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IPM Model for Management of *Bemisia tabaci* (Aleyrodidea: Hemiptera) on Tomato Crop

Hamid Rehman*, Aslam Bukaro, Abdul Ghani Lanjar and Lubna Bashir
Department of Entomology, Sindh Agriculture University, Jamshoro-70060, Pakistan

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Abstract. The whitefly (*Bemisia tabaci*) is a notable pest of vegetables and elaborate cash crops include tomato plant. The current study was carried out to develop an IPM model to control *B. Tobacco* on tomato crop. The following techniques have been utilized in controlling the population of whitefly, such as mechanical traps (yellow sticky card), biological control agent (*Chrysoperla carnea*), organic pesticide (Neem leaf extracts), integrated (Sticky card trap, *C. Cornea*, NLE) and un-treated. The adult population reduction % was recorded, (77.36%) in yellow sticky card trap, (63.97%) in *C. Carnea,* (85.20%) in NLE and in integrated plot (80.66%). In nymph population, (33.65%) in yellow sticky card trap, (82.15%) in *C. Carnea,* (92.26%) in the NLE and in integrated plot (89.86%) reduction was recorded. Therefore, the use of NLE and yellow sticky card traps the proposed IMP strategy which are highly effective in protecting the tomato crops from the whitefly on a large scale.

Keywords: IPM model, component, population, density, whitefly

Introduction

The whitefly has developed resistance against many insecticides such as three organophosphate and four pyrethroid groups from 1992 to 2000 in Pakistan (Ahmad *et al*., 2010). Similarly dimethoate, deltamerthrin and recently monocrotophos are also observed to be less effective during 1992 to 1996. Additionally, whitefly has built resistance against synthetic insecticid such as acephate, fenpropathrin and lambdacyhalothrin (Ahmad *et al*., 2010). Pakistan, like many other developing nation, uses the highest number of pesticides against pests. This is one of the major reasons of ecological issues and expansion of contamination, particularly in the provinces of Sindh and Punjab. In these regions the groundwater is tainted because the excess use of pesticides (Tariq *et al*., 2007). Its broad host run covers 481 host plants having a place with 295 genera and 90 families, including a few vegetables, ornamentals crops and trees (Srinivasa, 2000). In India, it has been accounted more than 253 plant species having a place with 176 genera and 60 families (Gopi *et al*., 2001).

Chu and Henneberry (1998), during 1996, 1997 and 1999 used cotton, sugar beets, horse feed, yard long bean and shelled nut fields, finding adult whitefly getting trapped in CC traps that are furnished with various trap base colours. Among them, lime green, yellow and spring green were observed to be the three most appealing trap for whitefly (*Bemisia argentifolii)* and leafhopper (*Empoasca* spp.).

Prema *et al*. (2018) different colours sticky traps, that included blue, white, yellow, red and green used for the screening of the development of thrips and the number of thrips catched at various developmental phases of cotton. After two field trials, it was observed that the yellow sticky trap captured a number of thrips as compared with other colours. The yellow sticky trap is recorded to have the highest mean thrips equal to 124.00 and 102.47 /trap in the first and second trial, separately. The blue and white shaded traps are favoured the most by thrips in the cotton crop. Very less thrips count were recorded in the red and green traps in both the trials.

Atakan and Canhilal (2004) sticky yellow traps at various ground levels, *i.e*. 60, 80, 100 and 120 cm to evaluate in the different vegetative growth stage of cotton for their relative proficiency in catching the accompanying pest in the Cukurova, Turkey in 2001 and 2002.

Chen *et al*. (2004) used different mechanical traps in poinsettia (*Euphorbia pulcherrima*) nursery such as a yellow sticky card (YC) traps and YC outfitted with 530 nm lime green light-discharging diodes (LED-YC) traps from 3 June to 25 Nov. 2002. The outcomes concluded that LED-YC traps might be valuable in screening and decreasing the pest population in nurseries.

*Author for correspondence;
E-mail: hamidrehman711@gmail.com

Sarwar in (2014) the green Lacewings Technology (Neuroptera: Chrysopidae) are considered the most effective predators of aphids. Four life stages of predator's 1st, 2nd and 3rd instar were used against aphid in canola field. Biological control is a strategy for controlling pests using common predator in horticulture that is naturally a solid. This is a viable method for the management of pest populations in agriculture.

The utilization of chemical has been viewed as an effective method to control pest. Since the utilization of pesticides also created some detriments at contrary organic control methods in the control of pest is a more balanced methodology Ahmad *et al.* (2010).

