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Efficacy of newer molecules of insecticides against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Crambidae) and fruit yield

Mou Biswas, Ipsita Mishra and BK Mishra

Abstract
Six insecticides, *viz.*, Rynaxypyr 18.5%SC, Spinosad 45%SC, Indoxacarb 15.8%EC, Abamectin 1.9%EC, Emamectin benzoate 5%SG and Flubendiamide 20%WDG were evaluated in the field against brinjal fruit and shoot borer *Leucinodes orbonalis* Guen. during *Rabi* and summer of 2012-13, *Kharif* and *Rabi* of 2013-14 at the Central Research Station farm, Orissa University of Agriculture and Technology (OUAT) Bhubaneswar with brinjal variety cv." Utkal Anushree". Four foliar spray applications of the chemicals were given at 15, 30, 45, 60, 75 and 90 days after transplanting (DAT). Observations were taken on the incidence of shoot and fruit borer at 7 and 14 days after spraying. Altogether six sprays were given. Observation of shoot damage was taken at 15, 30, 45 and 60 (DAT) and fruit damage was taken at 45, 60, 75 and 90 DAT. Lowest shoot and fruit infestation and highest fruit yield were obtained in plots treated with Flubendiamide and Rynaxypyr followed by Emamectin benzoate. Maximum benefit-cost ratio was obtained with Flubendiamide 20%WDG in both the years.

Keywords: Brinjal shoot and fruit borer, *Leucinodes orbonalis,* new molecules, insecticides, benefit-cost ratio

Introduction
Brinjal (*Solanum melongena* Linn.) also known as eggplant is referred as King of vegetables, originated from Indian sub-continent, with as the probable centre of origin (Omprakash and Raju, 2014 [11]. Brinjal, *Solanum melongena* L. is one of the major vegetables in India extensively grown under diverse agro-climatic conditions throughout the year. Brinjal occupies about 8.45% of the total area under vegetables in India and 42.0% in Orissa (Patnaik *et al.*, 2004 [14]. It harbours more than 140 species of insect-pests (Prempong and Bauhiun, 1977 [12]; Sohi, 1996 [17]. Among the insect-pests the most destructive and serious pest of brinjal is brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee. It remained a major pest and main constraint as it damages the crop throughout the year. It is known to damage shoot and fruits of brinjal in all stages of its growth and the apparent yield loss varying from 20-90% in various parts of the country Raju *et al*., 2007 [16]; Patnaik, 2000 [13]; Misra, 2008 [7] ; Jagginavar *et al*., 2009 [5].
Although insecticidal control is one of the common means against the fruit borer, many of the insecticides applied are not effective in the satisfactory control of this pest. Beside this, sole dependence on insecticides for the control of this pest has led to insecticidal resistance by the pest Natekar *et al.*, 1987 [8]; Harish *et al.*, 2011 [4] trade implications, poisoning, hazards to non-target organisms, increased production costs etc. Abrol *et al.*, 2003 [1]. Among the several avenues to overcome the insecticidal resistance problem, replacement with new molecules of insecticide is one of the important considerations. Evaluation of newer molecules for their efficacy against *L. orbonalis* is also a continuous process as newer molecules having novel mode of action are introduced in the market. Considering above facts, the present investigation was undertaken to test the efficacy of six new insecticide formulations *viz*., Rynaxypyr, Spinosad, Indoxacarb, Abamectin, Emamectin benzoate and Flubendiamide against *L. orbonalis.*

Materials and Methods
Field experiments were conducted during *Rabi* and summer of 2012-13, *Kharif* and *Rabi* of 2013-14 at the Central Research Station, Orissa University of Agriculture and Technology,

