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Evaluation of Sequences of Insecticides, Biopesticides and Bioagents Against Major Insect Pests of Brinjal, *Solanum Melongena* Linn.

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Abstract

Out of ten sequences of insecticides, biopesticides and bioagents tested at S.K.N. College of Agriculture, Jobner (Rajasthan), the T_3 (imidacloprid 0.05%+ *Beauveria bassiana* 1 g l^{-1}+ spinosad 0.01%+ two inundative releases of *Chrysoperla zastrowi arabica* 75,000 eggs ha^{-1} + destruction of infested shoots and fruits), T_9 (dimethoate 0.03% with alternate spray of endosulfan 0.005% (check), and T_7 (acephate 0.037% + *Metarhizium anisopliae* 1 g l^{-1} + spinosad + *Chrysoperla.zastrowi arabiba* + destruction of infested shoots and fruits) afforded highest protection in controlling jassid, *Amrasca biguttula biguttula* (Ishida) and whitefly, *Bemisia tabaci* (Genn.) and found at par one another. The sequences T_2 (*Beauveria bassiana* + NSKE 5% + spinosad+ two inundative releases of *Trichogramma chilonis* 1.5 lac ha^{-1}+ destruction of infested shoots and fruits), T_9 (dimethoate with alternate spray of endosulfan (check), T_4 (*Beauveria bassiana*+ NSKE+ acephate + *Bacillus thuringiensis* var. *kurstaki, Btk* 1 ml l^{-1} + destruction of infested shoots and fruits), T_6 (*M. anisopliae* + NSKE+ acephate + *T. chilonis* + destruction of infested shoots and fruits), and T_8 (*Metarhizium anisopliae* + NSKE+ spinosad + *Btk* +destruction of infested shoots and fruits) revealed low shoot and fruit damage of 4.58-5.04, 6.11-7.52 per cent, respectively due to shoot and fruit borer, *Leucinodes orbonalis* Guen., formed a non-significant group and differed significantly over other treatments. The highest fruit yield of 188.93 q ha^{-1} was observed in T_2 which was found at par with T_4, T_9, T_6 and T_8. The benefit cost ratio was highest in the sequence T_9 (30.46) followed by T_6 (21.39) and T_4 (18.21).

Keywords: *Amrasca Biguttula Biguttula, Bemisia tabaci, Leucinodes orbonalis*, Insecticides, Biopesticides.

Introduction

The Brinjal (egg plant or aubergine), *Solanum melongena* Linn. (Family: Solanaceae) is attacked by as many as 26 species of insect and non-insect pests right from germination to harvesting (Vevai, 1970). Among these, shoot and fruit borer, *Leucinodes orbonalis* Guen.; jassid, *Amrasca biguttula biguttula* (Ishida); aphid, *Aphis gossypii* Glover; lace wing bug, *Urentius echinus* Distant; epilachna beetle, *Epilachna vigintioctopunctata* Fab., *Bemisia tabaci* (Genn.) and stem borer, *Euzophera perticella* Rag. are major constraints in achieving potential yield. In order to prevent the loss caused by insect pests and to harvest a quality produce, it is essential to manage the pest populations at appropriate time with suitable control measures. The chemical control has been suggested by many researchers to combat with the insect pests of brinjal (Deore and Patil, 1995; Singh *et al*., 1996; Abrol and Singh, 2003; Panda *et al.*, 2005) but due to one or the other reasons, could not become universal remedy. Therefore, development of integrated pest management (IPM) modules may be considered as one of the measures controlling the insect pests. The insect natural enemies have received much less attention as natural control agents. The use of predators, parasitoids and pathogens may prove to be better choice among various groups of bioagents. The green lacewing, *Chrysoperla zastrowi arabica* Henry *et al.* (Chrysopidae, Neuroptera) is an efficient predator of aphids, whiteflies, jassids, eggs and neonate larvae of insect pests on different crops. The *Trichogramma chilonis* Ishii (Trichogrammatidae, Hymenoptera) has prime position among the parasitoid fauna of lepidopterous eggs (Gautam, 1994). A perusal of available literature revealed that very little attention has been paid toquantify the response of natural enemies against insect pests of brinjal crop. The clipping or the destruction of infested parts is one of the managerial practices which can be done during interculture operations, like irrigation, hoeing-weeding and fruit harvesting, and needs evaluation in the sequences of insecticides, biopesticides and bioagents to develop effective IPM module. Therefore, the study was conducted at S.K.N. College of Agriculture, Jobner on this aspect.

