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Efficacy of different treatment modules against tomato fruit borer, *Helicoverpa armigera* Hubner on tomato

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Abstract
Seven different treatment modules were laid out in randomized block design (RBD) consisting of botanicals *viz*., Neem seed Extract 5%, Azadirachtin 10,000 ppm, Azadirachtin 300 ppm and bio-pesticides like HaNPV 250 LE/ha, *Beauveria bassiana* 1 x 10^8 CFU, *Metarhizium anisopliae* 1 x 10^8 CFU, *Bacillus thuringiensis* 1000 g/ha and *Trichogramma chilonis* @ 1.5 lakh/ha along with untreated control at days after planting (DAP) in each module for the management of *H. armigera*. The observations on tomato fruit borer infestation and it's natural enemies were recorded after the initiation of fruit formation on the plant. The treatment module M5 (Application of Azadirachtin 10,000 ppm @ 3 ml/lit at 35 and 45 DAP, Application of HaNPV 250 LE at 55 DAP and Release of *T. chilonis* @ 1.5 lakh/ha at 65, 75 and 85 DAP) had shown the positive impact against tomato fruit borer. The treatment module M4 and M3 were found promising in minimizing the percent fruit infestation of tomato fruit borer. Similarly the treatment modules M5, M4 and M3 were found safer to natural enemies as well as proved to be promising in retaining the spider population.

Keywords: *Helicoverpa armigera* botanicals, bio-pesticides, *Trichogramma chilonis,* natural enemies

Introduction
Tomato, *Lycopersicon esculentum* Mill, is an important and widely used vegetable crop. It is very nutritive and delicious; very few vegetables can match its nutritional value. Tomato is one of the most important vegetable crop cultivated for its fleshy fruits and considered as important commercial and dietary vegetable crop. It is short duration crop and gives high yield, it is important from economic point of view and hence area under its cultivation is increasing day by day. The major constrain in achieving maximum yield potential is the menace of insect pests. The crop is attacked by many pests, out of which tomato fruit borer (*H. armigera* Hubner), Tomato leaf miner (*L. trifolii* Burgess) and Pinworm (*Tuta absulata* Meyrick), are very serious and reported to cause maximum damage to the crop. The fruit borer, *H. armigera* (Lepidoptera: Noctuidae) is the most important pest infesting tomato. This is a key pest as it attacks fruits and makes it unfit for human consumption causing considerable crop loss upto 55 percent in yield. The botanicals and bio-pesticides have given encouraging results against the insect pest of agricultural importance. In India tomato fruit borer, *H. armigera* is one of the most remarkable pest, limiting production and market value of the crop produce. It is the most destructive pest of tomato in India, which is commonly known as gram pod borer, American bollworm and tomato fruit borer. Indiscriminate pesticide use is detrimental to the environment and human health and increases insect's resistance to pesticides. Alternative pest management strategies are hence warranted to reduce the misuse of chemical pesticides in vegetables. Therefore, an eco-friendly alternative is the need of the hours. Botanicals and bio-pesticides have the potential to help in the management of these pests as safe alternative to synthetic insecticides.

Materials and Methods
An experiment was undertaken on tomato crop (Variety Pusa Ruby) under field condition at Department of Entomology, Dr. Panjabaro Deshmukh Krishi Vidhyapeeth, Akola during Kharif season of 2018-19. A field experiment was laid out in randomized block design (RBD) with eight treatments including untreated control. Replicated three times (Table 1). The crop was sown in second week of November 2019 in plot size of 4.2m × 3m with 30cm row to row distance and 10cm plant to plant distance. Seven different treatment modules consisting of botanicals like Neem Seed Extract (NSE) 5%, Azadirachtin 10,000 ppm, Azadirachtin 300ppm

and bio-pesticides like HaNPV 250 LE/ha, *B. bassiana* $1x10^8$ CFU, *M. anisopliae* $1x10^8$ CFU, *B. thuringiensis* 1000 gm or ml/ha and *T. chilonis* @ 1.5 lack/ha along with untreated control were evaluated at different days after planting (DAP) in each module for the management of major insect pests of tomato. The treatments details of each module were as in the table 1.

