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Integration of parasitoid, *Encarsia formosa* Gahan in greenhouse whitefly management programme in tomato under protected environment

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Abstract

***Encarsia formosa*, an endoparasitoid of greenhouse whitefly, *Trialeurodes vaporariorum* was incorporated for its management programme in tomato grown under protected environment. Whitefly management programme comprised mass trapping of whitefly adults by using yellow sticky traps, potassium (K) nutrition (@125% of RDF), inoculative release of *E. formosa*, preventive use of insecticides and natural products comprising soil application of imidacloprid (0.009%), foliar application of azadirachtin (0.0003%) and alternate foliar application of *Tamarlassi* (10%) and cow urine (5%) and need based curative use of chemical insecticides. The integrated measures proved efficacious in checking population build-up of *T. vaporariorum*. The evaluated treatments as preventive measures resulted in adult population to vary from 0.01 to 1.51 adults /leaf, being well below the economic threshold level of 5 adults/ leaf. Population was minimum in soil application of imidacloprid (0.009%) followed by foliar application of azadirachtin (0.0003%) and alternate application of *Tamarlassi* (10%) and cow urine (5%). Fruit yield was significantly higher in the treatment comprising alternate foliar application of *Tamarlassi* (10%) and cow urine (5%) followed by the yield obtained in soil application of imidacloprid (0.009%).**

Key words: *Trialeurodes vaporariorum, Encarsia formosa,* Greenhouse whitefly, Natural products, Management programme

Protected cultivation also known as "Controlled Environment Agriculture" holds extreme potential for more production with higher productivity per unit land area. It entails growing crops in an environment where variables such as temperature, relative humidity, soil, water and plant nutrition are controlled for yield maximization (Jensen 2002). The area under protected cultivation in the world is nearly 6 lakh hectares and in India over 70 thousand hectares is under this system (Sabir and Singh 2013). Protected cultivation allows the farmers to grow high-value crops with year-round production to take advantage of market, seasonality and higher prices. In Himachal Pradesh, capsicum, parthenocarpic cucumber and tomato are the important vegetable crops grown under protected environment. However, these are affected by the vagaries of insect and mite pest namely, *Aculops lycopersicae,* (Massee), *Myzus persicae* (Sulzer), *Polyphagotarsonemus latus* (Banks),*Tetranychus urticae* Koch and *Trialeurodes vaporariorum* (Westwood) (Kashyap *et al*. 2015; Sood *et al*. 2018; Thakur and Sood 2019; Ghongade and Sood 2019; Ghongade and Sood 2021; Sharma *et al*. 2021; Thakur and Sood 2022).

In India whiteflies from 64 genera and 443 species have been found to feed on numerous crop plants (Singh *et al*. 2012; Selvaraj *et al.* 2017). However, two species namely, *Bemisia tabaci* and *T. vaporariorum* are of importance in India under protected environment. *Trialeurodes vaporariorum* commonly known as greenhouse whitefly (GHWF) is of significance in Himachal Pradesh (Sood and David 2012; Sood *et al*. 2018). Both nymphs and adults damage crops by extracting large quantities of phloem sap from the under surface of leaves. Excessive feeding by greenhouse whitefly leads to stunted plant growth and production of fewer and smaller fruits.

Endoparasitoid, *Encarsia formosa* Gahan (*Hymenoptera: Aphelinidae*), a solitary, thelytokous endoparasitoid is one of the most popular and important bioagents for the control of greenhouse whitefly on vegetable and ornamental plants in th greenhouses abroad. Principal greenhouse crops in which *E. formosa* is used to control GHWF includes tomato and cucumber. In India, Singh and Sood (2018) and Singh *et al*. (2018) recorded the parasitoid for the first time from Palampur, Himachal Pradesh resulting in parasitization to the extent of 93.6 per cent. The parasitoid can be helpful for its inclusion in integrated management plan of GHWF. Keeping this in consideration present studies were planned and undertaken by integrating augmentative release of the parasitoid and the management plan comprising use of yellow sticky traps for mass trapping, regulating plant nutrition, preventive and curative use of chemical insecticides, biopesticides and natural products.