Materials and Methods

The experiment was laid out in a simple Randomized Block Design (RBD) with nine sequences and an untreated control, each replicated thrice. The plot size was 3.0 x 2.4 m^2 keeping row to row and plant to plant distance of 60 cm each. An isolation zone of 1.0 m was maintained between the plots. The brinjal variety 'Pusa purple round' was used in the experiment and transplanted on 8th July, 2010. The recommended package of practices was followed to raise the crop.

In the present study, nine sequences of insecticidal molecules, biopesticides and bioagents, *viz.,* T_1 (imidacloprid 0.005%+ *B. bassiana* 1 g l^{-1} + spinosad 0.01%), T_2 (*B. bassiana*+ NSKE 5% + spinosad + two inundative releases of *Trichogramma chilonis* 1.5 lac eggs ha^{-1} + destruction of infested shoots and fruits), T_3 (imidacloprid+ *B. bassiana*+ spinosad + two inundative releases of *Chrysoperla zastrowi arabica* 75,000 eggs ha^{-1} + destruction of infested shoots and fruits), T_4 (*B. bassiana*+ NSKE+ acephate 0.037% + *Bacillus thuringiensis* var. *kurstaki* 1 ml l^{-1} + destruction of infested shoots and fruits), T_5 (acephate+ *M. anisopliae* 1 g l^{-1} + spinosad), T_6 (*M. anisopliae* + NSKE+ acephate + *T. chilonis* + destruction of infested shoots and fruits), T_7 (acephate + *M. anisopliae* + spinosad + *C. zastrowi arabica* + destruction of infested shoots and fruits), T_8 (*M. anisopliae* + NSKE+ spinosad + *Btk* 1 ml l^{-1} + destruction of infested shoots and fruits), T_9 (dimethoate 0.03% with alternate spray of endosulfan 0.05% (check) and T_{10} (a control or untreated) against major insect pests of brinjal were evaluated. Two inundative releases of *Trichogramma chilonis* and *Chrysoperla zastrowi arabica* @ 1.5 lac eggs ha^{-1} and 75,000 eggs ha^{-1}, respectively were made at weekly interval. The spray was done by a knap sack sprayer. The quantity of spray solution was 600 l ha^{-1} in each spray application. In each sequence proper gap between various techniques to be followed was kept.

The populations of major sucking insect pests (jassid, *A. biguttula biguttula* and whitefly, *B. tabaci*) were recorded one day before and 1 and 7 days after the application of treatments (first spray). The second and third spray was done at three weeks interval and again the observations were recorded as in the case of first spray. The mean population of sucking insect pests was worked out. The shoot damage (shoot and fruit borer) was recorded at weekly interval and fruit damage at each picking. The mean shoot and fruit damage of the season was worked out. The yield data were recorded after harvesting of the crop and converted per hectare. The data of population of sucking insect pests were transformed into $\sqrt{(X+0.5)}$ values and per cent damage of shoot and fruit borer into angular values, and subjected to analysis of variance. To determine the most effective and economical treatment, the net return and benefit-cost ratio was worked out by taking the expenditure on individual insecticidal treatment and the corresponding yield into account.

Results and Discussion

The pooled population of jassid, *A. biguttula biguttula* (*kharif,* 2010 and 2011) revealed non-significant difference between T_3 (2.36 jassids/ 3 leaves), T_9 (2.65 jassids/ 3 leaves) and T_7 (2.68 jassids/ 3 leaves) as evident in table-1. The next effective treatments were T_1 (3.47 jassids/ 3 leaves) and T_5 (3.48 jassids /3 leaves). The rest of the treatments ranked in the lower order of efficacy in reducing the jassid population, although, all the treatment revealed significant difference over control (9.50 jassids /3 leaves). The present findings partially corroborated with the findings of Kadam (2005) who reported that insecticidal control proved to be superior over the IPM schedule after three days of application, however, after seven days, the IPM schedule comprising *Trichoderma* ST+ imidacloprid+ NSKE+ *Trichogramma chilonis*+ imidacloprid proved effective in suppressing the nymphal population of *A. biguttula biguttula*.

