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Evaluation of Newer Insecticide Molecules Against Major Insect Pests in Castor (*Ricinus communis* L.)

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ABSTRACT

Newer insecticide molecules were evaluated against major insect pests' *viz. Achaea janata L.*, *Spodoptera litura* (F.), *Spilosoma obliqua*, *Conogethes punctiferalis* Guen. and *Empoasca flavescens* (F.) in a field experiment conducted at the Agricultural Research Station, Darsi, Prakasam district on red sandy loam soils for three years (2014–15, 2015-16 and 2016–17) during the *kharif* season. In this experiment popular hybrid PCH 111 was sown and ten treatments were evaluated *viz.* spinosad 45% SC, chlorfenapyr 10% SC, cyantraniliprole 10% OD, pyridalyl 10%EC, flubendiamide 20% WDG, betacyfluthrin 9% + imidacloprid 21% OD, bifenthrin 10% EC, acephate 50% + imidacloprid 1.8% SP, indoxacarb 15.8% EC and control. The treatments were imposed twice during first week of October and November when infestation crossed above economic threshold level. Cumulative mean of two sprays showed that spinosad and cyantraniliprole recorded significantly lower identical population of semilooper (0.28 larvae.plant^{-1}) compared to untreated control which recorded 2.23 larvae.plant^{-1}. Significant reduction in the incidence of *S. litura* larvae was recorded with cyantraniliprole (0.45 larvae.plant^{-1}) followed by chlorfenapyr (0.68 larvae.plant^{-1}), spinosad (0.78 larvae.plant^{-1}) and indoxacarb (0.82 larvae.plant^{-1}). Cyantraniliprole registered significantly low incidence of Bihar hairy caterpillar (0.16 larvae.plant^{-1}) followed by chlorfenapyr, flubendiamide (identical population of 0.24 larvae.plant^{-1}), betacyfluthrin + imidacloprid (0.25 larvae.plant^{-1}) and indoxacarb (0.26 larvae /plant) which were at par with each other. The population of leaf hopper was also fluctuated significantly and varied across different insecticide treatments. Significantly lower overall mean population levels were recorded with betacyfluthrin + imidacloprid (4.78/ 3 leaves) followed by acephate + imidachloprid (5.07/ 3 leaves) which was on par with bifenthrin (5.36/ 3 leaves). The test insecticides significantly altered capsule damage by capsule borer and over all mean damage was less with spinosad (10.1%) followed by indoxacarb (10.6%) and cyantraniliprole (10.7%) which were significantly superior over rest of the insecticides. Significantly high seed yield was recorded with spinosad (1004 kg.ha^{-1}) which was at par with cyantraniliprole (974 kg.ha^{-1}) followed by flubendiamide (858 kg.ha^{-1}). The treatments spinosad and flubendiamide apart from recording higher yield also gave higher Incremental Cost Benefit Ratio ICBR of 6.76 and 5.40.

Key words: *Castor, foliage feeders, capsule borer, leafhopper, insecticides, management*

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop and is grown especially in arid and semi arid regions. It is grown for its beans, which contain up to 48% oil, mainly used in manufacturing of paints, lubricants, soaps, hydraulic brake fluids, polymers and perfumery products. Castor crop suffers from many biotic stresses. So far, over 100 insect pests are recorded on castor and among them foliage feeders and sucking insects are of economic importance (Basappa and Lingappa, 2001).

Pesticides are the most powerful tools available for the control of pests infesting the economic produce in castor. However, over time targeted pests have developed resistance to pesticides necessitating increased applications. The right choice of chemical pesticides is not governed by its toxicity alone, but depends on their safety to natural enemies in the ecosystem and the environment (Stanely, 2007). Registered insecticides require repeated application in higher doses and it might result in adverse effects on the environment and health. In order to circumvent the problems, replacement of conventional insecticides with novel molecules at lower dose is necessary (Shivanna *et al*., 2012). New formulations and new sources of existing molecules are likely to hold superiority in terms of higher toxicity, pest suppression, safety to natural enemies and non-target organisms, reduced spray dosages and rounds of spray and the benefits accrued in terms of savings in labour and time. Considering this, newer insecticides with novel modes of action were evaluated against major insect pests of castor in the present experiment.

MATERIAL AND METHODS

A field experiment was conducted at Agricultural Research Station, Darsi, Prakasam district on red sandy loam soils for three years (2014–15, 2015-16 and 2016–17) during the *kharif* season in a Randomized Block Design to evaluate the efficacy of newer insecticides against major defoliator pests' *viz.*

Achaea janata L., *Spodoptera litura* (F.), *Spilosoma obliqua*, capsule borer, *Conogethes punctiferalis* Guen. and a sucking pest, *Empoasca flavescens* (F.). The experiment consisted of ten treatments *viz.* spinosad 45% SC, chlorfenapyr 10% SC, cyantraniliprole 10% OD, pyridalyl 10% EC, flubendiamide 20% WDG, betacyfluthrin 9% + imidacloprid 21% OD, bifenthrin 10% EC, acephate 50% + imidacloprid 1.8% SP, indoxacarb 15.8% EC including control and three replications. "PCH-111" a popular castor hybrid was grown in well ploughed field having uniform plot size (Gross: 6.00 m x 4.50 m and Net: 5.00 m x 2.70 m) with a spacing of 90X60 cm and followed all required agronomic practices. Insecticide treatments included in this experiment were applied at respective dose with knapsack sprayer. Two sprayings were given one at vegetative stage (first week of October) and other at spike development stage (first week of November). Pre-treatment data was taken 1 day before spraying and post-treatment was taken at 3, 7 and 10 days after first and second spraying for all the observed major pests except for capsule borer where post treatment data was taken at 3, 5, 10 and 15 days after second spraying.

Infestation of semilooper, tobacco caterpillar, Bihar hairy caterpillar was assessed by recording the number of larva per plant on the five randomly selected plants in each plot. Infestation of shoot and capsule borer was assessed by recording the number of total and affected capsules on each of the five randomly selected plants per treatment and per cent infestation of capsules for each plant was calculated. Number of nymphs and adult population of leafhopper on top three leaves per plant were recorded on the five randomly selected plants in each plot. Overall mean insect numbers and percent damage across sampling intervals were determined for making comparisons. The final pooled mean data across three cropping seasons was analyzed and presented. Plot wise seed yields of castor were computed on hectare basis for statistical interpretations. The per cent values were transformed in to angular values and insect population counts into square root values which were statistical analysed by Least Significant Difference (LSD) to observe the effect of the treatments on different insect pests of castor.

The economics of different treatments were worked out based on the seed yield and cost of protection. The cost, sale price of the seed yield of respective treatment was considered to calculate gross profit. Based on the cost of treatment and the gross profit in different treatments, the Incremental Cost Benefit Ratio (ICBR) and net profit was calculated.