The species in class *Chrysoperla* have been viewed as the most vital, naturelly occuring predators, in control farming of different crops, including vegetables, natural products such as nuts, fiber and scavenge crops for example brassica and ornamentals etc. Around the world, this is one of the most advanced control strategy. Their hatching, usually called an aphidlion, is an unquenchable predator and can consume up to 200 aphids every week. Not only aphids, it can eat adult and larvae of others, including thrips, mealy bugs, juvenile whiteflies, little caterpillars and bug eggs Tauber *et al*. (2000).

Khan *et al*. (2012) green lacewing well known biological control agent to eat a wide range of other delicate bodied arthropods including many aphid species. It is a ravenous feeder on the first instar larva of mealy bug (*Phenacoccus solenopsis*).

The development of the worldwide bio-pesticide, azadirachtin an insecticide that is used as a key pest spray and available market. US Environmental Protection Agency confirmed Azadirachtin has reduced the factors involved in resistance. Azadirachtin also control other major agricultural pests for example, whiteflies, leafminers, parasite gnats, thrips, aphids and numerous leaf-eating caterpillars (Immaraju, 1998). Neem plant parts pose all insecticidal and pest repellent properties (Jacobson, 1986). Insect growth regulator (IGR) impacts the juvenile phases of pest, while the impacts of azadirachtin for example, antifeedant and IGR on numerous types of pets are known by (Mordue and Blackwell, 1993).

Immaraju (1998) reported that there are more than 200 pest species which are considered determental insects of seven orders and out of nine major orders of insect pest of agriculture included Coleoptera, Diptera, Hymenoptera, Homoptera, Lepidoptera, Orthoptera and Hemiptera that are defenseless to azadirachtin. It is suggested that no less than a few applications are applied in a period of seven to ten days that successfully control the life cycle of the pest (Saxena and Khan, 1985). Whitefly (*B. tabaci*) and aphid, adult and nymph are critical for the tomato crops (*Solanum lycopersicum*). Adult and nymph of whitefly draw the honeydew from plant leaves and that could effect the ability of photosynthesis. It was observed that watery leaves and organic product extracts from neem, more prominent controling of whiteflies, than on un-treated plants (Jazzar and Hammad, 2003). Which can result in complication that inhibit the plant to take in protein and that in turn effects plant growth (Walling, 2008; Kaloshian and Walling, 2005). Neem leaves and garlic extracts control whitefly and aphid population in the field condition. In south Africa, neem leaves extracts are regularly utilized to control the whitefly and aphid population reported by (Nzanza and Mashela, 2012).

This field explores different possibilities regarding tomato, that neem and wild garlic, alone or a mixture of both have insecticidal properties to control whitefly and aphid. All parts of neem contain insecticidal properties (Chawla *et al*., 1995; Van der Nat *et al*., 1991). Neem extracts also control whitefly and aphid population on cabbage (Zaki, 2008). Likewise, leaf concentrated of neem are observed in critical mortality of bean aphids. Additionally, extricates from the *Alliacae* family appear to decrease the population density of sucking insect (Prabal *et al*., 2000). The expanding enthusiasm for bio insecticides have conveyed new regard for the neem tree, certainly known on the Indian sub-mainland (Philogene *et al*., 2002).

Materials and Methods

Integrated pest management model (IPM model). On all outcomes of all experiments the IPM model was developed for the control whitefly on tomato.

Experimental techniques used. Tomato crop was sown at a tomato growing area near Hoshri, Hyderabad. There were five treatments were used included control/un-treated. Treatment was replicated three times. Used randomized complete block design (RCBD). The distance between blocks 15 m. Each block was divided into five segments each size 4 m^2. Twenty plants were used for each treatment.

Experimental design

R_1	R_1	R_1
T_5	T_1	T_2
T_4	T_5	T_1
T_3	T_4	T_5
T_2	T_3	T_4
T_1	T_2	T_3

Components used. The raw materials for building the IPM model for whitefly control can be observed in (Fig. 1). Pyramid basic components included (I) sticky card trap (yellow sticky card trap), (II) biological control agent (*Chrysoperla carnea*), (III) organic pesticide (neem leaves extracts), (IV) integrated (Sticky card trap, *C. Carnea*, NLE) and (V) un-treated. All the components were selected based on the outcomes obtained as a result of previous investigations.

Component (I) (yellow sticky card trap). In this component used yellow sticky card trap. All traps installed adjacent to one another, having the same direction. The installation of traps is replicated 3 times. The population of whitefly is counted daily after traps set up for 24 h and 48 h.

