegetative to early reproductive phase of the crop (Lakshminarayana and Raoof, 2005) [5].

The yield loss due to insects pests has been estimated in the range of 35-40 per cent. Pesticides are the most powerful tools available for the control of pests infesting the economic produce in castor. Spinosad, Flubendiamide, chlorantraniliprole, emamectin benzoate are new molecules with novel mode of action and very effective against lepidopteran pests (Gadhiya *et al*, 2014) [3]. However, information on the Bioefficacy of these newer molecules against lepidopteran pests in castor is very limited (Lakshminarayanamma *et al*, 2013) [6]. The present study was, therefore, planned to evaluate some alternate newer insecticides against castor pests under field condition.

Materials and methods
An experiment was laid out in Randomized Block Design with nine treatments and three replications in a plot size of 5.4m×4.2 m. The seeds were dibbled with a spacing of 90cm × 60cm on and all the recommended agronomic practices were followed except plant protection measures. The treatments were imposed when the pest reached economic threshold level (3-4 larvae/plant).

Observations on the larval population counts of lepidopteran insects and in case of capsule borer the per cent capsule damage were made one day before spraying and three, seven and fifteen days after spraying on five randomly selected and tagged plants in each treatment. The per cent reduction in population was worked out and statistically analyzed with ANOVA and WASP-2. The second spray was taken up 30 days after first spray. Finally, the yield was recorded and computed to hectare basis, C: B ratio was worked out for all the insecticides used for evaluation. Per cent reduction was carried out by using following formula (Henderson and Tilton, 1955) [4].

Results and discussion

Per cent reduction over untreated control in each spraying of major lepidopteran insect pests due to all the 2 sprayings were calculated and the results are presented in the tables.

After First Spraying

Castor Semilooper (*Achaea janata*)

Pre-treatment count

There was no significant difference between the treatments with respect to mean no. of larvae per plant before the imposition of treatments on the crop. The mean larval population ranged from 3.20 to 4.02 per plant (Table1).

Three Days after Spraying

The plots sprayed with spinosad 45 SC recorded least number of larvae per plant (1.00) which was on par with chlorantraniliprole 18.5 SC (1.20 larvae / plant). They were followed by flubendiamide 480 SC and indoxacarb 15.8 EC (1.33 and 1.43 larvae / plant, respectively). The next best treatment was emamectin benzoate 5 SG. Lambda cyhalothrin 2.5 EC and quinalphos 25 EC were found to be on par with one another (2.06 and 2.20 larvae / plant). Novaluron 10 EC with larval count 2.33 larvae per plant was noticed to be less effective.

Seven days after spray

The lowest number of larvae per plant (0.73) was recorded in chlorantraniliprole 18.5 SC which was followed by spinosad 45 SC (0.80 larvae / plant). The next best treatment was found to be flubendiamide 480 SC, followed by indoxacarb 15.8 EC (1.25 larvae / plant) in which emamectin benzoate 5 SG and lambda cyhalothrin 2.5 EC were on par with each other (1.33 larvae / plant). The maximum numbers of larvae (2.13 larvae / plant) were observed in novaluron 10 EC which was on par with quinalphos 25 EC (1.93 larvae / plant).

Fifteen days after spray

It is evident from the data that on 15 days after spraying chlorantraniliprole 18.5 SC was highly effective in reducing the larval population to 0.80 larvae per plant and emerged as the best treatment. The next treatments were spinosad 45 SC (1.20 larvae / plant) closely on par with flubendiamide 480 SC (1.26 larvae / plant) and differed significantly with other treatments.

Per cent reduction over untreated control

With regard to percent reduction, the highest reduction of the population (80.40%) was observed in the plot treated with chlorantraniliprole 18.5 SC, followed by spinosad 45 SC (75.6%) and flubendiamide 480 SC (71.41%). The least per cent reduction (45.10%) of the population over untreated control was recorded in novaluron 10 EC.

After Second Spraying

Castor Semilooper (*Achaea janata*)

Pre-treatment count

There was a significant difference between the treatments with respect to mean no. of larvae per plant before the imposition of treatments on the crop. The mean larval population ranged between 2.53 and 4.73 per plant (Table2).

