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Impact of Inoculative Releases of *Trichogramma chilonis* for *Helicoverpa armigera and Hippodamia variegata* for *Myzus persicae* in Ecologically Engineered Tomato Ecosystem of Kashmir

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Abstract: Field experiments were conducted to determine the impact of inoculative releases of two natural enemies, *Trichogramma chilonis and Hippodamia variegata* for the suppression of *Helicoverpa armigera* and *Myzus persicae*, respectively in ecological engineering practiced tomato field of Kashmir. The application of *T. chilonis* @150, 000 per ha significantly reduced *H. armigera* population (90.0 %) as compared to the only ecological engineering practiced field (62.46%). *H. variegata* @ 25,000/ha significantly suppressed *M. persicae* population with a reduction of 90.38% as compared to the only ecological engineering practiced field (60.64%). The study indicate that *T. chilonis* @150, 000/ha and *H. variegata* @ 25,000/ha significantly managed the population of *H. armigera* and *M. persicae*, respectively in ecological engineering practiced tomato field helps in avoidance of pesticidal applications.

Keywords: *Helicoverpa armigera, Myzus persicae, Trichogramma chilonis*, *Hippodamia variegata*, Biological control, Ecological engineering, Tomato

Tomato (*Solanum lycopersicum*) is one of the most common and important vegetable crops in terms of production and consumption all over the world. Among various insect pest of tomato, *Helicoverpa armigera* and *Myzus persica a*re most destructive pest that causes significant losses about 50-60% and 19.43%, respectively (Rawat 2020 , Sharma et al 2022). Since their habitats are in constant flux and the area under cultivation is often small, and only biological control strategies cannot be effectively used in short-term annual vegetables, ornamentals and field crops (Rusch et al 2010, Khan et al 2020). This strongly suggests that new approaches to solving the problem are needed. The active biological control system i.e., inundative release or inoculative release of biological control agents, overcomes a large number of pest problems that come with short-lived crops (Tang et al 2009). Potential biological agents should therefore be targeted during this period to effectively destroy the pest(s) before causing significant economic loss. In comparison to insecticides, there is no variety of biological control agents (Khan and Riyaz 2017a). Since tomato is a short-duration crop, the combination of habitat manipulation and inoculative releases of natural enemies (*Trichogramma chilonis* and *Hippodamia variegata*) might prove effective in the biological control of tomato pests (Kumar et al 2014, Baber and Khan 2022). The most commonly used biological control agent in the Indian subcontinent, *Trichogramma chilonis* Ishii is responsible for suppression of *Helicoverpa armigera* (Hubner) in several crops (Tscharntke et al 2016). The parasitoids occurs naturally in tomato ecosystem, but the population of tomato fruit borers in the tomato ecosystem cannot be reduced below the ET level significantly. The inoculative release of egg parasitoids can manage the *Helicoverpa armigera* (Hubner) populations. In many crops, ladybeetles are play an important role in pest control. Aphids and other soft-bodied insects are favorites of adults and larvae of ladybeetles and their efficacy is documented in controlling pests. The research has also been performed on the feeding patterns of various coccinellids on various aphids (Khan et al 2017). One of such species, *Hippodamia variegata* (Coleoptera: Coccinellidae), a polyphagous predator of medium size, is a potential biological agent for *Myzus persicae*. The inclusion of *Hippodamia variegata* in a biocontrol program necessitates comprehensive information on its critical functions, including numerical and functional responses, with predation effectiveness being a key component of functional response (Shah and Khan 2014).

Ecological engineering, also known as habitat manipulation, might be of great help in the conservation and enhancement of the natural enemy population by plant diversity enhancement and providing agro-ecosystem with sufficient refugee (Khan et al 2020). Hence for the purpose of coupling the benefits of ecological engineering and inoculative bio-agent releases for pest management, study aimed at the biological control of these pests using tomato crops maintained in ecologically engineered field conditions at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar, was conducted during 2019.