RESULTS AND DISCUSSIONS

The data on population of foliage feeders, leafhopper and capsule borer damage recorded at varied intervals after first and second application of various insecticides are summarized and presented hereunder.

Efficacy of Newer Insecticides Against Semilooper, *Achaea janata* L.

The results presented in Table 1 revealed that uniform population in all the plots before application of treatments indicating non-significant differences among various plots. At three days after first spraying, spinosad (0.27 larvae.plant^{-1}) followed by betacyfluthrin + imidacloprid (0.33 larvae.plant^{-1}) was found to be superior in recording the semilooper. Among the other treatments the best treatments observed were cyantraniliprole (0.40 larvae.plant^{-1}), chlorfenapyr (0.43 larvae.plant^{-1}), flubendiamide (0.47 larvae.plant^{-1}), pyridalyl (0.53 larvae.plant^{-1}) and acephate + imidacloprid (0.60 larvae.plant^{-1}). The treatments indoxacarb (0.67 larvae.plant^{-1}) and bifenthrin (0.73 larvae.plant^{-1}) were found to be moderately effective. At seven days after first spraying, all the treatments were significantly superior in bringing down the semilooper population ranged from 0.30 to 0.77 larvae.plant^{-1} over untreated control which has an abundance of 1.93 larvae.plant^{-1}. At ten days after first spraying, cyantraniliprole (0.37 larvae.plant^{-1}) and flubendiamide (0.40 larvae.plant^{-1}) were significantly superior in controlling the semilooper. The next best treatments observed were spinosad (0.47 larvae.plant^{-1}), indoxacarb (0.57 larvae.plant^{-1}), chlorfenapyr (0.63 larvae.plant^{-1}) and pyridalyl (0.73 larvae.plant^{-1}). Among the other treatments, betacyfluthrin + imidacloprid (1.07 larvae.plant^{-1}) and bifenthrin (1.20 larvae.plant^{-1}) were found to be moderately effective. Acephate + imidacloprid (1.90 larvae.plant^{-1}) was found least in reducing semilooper which was on par with untreated control (2.17 larvae.plant^{-1}).

A day before second spraying uniform population of semilooper ranged from 1.67 to 2.50 larvae.plant^{-1} was recorded in different treatments. Three days after second spraying, indoxacarb (0.20 larvae.plant^{-1}) significantly followed by spinosad (0.27 larvae.plant^{-1}) and cyantraniliprole (0.30 larvae.plant^{-1}) recorded the least population of semilooper over the other treatments. The next best treatments were observed to be bifenthrin (0.40 larvae.plant^{-1}), betacyfluthrin + imidacloprid (0.47 larvae.plant^{-1}) and flubendiamide (0.53 larvae.plant^{-1}). The treatments pyridalyl (0.70 larvae.plant^{-1}), chlorfenapyr (0.73 larvae.plant^{-1}) and acephate + imidacloprid (0.77 larvae.plant^{-1}) were found to be moderately effective in reducing the larval population which were significantly different from untreated control (1.70 larvae.plant^{-1}).

Seven days after second spraying, cyantraniliprole (0.13 larvae.plant^{-1}) followed by spinosad (0.23 larvae.plant^{-1}) and indoxacarb (0.30 larvae.plant^{-1}) were significantly superior in bringing down the semilooper population over rest of the treatments. Among the other treatments the best treatments observed were flubendiamide (0.37 larvae.plant^{-1}), chlorfenapyr and betacyfluthrin + imidacloprid (identical population of 0.40 larvae.plant^{-1}). The treatments bifenthrin (0.47 larvae.plant^{-1}), pyridalyl (0.73 larvae.plant^{-1}) and acephate + imidacloprid (0.87 larvae.plant^{-1}) were found to be moderately effective in reducing the larval population of semilooper and were significantly different from untreated control (2.40 larvae.plant^{-1}). Ten days after second spraying, spinosad and cyantraniliprole (0.17 larvae.plant^{-1}) were found to be significantly superior treatments against semilooper over rest of the treatments. Among the other treatments, chlorfenapyr (0.40 larvae.plant^{-1}), flubendiamide (0.47 larvae.plant^{-1}), betacyfluthrin + imidacloprid, indoxacarb (0.50 larvae.plant^{-1} each) and Pyridalyl (0.53 larvae.plant^{-1}) were effective against semilooper. The treatments, bifenthrin and acephate + imidacloprid (identical population of 0.80 larvae.plant^{-1}) were found to be moderately effective in reducing the larval population.

Cumulative mean of two sprays showed that spinosad and cyantraniliprole recorded significantly lower identical population of semilooper (0.28 larvae.plant^{-1}) compared to untreated control which recorded 2.23 larvae.plant^{-1}. The next best treatments in the order of their efficacy were flubendiamide (0.46 larvae.plant^{-1}), chlorfenapyr, indoxacarb (0.49 larvae.plant^{-1}), and betacyfluthrin + imidacloprid (0.51 larvae.plant^{-1}) which were at par without any significant differences among them. The other treatments pyridalyl (0.60 larvae.plant^{-1}), bifenthrin (0.73 larvae.plant^{-1}) and acephate + imidacloprid (0.93 larvae.plant^{-1}) were found to be moderately effective and on par with each other. This significant control of semilooper larval population was due to the new broad spectrum and high insecticidal activity of spinosad, cyantraniliprole and flubendiamide with novel mode of action against lepidopteran caterpillars. The results are in conformity with the findings of Nauen *et al.* (2007) and Narayanamma *et al*. (2014) who asserted that flubendiamide and spinosad are new chemical options for control of multi-resistant noctuid pests and an excellent choice for lepidopteran pests in general.

Efficacy of Newer Insecticides Against Tobacco Caterpillar, *Spodoptera litura* Fab.

The larval population was uniform and the treatments did not show any significant difference a day before first spray. Results (Table 2) revealed that at three days after first spraying, among all the treatments cyantraniliprole (0.23 larvae.plant^{-1}) was found to be the superior treatment against tobacco caterpillar followed by spinosad (0.43 larvae.plant^{-1}). The next best treatments were chlorfenapyr (0.63 larvae.plant^{-1}), flubendiamide (0.67 larvae.plant^{-1}), and indoxacarb (1.10 larvae.plant^{-1}). The other treatments betacyfluthrin + imidacloprid (2.10 larvae.plant^{-1}) and pyridalyl (2.23 larvae.plant^{-1}) found to be moderately effective and on par with each other. The treatments acephate + imidacloprid (2.73 larvae.plant^{-1}) and bifenthrin (3.03 larvae.plant^{-1}) were found to be less effective and significantly different from untreated control which recorded a population abundance of 7.07 larvae.plant^{-1}. Seven days after first spraying, cyantraniliprole recorded a larval population of 0.40 larvae.plant^{-1}and found significantly superior in bringing down the larval population over rest of the treatments. Indoxacarb (0.70 larvae.plant^{-1}) and pyridalyl (0.83 larvae.plant^{-1}) were found to be the next best treatments. The other treatments bifenthrin (1.00 larvae.plant^{-1}), chlorfenapyr (1.17 larvae.plant^{-1}), acephate + imidacloprid (1.33 larvae.plant^{-1}), betacyfluthrin + imidacloprid (1.67 larvae.plant^{-1}), flubendiamide (1.97 larvae.plant^{-1}) and spinosad (2.10 larvae.plant^{-1}) were found to be moderately effective and on par with each other. At ten days after first spraying, the efficacy of chlorfenapyr (0.33 larvae.plant^{-1}) was found to be superior in reducing the larval population of *S.litura*. The other treatments were found to be moderately effective with a population ranged from 0.43 to 1.90 larvae.plant^{-1} and were at par. The treatment acephate + imidacloprid (5.43 larvae.plant^{-1}) was less effective in reducing the larval population, but found significantly superior than untreated control (10.03 larvae.plant^{-1}).