Bhubaneswar. Seedlings of variety "Utkal Anushree" were raised in nursery beds from December-2012 and seedlings were transplanted on 09.01.2013 *at* 60 X 45 cm spacing in plots of 6 x 5 meter. The crop was raised by following recommended agronomic package of practices and also plant protection measures were taken as and when necessary to check the sucking insects as well as foliage feeders.
The study was established in a complete block design consisting of seven treatments which included six insecticidal treatments consisted of Rynaxypyr, Emamectin benzoate, Flubendiamide, Spinosad, Abamectin, Indoxacarb and untreated control (water spray), replicated thrice were applied with a knapsack sprayer up to runoff stage at 15, 30, 45, 60, 75 and 90 days after transplanting (DAT). Observations were taken on the incidence of shoot and fruit borer at 7 and 14 days after spraying. Altogether six sprays were given. Observation of shoot damage was taken at 15, 30, 45 and 60 (DAT) and fruit damage was taken at 45, 60, 75 and 90 DAT.
The number of healthy and damaged shoots and fruits from each treatment was recorded at each picking. Fruits from each sub-plot were plucked, and sorted carefully as healthy or damaged one. Benefit-cost ratio was calculated, the healthy fruits per plot were recorded as the yield unit of quintals per ha. The net gain was calculated on deducting the cost of applications from the total cost of marketable fruits. The benefit-cost ratio for each insecticide applied was recorded. The recorded data were analyzed using analysis of variance Gomez and Gomez., 1984 [3].

Results and Discussion

The percent infestation in shoot was recorded during 2012-13 and 2013-14, are presented in the (Table 1 and 2) and percent fruit infestation along with fruit yield was recorded in terms of quintals/ha during 2012-13 and 2013-14, are presented in the (Table 3 and 4). In 2012-13 (Table 1), among all the insecticides, Flubendiamide treatment after seven and fourteen days, recorded lowest percent of shoot infestation (4.40, 2.62%) and highest shoot infestation (11.92, 9.56%) found in Abamectin by the shoot and fruit borer than untreated check (15.58, 13.26%). Mean percent shoot infestation recorded lowest in all the four sprays (3.51, 1.81, 1.34 and 0.81%) when treated with Flubendiamide. A similar trend was recorded in shoot infestation during 2013-14 (Table2). Flubendiamide treatments after seven and fourteen days, recorded lowest percent of shoot infestation (3.13, 2.52%) and highest shoot infestation (11.98, 12.02%) found in Abamectin by the shoot and fruit borer than untreated check (12.14, 10.67%). During 2013-14 Flubendiamide recorded lowest mean percent shoot infestation of (2.83, 2.31, 0.15 and 0.90%) in all the four sprays respectively.

Table 1: Field efficacy of different insecticides against *Leucinodes orbonalis* in shoots during 2012-2013

Treatment	Dose (g/ha)	1DBS	Shoot Infestation (%) days after spray application												Mean
			Spray I			Spray II			Spray III			Spray IV			
			7	14	Mean	7	14	Mean	7	14	Mean	7	14	Mean	
T1 Rynaxypyr 18.5%SC	200	10.65	5.35 (2.31)	6.10 (2.47)	5.73 (2.39)	3.86 (1.96)	1.87 (1.37)	2.86 (1.69)	1.82 (1.35)	1.44 (1.20)	1.63 (1.28	1.21 (1.10)	1.11 ((1.05)	1.16 (1.08)	2.85 (1.69)
T2 Spinosad 45% SC	200	13.26	10.32 (3.21)	7.13 (2.67)	8.73 (2.84)	8.00 (2.83)	6.00 (2.45)	7.29 (2.70)	6.65 (2.58)	4.67 (2.16)	4.88 (2.21)	4.05 (2.01)	2.92 (1.71)	3.21 (1.79)	6.03 (2.46)
T3 Indoxacarb 15.8% EC	500	14.81	10.72 (3.27)	7.55 (2.75)	9.14 (3.07)	8.44 (2.91)	6.11 (2.47)	7.28 (2.69)	8.10 (2.85)	5.71 (2.38)	4.50 (2.12)	5.75 (2.40)	4.06 (2.01)	2.99 (1.72)	6.45 (2.54)
T4 Abamectin 1.9% EC	500	12.48	11.92 (3.45)	9.56 (3.09)	10.74 (3.03)	9.00 (3.00)	6.67 (2.58)	7.34 (2.71)	9.35 (3.06)	5.86 (2.42)	6.13 (2.46)	7.96 (2.82)	6.96 (2.64)	4.53 (2.13)	7.19 (2.68)
T5 Flubendiamide 20% WDG	400	10.48	4.40 (2.10)	2.62 (1.62)	3.51 (1.87)	2.42 (1.56)	1.19 (1.09)	1.81 (1.34)	1.59 (1.26)	1.10 (1.05)	1.34 (1.16)	1.05 (1.02)	0.57 (0.75)	0.81 (0.90)	1.86 (1.36)
T6 Emamectin Benzoate 5%SG	200	11.08	5.97 (2.44)	6.68 (2.58)	6.32 (2.51)	4.61 (2.15)	3.83 (1.96)	4.22 (2.05)	3.08 (1.75)	2.69 (1.64)	2.89 (1.70)	2.03 (1.42)	1.29 (1.14)	1.66 (1.28)	3.77 (1.94)
T7 Untreated check		15.71	15.58 (3.95)	13.26 (3.64)	14.42 (3.80)	14.39 (3.79)	17.84 (4.22)	16.11 (4.01)	15.07 (3.88)	16.93 (4.11)	16.00 (4.00)	17.23 (4.15)	15.08 (3.88)	16.16 (4.02)	15.67 (3.96)
SE(m)±		(1.69)	(0.33)	(0.32)		(0.41)	(0.42)		(0.41)	(0.35)		(0.31)	(0.30)		(0.32)
CD(p=0.05)		(5.21)	(1.02)	(0.98)		(1.26)	(1.29)		(1.26)	(1.10)		(0.95)	(0.92)		(0.98)
1DBS = One day before spray, Figures in parentheses are √ values.															