Table 1: Details of treatment Modules

Module-1	a. Application of NSE 5% at 35 and 45 DAP b. Release of *Trichogramma chilonis* @ 1.5 lakh/ha. at 55, 65, 75, 85 DAP
Module-2	a. Application of Azadirachtin 10,000 ppm @ 3ml/lit. at 35 and 45 DAP b. Release of *Trichogramma chilonis* @ 1.5 lakh/ ha. at 55, 65, 75 and 85 DAP
Module-3	a. Application of Azadirachtin 300 ppm @ 5 ml per lit at 35 and 45 DAP b. Application of *Beauveria bassiana* at 55 DAP c. Release of *Trichogramma chilonis* @1.5 lakh/ha at 65, 75 and 85 DAP
Module-4	a. Application of Azadirachtin 300 ppm @ 5 ml/lit at 35 and 45 DAP b. Application of *Metarhizium anisopliae* at 55 DAP c. Release of *Trichogramma chilonis* @1.5 lakh/ha at 65, 75, 85 DAP
Module-5	a. Application of Azadirachtin 10,000 ppm @ 3 ml/lit at 35 and 45 DAP b. Application of *HaNPV* 250 LE/ha at 55 DAP c. Release of *Trichogramma chilonis* @1.5 lakh/ha at 65, 75 and 85 DAP
Module-6	a. Application of Azadirachtin 10,000 ppm @ 3 ml/lit at 35 and 45 DAP b. Application of *Bt*. 1000 gm or ml/ha at 55 DAP c. Release of *Trichogramma chilonis* @1.5 lakh/ha at 65, 75 and 85 DAP
Module-7	Control Plot

Method of recording observations: The observations on the tomato fruit borer were recorded after the initiation of fruit formation on the plant and application of each treatment module at 3, 5 and 10 days. The number of total healthy and affected fruits of plants was counted from randomly selected five plants from each net plot and percent infested fruits due to tomato fruit borer was calculated.

$$\% \text{ fruit borer infestation} = \frac{\text{No of infested fruits}}{\text{Total No. of fruits to be plucked}} \times 100$$

Yield of tomato: In order to compare the response of different treatment modules on fruit yield, the pickings of marketable tomato fruits was done periodically and the yield obtained in the net plot of each treatment module was recorded. The plot wise yield thus recorded and further converted into hector basis.

Incremental Cost Benefit Ratio (ICBR): In order to work out cost effective treatment modules against tomato fruit borer on tomato the “Incremental Cost Benefit Ratio” was worked out based on the total tomato fruit yield in terms of rupees per hector, cost of inputs including treatment modules and labour charges, cost of application etc. and net monetary returns were calculated at the prevailing market rates during the period of experimentation.

Statistical analysis: As per Gomez and Gomez (1984) the data obtained from the field experiments on the various parameters during the season were converted to appropriate transformation and were subjected to statistical analysis to test the level of significance. The yield data were also statistically analysed in order to compare the effect of different treatment modules. The pest and yield data collected during the course of experimentation were subjected to statistical analysis after appropriate transformation for interpretation of results of various parameters.

Result and Discussion

Efficacy of treatment modules on percent fruit infestation of tomato fruit borer (*Helicoverpa armigera*) 3, 5 and 10 days after spray at 55 DAP, 65 DAP, 75 DAP and 85 DAP: The data presented in Table 2 results revealed that all the treatment modules at 3, 5 and 10 days were found significantly superior to untreated control. However, the lowest fruit infestations were noticed due to the treatment module of M5 followed by M4 both these treatment modules individually were found significantly superior to rest of the treatment modules. The next effective treatment modules were M3, M6 and M1 recorded fruit infestation, respectively and all these three treatment modules were found statistically at par with each other. The untreated control recorded the highest fruit infestation caused due to *H. armigera*.