The two years pooled data of whitefly, *B. tabaci* revealed low population in T_3 (2.96 whiteflies/ 3 leaves), T_7 (3.00 whiteflies/ 3 leaves) and T_9 (3.12 whiteflies/ 3 leaves) which formed an effective group (Table-1). The high population was observed in T_8, T_4, T_6 and T_2 which formed a non-significant group and differed significantly from control (12.04 whiteflies/ 3 leaves). The present findings got partial support from the observations of Kadam (2005) who reported that sequences comprising chemical insecticides alone and IPM schedules were found at par after three and seven days of application against *B. tabaci*. Satpute *et al.* (2002) reported that treatment with Spark (deltamethrin+ triazophos) followed by azadirachtin or *B.t.* or *vice-versa* significantly controlled the sucking pest complex.

In the pooled data, the sequence T_2 (4.58%) was found at par with T_6 (4.67%), T_4 (4.70%), T_8 (4.86%) and T_9 (5.04%) in exhibiting shoot damage due to *L. orbonalis*, these formed a non-significant group and differed significantly over other sequences (Table-2). The sequences T_3, T_7, T_5, T_1 formed a non-significant group and revealed high shoot damage, *viz.,* 8.67, 8.71, 9.50 and 9.91 per cent, respectively and differed significantly over the control, T_{10} (20.69%). The sequences T_2, T_9, T_4, T_6 and T_8 revealed fruit damage of 6.11, 6.71, 6.49, 7.05 and 7.52 per cent, respectively, formed a non-significant group and differed significantly over other treatments. Kadam (2005) reported the minimum fruit damage (13.1%) upon treatment *Trichoderma* ST+ NSKE+ *Bt*.+ *Trchogramma chilonis* + NSKE which was found at par with the schedule *Trichoderma* ST+ spinosad+ NSKE+ *Bt*. + spinosad, *Trichoderma* ST+ *Verticillium lecanii*+ NSKE+ B.t.+ *Trichogramma chilonis* and *Trichoderma* ST+ imidacloprid+ NSKE+ B.t.+ *Trichogramma chilonis.*

The highest fruit yield was registered in T_2 (188.93 q ha^{-1}) which was found at par with T_4, T_9, T_6 and T_8. The lowest yield was observed in the untreated control (103.63 q ha^{-1}) as evident in table-3. These results were in partial conformity with the findings of Bajpai *et al.* (2005) who reported use of insecticides + destruction of infested parts as superior treatment. Rath and Dash (2005) reported that IPM system resulted in high yield of brinjal and benefit cost ratio than the conventional system during both the summer and *kharif* seasons. The highest net return was obtained in T_4 (Rs. 47,552.10) followed by T_9 (Rs. 46,224.48) and T_6 (Rs. 45,036.60) as evident in table-4. The benefit cost ratio was highest in the sequence T_9 (30.46) followed by T_6 (21.39) and T_4 (18.21). It is also evident that the *B. bassiana, M. anisopliae* and *Btk* as individual treatments were not so effective but in sequences (T_4 and T_6) with NSKE, acephate and destruction of infested shoots and fruits exhibited satisfactory benefit cost ratio and, therefore, have ample scope to replace the sole chemical control (T_9) keeping in view the environmental safety. The high benefit cost ratio exhibited by in these sequences could be possible due to low price of these products as compared to spinosad which was included in other sequences (T_1, T_2, T_3, T_5, T_7 and T_8). In the present investigation, the sequence of chemical insecticides, T_9 registered highest benefit cost ratio, which got support from the findings of Singh *et al.* (2008).