Three days after spray

Three days after spraying, chlorantraniliprole 18.5 SC and spinosad 45 SC reduced the larval population to 0.53 larvae per plant and 0.73 larvae per plant respectively and found to be superior. The next best chemical was flubendiamide 480 SC (1.20 larvae / plant) which was followed by emamectin benzoate 5 SG (1.46 larvae / plant). Among all these treatments maximum larval population was recorded in quinalphos 25 EC (2.41 larvae / plant).

Seven days after spray

Data recorded on seven days after spraying depicts that chlorantraniliprole 18.5 SC recorded least number of larvae per plant (0.24) which was on par with spinosad 45 SC (0.33 larvae / plant), flubendiamide 480 SC (0.54 larvae / plant) and indoxacarb 15.8 EC (0.74 larvae / plant) but differed significantly with other treatments. Quinalphos 25 EC was found to be least effective with maximum number of larval counts of 1.93 larvae per plant.

Fifteen days after spray

It is evident from the data that on 15 days after spraying chlorantraniliprole 18.5 SC was highly effective in reducing the larval population to 0.31 larvae per plant and emerged as the best treatment followed by spinosad 45 SC (0.60 larvae / plant). The next best treatments were flubendiamide 480 SC and emamectin benzoate 5 SG with larval count of 0.86 and 1.10 larvae per plant. Whereas, the highest mean larval population of 2.21 larvae per plant was recorded in quinalphos 25 EC.

Per cent reduction over untreated control

The highest reduction of the population (87.50%) was recorded in chlorantraniliprole 18.5 SC, followed by spinosad 45 EC (82.32%), flubendiamide 480 SC (77.23%). The least per cent reduction (58.71%) of the population was recorded in quinalphos 25 EC (60.31%). The decreasing order of efficacy was chlorantraniliprole 18.5 EC > spinosad 45 SC > flubendiamide 480 SC > emamectin benzoate 5 SG > indoxacarb 15.8 EC > lambda cyhalothrin 2.5 EC > novaluron 10 EC > quinalphos 25 EC.

A similar trend was also reported by Gadhiya *et al.*, (2014) [3] in that chlorantraniliprole (0.006%), spinosad (0.018%) and emamectin benzoate (0.002%) were the most effective and which were statistically at par with each other in protecting the groundnut crop against *H. armigera* and *S. litura.*

Table 1: Efficacy of different Insecticides against *Acathodelta janata* of Castor during *Kharif*-2018 (First spray)

Sl. No.	Treatment details	Dosage	Mean no. of larvae per plant				Overall mean	Per cent reduction over untreated control
			1 DBS	3 DAS	7 DAS	15 DAS		
1	Emamectin benzoate 5 SG	0.5 g/lit	3.36 (1.82)	1.73 (1.31)^{cd}	1.33 (1.15)^{c}	1.46 (1.20)^{d}	1.51 (1.22)^{c}	61.35
2	Flubendiamide 480S C	0.2 ml/lit	3.73 (1.92)	1.33 (1.15)^{def}	1.13 (1.05)^{cd}	1.26 (1.11)^{de}	1.24 (1.11)^{d}	71.41
3	Chlorantraniliprole 18.5 SC	0.3 ml/lit	4.02 (2.0)	1.20 (1.09)^{ef}	0.73 (0.84)^{e}	0.80 (0.87)^{e}	0.91 (0.94)^{e}	80.40
4	Spinosad 45 SC	0.3 ml/lit	3.53 (1.87)	1.0 (0.99)^{f}	0.8 (0.88)^{de}	1.20 (1.08)^{de}	1.0 (0.99)^{e}	75.63
5	Indoxacarb 15.8 EC	1 ml/lit	3.40 (1.84)	1.43 (1.19)^{de}	1.25 (1.11)^{c}	1.46 (1.19)^{d}	1.38 (1.17)^{cd}	65.0
6	Novaluron 10 EC	1 ml/lit	3.57 (1.88)	2.33 (1.52)^{b}	2.13 (1.45)^{b}	2.46 (1.57)^{b}	2.31 (1.51)^{b}	45.10
7	Lambda cyhalothrin 2.5 EC	1ml/lit	3.49 (1.86)	2.06 (1.43)^{bc}	1.33 (1.14)^{c}	1.55 (1.24)^{cd}	1.65 (1.27)^{c}	60.0
8	Quinalphos 25 EC	2ml/lit	3.69 (1.92)	2.20 (1.47)^{bc}	1.93 (1.38)^{b}	2.20 (1.48)^{bc}	2.11 (1.45)^{b}	51.10
9	Untreated Control	-	3.20 (1.78)	3.53 (1.87)^{a}	3.61 (1.89)^{a}	4.0 (1.99)^{a}	3.71 (1.92)^{a}	-
SEm±			NS	0.188	0.067	0.085	0.354	
CD (P=0.05)			NS	0.187	0.206	0.255	0.106	
CV%			7.53	7.96	9.90	11.14	4.89	

Figures in parentheses are √X +0.5 transformed values, Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBD- Day before spray; DAS- Days after spray.