Materials and Methods

Tomato crop (Palam Tomato Hybrid-1) was raised under two quonset type naturally ventilated polyhouses of size 105 m^2. The polyhouse had double door system and was fitted with 38 mesh nylon net on side and top vents. In order to avoid soil-borne diseases, the nursery was raised in soil-less medium comprising cocopeat, perlite and vermiculite (3:1:1) in pro-trays having 98 cavities of 2.5 cm depth. Nursery of the crop was raised by sowing the seeds in the environment-controlled growth chamber on March 9, 2022. Single seed was sown in each cavity. The nursery was irrigated and inspected regularly to avoid any incidence of insect-pests and diseases. Seedlings were transplanted in raised beds (15 cm) of 90 cm width, spaced 70 cm apart in rows with plant to plant spacing of 30 cm. The crop was transplanted on April 12, 2022. Fertilizers were applied at recommended dose of fertilizer (N:P:K::150:120:55 kg/ha) for tomato crop, 50 per cent of which was applied as basal dose in the form of urea, single super phosphate and muriate of potash. The rest was applied in splits at weekly intervals starting 21 days after transplanting (DAT) using water soluble fertilizer (N:P:K :: 19:19:19) through drip irrigation. The plants were trained on two shoots and extra shoots were pruned regularly to optimize the growth of plants. Crop was raised following all agronomic practices as per the package of practices for vegetable crops (Anonymous 2017) except the use of insecticides.

The parasitoid was integrated with the university recommended whitefly management plan presented in Table 1 comprising clean cultivation (fallowing polyhouse for 15 days prior to crop raising), use of 125% K of recommended dose of fertilizer, installing self-made yellow sticky traps @ 1 trap/ 10 m^2ten days before transplanting, soil application of imidacloprid (0.009%) one day after transplanting and repeating 45DAT, preventive application of azadirachtin (0.0003%) starting with the initiation of GHWF infestation at 10 days interval, need-based alternate application of spiromesifen (0.02%) and

Table 1. Details of the treatments evaluated for integrating *Encarsia formosa* in management plan of greenhouse whitefly in tomato

Treatment		Application rate	Method and time of application
Preventive measures			
T1	Imidacloprid 17.8 SL	0.009%	Soil application 1 and 45 DAT
T2	Azadirachtin 0.15% EC	0.0003%	Foliar application at ten days interval initiating 10 DAT
T3	*Tamarlassi* and Cow urine	10% 5%	Alternate foliar applications at ten days interval initiating 10 DAT
Curative measures			
T4	Spiromesifen 22.9 SC and Thiamethoxam 25 WG	0.02% 0.01%	Need based alternate foliar application of spiromesifen and thiamethoxam when the GHWF population reaches 5 adults/ leaf
T5	Cyantraniliprole 10.26 OD	0.02%	Need based foliar application when the GHWF population reaches 5 adults/ leaf
T6	Untreated check	-	-

thiamethoxam (0.01%) when the population level exceeded Economic Threshold Level (ETL) of 5 adults/ leaf. In all, there were six treatments (including UTC) which were replicated thrice. There were 16 plants in each treatment, and were separated by two plants to avoid insecticidal interference owing to drift in adjacent treatments. Inoculative release of *Encarsia* was done after 10 DAT by keeping 2 banker plants in the polyhouse which were covered with nylon net of 40 mesh.

In-situ observations were recorded on adult trap catch, population buildup and parasitization of GHWF at ten days interval using non-destructive method of sampling. The observations were initiated on the day of transplanting and continued till harvesting of the crop. For this, number of GHWF adults were counted on three leaves, one each from upper, middle and lower canopy from five randomly selected plants in each treatment. Observations on parasitization of GHWF nymphs by *Encarsia* were initiated 50 DAT onward. For this, total nymphs (healthy and parasitized) were counted from two leaves, one each from middle and lower canopy of five randomly selected plants.

Results and Discussion

Mass trapping of adult whiteflies

Observations recorded on trap catch of adult GHWF using self-made yellow sticky traps installed 10 days before transplanting of the crop are being presented in the Fig.1. Cumulative trap catches for ten days varied from 2 to 35 adults/10 traps. The catch increased slowly but steadily from two adults (1 DAT) to 30 adults on 80 DAT. Thereafter, the rate of increase became almost static and the trap catch of 35 adults/ 10 traps was achieved on 120 DAT. In total, 247 adults were got trapped during the cropping season. The findings depicted the influx of GHWF adults as evident from the trap catch observed on the day of transplanting.