Conclusion

The T_3 (imidacloprid 0.05%+ *B. bassiana* 1 g l^{-1}+ spinosad 0.01%+ two inundative releases of *Chrysoperla zastrowi arabica* 75,000 eggs ha^{-1} + destruction of infested shoots and fruits), T_9 (dimethoate 0.03% with alternate spray of endosulfan 0.005% (check), and T_7 (acephate 0.037% + *M. anisopliae* 1 g l^{-1} + spinosad + *C. zastrowi arabica* + destruction of infested shoots and fruits) afforded highest protection in controlling jassid, *Amrasca biguttula biguttula* (Ishida) and whitefly, *Bemisia tabaci* (Genn.) and found at par one another. The sequences T_2 (*B. bassiana*+ NSKE 5% + spinosad+ two inundative releases of *Trichogramma chilonis* 1.5 lac ha^{-1}+ destruction of infested shoots and fruits), T_9 (dimethoate with alternate spray of endosulfan (check), T_4 (*B. bassiana*+ NSKE+ acephate + *Bacillus thuringiensis* var. *kurstaki, Btk* 1 ml l^{-1} + destruction of infested shoots and fruits), T_6 (*M. anisopliae* + NSKE+ acephate + *T. chilonis* + destruction of infested shoots and fruits), and T_8 (*M. anisopliae* + NSKE+ spinosad + *Btk* +destruction of infested shoots and fruits) revealed low shoot and fruit damage of 4.58-5.04, 6.11-7.52 per cent, respectively due to shoot and fruit borer, *Leucinodes orbonalis* Guen., formed a non-significant group and differed significantly over other treatments. The highest fruit yield of 188.93 q ha^{-1} was observed in T_2 which was found at par with T_4, T_9, T_6 and T_8. The benefit cost ratio was highest in the sequence T_9 (30.46) followed by T_6 (21.39) and T_4 (18.21).

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Table-1

Population of *Amrasca biguttula biguttula* (Ishida) and *Bemisia tabaci* (Genn.) as influenced by different sequences of insecticides, biopesticides and bioagents

Sequences	***A. biguttula biguttulal* three leaves**			***B. tabacil* three leaves**		
	2010	**2011**	**Pooled**	**2010**	**2011**	**Pooled**
T_1 (Imidacloprid+ *Beauveria bassiana* + Spinosad)	3.38 (1.84)	3.56 (1.89)	3.47 (1.86)	4.12 (2.03)	4.28 (2.07)	4.20 (2.05)
T_2 **(** *B. bassiana*+ NSKE+ Spinosad+ *Trichogramma chilonis* + Destruction of infested shoots and fruits)	4.07 (2.02)	4.18 (2.04)	4.13 (2.03)	5.40 (2.32)	5.52 (2.34)	5.46 (2.34)
T_3 **(**Imidacloprid+ *B. bassiana*+ Spinosad + *Chrysoperla zastrowi arabica* + Destruction of infested shoots and fruits)	2.23 (1.49)	2.49 (1.58)	2.36 (1.54)	2.84 (1.69)	3.08 (1.75)	2.96 (1.72)
T_4 **(***B. bassiana*+ NSKE+ Acephate + *Bacillus thuringiensis* var. *kurstaki* (Btk) + Destruction of infested shoots and fruits)	4.28 (2.07)	4.40 (2.10)	4.34 (2.08)	5.60 (2.37)	5.71 (2.39)	5.66 (2.38)
T_5 (Acephate+ *Metarhizium anisopliae* + Spinosad)	3.44 (1.85)	3.52 (1.88)	3.48 (1.87)	4.15 (2.04)	4.33 (2.08)	4.24 (2.06)
T_6 (*M. anisopliae* + NSKE+ Acephate + *T. chilonis* + Destruction of infested shoots and fruits)	4.10 (2.04)	4.23 (2.06)	4.17 (2.04)	5.42 (2.33)	5.54 (2.35)	5.48 (2.34)
T_7 **(**Acephate + *M. anisopliae* + Spinosad + *C. zastrowi arabica* + Destruction of infested shoots and fruits)	2.54 (1.59)	2.82 (1.68)	2.68 (1.64)	2.90 (1.72)	3.10 (1.76)	3.00 (1.73)
T_8 (*M. anisopliae* + NSKE+ Spinosad + *Btk* +Destruction of infested shoots and fruits)	4.30 (2.07)	4.46 (2.11)	4.38 (2.09)	5.64 (2.37)	5.75 (2.40)	5.70 (2.39)
T_9 (Dimethoate with alternate spray of endosulfan (Check)	2.61 (1.62)	2.68 (1.64)	2.65 (1.63)	3.06 (1.75)	3.18 (1.78)	3.12 (1.77)
T_{10} **(** Control (Untreated)	9.24 (3.04)	9.75 (3.12)	9.50 (3.09)	11.60 (3.41)	12.48 (3.53)	12.04 (3.47)
S.Em.±	0.07	0.08	0.07	0.08	0.07	0.09
CD (p = 0.05)	0.20	0.23	0.22	0.22	0.22	0.27