Table 2: Efficacy of different Insecticides against *Acathodelta janata* of Castor during *Kharif*-2018 (Second spray)

Sl. No.	Treatment details	Dosage	Mean no. of larvae per plant				Overall mean	Per cent reduction over untreated control
			1DBS	3DAS	7DAS	15 DAS		
1	Emamectin benzoate 5 SG	0.5 g/lit	4.0 (1.99)	1.46 (1.20)^{cd}	0.93 (0.95)^{de}	1.10 (0.99)^{de}	1.13 (1.06)^{c}	74.5
2	Flubendiamide 480S C	0.2 ml/lit	3.40 (1.84)	1.20 (1.08)^{d}	0.54 (0.70)^{fg}	0.86 (0.92)^{ef}	0.86 (0.91)^{d}	77.23
3	Chlorantraniliprole 18.5 SC	0.3 ml/lit	2.53 (1.58)	0.53 (0.70)^{e}	0.24 (0.50)^{g}	0.31 (0.57)^{g}	0.36 (0.58)^{f}	87.50
4	Spinosad 45 SC	0.3 ml/lit	2.80 (1.67)	0.73 (0.84)^{e}	0.33 (0.57)^{g}	0.60 (0.761)^{fg}	0.55 (0.73)^{e}	82.32
5	Indoxacarb 15.8 EC	1 ml/lit	3.91 (1.97)	1.60 (1.26)^{cd}	0.74 (0.84)^{ef}	1.40 (1.18)^{cd}	1.24 (1.09)^{c}	71.8
6	Novaluron 10 EC	1 ml/lit	4.33 (2.06)	2.26 (1.50)^{b}	1.6 (1.26)^{bc}	1.86 (1.36)^{bc}	1.91 (1.38)^{b}	60.31
7	Lambda cyhalothrin 2.5 EC	1ml/lit	4.21 (2.04)	1.80 (1.34)^{bc}	1.20 (1.12)^{cd}	1.40 (1.08)^{de}	1.46 (1.19)^{c}	69.57
8	Quinalphos 25 EC	2ml/lit	4.73 (2.17)	2.41 (1.54)^{b}	1.93 (1.39)^{b}	2.21 (1.48)^{b}	2.11 (1.45)^{b}	58.71
9	Untreated Control	-	4.4 (2.09)	4.61 (2.11)^{a}	4.93 (2.22)^{a}	5.13 (2.26)^{a}	4.88 (2.20)^{a}	-
SEm±			0.088	0.074	0.069	0.067	0.049	
CD (P=0.05)			0.265	0.224	0.210	0.198	0.149	
CV%			7.99	10.24	11.4	9.6	7.21	

Figures in parentheses are √X +0.5 transformed values, Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBD- Day before spray; DAS- Days after spray.

After First Spraying

Tobacco Caterpillar (*Spodoptera litura*)

Pre-treatment count

The pre-treatment count of larvae ranged from 4.51 to 5.33 larvae per plant and the treatments differences were non – significant (Table3).

Three days after spraying

Flubendiamide 480 SC recorded least number of larvae per plant (1.41) which was followed by chlorantraniliprole 18.5 SC (1.73 larvae / plant) and spinosad 45 SC (1.93 larvae / plant). After these three treatments, other insecticides in the order of superiority were indoxacarb 15.8 EC, emamectin benzoate 5 SG, lambda cyhalothrin 2.5 EC and quinalphos 25 EC. The higher larval count was recorded in novaluron *i.e.*, 3.13 larvae per plant and it was found to be least effective among the insecticides tested.