Population build-up of GHWF in tomato

Population of GHWF indifferent integrated management module ranged from 0.01 to 1.51

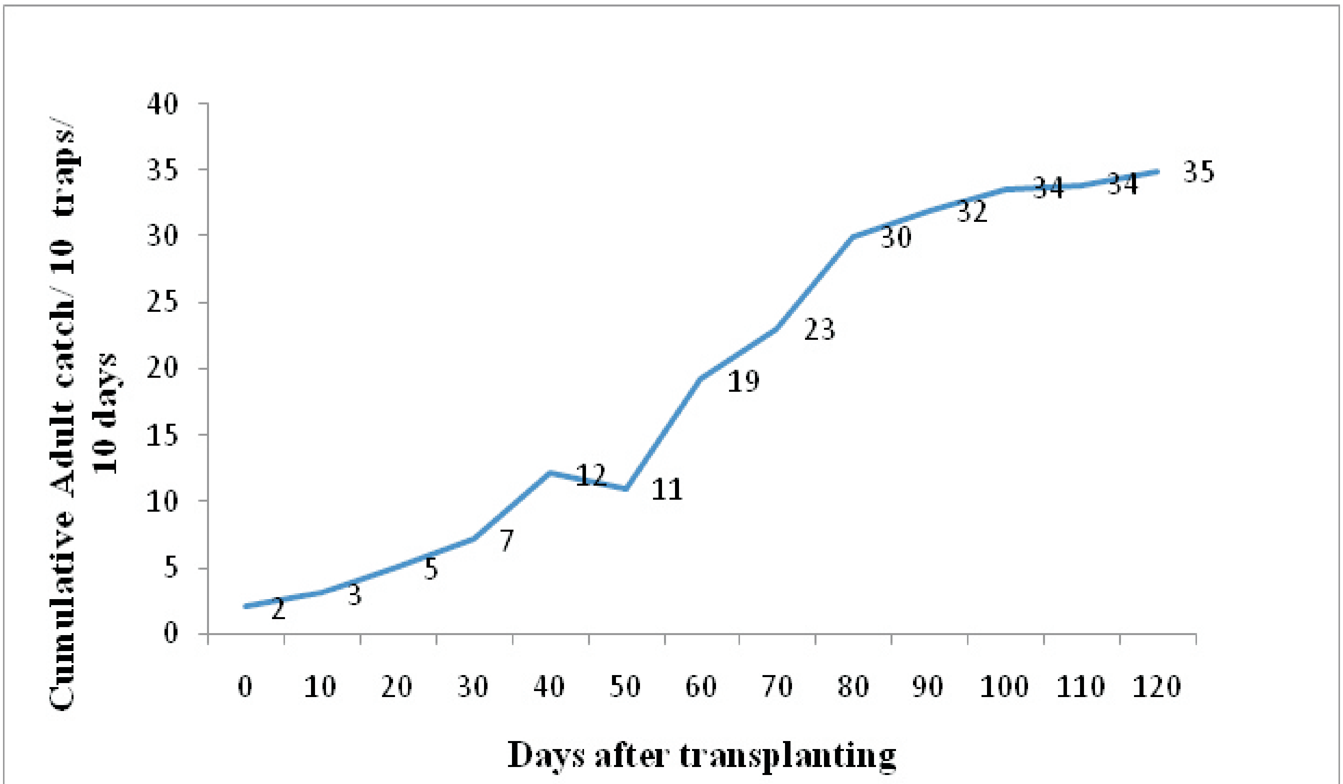

Fig. 1 Adult trap catch of *Trialeurodes vaporariorum* in integrated GHWF management plan

adults/leaf (Table 2). Throughout the period of study, populations remained below economic threshold level of 5 adults/ leaf resulting in no application of insecticides in T4 (alternate foliar application of spiromesifen and thiamethoxam) and T5 (cyantraniliprole). In the treatment comprising soil application of imidacloprid (0.009%) (T1), two applications were made. Whereas, in the treatments namely, azadirachtin (T2) and alternate application of *Tamarlassi* & cow urine (T3), a total of twelve foliar applications were made.

Population of GHWF was minimum in the treatment having soil application of imidacloprid (0.009%) (T1)and was followed by foliar application of azadirachtin (0.003%) (T2) and alternate application of *Tamarlassi* (10%) and cow urine (5%) (T3), these were at par to each other. Greenhouse whitefly population was significantly more in the plants where alternate application of spiromesifen (0.02%) and thiamethoxam (0.01%) (T4), cyantraniliprole (0.02%) (T5) was planned. These remained at par to the population level observed in untreated check.