At three days after second spraying, all the treatments were proved significantly superior in bringing down the *S. litura* population ranged from 0.77 to 1.30 larvae.plant^{-1} over untreated control where there was an increase in population (3.53 larvae.plant^{-1}). Seven days after second spraying, spinosad (0.17 larvae.plant^{-1}) and cyantraniliprole (0.23 larvae.plant^{-1}) recorded significantly less number of *S.litura* larvae. The next best treatments were observed to be chlorfenapyr, bifenthrin with an identical population of 0.37 larvae.plant^{-1} and flubendiamide (0.40 larvae.plant^{-1}). The other treatments betacyfluthrin + imidacloprid (0.67 larvae.plant^{-1}), indoxacarb (1.10 larvae.plant^{-1}), pyridalyl (1.70 larvae.plant^{-1}) and acephate + imidacloprid (2.20 larvae.plant^{-1}) were found to be moderately effective in reducing the larval population. Ten days after second spray, chlorfenapyr (0.30 larvae.plant^{-1}) was found to be the most superior treatment against *S. litura* over rest of the treatments. Among the other treatments the effective treatments were spinosad (0.53 larvae.plant^{-1}), cyantraniliprole,

Table 1. Efficacy of new insecticides against semilooper, *Achaea janata* L. in castor (pooled data of *kharif*, 2014-15 to 2016-17)

Treatment	Dose	No. of larvae. plant^{-1}								
		First spray				Second spray				Mean of two sprays
		PTC	Post treatment			PTC	Post treatment			
			3 DAS	7 DAS	10 DAS		3 DAS	7 DAS	10 DAS	
Spinosad 45%SC	150 ml.ha^{-1}	2.3	0.27	0.3	0.47	1.93	0.27	0.23	0.17	0.28
		(1.67)	(0.51)^{d}	(0.54)^{b}	(0.68)^{de}	(1.39)	(0.49)^{cd}	(0.86)^{d}	(0.81)^{d}	(0.52)^{e}
Chlorfenapyr 10% SC	1000 ml.ha^{-1}	2.4	0.43	0.33	0.63	1.7	0.73	0.4	0.4	0.49
		(1.70)	(0.66)^{bcd}	(0.54)^{b}	(0.78)^{cde}	(1.30)	(0.84)^{b}	(0.95)^{cd}	(0.95)^{cd}	(0.69)^{d}
Cyantraniliprole 10% OD	600 ml.ha^{-1}	2.87	0.4	0.33	0.37	1.8	0.3	0.13	0.17	0.28
		(1.84)	(0.62)^{bcd}	(0.58)^{b}	(0.61)^{e}	(1.33)	(0.54)^{cd}	(0.79)^{d}	(0.82)^{d}	(0.54)^{e}
Pyridalyl 10%EC	625 ml.ha^{-1}	1.67	0.53	0.37	0.73	1.67	0.7	0.73	0.53	0.6
		(1.52)	(0.71)^{bcd}	(0.60)^{b}	(0.79)^{cde}	(1.29)	(0.82)^{b}	(1.11)^{bc}	(1.02)^{bc}	(0.77)^{cd}
Flubendiamide 20%WDG	250 g.ha^{-1}	1.73	0.47	0.5	0.4	1.73	0.53	0.37	0.47	0.46
		(1.65)	(0.67)^{bcd}	(0.66)^{b}	(0.62)^{e}	(1.32)	(0.72)^{bc}	(0.94)^{cd}	(0.98)^{bc}	(0.68)^{d}
Betacyfluthrin 9%+ Imidacloprid 21% OD	250 ml.ha^{-1}	2.03	0.33	0.3	1.07	2	0.47	0.4	0.5	0.51
		(1.65)	(0.54)^{cd}	(0.54)^{b}	(0.98)^{cd}	(1.41)	(0.67)^{bcd}	(0.95)^{cd}	(0.99)^{bc}	(0.71)^{d}
Bifenthrin 10%EC	625 ml.ha^{-1}	1.47	0.73	0.77	1.2	1.8	0.4	0.47	0.8	0.73
		(1.45)	(0.85)^{b}	(0.86)^{b}	(1.08)^{bc}	(1.34)	(0.62)^{bcd}	(0.98)^{bcd}	(1.14)^{b}	(0.84)^{bc}
Acephate 50%+ Imidacloprid 1.8% SP	1250 g.ha^{-1}	1.63	0.6	0.63	1.9	1.8	0.77	0.87	0.8	0.93
		(1.62)	(0.78)^{bcd}	(0.77)^{b}	(1.37)^{ab}	(1.33)	(0.87)^{b}	(1.17)^{b}	(1.14)^{b}	(0.97)^{b}
Indoxacarb 15.8%EC	500 ml.ha^{-1}	1.77	0.67	0.7	0.57	1.7	0.2	0.3	0.5	0.49
		(1.56)	(0.81)^{bc}	(0.74)^{b}	(0.72)^{de}	(1.30)	(0.43)^{d}	(0.89)^{d}	(0.99)^{bc}	(0.68)^{d}
Untreated control	--	1.93	1.43	1.93	2.17	2.5	2.93	2.4	2.53	2.23
		(1.55)	(1.18)^{a}	(1.38)^{a}	(1.48)^{a}	(1.58)	(1.70)^{a}	(1.69)^{a}	(1.74)^{a}	(1.49)^{a}
CD (P=0.05)		NS	0.33	0.33	0.32	NS	0.26	0.19	0.16	0.13
CV%		7.6	22.7	26.1	20.4	7.6	19.3	10.4	8.9	9.31

PTC – Pre Treatment Count, DAS – Days after spraying
Values in Parenthesis are square root transformed values
Figures followed by the same letter did not differ significantly at 5% level

Table 2. Efficacy of new insecticides against tobacco caterpillar, *Spodoptera litura* in castor (pooled data of *kharif*, 2014-15 to 2016-17)