Seven days after spraying

Similar trend was observed, flubendiamide 480 SC reduced the larval population to 0.46 larvae per plant and found to be superior, followed by chlorantraniliprole 18.5 SC (0.66 larvae / plant) and spinosad 45 SC (0.86 larvae / plant). Novaluron 10 EC registered with a maximum number of larval population of 2.27 larvae per plant. Untreated control mean larval population was found to be increased to 5.22 larvae per plant.

Fifteen days after spraying

The lowest number of larvae per plant (1.06) was recorded in flubendiamide 480 SC which was closely followed by chlorantraniliprole 18.5 SC (1.13 larvae / plant). The next best treatment was found to be spinosad 45 SC and indoxacarb 15.8 EC which were on par with one another with 1.26 and 1.33 larvae per plant. Novaluron 10 EC was noticed to be least effective with a maximum larval population of 2.66 larvae per plant.

Per cent reduction over untreated control

With a maximum reduction of larval count over untreated control 81.80 per cent flubendiamide 480 SC stood as superior treatment followed by chlorantraniliprole 18.5 SC (78.21%) which were significant over the other treatments. Whereas, novaluron 10 EC with 50.00 per cent larval reduction over the untreated control noticed as least effective.

After Second Spraying

Tobacco Caterpillar (*Spodoptera litura*)

Pre-treatment count

The pre-treatment count of larvae ranged from 3.12 to 5.30 larvae per plant and the treatments found to be significant. (Table4).

Three days after spraying

All the treatments were significantly superior over untreated

control in reducing the larval count. However, among these treatments chlorantraniliprole 18.5 SC successfully reduced the larval population to lowest level 0.72 larvae per plant followed by flubendiamide 480 SC (0.93 larvae / plant). The next best treatments were spinosad 45 SC and emamectin benzoate 5 SG which were on par with each other.

Seven days after spraying

Chlorantraniliprole 18.5 SC was highly effective in reducing the larval population to 0.25 larvae per plant and emerged as the best treatment followed by flubendiamide 480 SC (0.39 larvae / plant) and spinosad 45 SC (0.47 larvae / plant). Whereas, the highest mean larval population of 1.22 larvae per plant was recorded in novaluron 10 EC.

Fifteen days after spraying

The lowest number of larvae per plant (0.59) was recorded in chlorantraniliprole 18.5 SC found to be the best treatment. The next best treatment was found to be flubendiamide 480 SC (0.65 larvae / plant) which was on par with spinosad 45 SC. The highest number of larval population of 1.69 larvae per plant was reported in novaluron 10 EC emerged as the least effective treatment.

Per cent reduction over untreated control

With regard to percent reduction, the highest reduction of the population (89.00%) was observed in the plot treated with chlorantraniliprole 18.5 SC, followed by flubendiamide 480 SC (85.37%) and spinosad 45 SC (82.65%). The least per cent reduction (56.51%) of the population over untreated control was recorded in novaluron 10 EC.

These current findings are in agreement with Narayanamma *et al.* (2013) [7], who reported that flubendiamide and chlorantraniliprole were found to be the most effective chemicals for the control of *S. litura* in castor.

Table 3: Efficacy of different Insecticides against *Spodoptera litura* of Castor during *Kharif*-2018 (First spray)