MATERIAL AND METHODS

Tomato crop was maintained under ecologically engineered, a form of conservation biological control, is an ecologically based approach aimed at favoring natural enemies and enhancing biological control in agricultural systems and its provide resources such as food for adult natural enemies, alternative prey or hosts, and shelter for survival in adverse conditions)field conditions at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar, India, during 2019. In order to count the insect pests and natural enemies population, a hybrid tomato variety (Shalimar Hybrid 1) was raised in plots of size 3.00 x 3.30 m. In order to maintain healthy crop growth, all the recommended agronomic practices were carried out except pesticide application. The design of experiments under ecologically engineered tomato were buckwheat (*Fagopyrum esculentum* Moench) was grown as cover crop on boarder three line a row (width of row of 30cm) for pollen, nectars and shelter of natural enemies; after that a line row of marigold (*Tagetes* spp.) was grown as trap crop (width of row of 30cm) and expected to avoiding egg laying of tomato fruit borer damage of main tomato crop, after each plot of tomato crops one row of maize (*Zea mays* L.) crop in between two plots of tomato, grown as barrier crop expected to check the movement of aphid and flying insect such as tomato fruit borer. Similarly, one row of cowpea (*Vigna unguiculata* L.) grown as trap crop opposite direction of maize crop expected to prefer as host for aphid and avoid egg laying of tomato fruit borer damage of tomato crop and results were compared with the control plot which was grown away from ecological engineering plots to avoid effect of their follow the General Management Practices.

To evaluate the impact of inoculative releases of natural enemies in ecologically engineered tomato field, experiments were laid out in a randomized block design with five treatments and four replications. Comprising of *T. chilonis* with 3 dosages (1, 00, 000, 1, 50, 000 and 2, 00, 000/ha) against *Helicoverpa armigera* and *Hippodamia variegata* with 3 dosages (20,000, 25,000 and 30,000/ha) against *M. persicae.* Each experiment also consisted of a standard check (ecologically engineered field plot) and a control away from the ecologically engineered field plot (following the general management practices). *T. chilonis* were released in the field in the form of tricho-cards by tying them to the tomato plants at the flowering stage (35 days after transplanting of tomato) . The randomly selected plants were observed at weekly intervals to observe the effects of *T. chilonis* releases on larval population of *H. armigera*. The efficacy of *H. variegata* was worked out by computing the number of aphids (per plant) before release and after release from the 3 randomly selected plants in each replication. Percent reduction was worked out by computing the difference between the pre and post-treatment populations of *M. persicae* (Abbott, 1925). The observation regarding the recovery of natural enemies was taken one day before release and 30 days after release.

To record the fruit damage by *H. armigera* number of healthy and damaged fruits was recorded from each of the 3 randomly selected plants in each replication. The yield of tomatoes was recorded from and worked out on hectare basis. The effect of *T. chilonis* releases on fruit damage by *H. armigera* was also estimated by comparing the percent damage with the control. Total number of damaged fruits and healthy fruits from each replication at each picking . Analysis of data was done by using R software (R Development Core Team, 2016).

RESULTS AND DISCUSSION

Impact of Releases of *Trichogramma chilonis* on *Helicoverpa armigera*

Larval population: There was a decrease in the population of *Helicoverpa armigera* after installing tricho-cards of *Trichogramma chilonis* in the tomato field (Table 1). There was a significant difference in the larval population in different treatments on all the dates of observation. The mean larval population in the control was significantly higher (2.96 larvae/plant) than all the treatments. The lowest 0.24 larvae per plant population were recorded when *T. chilonis* was released @ 2, 00, 000/ha and was significantly lower than dosage of *T. chilonis* @ 1, 00, 000/ha. *T. chilonis* released @ 1, 50, 000/ha and *T. chilonis* @ 2, 00, 000/ha were at par with each other having no significant difference. The population decrease due to inoculative releases in the ecologically engineered field proved effective as compared to the standard check where no inoculation was done. Similar results were observed by Khan (2011) and Ballal and Singh (2003).

Fruit damage and yield: The mean fruit damage in all the treatments was significantly lower than control. Lowest fruit damage was when *T. chilonis* was released @ 2, 00, 000/ha (5.05%) and highest in the control (17.19%) followed by ecologically engineered field (7.59%) where no inoculative release was done. Mean fruit damage in *T. chilonis* @ 1, 50, 000/ha was significantly lower than *T. chilonis* @ 1, 00, 000/ha but mean fruit damage in *T. chilonis* @ 1, 50, 000/ha and *T. chilonis* @ 2, 00, 000/ha was at par. Similarly, the marketable yield when *T. chilonis* was released @ 2, 00, 000/ha was statistically not significant different from *T. chilonis* @ 1, 50, 000/ha but was significantly high than the other dose and standard check as well as control. Liang *et al*. (2013) also observed that fruit damage in all the treatments containing different dosages of trichogrammatids was significantly lower than that of control.