Treatment	Dose	No. of larvae. plant^{-1}								
		First spray				Second spray				Mean of two sprays
		PTC	Post treatment			PTC	Post treatment			
			3 DAS	7 DAS	10 DAS		3 DAS	7 DAS	10 DAS	
Spinosad 45%SC	150 ml.ha^{-1}	2.83	0.43	2.1	0.5	1.83	0.77	0.17	0.53	0.75
		(1.66)	$(0.97)^{ef}$	$(1.43)^{b}$	$(0.71)^{bc}$	(1.34)	$(0.86)^{b}$	$(0.39)^{f}$	$(0.72)^{de}$	$(0.86)^{e}$
Chlorfenapyr 10% SC	1000 ml.ha^{-1}	2.07	0.63	1.17	0.33	4.43	1.3	0.37	0.3	0.68
		(1.42)	$(1.05)^{e}$	$(1.06)^{bcd}$	$(0.58)^{c}$	(2.09)	$(1.11)^{b}$	$(0.57)^{ef}$	$(0.54)^{e}$	$(0.82)^{e}$
Cyantraniliprole 10% OD	600 ml.ha^{-1}	2.53	0.23	0.4	0.4	1.63	0.87	0.23	0.57	0.45
		(1.52)	$(0.85)^{f}$	$(0.62)^{e}$	$(0.62)^{bc}$	(1.27)	$(0.93)^{b}$	$(0.46)^{f}$	$(0.75)^{de}$	$(0.67)^{f}$
Pyridalyl 10%EC	625 ml.ha^{-1}	3.07	2.23	0.83	0.53	2.17	1.17	1.7	0.63	1.18
		(1.72)	$(1.65)^{c}$	$(0.91)^{cde}$	$(0.72)^{bc}$	(1.45)	$(1.05)^{b}$	$(1.30)^{bc}$	$(0.79)^{de}$	$(1.09)^{cd}$
Flubendiamide 20%WDG	250 g.ha^{-1}	2.33	0.67	1.97	1.57	2.47	0.77	0.4	0.77	1.02
		(1.52)	$(1.07)^{de}$	$(1.39)^{b}$	$(1.08)^{bc}$	(1.48)	$(0.85)^{b}$	$(0.59)^{ef}$	$(0.87)^{cd}$	$(1.00)^{d}$
Betacyfluthrin 9%+ Imidacloprid 21%	250 ml.ha^{-1}	2.27	2.1	1.67	1.47	4.3	0.77	0.67	1.17	1.31
		(1.50)	$(1.60)^{c}$	$(1.28)^{bc}$	$(1.19)^{bc}$	(1.97)	$(0.86)^{b}$	$(0.81)^{de}$	$(1.07)^{bc}$	$(1.15)^{c}$
Bifenthrin 10%EC	625 ml.ha^{-1}	2.83	3.03	1	1.9	2.6	0.97	0.37	0.83	1.35
		(1.69)	$(1.87)^{b}$	$(0.98)^{cde}$	$(1.22)^{bc}$	(1.60)	$(0.94)^{b}$	$(0.60)^{ef}$	$(0.91)^{bcd}$	$(1.17)^{c}$
Acephate 50%+ Imida	1250 g.ha^{-1}	2.37	2.73	1.33	5.43	3.57	1.2	2.2	1.3	2.37
		(1.52)	$(1.79)^{bc}$	$(1.12)^{bcd}$	$(1.85)^{ab}$	(1.81)	$(1.09)^{b}$	$(1.48)^{b}$	$(1.13)^{b}$	$(1.53)^{b}$
Indoxacarb 15.8%EC	500 ml.ha^{-1}	1.53	1.1	0.7	0.43	2.73	1	1.1	0.57	0.82
		(1.20)	$(1.26)^{d}$	$(0.82)^{de}$	$(0.65)^{bc}$	(1.63)	$(0.97)^{b}$	$(1.05)^{cd}$	$(0.74)^{de}$	$(0.90)^{e}$
Untreated control	--	2.33	7.07	11.33	10.03	2.93	3.53	4.5	3.27	6.62
		(1.52)	$(2.75)^{a}$	$(3.34)^{a}$	$(3.01)^{a}$	(1.71)	$(1.87)^{a}$	$(2.12)^{a}$	$(1.80)^{a}$	$(2.58)^{a}$
CD (P=0.05)		NS	0.2	0.41	1.27	NS	0.27	0.27	0.25	0.08
CV%		18.2	7.7	18	63.7	27.7	14.8	17.1	16	3.98

PTC – Pre Treatment Count, DAS – Days after spraying
Values in Parenthesis are square root transformed values
Figures followed by the same letter did not differ significantly at 5% level

Table 3. Efficacy of new insecticides against Bihar hairy caterpillar, *Spilosoma oblique* in castor (pooled data of *kharif*, 2014-15 to 2016-17)

Treatment	Dose	No. of larvae. plant^{-1}								
		First spray				Second spray				Mean of two sprays
		PTC	Post treatment			PTC	Post treatment			
			3 DAS	7 DAS	10 DAS		3 DAS	7 DAS	10 DAS	
Spinosad 45%SC	150 ml.ha^{-1}	1.50	1.00	0.03	0.13	2.33	0.50	0.07	0.30	0.34
		(1.38)	(1.18)^{bc}	(0.73)^{cd}	(0.79)^{b}	(1.67)	(0.95)^{d}	(0.75)^{cd}	(0.89)^{c}	(0.90)^{bc}
Chlorfenapyr 10% SC	1000 ml.ha^{-1}	1.67	0.83	0.03	0.13	3	0.33	0	0.10	0.24
		(1.42)	(1.15)^{bc}	(0.73)^{cd}	(0.79)^{b}	(1.85)	(0.88)^{d}	(0.70)^{d}	(0.78)^{cd}	(0.86)^{c}
Cyantraniliprole 10% OD	600 ml.ha^{-1}	2.17	0.33	0.00	0.1	2.55	0.5	0	0.03	0.16
		(1.63)	(0.88)^{c}	(0.70)^{d}	(0.78)^{b}	(1.72)	(1.00)^{d}	(0.70)^{d}	(0.73)^{d}	(0.82)^{c}
Pyridalyl 10%EC	625 ml.ha^{-1}	2.33	1.83	0.07	0.07	2.83	0.17	0.03	0.2	0.39
		(1.68)	(1.52)^{b}	(0.75)^{bcd}	(0.75)^{b}	(1.81)	(0.81)^{d}	(0.73)^{cd}	(0.83)^{cd}	(0.94)^{bc}
Flubendiamide 20%WDG	250 g.ha^{-1}	1.17	0.83	0.03	0.07	3.17	0.33	0	0.17	0.24
		(1.22)	(1.09)^{bc}	(0.73)^{cd}	(0.75)^{b}	(1.91)	(0.90)^{d}	(0.70)^{d}	(0.82)^{cd}	(0.85)^{c}
Betacyfluthrin 9%+ Imidacloprid 21% OD	250 ml.ha^{-1}	1.33	0.33	0.17	0.17	2.50	0.67	0.07	0.10	0.25
		(1.34)	(0.88)^{c}	(0.81)^{bc}	(0.82)^{b}	(1.66)	(1.05)^{cd}	(0.75)^{cd}	(0.78)^{cd}	(0.86)^{c}
Bifenthrin 10%EC	625 ml.ha^{-1}	1.33	0.50	0.20	0.20	3.50	2.17	0.13	0.30	0.58
		(1.35)	(0.97)^{c}	(0.84)^{b}	(0.82)^{b}	(1.99)	(1.62)^{b}	(0.79)^{c}	(0.89)^{c}	(1.03)^{b}
Acephate 50%+ Imidacloprid 1.8% SP	1250 g.ha^{-1}	1.00	0.33	0.13	0.6	2.50	1.67	0.3	0.60	0.61
		(1.18)	(0.90)^{c}	(0.79)^{bcd}	(1.02)^{b}	(1.72)	(1.44)^{bc}	(0.89)^{b}	(1.05)^{b}	(1.06)^{b}
Indoxacarb 15.8%EC	500 ml.ha^{-1}	0.83	1.00	0.07	0.17	3.50	0.17	0.07	0.100	0.26
		(1.11)	(1.23)^{bc}	(0.75)^{bcd}	(0.82)^{b}	(1.99)	(0.81)^{d}	(0.75)^{cd}	(0.78)^{cd}	(0.89)^{c}
Untreated control	--	1.50	4.83	3.35	4.5	3.83	3.83	4.85	5.65	4.5
		(1.38)	(2.29)^{a}	(1.59)^{a}	(2.13)^{a}	(2.03)	(2.07)^{a}	(2.30)^{a}	(2.68)^{a}	(2.13)^{a}
CD (P=0.05)		NS	0.49	0.09	0.18	NS	0.43	0.09	0.13	0.16
CV%		23.2	2.4	7.03	12.9	11.5	21.7	5.95	9.02	9.85