Sl. No.	Treatment details	Dosage	Mean no. of larvae per plant				Overall mean	Per cent reduction over untreated control
			1 DBS	3 DAS	7 DAS	15 DAS		
1	Emamectin benzoate 5 SG	0.5 g/lit	5.33 (2.30)	2.20 (1.47)^{cde}	1.20 (1.08)^{cde}	1.79 (1.33)^{cd}	1.73 (1.30)^{de}	70.10
2	Flubendiamide 480S C	0.2 ml/lit	4.93 (2.21)	1.41 (1.18)^{f}	0.46 (0.65)^{f}	1.06 (1.02)^{e}	0.97 (0.96)^{g}	81.80
3	Chlorantraniliprole 18.5 SC	0.3 ml/lit	4.72 (2.17)	1.73 (1.30)^{ef}	0.66 (0.80)^{ef}	1.13 (1.05)^{de}	1.17 (1.06)^{fg}	78.21
4	Spinosad 45 SC	0.3 ml/lit	5.21 (2.27)	1.93 (1.38)^{def}	0.86 (0.92)^{def}	1.26 (1.12)^{de}	1.35 (1.14)^{ef}	76.11
5	Indoxacarb 15.8 EC	1 ml/lit	4.51 (2.12)	2.06 (1.43)^{cde}	1.05 (1.02)^{de}	1.33 (1.13)^{de}	1.48 (1.20)^{ef}	71.50
6	Novaluron 10 EC	1 ml/lit	4.93 (2.21)	3.13 (1.76)^{b}	2.27 (1.50)^{b}	2.66 (1.62)^{b}	2.68 (1.63)^{b}	50.0
7	Lambda cyhalothrin 2.5 EC	1ml/lit	5.13 (2.26)	2.46 (1.56)^{bcd}	1.40 (1.16)^{cd}	2.06 (1.43)^{bc}	1.97 (1.39)^{cd}	64.61
8	Quinalphos 25 EC	2ml/lit	5.20 (2.28)	2.73 (1.65)^{bc}	1.81 (1.33)^{bc}	2.33 (1.52)^{bc}	2.27 (1.50)^{bc}	59.60
9	Untreated Control	-	4.80 (2.18)	4.92 (2.22)^{a}	5.22 (2.28)^{a}	5.40 (2.32)^{a}	5.17 (2.27)^{a}	-
SEm±			NS	0.082	0.105	0.075	0.053	
CD (P=0.05)			NS	0.249	0.317	0.230	0.160	
CV%			7.20	9.14	9.56	8.51	6.68	

Figures in parentheses are √X +0.5 transformed values, Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBD- Day before spray; DAS- Days after spray.

Table 4: Efficacy of different Insecticides against *Spodoptera litura* of Castor during *Kharif*-2018 (Second spray)

Sl. No.	Treatment details	Dosage	Mean no. of larvae per plant				Overall mean	Per cent reduction over untreated control
			1 DBS	3 DAS	7 DAS	15 DAS		
1	Emamectin benzoate 5 SG	0.5 g/lit	3.80 (1.94)	1.10 (1.05)^{cd}	0.61 (0.76)^{cde}	0.91 (0.95)^{cd}	0.87 (0.92)^{ef}	79.3
2	Flubendiamide 480S C	0.2 ml/lit	4.0 (2.0)	0.93 (0.95)^{de}	0.39 (0.61)^{ef}	0.65 (0.76)^{de}	0.65 (0.79)^{gh}	85.37
3	Chlorantraniliprole 18.5 SC	0.3 ml/lit	3.91 (1.94)	0.72 (0.84)^{e}	0.25 (0.50)^{f}	0.59 (0.71)^{e}	1.51 (0.70)^{h}	89.0
4	Spinosad 45 SC	0.3 ml/lit	4.12 (2.03)	1.10 (1.06)^{cd}	0.47 (0.65)^{def}	0.80 (0.88)^{de}	0.79 (0.87)^{fg}	82.65
5	Indoxacarb 15.8 EC	1 ml/lit	4.30 (2.08)	1.29 (1.12)^{bcd}	0.80 (0.88)^{bcd}	1.20 (1.09)^{bc}	1.09 (1.04)^{de}	79.46
6	Novaluron 10 EC	1 ml/lit	3.12 (1.76)	1.61 (1.25)^{b}	1.20 (1.08)^{b}	1.69 (1.28)^{b}	1.50 (1.22)^{b}	56.51
7	Lambda cyhalothrin 2.5 EC	1ml/lit	4.0 (1.99)	1.33 (1.11)^{bcd}	0.89 (0.90)^{bc}	1.29 (1.12)^{bc}	1.17 (1.07)^{cd}	73.60
8	Quinalphos 25 EC	2ml/lit	4.20 (2.04)	1.43 (1.15)^{bc}	1.22 (1.09)^{b}	1.58 (1.23)^{b}	1.40 (1.18)^{bc}	70.0
9	Untreated Control	-	5.30 (2.30)	5.51 (2.34)^{a}	5.90 (2.42)^{a}	6.1 (2.46)^{a}	5.83 (2.41)^{a}	-
SEm±			0.085	0.054	0.078	0.065	0.041	
CD (P=0.05)			0.255	0.170	0.237	0.200	0.124	
CV%			7.21	8.48	11.10	9.87	6.52	

Figures in parentheses are √X +0.5 transformed values, Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBD- Day before spray; DAS- Days after spray.