Component (II) (*C. Carnea* larvae). *C. Carnea* larvae were obtained from the biological control laboratory, department of entomology, Sindh Agriculture University Tandojam. Larvae of *C. Carnea* was transferred to the field with a piece of black cloth that was attached to plant *via* a paper pin. The collected *C. carnea* ten larvae were released per tomato plant in the field (Fig. 1).

Component (III) (neem plants extracts). Fresh neem leaves were collected from the locally available neem tree. A total of 2 Kg fresh neem leaves was collected and chopped, adding 10 L of hot water along with ordinary liquid soap for increasing residual effectiveness. This entire setup was stored for 15 days.

Component (IV) (integrated). In this treatment all components are applied integrated, in randomized complete block design (RCBD) e.g. yellow sticky card trap, *Chrysoperla carnea* and neem leaves extracts.

Component (V) (un-treated). The un-treated plot was left free of treatment throughout the experiment.

Observation. The field is observed twice a week, five successive weeks during the cropping season in October 2018. In this experiment, 10 leaves per plot were randomly selected from the top, middle and bottom. General ANOVA was used to statistically analyze the data using STATIX 8.0.

The performance of the IPM model was assessed by the percentage of whitefly population reduction, by using Abbot's formula mentioned by (Flemings and Ratnakaran, 1985) as given below:

$$\text{Population change \%} = \left(1 - \frac{\text{n in Co before treatment} \times \text{n in T after treatment}}{\text{n in Co after treatment} \times \text{n in T before treatment}}\right) \times 100$$

where:

n = Insect population; Co = Control and T= Treatment.

In control plot:

$$\text{Change \% in control plot population} = \frac{(\text{n in Co after treatment - n in Co before treatment})}{\text{Population in control plot before treatment}} \times 100$$

Results and Discussion

The result showed that the applied IPM model significantly reduced the whitefly population throughout the experiment as compared to the un-treated plots (Table 1-2). Approximately 85% of the whitefly population is observed to decrease in plots, where IPM components applied. This is the second highest reduction and the post treatment population are as follows: adult 80.66% (2.57±0.64) and nymph 89.86% (1.03±0.50) (Table 1-2). In the biological control plot (*C. Carnea*) adult are as follows: (3.86±0.85), while the nymph is (1.45±0.71) (Table 1-2). In case of *C. carnea* released plots, there is a 63.97% reduction was observed in the adult whitefly population. There is a 82.15% of the nymph population as compared to the un-treated plots, positioned at 4th in the IPM model. Throughout, the experiment, neem leaves extract (NLE) plots continued to exist with a lower number of whitefly (*B. tabaci*) as compared to the un-treated plots. The observed adult is (1.95±0.70), while nymphs are (0.75±0.65), and it remained fairly the same throughout the experiment. In contrary, in a higher density of whiteflies is recorded in the un-treated plot (12.40±1.90) at the end of 2nd week and start of the 3rd week (13.60±1.10) (Fig. 1). The nymphs began with (9.80±2.20) and slightly increased up a peak (14.00±1.55) (Fig. 2). As many as 90% whitefly reductions were observed in NLE treated plots as compared to the un-treated. In integrated plots, the whitefly population is recorded (2.57±0.64) in adult and (1.03±0.50) in nymph (Table 1-2). Integrated treated plots possess 3rd and 2nd position in the adult and nymph respectively in the IPM model.

Based on the percentage (%) change in a population of *B. tabaci* adult and nymph fixed the efficiency of different IPM model components. For example, the yellow sticky trap is used as mechanical traps, *Chrysoperla carnea* is released as a natural control operator, Neem leaves extracts as an organic pesticide, integration of all components and control or un-treated. The % change in adult population of *B. tabaci* is recorded as, T1 (77.36%), T2 (63.97%), T3 (85.20%), T4 (80.66%) and T5 (-7.14%) (Table 1). The maximum change density in the nymph population is recorded as T1 (33.65%), T2 (82.15%), T3 (92.26%), T4 (89.86%) and T5 (-7.69%) (Table 2). The decline was observed in the whitefly population as a result of all treatments, excluding un-treated plots. The excellent implications of neem concentrate was seen afterward.

In the nymph density of whitefly population, % change is the line up from high to low, T3(92.26%) > T4(89.86%) > T2(82.15%) > T1(33.65%) > T5(7.69%). In adults, treatment possessed position and from high to low in % change in density T3(85.20%) >T4(80.66%) > T1(77.36%) > T2(63.97%) > T5(-7.14%).