PTC – Pre Treatment Count, DAS – Days after spraying
Values in Parenthesis are square root transformed values
Figures followed by the same letter did not differ significantly at 5% level

Table 4. Efficacy of new insecticides against leaf hopper, *Empoasca flavescens* Fabricius in castor (pooled data of *kharif*, 2014-15 to 2016-17)

Treatment	Dose	No. of nymphs and adults / 3 leaves								
		First spray				Second spray				Mean of two sprays
		PTC	Post treatment			PTC	Post treatment			
			3 DAS	7 DAS	10 DAS		3 DAS	7 DAS	10 DAS	
Spinosad 45%SC	150 ml.ha^{-1}	9.63	8.27	9.1	8.13	8.67	5.83	5.57	6.3	7.2
		(3.16)	(2.96)^{de}	(3.10)^{b}	(2.93)^{b}	(3.01)	(2.51)^{b}	(2.47)^{bc}	(2.60)^{b}	(2.77)^{b}
Chlorfenapyr 10% SC	1000 ml.ha^{-1}	9.17	8.83	7.67	7.4	7.97	5.57	5.47	6.13	6.84
		(3.10)	(3.06)^{cd}	(2.85)^{bc}	(2.81)^{bc}	(2.90)	(2.47)^{bc}	(2.44)^{bc}	(2.58)^{b}	(2.71)^{b}
Cyantraniliprole 10% OD	600 ml.ha^{-1}	9.13	7.63	7.23	6.37	7.5	4.27	3.93	3.73	5.53
		(3.10)	(2.85)^{de}	(2.77)^{bc}	(2.61)^{cde}	(2.83)	(2.17)^{def}	(2.10)^{de}	(2.05)^{e}	(2.46)^{c}
Pyridalyl 10%EC	625 ml.ha^{-1}	11.17	9.83	7.47	8.33	8.3	5.73	5.8	5.73	7.15
		(3.40)	(3.22)^{bc}	(2.81)^{bc}	(2.97)^{b}	(2.96)	(2.49)^{bc}	(2.50)^{b}	(2.49)^{bc}	(2.77)^{b}
Flubendiamide 20%WDG	250 g.ha^{-1}	7.67	10.37	6.93	7.03	7.6	4.93	5.57	5.7	6.76
		(2.86)	(3.28)^{bc}	(2.70)^{bc}	(2.74)^{bcde}	(2.84)	(2.33)^{bcd}	(2.47)^{bc}	(2.48)^{bc}	(2.69)^{b}
Betacyfluthrin 9%+ Imidacloprid 21%	250 ml.ha^{-1}	9.2	6.97	5.57	5.47	8.28	3.9	2.93	3.83	4.78
		(3.11)	(2.74)^{e}	(2.47)^{c}	(2.45)^{e}	(2.96)	(2.10)^{ef}	(1.85)^{f}	(2.07)^{e}	(2.30)^{d}
Bifenthrin 10%EC	625 ml.ha^{-1}	8.43	8.23	6.07	5.6	7.9	4.07	3.83	4.33	5.36
		(2.99)	(2.96)^{de}	(2.56)^{c}	(2.47)^{de}	(2.90)	(2.12)^{def}	(2.08)^{e}	(2.19)^{de}	(2.42)^{cd}
Acephate 50%+ Imidacloprid 1.8%	1250 g.ha^{-1}	7.83	7.3	5.5	5.8	8.73	3.73	3.2	4.9	5.07
		(2.88)	(2.80)^{e}	(2.44)^{c}	(2.51)^{cde}	(3.04)	(2.05)^{f}	(1.92)^{ef}	(2.33)^{cd}	(2.35)^{cd}
Indoxacarb 15.8%EC	500 ml.ha^{-1}	10.17	10.83	7.2	7.17	7.87	4.77	4.77	5.53	6.71
		(3.26)	(3.36)^{ab}	(2.76)^{bc}	(2.77)^{bcd}	(2.89)	(2.28)^{cde}	(2.30)^{cd}	(2.45)^{bc}	(2.68)^{b}
Untreated control	--	10.2	12.43	12.83	13.67	9.17	10.43	9.83	10.83	11.67
		(3.26)	(3.60)^{a}	(3.63)^{a}	(3.76)^{a}	(3.11)	(3.31)^{a}	(3.21)^{a}	(3.37)^{a}	(3.48)^{a}
CD (P=0.05)		NS	0.24	0.51	0.31	NS	0.22	0.2	0.21	0.12
CV%		9.02	4.38	10.48	6.28	6.71	5.41	4.81	5.1	2.66

PTC – Pre Treatment Count, DAS – Days after spraying

Values in Parenthesis are square root transformed values

Figures followed by the same letter did not differ significantly at 5% level

Table 5. Efficacy of new insecticides against shoot and capsule borer, *Conogethes punctiferalis* Guenee (pooled data of *kharif,* 2014-15 to 2016-17)