Cumulative efficacy of treatment modules on percent fruit infestation of tomato fruit borer (*H. armigera*) at 3, 5 and 10 DATS: The cumulative data presented in Table 3 are found statistically significant. It is evident that all the treatment modules were found significantly superior to untreated control. The least cumulative mean fruit infestation due to tomato fruit borer (6.66 percent) was noticed due to the treatment module of M5. It was followed by the treatment module M4 and M3 that recorded 10.05 and 10.80% mean fruit infestation, respectively and both these treatment modules were at par with each other. The next best treatment modules *viz*., M6, M1 and M2 have shown statistically equal effectiveness by recording 14.92, 15.97 and 18.47% mean fruit infestation, respectively. However, the untreated control in which the highest fruit infestation of 24.30% was observed.
Such effectiveness of treatment modules M5 (botanicals and bio-pesticides) including the application of Azadirachtin 10,000 ppm against tomato fruit borer has been demonstrated by the several workers like Aggarwal *et al.* (2006) [2], Mehta *et al*. (2010) [17], Shafie an Abdelraheem (2012) [29] and Patil *et al.* (2018) [19] in minimizing the fruit infestation by *H. armigera* thus supports the present findings. Similarly,

Karabhantal and Awaknavar (2012) [12], Jat and Ameta (2013) [11], Rahman *et al.* (2014) [22, 23], Rahman *et al.* (2016) [21] and Satish *et al.* (2018) [28] recorded the minimum fruit infestation by using NSE and *HaNPV* in combination treatments and hence the results are in aggrement with the present findings. Likewise, the effectiveness of *Trichogramma chilonis* was reported by Kumar *et al.* (2004) [14], Usman *et al.* (2012) [31], Hussain (2015), Usman *et al.* (2015) [32] and Rahman *et al.* (2016) [21] in sole application as well as combination of treatments against tomato fruit borer and therefore these findings are comparable with the results. The treatment modules of bio-pesticides like *M. anisopliae* and *B. bassiana* have also shown good performance in registering the minimum fruit infestation due to *H. armigera*.

Table 2: Efficacy of treatment modules on percent fruit infestation of tomato fruit borer (*H. armigera*) 3, 5 and 10 days after spray at 55, 65, 75 and 85 DAP.

Module numbers	Percent fruit infestation of *H. armigera* / plant			Percent fruit infestation of *H. armigera* / plant			Percent fruit infestation of *H. armigera* / plant			Percent fruit infestation of *H. armigera* / plant		
	55DAP			65DAP			75 DAP			85 DAP		
	3 DAS	5 DAS	10 DAS	3 DAS	5 DAS	10 DAS	3 DAS	5 DAS	10 DAS	3 DAS	5 DAS	10 DAS
M1	15.27 (3.90)	14.42 (3.77)	15.61 (3.94)	18.29 (4.27)	17.75 (4.21)	18.81 (4.31)	15.27 (3.90)	14.42 (3.77)	15.61 (3.94)	13.42 (3.65)	12.67 (3.55)	13.78 (3.68)
M2	18.35 (4.26)	17.21 (4.13)	18.72 (4.33)	20.65 (4.54)	19.43 (4.40)	20.93 (4.57)	18.35 (4.26)	17.21 (4.13)	18.72 (4.33)	16.74 (4.08)	14.35 (3.78)	17.65 (4.20)
M3	11.28 (3.35)	9.76 (3.11)	10.25 (3.18)	12.65 (3.54)	11.45 (3.35)	13.21 (3.62)	11.28 (3.35)	9.76 (3.11)	10.25 (3.18)	9.22 (3.03)	6.73 (2.59)	9.67 (3.09)
M4	9.34 (3.05)	9.45 (3.07)	9.78 (3.12)	12.03 (3.46)	10.79 (3.28)	12.89 (3.58)	9.34 (3.05)	9.45 (3.07)	9.78 (3.12)	8.13 (2.84)	5.46 (2.32)	8.23 (2.84)
M5	7.42 (2.71)	4.23 (2.02)	6.12 (2.36)	8.78 (2.95)	8.61 (2.93)	9.12 (2.99)	7.42 (2.71)	4.23 (2.02)	6.12 (2.36)	5.14 (2.26)	3.42 (1.84)	4.98 (2.22)
M6	13.61 (3.68)	14.67 (3.82)	15.72 (3.96)	16.78 (4.09)	14.67 (3.82)	16.72 (4.09)	13.61 (3.68)	14.67 (3.82)	15.72 (3.96)	12.89 (3.59)	9.82 (3.13)	13.65 (3.68)
M7	24.32 (4.90)	21.29 (4.56)	25.16 (5.00)	26.42 (5.13)	24.54 (4.93)	26.91 (5.19)	24.32 (4.90)	21.29 (4.56)	25.16 (5.00)	23.72 (4.86)	20.47 (4.51)	24.71 (4.96)
F 'test'	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SE (m)±	0.19	0.23	0.24	0.16	0.20	0.19	0.19	0.23	0.24	0.16	0.15	0.19
CD at 5%	0.58	0.71	0.75	0.50	0.64	0.58	0.58	0.71	0.75	0.50	0.46	0.58
CV (%)	8.91	11.51	11.42	7.06	9.40	8.06	8.91	11.51	11.42	8.19	8.44	9.33