Impact of Releases of *Hippodamia variegata* on *Myzus persicae*

Population of *M. persicae*: *M. persicae* population was reduced during the course of time which was less than the pre-treatment count ecologically engineered check also showed decreasing trend (Table 2). *H. variegata* released at different doses showed decreasing trend in the population of *M. persicae* on increasing the dosage as compared to ecologically engineered check and control. However, *H. variegata* @ 25,000/ha showed a significant reduction in aphid population (3.07 aphids/plant) as compared to *H. variegata* @ 20,000/ha but was at pat with @ 30,000/ha. Earlier study also reported that *H. variegata* is a potential predator and significantly reduces aphid population after release which are in support with this study (Franzmann 2002, Kontodimas and Stathas 2005, Khan and Riyaz 2017b). The recovery of *H. variegata* was also recorded after 30 days of release and highest recovery of 43.06 % was when *H. variegata* was released @ 30,000/ha followed by *H.*

Table 1. Impact of inoculative releases of *T. chilonis* on the population of *H. armigera*, fruit damage and yield in ecologically engineered tomato ecosystem of Kashmir (2019)

Treatment	Dosage/ha	Population of *H. armigera* larvae (per plant)					Mean fruit damage# (%)	Yield (Q/ha)**
		July 22	July 29	August 5	August 12	Mean*		
Trichogramma chilonis	100000	0.87[a]	0.73[a]	0.47[a]	0.32[a]	0.59[a] (80.05)	6.97[a] (2.82)	642.58[a]
	150000	0.46[a]	0.31[a]	0.22[a]	0.23[a]	0.30[b] (89.68)	5.61[b] (2.57)	764.52[b]
	200000	0.3[a]	0.21[a]	0.23[a]	0.21[a]	0.24[b] (91.96)	5.05[b] (2.46)	777.32[b]
Ecologically engineered field	Standard check	1.31[b]	1.23[b]	1.03[b]	0.87[b]	1.11[c] (62.46)	7.59[c] (2.93)	571.75[c]
Control	_	4.03[c]	3.15[c]	2.49[c]	2.16[c]	2.96[d]	17.19[d] (4.26)	431.87[d]
CD (p = 0.05)	-	0.76	0.47	0.39	0.64	0.27	(0.13)	100.84

*Figures in the parenthesis are the per cent mean reduction over control, #Date of release = July 18, 2019
**(Q/ha) = Yield of tomato quintals per hectare, #Figures in the parenthesis of are the square root transformed values

Table 2. Impact of inoculative releases of *H. variegata* on the populations of *M. persicae* in ecologically engineered tomato ecosystem of Kashmir

Treatment	Dosage/ ha	Number of aphids (Per plant) before treatment	Number of aphids (Per plant) after treatment					Per cent reduction*	Yield (q/ha)	Recovery of natural enemies	
			July 22	July 29	August 5	August 12	Mean			Before treatment	After treatment (30 days after release)
Hippodamia variegata	20,000	16.35[a]	9.34[a]	7.07[a]	6.43[a]	6.07[a]	7.23	55.77 (77.34)	687.46[a]	2.21	3.19 (30.72)
	25,000	16.46[a]	4.64[b]	3.66[b]	2.01[b]	1.96[b]	3.07	81.34 (90.38)	775.27[b]	1.95	3.38 (42.38)
	30,000	14.23[b]	3.49[c]	3.12[b]	1.08[c]	1.51[b]	2.3	83.83 (92.78)	787.09[b]	2.3	4.04 (43.07)
Ecologically engineered field	Standard check	16.34[a]	15.4[d]	14.25[c]	9.55[d]	11.01[c]	12.55	23.19 (60.64)	638.58[c]	2.43	3.12 (22.11)
Control	_	36.88[c]	34.2[e]	30.23[d]	31.05[e]	32.11[d]	31.89	13.53	457.87[d]	0.95	1.03 (7.77)
CD (p=0.05)	-	1.46	0.87	0.77	0.28	0.54	3.70	-	75.34	-	-

* Figures in parenthesis represent per cent reduction over control, #Date of release = July 15, 2019, # Figures in the parenthesis shows % recovery of natural enemies

variegata @ 25,000/ha (42.30%) and both were statistically similar to each other than other treatments including ecologically engineered standard check and control (Table 2). Khan et al (2017) also mentioned that on increasing the dosage percent recovery also.

Yield: Highest yield (787.09 Q/ha) was observed when the *H. variegata* released @30,000/ha which was at par with @ 25,000/ha (775.27 Q/ha) but was significantly higher than the other dose and standard check (638.58Q/ha) as well as control.

CONCLUSION

This study showed that the inoculative releases of two natural enemies, *T. chilonis*@1,50,0,00 and *H. variegata* @ 25,000/ha were significantly reduced the population of *H. armigera* and *M. persicae*, respectively and helps in avoidance of pesticidal applications by maintaining the pest defender ratio in ecological engineering tomato practiced fields.

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