Rate of parasitization

Parasitization rate of *T. vaporariorum* by *E. formosa* varied from 20.00 to 80.71 per cent in different treatments (Table 3). The mean parasitization on different days of observation varied significantly up to 70 DAT and became at par thereafter up to 120 DAT.Amongst the evaluated treatments, mean parasitization of GHWF immature stages by *E. formosa* was significantly maximum in untreated check followed by the treatment comprising alternate application of spiromesifen and thiamethoxam and cyantraniliprole, and all were at par to each other. Parasitization was minimum in the treatment having foliar application of azadirachtin and soil application of imidacloprid, which were at par to each other. The interaction effect of both the parameters evaluated was found to be non-significant.

Marketable fruit yield

Cumulative marketable fruit yield of tomato ranged from 10.70 to 12.30 kg/m^2 in different treatments evaluated for developing integrated management plan for GHWF (Table 4). Fruit yield was significantly higher in alternate foliar applications of *Tamarlassi* (10%) and cow urine (5%) and was followed by the yield obtained in soil application of imidacloprid (0.009%) and foliar application of azadirachtin (0.0003%), differing significantly from each other. Fruit yield in the plots meant for spiromesifen & thiamethoxam, cyantraniliprole untreated check was at par to each other.

Among all the treatments evaluated, population of GHWF remained lower to ETL of 5 adults/ leaf. Findings of Singh (2017) are supportive to our results as he observed the soil application of imidacloprid followed by foliar application of spiromesifen and thiamethoxam to be significantly superior in suppressing greenhouse whitefly. Schuster (2002) in tomato and Bi *et al*. (2002) in strawberry also observed soil application of imidacloprid to suppress the whitefly population up to 6-9 weeks. The findings of Sood *et al*. (2010) and Kashyap (2013) confirm the findings of the current investigations because they also recorded that azadirachtin (@ 0.0005%) was effective against GHWF in tomato under protected conditions. Moreover, azadirachtin was found to be extremely toxic to young greenhouse whiteflies by Kashyap *et al*. (2015).

Efficacy of *Tamarlassi* and cow urine under field conditions are in line to the findings of Kumar and Gupta (2006) and Ahirwar *et al*. (2010) who reported reduction in insect-pest population in different crops using cow urine. Findings of Kumari (2021) and Kumari (2022) are supportive to present finding as they observed natural products to reduce the population of GHWF in cucumber grown under protected environment to a moderate level. Minimum parasitization recorded in foliar applications of azadirachtin and soil application of imidacloprid also derives support from the findings of Singh (2017) who observed the parasitization by *E. formosa* to be minimum in insecticidal treatment comprising soil application of imidacloprid at 1 DAT and 45 DAT. Contrary to present findings, where azadirachtin resulted in minimum parasitization. Simmonds (2002) observed significant mortality of whitefly nymphs with no adverse effect on *E. formosa* emerging from them.

Marketable yield was higher in the treatment comprising alternate foliar application of *Tamarlassi* (10 %)and cow urine (5%) at 10 days interval and followed by the yield obtained in the treatments

Table 2. Population build -up of *Trialeurodes vaporariorum* under integrated management plan in tomato crop

	Treatment	Application rate	Mean population of greenhouse whitefly adults per leaf on indicated days after transplanting (DAT)												
			10	20	30	40	50	60	70	80	90	100	110	120	Mean
T1	Imidacloprid 17.8 SL (Soil application)	0.009%	0.00	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.03	0.00	0.00	0.05	0.01
T2	Azadirachtin0.15 EC (Foliar application)	0.0003%	0.00	0.00	0.01	0.01	0.00	0.02	0.00	0.00	0.08	0.02	0.04	0.04	0.02
T3	*Tamarlassi* and Cow urine (Alternate foliar application)	10%, 5%	0.00	0.00	0.02	0.01	0.00	0.03	0.00	0.22	0.07	0.07	0.15	0.03	0.05
T4	Spiromesifen 22.9 SC &Thiamethoxam 25 WG (Alternate foliar application)	0.02% 0.01%	0.00	0.00	0.16	0.41	0.62	0.86	0.77	0.76	0.82	1.08	0.85	1.26	0.63
T5	Cyantraniliprole 10.26 OD (Foliar application)	0.02%	0.00	0.00	0.04	0.41	0.98	0.70	0.47	0.78	0.82	1.02	0.70	1.51	0.62
T6	Untreated check	-	0.00	0.11	0.16	0.21	0.74	0.54	0.34	0.91	0.89	1.05	0.89	1.39	0.60
	Mean		0.00	0.02	0.07	0.18	0.40	0.36	0.27	0.45	0.45	0.54	0.44	0.71	