Treatments	Dose	Capsule damage %					
		PTC	3 DAS	5 DAS	10 DAS	15 DAS	Overall Mean
Spinosad 45%SC	150 ml.ha^{-1}	21.1	14.3	10.5	8.1	7.6	10.1
		(27.30)	(22.1)^{d}	(18.9)^{de}	(16.5)^{d}	(16.0)^{c}	(18.5)^{e}
Chlorfenapyr 10% SC	1000 ml.ha^{-1}	20.5	23.9	15.5	12.1	11.2	15.7
		(26.90)	(29.3)^{b}	(23.2)^{bc}	(20.3)^{bc}	(19.3)^{bc}	(23.3)^{bc}
Cyantraniliprole 10% OD	600 ml.ha^{-1}	21.3	15.3	9.1	9.4	8.9	10.7
		(27.50)	(22.8)^{d}	(17.5)^{e}	(17.9)^{cd}	(17.3)^{c}	(19.0)^{e}
Pyridalyl 10%EC	625 ml.ha^{-1}	21.7	19.7	17.5	11.9	11.8	15.2
		(27.70)	(26.4)^{bcd}	(24.7)^{b}	(20.1)^{bc}	(20.0)^{bc}	(23.0)^{bcd}
Flubendiamide 20%WDG	250 g.ha^{-1}	21.9	15.6	15.4	9.0	9.1	12.3
		(27.90)	(23.3)^{cd}	(23.1)^{bc}	(17.4)^{cd}	(17.5)^{c}	(20.5)^{de}
Betacyfluthrin 9% + Imidacloprid 21% OD	250 ml.ha^{-1}	24.7	18.2	19.2	11.0	10.3	14.7
		(29.70)	(25.2)^{bcd}	(25.9)^{b}	(19.3)^{bcd}	(18.5)^{bc}	(22.5)^{bcd}
Bifenthrin 10%EC	625 ml.ha^{-1}	21.3	18.4	13.8	10.6	12.3	13.8
		(27.50)	(25.4)^{bcd}	(21.7)^{cd}	(18.8)^{bcd}	(20.4)^{bc}	(21.7)^{cd}
Acephate 50%+ Imidacloprid 1.8% SP	1250 g.ha^{-1}	19.4	21.5	19.2	13.6	15.6	17.5
		(26.10)	(27.6)^{bc}	(26.0)^{b}	(21.6)^{b}	(22.9)^{b}	(24.7)^{b}
Indoxacarb 15.8% EC	500 ml.ha^{-1}	20.0	14.5	11.5	8.6	7.6	10.6
		(26.60)	(22.4)^{d}	(19.8)^{de}	(17.1)^{cd}	(15.9)^{c}	(19.0)^{e}
Untreated control	-	21.9	35.3	23.8	25.5	37.7	30.6
		(27.90)	(36.4)^{a}	(29.1)^{a}	(30.3)^{a}	(37.8)^{a}	(33.6)^{a}
CD (P=0.05)		NS	4.8	2.9	3.5	5.3	2.5
CV%		6.5	10.6	7.3	10.2	15	6.5

PTC – Pre Treatment Count, DAS – Days after spraying
Figures followed by the same letter did not differ significantly at 5% level
Values in Parenthesis are arcsine transformed values

indoxacarb (identical population of 0.57 larvae.plant^{-1}) and pyridalyl (0.63 larvae.plant^{-1}). The treatments flubendiamide (0.77 larvae.plant^{-1}), bifenthrin (0.83 larvae.plant^{-1}), betacyfluthrin + imidacloprid (1.17 larvae.plant^{-1}) and acephate + imidacloprid (1.30 larvae.plant^{-1}) were found to be moderately effective in reducing the larval population.

Significant reduction in the incidence of *S. litura* larvae was recorded with cyantraniliprole (0.45 larvae /plant) in pooled mean of two sprays followed by chlorfenapyr (0.68 larvae.plant^{-1}), spinosad (0.78 larvae.plant^{-1}) and indoxacarb (0.82 larvae.plant^{-1}). Flubendiamide recorded 1.02 larvae.plant^{-1} which was on par with pyridalyl (1.18 larvae.plant^{-1}) which in turn on par with betacyfluthrin + imidacloprid and bifenthrin by recording 1.31 and 1.35 larvae.plant^{-1}, respectively. Whereas acephate + imidacloprid (2.37 larvae.plant^{-1}) recorded significantly higher number of larvae compared to all other treatments but found superior over untreated control (6.62 larvae.plant^{-1}). The present findings are more or less similar to the results reported by Munir and Saleem (2004); Narayanamma *et al*. (2014); Mukesh *et al*. (2016) and Shilpakala and Muralikrishna (2016).

Efficacy of Newer Insecticides Against Bihar Hairy Caterpillar, *Spilosoma obliqua*

The larval population was uniform and the treatments did not show any significant difference a day before first spray. Results furnished in Table 3 revealed that at 3 days after first spraying, the treatments cyantraniliprole, betacyfluthrin + imidacloprid, acephate + imidacloprid recorded significantly lesser number of identical population (0.33

Table 6. Yield and economics of new insecticides against pest complex in castor (pooled data of *kharif,* 2014-15 to 2016-17)

Treatments	Dose	Seed Yield (Kg.ha^{-1})	Additional seed yield over control (Kg.ha^{-1})	Cost of treatment with labour charges (Rs.ha^{-1})	Additional returns (Rs.ha^{-1})	Net returns (Rs.ha^{-1})	ICBR
Spinosad 45%SC	150 ml.ha^{-1}	1004^{a}	466	2400	18633	16233	6.76
Chlorfenapyr 10% SC	1000 ml.ha^{-1}	736^{c}	197	2170	7899	5729	2.64
Cyantraniliprole 10% OD	600 ml.ha^{-1}	974^{a}	436	3000	17449	14449	4.82
Pyridalyl 10%EC	625 ml.ha^{-1}	716^{c}	178	1450	7119	5669	3.91
Flubendiamide 20%WDG	250 g.ha^{-1}	858^{b}	320	2000	12796	10796	5.4
Betacyfluthrin 9% + Imidacloprid 21% OD	250 ml.ha^{-1}	718^{c}	180	1140	7207	6067	5.32
Bifenthrin 10%EC	625 ml.ha^{-1}	698^{c}	160	1188	6411	5223	4.4
Acephate 50%+ Imidacloprid 1.8% SP	1250 g.ha^{-1}	628^{d}	90	1125	3580	2455	2.18
Indoxacarb 15.8% EC	500 ml.ha^{-1}	832^{b}	294	2048	11758	9710	4.74
Untreated control	-	538^{e}					
CD (P=0.05)		48.8					
CV%		3.7					

Figures followed by the same letter did not differ significantly at 5% level
Incremental Cost Benefit Ratio (ICBR) = Net profit / cost of plant protection
Net profit = Additional returns – cost of plant protection

larvae.plant^{-1}) followed by bifenthrin (0.50 larvae.plant^{-1}) and were found on par with each other. The treatments, flubendiamide, chlorfenapyr, (identical larval population of 0.83/plant) indoxacarb and spinosad (identical population of 0.83 larvae.plant^{-1}) were found on par with each other. Pyridalyl (1.83 larvae.plant^{-1}) was found to be moderately effective in reducing the larval population of *S. obliqua* which is significantly superior to untreated check (4.83 larvae.plant^{-1}). On 7 days after first spraying, cyantraniliprole found to be significant by recording nil larval population and remaining treatments were found on par with each other with a population ranged from 0.03 to 0.20 larvae.plant^{-1}. Similar trend in treatment efficacy was observed on 10 days after first spraying also without any significant differences among the treatments with a population ranged from 0.07 to 0.60 larvae.plant^{-1}. However, the population was significantly increasing in untreated control (4.50 larvae.plant^{-1}).