Figures in parentheses are corresponding square root transformed values
DAP = Days after Planting

Table 3: Cumulative efficacy of treatment modules on percent fruit infestation of tomato fruit borer (*H. armigera*) at 3, 5 and 10 DATS

Treatment Modules	Cumulative % fruit infestation of *H. armigera*			Mean
	3 DAS	5 DAS	10 DAS	
M1	16.05 (4.00)	15.34 (3.91)	16.54 (4.05)	15.97 (3.98)
M2	18.74 (4.33)	17.41 (4.17)	19.26 (4.39)	18.47 (4.29)
M3	11.21 (3.34)	9.80 (3.12)	11.41 (3.37)	10.80 (3.27)
M4	10.44 (3.23)	9.11 (3.01)	10.60 (3.25)	10.05 (3.16)
M5	7.03 (2.64)	5.89 (2.42)	7.08 (2.63)	6.66 (2.56)
M6	15.45 (3.93)	13.60 (3.68)	15.72 (3.96)	14.92 (3.85)
M7	24.78 (4.96)	22.53 (4.74)	25.60 (5.05)	24.30 (4.91)
F 'test'	Sig	Sig	Sig	Sig
SE (m)±	0.15	0.12	0.16	0.14
CD at 5%	0.48	0.38	0.49	0.45
CV (%)	7.27	5.97	7.36	6.86

Figures in parentheses are corresponding square root transformed values
DAP = Days after Planting

Cumulative efficacy of treatment modules on population of spider at 55, 65, 75 and 85 DAP: The Cumulative data at 55 DAP presented in Table 4 reveal that the data are statistically significant. The highest population of 2.30 spider/plant was observed in the untreated control followed by the treatment modules of M5, M4, M3 and M1 which recorded 2.10, 2.00, 1.90 and 1.70 spider/plant and all these five treatment modules were found at par among themselves. At 65 DAP the highest population of 2.45 spider/plant was noticed in untreated control followed by the treatment modules of M5, M4 and M3 recording 2.30, 2.10 and 2.00 spider/plant. As well as at 75 DAP the Cumulative data, reveal that the data are statistically significant. The highest population of 2.10 spider/plant was recorded the untreated control treatment followed by the treatment modules of M5, M4, M3, M2, M1 and M6 recording the population of 2.05, 2.00, 1.85, 1.75, 1.65 and 1.45 spider/plant respectively. However, all these seven treatment modules were found statistically at par with each other. At 85 DAP It is revealed that all the treatments were statistically significant. The treatment of untreated control recorded the maximum population of 2.00 spider/plant followed by the treatment modules of M5, M4, M3 and M2 that recorded the population of 1.95, 1.85,1.75 and 1.55 spider/plant, respectively and all these five treatment modules were found statistically similar with each other.