CD (P=0.05)

DAT (A) = 0.17

Treatment (B) = 0.12

A×B = 0.42

Table 3.Rate of parasitization of *Trialeurodes vaporariorum* by *Encarsia formosa* under integrated management plan in tomato crop

	Treatment	Application rate	Parasitization (%) on indicated days after transplanting (DAT)								
			50	60	70	80	90	100	110	120	Mean
T1	Imidacloprid 17.8 SL	0.009%	0.00	0.00	20.00	20.33	46.67	53.33	63.33	70.00	34.45
	(Soil application)		(1.28)	(1.28)	(26.57)	(23.85)	(43.08)	(46.92)	(52.78)	(57.78)	(30.80)
T2	Azadirachtin 0.15EC	0.0003%	20.00	26.67	38.33	35.41	33.33	40.11	44.44	40.00	34.79
	(Foliar application)		(26.57)	(30.79)	(37.89)	(36.21)	(30.00)	(38.92)	(41.75)	(38.86)	(35.13)
T3	*Tamarlassi* and Cow urine	10%, 5%	20.00	33.33	52.22	49.29	48.48	58.04	53.93	51.84	45.89
	(Alternate foliar application)		(26.57)	(35.01)	(46.52)	(44.50)	(44.13)	(49.65)	(47.27)	(46.06)	(42.46)
T4	Spiromesifen 22.9 SC &	0.02%	27.00	40.00	80.00	80.00	73.33	80.00	76.33	80.00	67.08
	Thiamethoxam 25 WG	0.01%	(28.07)	(39.23)	(63.44)	(68.07)	(59.21)	(68.07)	(61.92)	(68.07)	(57.25)
	(Alternate foliar application)										
T5	Cyantraniliprole 10.26 OD	0.02%	26.67	46.67	73.33	73.33	76.67	80.00	73.33	76.67	65.67
	(Foliar application)		(30.79)	(43.07)	(59.21)	(64.22)	(61.44)	(68.07)	(53.78)	(61.93)	(56.50)
T6	Untreated check	-	33.33	56.70	81.55	76.82	80.71	80.10	80.32	80.58	71.26
			(35.01)	(48.92)	(65.02)	(62.75)	(64.64)	(64.15)	(64.86)	(64.38)	(58.72)
	Mean		21.33	34.06	57.57	55.87	59.86	65.26	68.12	67.63	
			(25.46)	(33.79)	(49.77)	(49.93)	(50.71)	(53.27)	(55.65)	(55.35)	

Figures in parentheses are the angular transformed values

CD (P=0.05)

DAT (A) = (9.08)

Treatment (B) = (7.86)

A×B = (NS)

Table 4. Tomato fruit yield in different integrated greenhouse whitefly management practices

	Treatment	Application rate	Cumulative marketable yield (kg/m²)
T1	Imidacloprid 17.8 SL (Soil application)	0.009%	11.84
T2	Azadirachtin 0.15EC(Foliar application)	0.0003%	11.04
T3	Tamarlassi and cow urine (Alternate foliar application)	10%, 5%	12.30
T4	Spiromesifen 22.9 SC & Thiamethoxam 25 WG (Alternate foliar application)	0.02%, 0.01%	10.70
T5	Cyantraniliprole 10.26 OD(Foliar application)	0.02%	10.74
T6	Untreated check	-	10.86
	CD (P=0.05)		0.17

comprising soil application of imidacloprid (0.009%) and foliar application of azadirachtin (0.0003%) as compared to curative treatments, where no insecticidal applications were made and UTC.

Conclusion

Encarsia formosa, an endo-parasitoid of *T. vaporariorum* can efficiently be utilized in integrated GHWF management plan under protected cultivation using augmentative release. The technology needs to be popularized amongst the stakeholders for whitefly management under protected environment.

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Conflict of interest: The authors declare that there is no conflict of interest in this research paper.

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