Table 2: Field efficacy of different insecticides against *Leucinodes orbonalis* in shoots during 2013-2014

Treatment	Dose (g/ha)	1DBS	Shoot Infestation (%) days after spray application												Mean
			Spray I			Spray II			Spray III			Spray IV			
			7	14	Mean	7	14	Mean	7	14	Mean	7	14	Mean	
T1 Rynaxypyr 18.5%SC	200	10.54	3.52 (1.88)	3.00 (1.73)	3.26	3.18 (1.78)	2.70 (1.64)	2.94	2.43 (1.56)	1.99 (1.41)	2.21	1.94 (1.39)	1.09 (1.04	1.52	2.48 (1.57)
T2 Spinosad 45% SC	200	11.12	8.64 (2.94)	7.45 (2.73)	8.05	7.48 (2.73)	6.69 (2.59)	7.09	6.28 (2.51)	5.02 (2.24)	5.65	4.12 (2.03)	3.32 (1.82)	3.72	6.13 (2.48)
T3 Indoxacarb 15.8% EC	500	12.60	9.99 (3.16)	10.20 (3.19)	10.10	8.72 (2.95)	9.01 (3.00)	10.24	7.85 (2.80)	8.07 (2.84)	7.96	6.84 (2.62)	7.22 (2.69)	7.03	8.83 (2.97)
T4 Abamectin 1.9% EC	500	13.25	11.98 (3.46)	12.02 (3.47)	12.00	10.55 (3.25)	9.92 (3.15)	10.24	9.81 (3.13)	9.19 (3.03)	9.50	8.53 (2.92)	8.01 (2.83)	8.27	10.00 (3.16)
T5 Flubendiamide 20% WDG	400	10.02	3.13 (1.77)	2.52 (1.59)	2.83	2.62 (1.62)	2.00 (1.41)	2.31	1.23 (1.11)	1.06 (1.03)	0.15	1.07 (1.03)	0.72 (0.85)	0.90	1.55 (1.24)
T6 Emamectin Benzoate 5%SG	200	10.90	5.94 (2.44)	4.96 (2.23)	5.45	4.95 (2.22)	3.44 (1.85)	4.20	4.19 (2.05)	3.43 (1.85)	3.81	2.68 (1.64)	1.25 (1.12)	1.97	3.86 (1.96)
T7 Untreated check		18.49	12.14 (3.48)	10.67 (3.27)	11.41	10.11 (3.18)	13.53 (3.68)	11.82	12.04 (3.47)	13.25 (3.64)	12.65	11.01 (3.32)	10.89 (3.30)	10.95	11.71 (2.49)

SE(m)±		(2.75)	(0.36)	(0.35)		(0.32)	(0.38)		(0.45)	(0.39)		(0.32)	(0.31)		(0.39)
CD(p=0.05)		(8.47)	(1.11)	(1.08)		(0.98)	(1.17)		(1.39)	(1.20)		(0.99)	(1.95)		(1.20)