After First Spraying

Shoot and Capsule Borer (*Conogethes punctiferalis*)

Pre-treatment count

There was no significant difference between the treatments with respect to per cent capsule damage before the imposition of treatments on the crop. The mean per cent capsule damage ranged between 15.06 and 20.93 per cent (Table5).

Three Days after Spraying

The lowest per cent damage was noticed in chlorantraniliprole 18.5 SC (8.50%) followed by flubendiamide 480 SC (9.76%), spinosad 45 SC (10.90%), indoxacarb 15.8 EC (11.26%) which were significantly superior over the treatments novaluron 10 EC (15.96%), whereas, the highest per cent damage (22.10%) of capsules was observed in untreated control.

Seven days after spraying

The least per cent capsule damage (7.17%) was recorded in chlorantraniliprole 18.5 SC followed by flubendiamide 480 SC (8.50%), spinosad 45 SC (9.40%), indoxacarb 15.8 EC (9.86%). The highest per cent capsule damage (14.43%) of capsules was observed in novaluron 10 EC and found to be least effective. 22.63 per cent capsule damage was recorded in untreated control.

Fifteen days after spraying

The lowest per cent damage was recorded in chlorantraniliprole 18.5 SC (8.83%) followed by flubendiamide 480 SC (10.26%), spinosad 45 SC (11.20%). The highest per cent capsule damage (16.16%) of capsules was observed in novaluron 10 EC and found to be least effective. Whereas the highest per cent damage (24.06%) of capsules was observed in untreated control.

Per cent reduction over untreated control

With regard to per cent reduction of capsule damage maximum per cent reduction was observed in chlorantraniliprole 18.5 SC (64.62%) emerged as highly effective treatment which was followed by flubendiamide 480 SC (59.29%) and spinosad 45 SC (54.86%). The least per cent reduction (32.31%) of capsule damage over untreated control was noticed in novaluron 10 EC.

After Second Spraying

Shoot and Capsule Borer (*Conogethes punctiferalis*)

Pre-treatment count

The pre-treatment counts on per cent capsule damage ranged from 16 to 28.30 per cent and the treatments were found to be significant (Table6).

Three days after spraying

All the treatments were significantly superior over untreated control in reducing the per cent capsule damage. However, among these treatments chlorantraniliprole 18.5 SC successfully reduced the per cent capsule damage to lowest level of 6.80 per cent and found on par with flubendiamide 480 SC (7.90%). The next best treatments were spinosad 45 SC (12.51%) and emamectin benzoate 5 SG (13.71%). Whereas, the highest per cent damage (28.03%) of capsules was observed in untreated control.

Seven days after spraying

Similar trend was observed, the lowest per cent damage was noticed in chlorantraniliprole 18.5 SC (4.01%), followed by flubendiamide 480 SC (5.30%) and found to be best treatments. The next best treatments were indoxacarb 15.8 EC (6.50%) and spinosad 45 SC (7.42%) which were on par with each other.

Fifteen days after spraying

The least per cent capsule damage (5.10%) was recorded in chlorantraniliprole 18.5 SC which was found to be highly effective. Flubendiamide 480 SC (6.93%) was the second effective chemical which was on par with indoxacarb 15.8 EC (7.70%). The highest per cent capsule damage (18.00%) was observed in novaluron 10 EC and found to be least effective. Whereas, the highest per cent damage (36.20%) of capsules was observed in the untreated control.

Per cent reduction over untreated control

With maximum reduction per cent capsule damage of 70.81 per cent chlorantraniliprole 18.5 SC stood as effective treatment followed by flubendiamide 480 SC (65.90%) which were significantly superior over the other treatments. Whereas, novaluron 10 EC with 40.82 per cent capsule damage reduction over the untreated control noticed as least effective. Order of efficacy was chlorantraniliprole 18.5 SC > flubendiamide 480 SC > indoxacarb 15.8 EC > spinosad 45 SC > emamectin benzoate 5 SG > lambda cyhalothrin 2.5 EC > quinalphos 25 EC > novaluron 10 EC.

These results are in agreement with the works of Narayanamma *et al*., (2013)[6] and Duraimurugan and Lakshminarayana (2014) [2],who found lower per cent capsule damage in the treatments Chlorantraniliprole 18.5 SC and flubendiamide 480 SC have superior compared to control and other treatments.