Table 4: Cumulative efficacy of treatment modules on population of spider at 55, 65, 75 and 85 DAP

Treatment Modules	Population of spider / plant				Mean
	55 DAP	65 DAP	75 DAP	85 DAP	
M1	1.70 (1.22)	1.95 (1.34)	1.65 (1.34)	1.35 (1.05)	1.66 (1.23)
M2	1.65 (1.05)	1.85 (1.22)	1.75 (1.46)	1.55 (1.17)	1.70 (1.22)
M3	1.90 (1.34)	2.00 (1.46)	1.85 (1.44)	1.75 (1.17)	1.87 (1.35)
M4	2.00 (1.44)	2.10 (1.44)	2.00 (1.58)	1.85 (1.34)	1.98 (1.45)
M5	2.10 (1.46)	2.30 (1.56)	2.05 (1.68)	1.95 (1.46)	2.10 (1.54)
M6	1.45 (0.88)	1.65 (1.34)	1.45 (1.34)	1.25 (0.88)	1.45 (1.11)
M7	2.30 (1.68)	2.45 (1.77)	2.10 (1.68)	2.00 (1.58)	2.21 (6.71)
F 'test'	Sig	Sig	Sig	Sig	Sig
SE (m)±	0.15	0.14	0.13	0.18	0.15
CD at 5%	0.47	0.42	0.39	0.57	0.46
CV (%)	20.56	16.43	14.60	26.12	19.42

Figures in parentheses are corresponding square root transformed values
DAP = Days after Planting

The earlier workers like Amutha and Manisegaran (2006) [3] and Ravi *et al.* (2008) [25] reported that the highest numbers of spiders was recorded in the untreated plot but comparable with those in *HaNPV*, *Btk* and azadirachtin treated plots on tomato crop which confirms the present investigation. They also reported that relatively higher number of spiders were recorded in the microbials and neem based applied plots could be the best alternatives for the sustainable management of *H. armigera* on tomato with less impact on the naturally occurring arthropods which supports the present findings.

Effects of treatment modules on the yield of tomato fruit: The data presented in Table 5 showing highest yield of tomato fruit was recorded in the treatment module of M5 (173.61 q/ha) followed by the treatment module of M4 which recorded 162.03 q/ha and both these treatment modules were found statistically at par with each other. The treatment module M3, M6 and M1 have recorded the yield of 144.67, 127.31 and 127.31 q/ha, respectively and all these three treatment modules were found at par among themselves. Such effectiveness of treatment module M5 (botanicals and bio-pesticides) including the application of Azadirachtin 10,000 ppm by the earlier workers like Mehata *et al.* (2010) [17], Shafie and Abdelraheem (2012) [29] reported maximum yield of tomato fruit and and therefore, these findings are in close agreement with the present findings. Similarly, Karabhantal and Awaknavar (2012) [12], Jat and Ameta (2013) [11], Rahman *et al.* (2014) [22, 23] and Satish *et al.* (2018) [28] obtained the maximum yield of tomato fruit by using NSE and *HaNPV* in combination treatments and therefore, these results are in agreement with the present findings.

Table 5: Effects of treatment modules on the yield of tomato fruit

Treatment Modules.	Replication			Total	Ave. Yield (q/ha)	Ave. yield Kg/plot
	R I	R II	R III			
M1	115.74	127.31	138.88	381.93	127.31	22.00
M2	104.16	115.74	127.31	347.21	115.74	20.00
M3	144.67	133.10	156.24	434.01	144.67	25.00
M4	162.03	173.61	150.46	486.10	162.03	28.00
M5	173.61	185.18	162.03	520.82	173.61	30.00
M6	144.67	121.52	115.74	381.93	127.31	22.00
M7	69.44	81.01	92.59	243.04	81.01	14.00
F test					Sig	Sig
SE (m) ±					7.47	1.29
CD at					23.01	3.97
CV (%)					9.72	9.72

Figures in parentheses are corresponding no transformed values
DAP = Days after Planting