On third day after second spraying, all the treatments showed similar tendency in reducing the larval population of *S. obliqua* ranged from 0.17 to 0.67 larvae.plant^{-1} except acephate + imidacloprid (1.67 larvae.plant^{-1}) and bifenthrin (2.17 larvae.plant^{-1}) but proved significantly superior to untreated check (3.83 larvae.plant^{-1}). On seventh and tenth day after second spraying also, all the treatments showed similar tendency in reducing the larval population and proved significantly superior to untreated check.

In pooled mean of two sprays, cyantraniliprole registered significantly low incidence of bihar hairy caterpillar (0.16 larvae.plant^{-1}) followed by chlorfenapyr, flubendiamide (identical population of 0.24 larvae.plant^{-1}), betacyfluthrin + imidacloprid (0.25 larvae.plant^{-1}) and indoxacarb (0.26 larvae /plant) which were at par with each other. Spinosad (0.34 larvae.plant^{-1}) and pyridalyl (0.39 larvae.plant^{-1}) were next best treatments which were on par with bifenthrin and acephate + imidacloprid by recording 0.58 and 0.61 larvae.plant^{-1}, respectively. Whereas, untreated control (4.50 larvae.plant^{-1}) recorded significantly higher number of larvae.

Efficacy of Newer Insecticides Against Leafhopper, *Empoasca flavescens*

The data on leafhopper population recorded after different intervals of application are summarized in Table 4. The data revealed that the leafhopper population ranged from 7.67 to 11.17/ 3 leaves and differences among various plots were non-significant before spray, which indicated a uniform leafhopper population equally distributed in experimental plots. The mean leafhopper population after 3 days of first spraying revealed that plots treated with betacyfluthrin + imidacloprid recorded lowest leafhopper population (6.97/ 3 leaves) which was at par with acephate + imidacloprid, cyantraniliprole, bifenthrin and spinosad, as they registered 7.30, 7.63, 8.23 and 8.27 leafhoppers/ 3 leaves, respectively. The other treatments *viz.,* chlorfenapyr, pyridalyl, and flubendiamide registered 8.83, 9.83 and 10.37 leafhoppers/ 3 leaves, respectively, which were less effective in reducing the leafhopper population. The spray with indoxacarb was least effective with a maximum population of 10.83 leafhoppers/ 3 leaves and found on par with untreated control (12.43 leafhoppers/ 3 leaves). The population of leafhoppers after 7 days of first spraying indicated minimum leafhopper population of 5.50, 5.57 and 6.07/ 3 leaves in the plots treated with acephate + imidacloprid, betacyfluthrin + imidacloprid and bifenthrin, respectively indicating effective treatments in lowering leafhopper population. However, they were at par with other treatments which registered 6.93 to 7.67 leafhoppers/ 3 leaves. The treatment with spinosad was found least effective with a population of 9.10 leafhoppers/ 3 leaves but significantly superior to untreated control (12.83 leafhoppers/ 3 leaves). Similar trend was observed 10 days after first spraying also where betacyfluthrin + imidacloprid was the most effective chemical with minimum leafhopper population of 5.47/ 3 leaves and it was followed by bifenthrin, acephate + imidacloprid and cyantraniliprole, as they exhibited 5.60, 5.80 and 6.37 leafhopper populations per 3 leaves, respectively. The remaining treatments were found moderately effective with a population ranged from 7.03 to 8.13 leafhoppers/ 3 leaves and showed superiority over control (13.67 leafhoppers/ 3 leaves).

A perusal of the data on the population of leafhoppers measured after 3 days of second spray revealed that acephate + imidacloprid was the most effective treatment with minimum leafhopper population per 3 leaves (3.73) and it was followed by betacyfluthrin + imidacloprid (3.90), bifenthrin (4.07) and cyantraniliprole (4.27). The remaining treatments were at par with leafhopper population ranged from 4.77 to 5.83/ 3 leaves and significantly effective than control (10.43 leafhoppers/ 3 leaves). After 7 days of second spray, all the treatments showed similar tendency in reducing the leafhopper population and proved significantly superior to untreated check. Ten days after second spray of insecticides, minimum leafhopper population was recorded in cyantraniliprole (3.73 leafhoppers/ 3 leaves), and it was at par with betacyfluthrin + imidacloprid (3.83/ 3 leaves) followed by bifenthrin (4.33/ 3 leaves) and acephate + imidacloprid (4.90/ 3 leaves). The treatment indoxacarb (5.53/ 3 leaves), flubendiamide (5.70/ 3 leaves) and pyridalyl (5.73/ 3 leaves) were at par in recording the population of leafhopper. The remaining treatments of chlorfenapyr (6.13 per 3 leaves) and spinosad (6.30/ 3 leaves) showed good results over control (10.83 leafhoppers/ 3 leaves).

The population of leaf hopper was fluctuated significantly and varied across different insecticide treatments after two sprays of insecticides. Significantly lower overall mean population levels were recorded with betacyfluthrin + imidacloprid (4.78/ 3 leaves) followed by acephate + imidachloprid (5.07/ 3 leaves) which was on par with bifenthrin (5.36/ 3 leaves). The treatment with cyantraniliprole was found moderately effective with a population of 5.53 / 3 leaves. The remaining treatments were less effective with leafhopper population ranged from 6.71 to 7.20/ 3 leaves but found significantly superior over control (11.67 leafhoppers/ 3 leaves). These findings are closely associated with many workers who have recommended imidacloprid and acephate for effective and economic control of castor leafhopper, *E. flavescens* (Parmar, 2004; Laxman, 2014 and Patel and Muralidharan, 2014).