Table 5: Efficacy of different Insecticides against *Conogethes punctiferalis* of Castor during *Kharif*-2018 (First spray)

S. No.	Treatment details	Dosage	Per cent capsule damage				Post Mean	Per cent reduction over control
			1DBS	3DAS	7DAS	15DAS		
1	Emamectin benzoate 5 SG	0.5 g/lit	18.3 (25.32)	11.96 (20.17)^{bcde}	10.93 (19.26)^{bcd}	13.56 (21.56)^{bcd}	12.14 (20.37)^{d}	47
2	Flubendiamide 480S C	0.2 l/lit	15.9 (23.46)	9.76 (18.02)^{de}	8.50 (16.91)^{de}	10.26 (18.65)^{de}	9.51 (17.94)^{f}	59.29
3	Chlorantraniliprole 18.5 SC	0.3 l/lit	15.06 22.82)	8.50 (16.81)^{e}	7.17 (15.45)^{e}	8.83 (17.17)^{e}	8.16 (16.58)^{g}	64.62
4	Spinosad 45 SC	0.3 l/lit	16.9 (24.21)	10.90 (19.18)^{cde}	9.40 (17.81)^{cde}	11.2 (19.50)^{cde}	10.5 (18.89)^{e}	54.86
5	Indoxacarb 15.8 EC	1 ml/lit	17.5 (24.64)	11.26 (19.53)^{cde}	9.86 (18.23)^{cde}	12.17 (20.37)^{cd}	11.1 (19.44)^{e}	51.96
6	Novaluron 10 EC	1 ml/lit	19.9 (26.43)	15.96 (23.53)^{b}	14.43 (22.28)^{b}	16.16 (23.68)^{b}	15.52 (23.19)^{b}	32.31
7	Lamda cyhalothrin 2.5 EC	1ml/lit	18.63 (25.46)	12.56 (20.72)^{bcd}	11.10 (19.39)^{bcd}	12.83 (20.95)^{bcd}	12.16 (20.40)^{d}	52.83
8	Quinalphos 25 EC	2ml/lit	19.20 (25.89)	14.06 (21.98)^{bc}	12.53 (20.68)^{bc}	13.92 (21.85)^{bc}	13.50 (21.55)^{c}	41.01
9	Untreated Control	-	20.93(27.19)	22.10 (28.03)^{a}	22.63 (28.39)^{a}	24.06 (29.36)^{a}	22.93 (28.60)^{a}	-
SEm±			NS	1.24	1.09	1.05	1.13	
CD (P=0.05)			NS	3.72	3.29	3.15	3.39	
CV%			9.8	10.30	9.60	8.49	7.20	

Figures in parentheses are angular transformed; Means in the columns followed by the same alphabet do not differ significantly by DMRT (*P*=0.05); DBD- Day before spray; DAS- Days after spray.

Table 6: Efficacy of different Insecticides against *Conogethes punctiferalis* of Castor during *Kharif*-2018 (Second spray)

S. No.	Treatment details	Dosage	Per cent capsule damage				Post Mean	Per cent reduction over control
			1DBS	3DAS	7DAS	15DAS		
1	Emamectin benzoate 5 SG	0.5 g/lit	20.06 (26.59)	13.71 (21.70)^{bcd}	8.31 (16.74)^{de}	9.50 (17.94)^{de}	10.50 (18.80)^{de}	53.80
2	Flubendiamide 480S C	0.2 l/lit	17.3 (24.54)	7.90 (16.28)^{e}	5.30 (13.29)^{fg}	6.93 (15.21)^{ef}	6.71 (14.95)^{fg}	65.90
3	Chlorantraniliprole 18.5 SC	0.3 l/lit	16.0 (23.54)	6.80 (15.03)^{e}	4.01 (11.52)^{g}	5.10 (13.02)^{f}	5.30 (13.23)^{g}	70.81
4	Spinosad 45 SC	0.3 l/lit	19.50 26.18)	12.51 20.67)^{cd}	7.42 (15.77)^{ef}	8.61 (17.04)^{e}	9.51 (17.84)^{e}	57.30
5	Indoxacarb 15.8 EC	1 ml/lit	18.70 25.52)	11.30 (19.55)^{d}	6.50 (14.70)^{ef}	7.70 (16.10)^{ef}	8.50 (16.84)^{ef}	60.0
6	Novaluron 10 EC	1 ml/lit	24.11 29.38)	16.52 (23.89)^{b}	14.10 21.99)^{b}	18.0 (24.99)^{b}	16.52 (23.70)^{b}	40.82
7	Lamda cyhalothrin 2.5 EC	1ml/lit	22.50 28.26)	14.91 22.66)^{bc}	10.33 8.67)^{cd}	12.30 20.50)^{cd}	12.51 (20.65)^{cd}	51.10
8	Quinalphos 25 EC	2ml/lit	23.53 28.97)	15.16 (23.38)^{bc}	12.12 (20.34)^{bc}	14.10 22.01)^{bc}	14.0 (21.94)^{bc}	47.23
9	Untreated Control	-	28.30 (32.13)	28.03 (31.96)^{a}	32.10 (34.44)^{a}	36.20 (36.91)^{a}	32.11 (34.46)^{a}	-
SEm±			1.22	1.015	0.828	1.083	0.876	
CD (P=0.05)			3.664	3.045	2.489	3.280	2.63	
CV%			7.76	8.10	7.70	9.28	7.50	