In 2012-13 (Table 3), among all the insecticides, Flubendiamide treatment after seven and fourteen days, recorded lowest percent fruit infestation (1.38, 6.67%) and highest fruit infestation (10.13, 22.16%) found in Abamectin by the shoot and fruit borer as compared to (15.69, 48.00%) in untreated control. Flubendiamide recorded lowest mean percent fruit infestation in all the four sprays (4.03, 14.62, 19.19 and 18.93%). During 2013-14 (Table 4), percent fruit infestation was lowest when treated with Flubendiamide after seven and fourteen days (2.87, 6.63%) and highest fruit infestation (11.93, 19.82%) found in Abamectin by the shoot and fruit borer than untreated check (24.61, 38.95%) with a lowest mean percent fruit infestation in all the four sprays(4.75, 8.62, 11.15 and 19.01%) respectively.

Fruit yield in both the years recorded highest when treated with Flubendiamide and lowest when treated with Abamectin. During 2012-13, Flubendiamide recorded highest fruit yield with 345 q/ha followed by 333q/ha (T1) followed by 320 q/ha (T6) against 141q/ha in untreated check. During 2013-14, highest yield 338q/ha in T5 followed by 321 q/ha in T1 against 156q/ha untreated check was recorded.

Table 3: Field efficacy of different insecticides against *Leucinodes orbonalis* in fruits during 2012-2013

Treatment	Dose (g/ha)	1 DBS	Fruit Infestation (%) days after spray application												Mean	Yield (q/ha)
			Spray I			Spray II			Spray III			Spray IV				
			7	14	Mean	7	14	Mean	7	14	Mean	7	14	Mean		
T1 Rynaxypyr 18.5%SC	200	1.70	2.15 (8.33)	7.68 (16.11)	4.92	15.42 (23.11)	18.48 (25.48)	16.95	19.15 (25.99)	20.81 (27.13)	19.98	19.82 (26.42)	20.14 (26.64)	19.98	16.28 (23.81)	333.00
T2 Spinosad 45% SC	200	2.40	5.80 (13.94)	11.58 (19.91)	8.69	24.02 (29.33)	26.00 (30.66)	25.01	27.52 (31.63)	27.96 (31.88)	27.74	26.40 (30.92)	27.10 (31.37)	26.75	22.05 (28.04)	309.00
T3 Indoxacarb 15.8% EC	500	7.15	8.07 (16.54)	19.30 (26.06)	13.69	27.10 (31.37)	28.54 (32.27)	27.82	29.22 (32.71)	30.62 (33.58)	29.92	25.23 (30.13)	27.65 (31.76)	26.44	24.47 (29.67)	280.00
T4 Abamectin 1.9% EC	500	10.00	10.13 18.53)	22.16 (28.11)	16.15	29.28 (32.77)	30.83 (33.71)	30.06	35.42 (36.51)	38.21 (38.17)	36.82	38.86 (38.53)	40.20 (39.35)	39.53	30.64 (33.58)	268.00
T5 Flubendiamide 20% WDG	400	1.12	1.38 6.80)	6.67 (15.00)	4.03	13.06 (21.22)	16.18 (23.73)	14.62	18.65 (25.62)	19.73 (26.35)	19.19	19.23 (25.99)	18.62 (25.55)	18.93	14.19 (22.14)	345.00
T6 Emamectin Benzoate 5%SG	200	2.00	2.80 (9.63)	8.02 (16.64)	5.41	16.18 (23.73)	19.74 (26.35)	17.96	21.35 (27.56)	23.07 (28.73)	22.21	20.71 (27.06)	21.63 (27.69)	21.17	16.68 (24.12)	320.00
T7 Untreated check		14.72	15.69 (23.34)	48.00 (43.85)	31.85	68.71 (55.98)	49.02 (44.43)	58.87	61.59 (51.71)	48.75 (44.25)	55.17	62.14 (52.00)	65.83 (54.21)	63.99	52.47 (46.43)	141.00
SE(m)± ±		(4.40)	(1.39)	(1.06)		(1.81)	(1.40)		(1.32)	(1.02)		(1.24)	(1.18)		(1.27)	(9.74)
CD (P= 0.05)		(13.56	(4.28)	(3.27)		(5.58)	(4.31)		(4.07)	(3.14)		(3.82)	(3.64)		(3.91)	(30.00)
1 DBS = One day before spray																

Figures in parentheses are sin√% values.