Figures in the parentheses are √X+0.5 values

Table -2 Efficact of sequences of insecticides, biopesticides and bioagents against shoot and fruit borer, *Leucinodes orbonalis* Guen.

Treatments	**Shoot damage (%)**			**Fruit damage (%)**		
	2010	**2011**	**pooled**	**2010**	**2011**	**Pooled**
T_1 (Imidacloprid+ *B. bassiana* + Spinosad)	8.85 (17.31)	10.96 (19.33)	9.91 (18.35)	12.80 (20.96)	14.60 (22.46)	13.70 (21.72)
T_2 **(** *B. bassiana*+ NSKE+ Spinosad+ *Trichogramma chilonis* + Destruction of infested shoots and fruits)	3.94 (11.45)	5.21 (13.19)	4.58 (12.36)	5.48 (13.54)	6.74 (15.05)	6.11 (14.31)
T_3 **(**Imidacloprid+ *B. bassiana*+ Spinosad + *Chrysoperla zastrowi arabica* + Destruction of infested shoots and fruits)	7.60 (16.00)	9.74 (18.19)	8.67 (17.12)	11.92 (20.20)	14.26 (22.19)	13.09 (21.21)
T_4 **(***B. bassiana*+ NSKE+ Acephate + *Bacillus thuringiensis* var. *kurstaki* + Destruction of infested shoots and fruits)	4.00 (11.54)	5.40 (13.44)	4.70 (12.52)	5.64 (13.74)	7.34 (15.72)	6.49 (14.76)
T_5 (Acephate+ M. anisopliae + Spinosad)	8.48 (16.93)	10.52 (18.93)	9.50 (17.95)	12.45 (20.66)	13.99 (21.96)	13.22 (21.32)
T_6 (*M. anisopliae* + NSKE+ Acephate + *T. chilonis* + Destruction of infested shoots and fruits)	4.11 (11.70)	5.23 (13.22)	4.67 (12.48)	6.15 (14.36)	7.95 (16.38)	7.05 (15.40)
T_7 **(**Acephate + *M. anisopliae* + Spinosad + *C. zastrowi arabica* + Destruction of infested shoots and fruits)	8.00 (16.43)	9.42 (17.87)	8.71 (17.17)	12.50 (20.70)	14.00 (21.97)	13.25 (21.35)
T_8 (*M. anisopliae* + NSKE+ Spinosad + Btk +Destruction of infested shoots and fruits)	4.25 (11.90)	5.46 (13.51)	4.86 (12.74)	6.90 (15.23)	8.14 (16.58)	7.52 (15.92)
T_9 (Dimethoate with alternate spray of endosulfan (Check)	4.40 (12.11)	5.68 (13.79)	5.04 (12.97)	6.22 (14.44)	7.20 (15.56)	6.71 (15.01)
T_{10} **(** Control (Untreated)	19.72 (26.36)	21.65 (27.73)	20.69 (27.06)	38.50 (38.35)	40.24 (39.37)	39.37 (38.86)
S.Em.±	0.77	0.91	0.80	0.94	1.02	0.90
CD (p = 0.05)	2.24	2.65	2.33	2.75	2.98	2.63