The yellow sticky card traps reduce the adult population up to 77.36%. During experiment found that the clear view and fluorescent colour more attract not only whitefly as well as other files. During the experiment up to 700 flies cateched in 48 h. The efficiency of yellow sticky card traps depends on timing, crop foliage and position of trap installation. The position of sticky card traps affects adeptness of traps because pests from a distance, identify the clearer view of the trap. The foliage of a crop also affects the view of the traps. Also mentioned by (Coombe, 1982; Mound, 1962) that dispersed whiteflies are attracted to shorter wave lengths. Flies in the range of 20 cm can see the yellow sticky trap and are attracted (Cohen, 1982) but our experiment did not confirm it. The highest numbers of whiteflies are captured in the day time or active period from 0900 to 1600 h. it is claimed that whiteflies are usually more active from 0900 to 1200 h (Gerling *et al*., 1980).

In *C. carnea* released plot 63.97% (3.86±0.85) in adult *B. tabaci* population and in nymphal population, 82.15% (1.45±0.71) reduction was recorded. *C. carnea* found more effective against nymph as compared to adults. *C. carnea* showed very remarkable result on all life stages of *B. tabaci* such as adult, nymph and also eggs because during experiment found lots of destroyed or

Table 1. Overall mean population of adult whitefly (*Bemisia tabaci*) in different components of IPM model

	B. Tabaci population		
Components	Pre treatment population	Adult	Max reduction %
Yellow sticky card traps	9.40±1.23	2.28±0.72C	77.36%
Chrysoperla carnea larvae	10.0±1.04	3.86±0.85B	63.97%
Neem leaves extracts (NLE)	12.3±1.55	1.95±0.70C	85.20%
Intregrated	12.4±1.89	2.57±0.64C	80.66%
Un-treated	9.80±1.25	10.5±1.40A	-7.14%

Overall mean in same column followed by same letter are not significantly different using general AOV/AOCV LSD ($\alpha = 0.05$).

Table 2. Overall mean population of nymph whitefly (*Bemisia tabaci*) in different components of IPM model

	B. Tabaci population		
Components	Pre-treatment population	NYMPH	Max reduction %
Yellow sticky card traps	4.00±1.00	2.45±0.76B	33.65%
Chrysoperla carnea larvae	8.80±2.15	1.45±0.71C	82.15%
Neem leaves extracts (NLE)	10.50±2.19	0.75±0.65C	92.26%
Intregrated	11.00±2.30	1.03±0.50C	89.86%
Un-treated	13.00±1.65	12.0±2.10	7.69%

Overall mean in the same column followed by the same letter are not significantly different using general AOV/AOCV LSD ($\alpha = 0.05$).

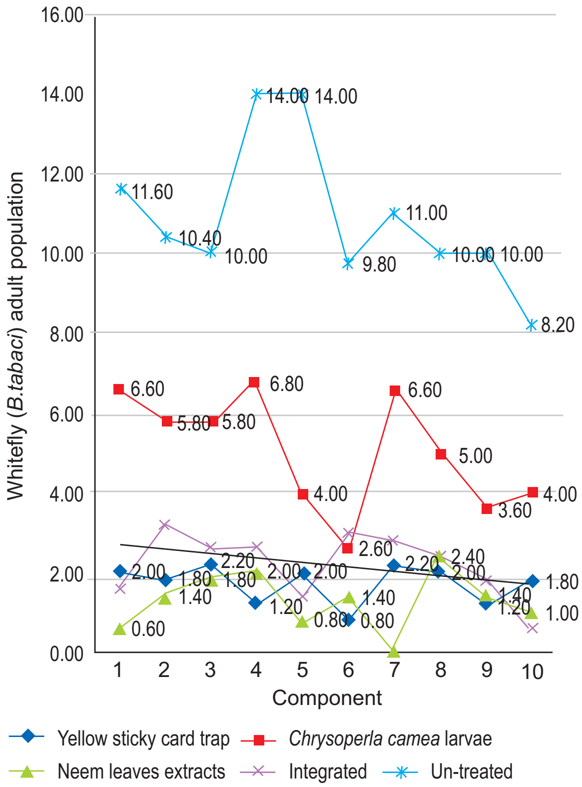

Fig. 1. Fluctuation and population abundance of whitefly (*B. tabaci*) adult in different components of IPM model plots.