Table 4: Field efficacy of different insecticides against *Leucinodes orbonalis* in fruits during 2013-2014

Treatment	Dose (g/ha)	1DBS	Fruit Infestation (%) days after spray application												Mean	Yield (q/ha)
			Spray I			Spray II			Spray III			Spray IV				
			7	14	Mean	7	14	Mean	7	14	Mean	7	14	Mean		
T1 Rynaxypyr 18.5%SC	200	12.78	3.33 (10.47)	7.40 (15.79)	5.37	7.81 (16.22)	12.81 (20.96)	10.31	10.41 (18.81)	15.99 (23.50)	13.20	18.35 (25.40)	23.79 (29.20)	21.07	12.49 (20.70)	238.00
T2 Spinosad 45% SC	200	14.27	7.52 (15.89)	10.50 (18.91)	9.01	14.36 (22.22)	19.52 (26.21)	16.34	17.54 (24.73)	24.20 (29.47)	20.87	26.56 (31.05)	36.30 (37.05)	31.43	19.41 (26.13)	147.00
T3 Indoxacarb 15.8% EC	500	12.22	9.32 (17.76)	13.75 (21.72)	11.54	19.50 (26.21)	27.99 (31.88)	23.75	34.72 (36.09)	39.40 (38.88)	37.06	43.11 (41.03)	49.07 (44.48)	46.09	29.61 (32.96)	128.00
T4 Abamectin 1.9% EC	500	11.00	11.39 (19.64)	19.82 (26.42)	15.61	26.84 (31.18)	30.38 (33.46)	28.61	39.36 (38.88)	46.80 (43.17)	43.08	50.75 (45.46)	54.43 (47.52)	52.59	34.97 (36.21)	121.00
T5 Flubendiamide 20% WDG	400	9.00	2.87 (9.81)	6.63 (14.89)	4.75	5.49 (13.56)	11.75 (20.09)	8.62	8.71 (17.26)	13.58 (21.64)	11.15	17.79 (24.95)	20.22 (26.71)	19.01	10.88 (19.28)	298.00
T6 Emamectin Benzoate 5%SG	200	10.89	4.49 (12.25)	8.68 (17.16)	6.59	8.97 (17.36)	14.46 (22.38)	11.72	12.88 (21.05)	18.92 (25.77)	15.90	20.61 (26.99)	26.65 (31.05)	23.63	14.46 (22.38)	189.00
T7 Untreated check		16.67	24.61 (29.73)	38.95 (38.59)	31.78	20.17 (26.71)	39.20 (38.76)	29.69	64.43 (53.37)	56.81 (48.91)	60.62	48.70 (44.25)	47.25 (43.45)	47.97	42.52 (43.69)	95.00
SE(m)± CD(p=0.05)		(2.49) (7.67)	(1.18) (3.64)	(1.02) (3.14)		(1.57) (4.84)	(0.70) (2.16)		(1.24) (3.82)	(1.39) (4.28)		(1.31) (4.04)	(1.95) (6.00)		(1.21) (3.73)	(36.00) (110.00)
1 DBS = One day before spray, Figures in parentheses are sin√% values.																

Benefit- Cost Ratio of Insecticidal treatments of brinjal

Comparative economics of insecticide treatments during 2013 and 2014 was obtained by calculating the benefit-cost ratio in both the years and result has been presented in Table 5 and 6 respectively**.** In 2013, highest benefit-cost ratio was obtained in case of Flubendiamide 20 WDG (1: 11.74) followed by Rynaxypyr 18.5SC (1: 10.05), Emamectin benzoate 5SG (1: 9.30), Spinosad 45SC (1: 9.02), Indoxacarb 15.8EC (1: 8.77), Abamectin 1.9EC (1: 8.62) and 1: 2.97 in control. In 2014, the highest benefit-cost ratio was obtained in case of Flubendiamide 20 WDG (1: 11.52) followed by Rynaxypyr 18.5SC (1: 10.11), Emamectin benzoate 5SG (1: 9.28), Spinosad 45SC (1: 9.07), Indoxacarb 15.8EC (1: 8.72), Abamectin 1.9EC (1: 8.60) and 1 : 3.03 in control, gave low benefit-cost ratio.