Efficacy of Newer Insecticides Against Shoot and Capsule Borer, *C. punctiferalis*

There was no record of incidence of *C. punciferalis* during the time of first spray as it was taken up at vegetative stage. The per cent capsule damage was uniform and the treatments did not show any significant difference a day before second spray. Three days after second spraying at the time of spike development (Table 5), among all the treatments spinosad, indoxacarb and cyantraniliprole recorded the lowest shoot and capsule borer damage of 14.3, 14.5 and 15.3 per cent, respectively. The next best treatment was observed to be flubendiamide (15.6%) which was at par with betacyfluthrin + imidacloprid (18.2%), bifenthrin (18.4%) and pyridalyl (19.7%). The treatments found to be moderately effective in reducing the capsule infestation were acephate + imidacloprid (21.5%) and chlorfenapyr (23.9%) which were significantly superior to control (35.3%). Five days after second spraying, among all the treatments cyantraniliprole recorded the lowest (9.1%) damage of shoot and capsule borer over control (23.8%). The next best treatments were observed to be spinosad (10.5%) and indoxacarb (11.5%) which are at par. The treatments bifenthrin (13.8%), flubendiamide (15.4%)

and chlorfenapyr (15.5%) found to be moderately effective in reducing the capsule damage. The less effective treatments were observed to be pyridalyl (17.5%), betacyfluthrin + imidacloprid and acephate + imidacloprid (19.2%). Ten days after second spraying, spinosad (8.1%) was found to be the most superior treatment against capsule borer over rest of the treatments. Among the other treatments the effective treatments were indoxacarb (8.6%), flubendiamide (9.0%), cyantraniliprole (9.4%), bifenthrin (10.6%) and betacyfluthrin + imidacloprid (11.0%). The treatments pyridalyl (11.9%), chlorfenapyr (12.1%) and acephate + imidacloprid (13.6%) were found to be moderately effective in reducing the capsule damage over untreated control (25.5%). Fifteen days after second spraying, the per cent capsule damage with spinosad and indoxacarb has shown significantly less damage of 7.6 per cent each, which were statistically comparable to that obtained in cyantraniliprole (8.9%) and flubendiamide (9.1%) followed by mixed formulation of betacyfluthrin + imidacloprid (10.3%), chlorfenapyr (11.2%), pyridalyl (11.8%) and bifenthrin (12.3%) which were at par. The treatment acephate + imidacloprid (15.6%) was less effective in reducing capsule damage but was significantly superior to that of untreated check (37.7%).

The test insecticides significantly altered capsule damage by capsule borer and over all mean damage was less with spinosad (10.1%) followed by indoxacarb (10.6%) and cyantraniliprole (10.7%) which were significantly superior over rest of the insecticides. The treatment flubendiamide (12.3%) and bifenthrin (13.8%) were next in the order to record less capsule damage in castor. Betacyfluthrin + imidacloprid (14.7%), pyridalyl (15.2%) and chlorfenapyr (15.7%) were moderately effective and at par with each other. Whereas, acephate + imidacloprid (17.5%) recorded higher capsule damage but was significantly superior to untreated control (30.6%). These results are in conformity with the findings of Narayanamma *et al.* (2014) and Shilpakala and Muralikrishna (2016) who reported flubendiamide was most effective in reducing capsule borer infestation in castor.

Yield and Economics of Newer Insecticides Against Pest Complex in Castor

Results pertaining to seed yield registered by different treatments are furnished in Table 6, which proved the supremacy of spinosad by recording significantly highest seed yield (1004 $kg.ha^{-1}$) followed by cyantraniliprole (974 $kg.ha^{-1}$) which were found statistically on par with each other. Next best were flubendiamide (858 $kg.ha^{-1}$) and indoxacarb (832 $kg.ha^{-1}$) significantly followed by chlorfenapyr (736 $kg.ha^{-1}$), pyridalyl (716 $kg.ha^{-1}$), betacyfluthrin + imidacloprid (718 $kg.ha^{-1}$) and bifenthrin (698 $kg.ha^{-1}$) which were par with each other. Acephate + imidacloprid recorded significantly lower seed yield (628 $kg.ha^{-1}$) compared to all other treatments, but it was found significantly superior to untreated control (538 $kg.ha^{-1}$). These results are in conformity with Narayanamma *et al*. (2014).

The treatments spinosad and flubendiamide apart from recording higher yield also gave higher Incremental Cost Benefit Ratio (ICBR) of 6.76 and 5.40 followed by betacyfluthrin + imidacloprid (5.32), cyantraniliprole (4.82) and indoxacarb (4.74), bifenthrin (4.40) and pyridalyl (3.91), whereas lowest ICBR of 2.64 and 2.18 was noticed with chlofenapyr and acephate + imidacloprid .

LITERATURE CITED

Basappa H and Lingappa S 2001 Studies on damage potential of *Achaea janata* at different phenological states of castor. *Indian Journal of Plant Protection*, 29: 17-24.

Laxman G 2014 Evaluation of genotypes and management of major defoliators and sucking insect pests of castor, *Ricinus communis* L. *M. Sc (Ag) Thesis*. Acharya N. G. Ranga Agricultural University, Rajendra Nagar, Hyderabad.

Mukesh B, Naveen Kumar N and Acharya M F 2016 Bioefficacy of Modern Insecticides Against *Spodoptera litura* Fabricius on Castor. *International Journal of Agriculture Innovations and Research*, 4 (4): 789-795

Munir A and Saleem M A 2004 Comparative efficacy of ten conventional and new chemistry insecticides against armyworm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) under laboratory condition. *Pakistan Entomologist*, 26(2): 1-4.

Narayanamma V L and Reddy K D 2014 Evaluation of newer insecticide molecules against lepidopteran pests in castor. *Indian Journal of Entomology*, 76 (4): 273-278.

Nauen R, Konanz S, Hirooka T, Nishimatsu T and Kodama H 2007 Flubendiamide: A unique tool in resistance management tactics for pest Lepidoptera difficult to control. *Pflanzenschutz - Nachrichten, Bayer*, 60 (2): 247-262.

Parmar P D 2004 Efficiency and economics of insecticide against castor leafhopper, *Empoasca flavescens*. *Indian Journal of Plant Protection,* 32 (1): 135-137.

Patel B C and Muralidharan C M 2014 Bio-efficacy of newer insecticides against sucking pest complex of castor (*Ricinus communis*

Linnaeus). *AGRES – An International e-Journal*, 3 (1): 47-61.

Shilpakala V and Muralikrishna T 2016 Evaluation of New Insecticide Molecules Against Lepidopteran Pests in Castor (*Ricinus communis* L.). *International Journal of Agricultural Science and Research*, 6 (6): 29-36.

Shivanna B K, Naik B G, Nagaraja R, Gayatridevi S, Naik R K and Shruthi H 2012 Evaluation of new molecules against scarlet mite, Raoiella indica Hirst in arecanut. *Journal of Entomology and Nematology*, 4(1): 4-6.

Stanely J 2007 Chemical and behavioral approaches for pest management in cardamom. *Ph.D thesis*. Tamil Nadu Agricultural University, Coimbattore, India, 210pp

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