Figures in parentheses are angular transformed; Means in the columns followed by the same alphabet do not differ significantly by DMRT (P=0.05); DBD- Day before spray; DAS- Days after spray

Effect on yield and economics

Data on yield revealed that there was significant impact of insecticidal treatments on seed yield of castor. Chlorantraniliprole 18.5 SC was most effective with regard to yield (13.80 q / ha) followed by flubendiamide 480 SC (13.10 q / ha). Spinosad 45 SC (11.77 q / ha) and indoxacarb 15.8 EC (11.44 q / ha) were the next best ones. However, all the treatments recorded higher yield and significantly superior over untreated control (2.25 q / ha) (Table7).

Lambda cyhalothrin 2.5 EC registered highest C:B ratio of 3.08 compared to rest of the treatments, followed by flubendiamide 480 SC (3.06) and chlorantraniliprole 18.5 SC (3.05). Novaluron 10 EC recorded the lowest C: B ratio of 2.32 compared to untreated control (1.99).

The C:B ratio was highest in case of lambda cyhalothrin 2.5 EC (1: 3.08) due to the lower cost of production and gave average yield of 10.83 q / ha followed by flubendiamide 480 SC (1: 3.06). Novaluron 10 EC recorded least cost benefit ratio (1: 2.32) due to lower yield (9.56 q / ha) compared to untreated control. The reason attributed could be highest pest population and per cent capsule damage.

Table 7: Cost economics of different insecticides

S. No.	Treatments	Dosage (g or ml/lit)	Yield (q/ha)	Cost of production (Rs/ha)	Cost of protection (Rs/ha)	Total cost of production (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	C:B ratio
1	Emamectin benzoate 5% SG	0.50	11.12^{cde}	14100	4040	18150	50040	31890	1: 2.76
2	Flubendiamide 480 SC	0.20	13.10^{ab}	14100	5140	19240	58950	39710	1: 3.06
3	Chlorantraniliprole 18.5 SC	0.30	13.8^{a}	14100	6260	20360	62100	41740	1: 3.05
4	Spinosad 45% SC	0.30	11.77^{bc}	14100	6760	20860	52965	32105	1: 2.54
5	Indoxacarb 15.8 EC	1.00	11.44^{bcd}	14100	7200	31200	51480	30180	1: 2.42
6	Novaluron 10 EC	1.00	9.56^{e}	14100	4460	18560	43020	24460	1: 2.32
7	Lmbda cyhalothrin 2.5% EC	1.00	10.83^{cde}	14100	1720	15820	48735	32915	1: 3.08
8	Quinalphos 25 EC	2.00	9.89^{de}	14100	2480	16580	44505	27925	1: 2.68
9	Untreated control	-	6.25^{f}	14100	-	14100	28080	13980	1: 1.99

Conclusion

From the results of the present investigation, it is reveals that all the tested treatments were effective in reducing the infestation of lepidopteran pests of castor over untreated control. Especially newer insecticide molecules like chlorantraniliprole 18.5 SC, flubendiamide 480 SC and spinosad 45 SC which were emerged as most promising in managing the major defoliators of castor, whereas novaluron 10 EC was found to be least effective because of their different mode of action and efficacy of the insecticide.

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