Table 5: Economics of different insecticides against *Leucinodes orbonalis* in brinjal during 2013

Treatments	Dose (g/ha)	Yield (q/ha)	Increase in yield	cost of produce (Rs)	Cost of protection (Rs)	Net profit (Rs)	Cost benefit ratio (C:B)
Rynaxypyr	200	333.00	192.00	333000.00	31045.00	311955.00	1:10.05
Spinosad	200	309.00	168.00	309000.00	30838.32	278161.68	1:9.02
Indoxacarb	50	280.00	139.00	280000.00	28657.16	251342.84	1:8.77
Abamectin	500	268.00	127.00	268000.00	27858.63	240141.37	1:8.62
Flubendiamide	200	345.00	204.00	345000.00	27078.00	317922.00	1:11.74
Emamectin benzoate	200	320.00	179.00	320000.00	31067.96	288932.04	1:9.30
Untreated check		141.00		141000.00	35516.37	105483.63	1:2.97

Table 6: Economics of different insecticides against *Leucinodes orbonalis* in brinjal during 2014

Treatments	Dose (g/ha)	Yield (q/ha)	Increase in yield	cost of produce (Rs)	Cost of protection (Rs)	Net profit (Rs)	Cost benefit ratio (C:B)
Rynaxypyr	200	321.00	165.00	321000.00	28892.89	292107.11	1:10.11
Spinosad	200	307.00	151.00	307000.00	30486.59	276513.41	1:9.07
Indoxacarb	50	288.00	132.00	288000.00	29629.63	258370.37	1:8.72
Abamectin	500	271.00	115.00	271000.00	28229.17	242770.83	1: 8.60
Flubendiamide	200	338.00	182.00	338000.00	26996.80	311003.20	1:11.52
Emamectin benzoate	200	316.00	160.00	316000.00	30739.30	285260.70	1:9.28
Untreated check		156.00		156000.00	38709.68	117290.32	1:3.03

The highest fruit yield and maximum per cent reduction in shoot and fruit borer was obtained in plots treated with Flubendiamide and Rynaxypyr followed by Emamectin benzoate. Misra, 2000 [7] found that two new insecticides, viz., Rynaxypyr 20% SC and Flubendiamide 480 SC could reduce maximum percent shoot and fruit infestation and healthy fruit yield was significantly highest which is in agreement with the present findings. (Naik, 2008 [9]; Nayak, 2011 [10] found that Spinosad was most effective in reducing percent shoot and fruit infestation in brinjal which is in agreement with the present findings. Latif *et al*., 2009 [7] found that Flubendiamide reduced the highest percent of shoot (87.46%) and fruit (81.43%) infestation over control and also produced the highest healthy (13.26 t/ha) and total fruit yield (13.77 t/ha) of brinjal which is in agreement with the present findings. Jagginavar *et al.*, 2009 [5] concluded that Flubendiamide was significantly superior in recording maximum fruit yield of 29.42 t/ha which is in agreement with the present findings. Pachori, 2013 [15] found that Rynaxypyr gave a good yield of 394.56 q/ha which is in agreement with the present findings. Coming to benefit-cost ratio, (Latif *et al*., 2009 [7]; Abdullah *et al.*, 2014 [2] found that Flubendiamide treated plots obtained highest benefit-cost ratio (7.45) which is in agreement with the results of present investigation.

Conclusion

Among the insecticides evaluated against the brinjal shoot and fruit borer, Flubendiamide was found to be the most effective one in respect to reducing the infestation of the borer and increase in yield. This was followed by Rhynaxypyr and Emamectin benzoate which were almost equal in their effectiveness in controlling the shoot and fruit borer and reduction in infestation and were at par with Flubendiamide. Spinosad proved to be the next best insecticide followed by Indoxacarb. Abamectin was recorded as the least effective among the insecticides. But all the insecticides were significantly superior to the untreated control and could reduce the pest infestation substantially with increased yield. Hence in the IPM programme for brinjal any two or three of the insecticide can be used alternatively for better control of the noxious pest.

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