Incremental cost benefit ratio (ICBR) of various treatment modules: The maximum incremental cost benefit ratio (ICBR) of 1:15.62 was obtained in the treatment modules of M5. The next best treatment modules in order of incremental cost benefit ratio were, M4 (1:10.95) and M1 (1:9.44). The treatment modules viz. M3, M6 and M2 were also found economically better in recording the ICBR of 1: 8.92, 1:6.76 and 1: 5.24, respectively depicted in Table 6. The similar kind of effectiveness of treatment modules M5 (botanicals and bio-pesticides) including the applicaton of Azadirachtin 10,000 ppm by the earlier workers like Amutha and Manisegaran (2006) [3] have shown comparable results of ICBR on tomato cropand thus support the findings. Similarly, Jat and Ameta (2013) [11] and Satish *et al.* (2018) [28] obtained the economically better ICBR by using the NSE and HaNPV in combination treatments and therefore these results are in agreement wit the present findings. Likewise, the ICBR regarding the effectiveness of *T. chilonis*was also demonstrated by the workers like Kumar *et al.* (2004) [14], Amutha and Manisegaran (2006) [3], Usman *et al*. (2012) [31] and Rahman *et al*. (2016) [21] in sole as well as combination of treatments shows maximum ICBR which is similar with the present findings.

Table 6: Incremental cost benefit ratio (ICBR) of various treatment modules in tomato

Treatment Module	No. of sprays	Qty. per ha.	Rate per kg or lit.	Cost of treatments				Yield (q/ha)	Yield increased over control (q/ha)	Value of increased yield (Rs.) B	Incremental benefit (Rs.) B-A	ICBR (B-A)/A	Rank
				Cost of insecticides (Rs./ha)		Labour cost and machinery charges (Rs./ha)	Total cost (Rs./ha) A						
M1	2 4	50 kg 6 lakh	25 375/ 1.5 lakh egg	1330 1500	2830	4260	7090	127.31	46.30	74080	66990	1: 9.44	3
M2	2 4	3 lit 6 lakh	1050 375/ 1.5 lakh egg	3150 1500	4650	4260	8910	115.74	34.73	55568	46658	1: 5.24	6
M3	2 1 3	5 lit 2 kg 4.5 lakh	800 440 375/1.5 lakh egg	4000 880 1125	6005	4260	10265	144.67	63.66	101856	91591	1: 8.92	4
M4	2 1 3	5 lit 2 kg 4.5 lakh	800 730 375/1.5 lakh egg	4000 1460 1125	6585	4260	10845	162.03	81.02	129632	118787	1: 10.95	2
M5	2 1 3	3 lit 250 LE 4.5 lakh	1050 1500 375/1.5 lakh egg	3150 375 1125	4650	4260	8910	173.61	92.60	148160	139250	1: 15.62	1
M6	2 1 3	3 lit 1 kg 4.5 lakh	1050 1000 375/1.5 lakh egg	3150 1000 1125	5275	4260	9535	127.31	46.30	74080	64545	1: 6.76	5
M7	-	-	-	-		-	-	81.01	-	-	-	-	-

Note:
1) Neem Seeds: Rs 25/ kg 2) Azadirachtin 10,000 ppm: Rs 1050/ lit 3) Azadirachtin 300 ppm: Rs 800/ lit 4) *B. bassiana*: Rs 400/kg
5) *M. anisopliae* : Rs 730/ kg 6) Ha.NPV 1000 LE : Rs 1500/lit 7) *B. thuringiensis*: Rs 1000/ Kg. 8) *T. chilonis* : Rs 50/ Card
9) Detergent powder : Rs 40/ kg. 10) Spray pump charges: Rs 50 / day. 11) Labour charges : Rs. 220 / day 12)Sale price tomato fruit : Rs 1600/q

Conclusion

The treatment module M5 (Application of Azadirachtin 10,000ppm @ 3 ml/lit at 35 and 45 DAP, *Ha*NPV 250 LE at 55 DAP and Release of *T. chilonis* @ 1.5 lakh/ha at 65, 75 and 85 DAP) had shown positive impact against tomato fruit borer. The treatment module M4 and M3 were found promising in minimizing the percent fruit infestation of tomato fruit borer. The treatment modules M5 and M4 were found safer to natural enemies like spider. Likewise, the treatment module M3 proved to be promising in retaining the spider population. The treatment modules M5 and M4 emerged as the most effective and economically viable treatment modules.

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