Figures in the parentheses are angular values

Table-3

Effect of sequences of insecticides, biopesticides and bioagents on fruit yield of brinjal , *Solanum melongena*

Sequences	Fruit yield (q ha^{-1})		
	2010	**2011**	**Pooled**
T_1 (Imidacloprid+ *B. bassiana* + Spinosad)	160.10	157.00	158.55
T_2 (*B. bassiana*+ NSKE+ Spinosad+ *Trichogramma chilonis* + Destruction of infested shoots and fruits)	190.15	187.70	188.93
T_3 (Imidacloprid+ *B. bassiana*+ Spinosad + *Chrysoperla zastrowi arabica* + Destruction of infested shoots and fruits)	169.78	167.10	168.44
T_4 (*B. bassiana*+ NSKE+ Acephate + *Bacillus thuringiensis* var. *kurstaki* + Destruction of infested shoots and fruits)	189.70	186.92	188.31
T_5 (Acephate+ M. anisopliae + Spinosad)	164.96	162.24	163.60
T_6 (*M. anisopliae* + NSKE+ Acephate + *T. chilonis* + Destruction of infested shoots and fruits)	185.04	182.45	183.75
T_7 (Acephate + *M. anisopliae* + Spinosad + *C. zastrowi arabica* + Destruction of infested shoots and fruits)	163.48	161.00	162.24
T_8 (*M. anisopliae* + NSKE+ Spinosad + Btk +Destruction of infested shoots and fruits)	184.54	182.18	183.36
T_9 (Dimethoate with alternate spray of endosulfan (Check)	186.00	183.50	184.75
T_{10} **(** Control (Untreated)	106.72	103.63	105.18
S.Em.$\pm$	6.95	6.80	6.81
CD (p = 0.05)	20.29	19.84	19.86

Figures in the parentheses are angular values-

Table-4 Comparative economics of sequences of insecticides, biopesticides and bioagents against major insect pests of brinjal (Pooled *kharif,* 2010 and *kharif,* 2011)

Sequences	**Conc. (%)/ doses**	**Yield (q ha^{-1})**	**Increase in yield over control (q ha^{-1})**	**Return of increased yield (Rs)**	**Total expenditure (Rs)**	**Net return (Rs ha^{-1})**	**B:C ratio**
T_1 - Imidacloprid + *B. bassiana* + Spinosad	0.005	158.55	53.37	32022	28284.90	3737.10	0.13: 1
T_2 - *B. bassiana*+NSKE + Spinosad+*T. chilonis*+DISF	0.037	188.93	83.75	50250	28840.50	21409.50	0.74: 1
T_3 - Imidaclorpid + *B. bassiana* +Spinosad + *C. zastrowi arabica* + DISF	1 ml l^{-1}	168.44	63.26	37956	28828.65	9127.35	0.32: 1
T_4 -*B. bassiana* + NSKE + Acephate + *Btk* + DISF	1g l^{-1}	188.31	83.13	49878	2595.90	47282.10	18.21: 1
T_5 -Acephate + *M. anisopliae* + Spinosad	1g l^{-1}	163.60	58.42	35052	28085.40	6966.60	0.25: 1
T_6 - *M. anisopliae*+NSKE+Acephate+*T. chilonis*+ DISF	5.0	183.75	78.57	47142	2105.40	45036.60	21.39: 1
T_7 - Acephate + *M. anisopliae* + Spinosad + *C. zastrowi arabica* + DISF	5.0	162.24	57.06	34236	28639.15	5596.85	0.20: 1
T_8 -*M. anisopliae* + NSKE + Spinosad +*Btk*+ DISF	0.01	183.36	78.18	46908	29310	17598.00	0.60: 1
T_9 -Dimethoate with alternate spray of endosulfan (check)	0.03/0.05	184.75	79.57	47742	1517.52	46224.48	30.46: 1
T_{10} -Control (untreated)	-	105.18	-	-	-	-	-

DISF: Destruction of infested shoots and fruits