consumed eggs. The use *C. carnea* has highly increased as a biological control agents as a key component of the IPM management program against pest in India (Nagarkatti, 1981). In our experiment as much as 80% reduction was observed. Also, up to 50% reduction was observed in India by (Sithanantham *et al*., 1982) 28% by (Yadav and Patel, 1987; Morrison, 1985). This confirmed the effectiveness of *C. carnea* larvae. Overall 83.07% of reduction in case of whitefly by *C. carnea* is reported by (Younes *et al*., 2013). Adly (2015) has reported that the introduced *C. carnea* is successful in managing the aphids and whiteflies. Our observation and data both completely agreed with (Morrison, 1985) reported that *C. carnea* larvae feeds on every stages of pest life and soft bodies pest. Also good immunizations to pesticide and predator increase their efficiency, also reported by (Lingren *et al*., 1968). Green lacewing is quite effective against all soft bodied insects reported by (Gupta and Rai, 2006). *C. carnea* is an effective predator of pests including thrips, aphid, mealy-bug, whitefly, caterpillar and eggs of insect (Tauber *et al*., 2000).

NLE showed outstanding results as compared to all rest of the factors. In adult 85.20 and 92.26% reduction in nymph of *B. tabaci*. Almost stopped regeneration of *B. tabaci*. Throughout experiment NLE treated plot very low population of *B. tabaci*. Neem leaves extracts (NLE) has insecticidal properties which control whitefly's density of the tomato crop. Neem tree parts, including leaves and kernels have antifeedant and insecticidal properties (Chawla *et al*., 1995; Van der Nat *et al*., 1991). Similer observations are reported that neem also has antifeedant qualities (Boeke *et al*., 2004; Ascher, 1993; Schmutterer, 1990). NLE equally control whitefly nymph and adult population. Throughout the experiment neem leaves extracts completely reduced insect pest especially the whitefly (Basedow *et al*., 2002). Similer findings are reported by (Bahar *et al*., 2007; Pareet, 2006; Lakshman, 2001).

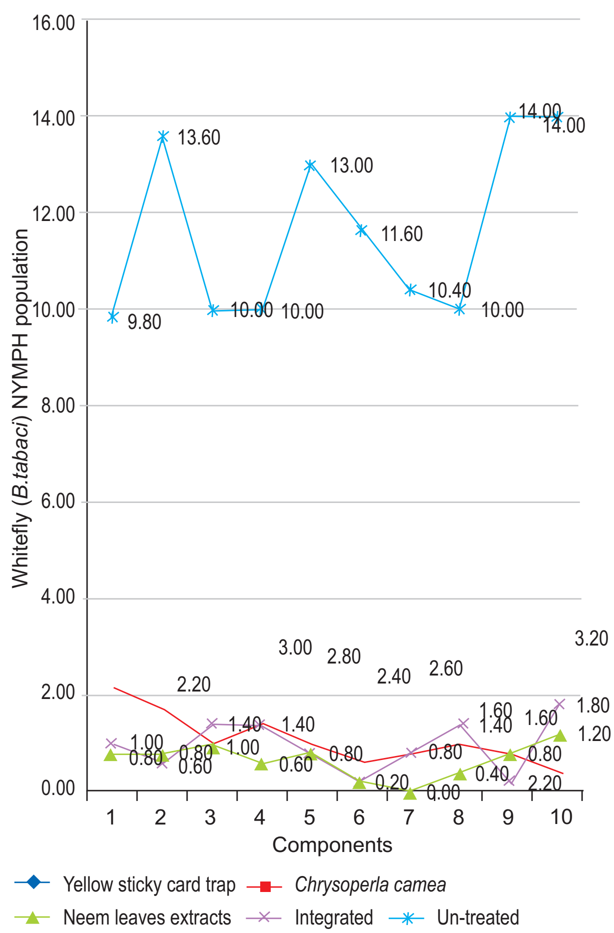

Fig. 2. Fluctuation and population abundance of whitefly (*B. tabaci*) NYMPH in different components of IPM model plots.

Conclusion

In summary, we systematically explored the three major components of IPM, to control whitefly population in tomato plants. This investigation proved evident, that Neem leaves extracts are a great choice when it comes to an organic insecticide. *Chrysoperla carnea* is a ground breaking organic operators and yellow sticky traps is solid, appealing shaded mechanical trap; fundamentally, this influences the whitefly adults and nymph population. These have a great impact on the whiteflies for example, nourishing, landing and ovipositional inclination. Specially, NLE is a most successive component of IPM. Thus, it is very presumed, that these combinations are increasingly defenseless aginst the whitefly, diminished upto 80% in density and outstanding tendency of whitefly to land, encouraging and oviposition. These examinations conceivably apply to practically all significant yields and vegetables, for eco-accommodating administration of whitefly.

Conflict of Interest. The authors declare no conflict of interest.

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