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Parasitism Efficiency of *Encarsia Lutea* Masi on *Bemisia tabaci* (Genn.) and its Interaction with Insecticides Applied on Cotton Crop in New Halfa Agricultural Scheme (Sudan)

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ABSTRACT

The study was conducted at the commercial field of New Halfa Agricultural Scheme (NHAS), during 2001/02 and 2002/03 seasons, to determine the parasitism efficiency of *Encarsia lutea* Masi (Hymenoptera: Aphelinidae) on *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae), and its interaction with the insecticidal treatments carried against the insect pests of cotton. The parasitoid, microscopically determined inside the whitefly nymphs, started to appear in both seasons since early November and increased towards the end of the season. Parasitism showed density dependence with the whitefly adult numbers leaf, In the first season, the highest level of parasitism was 45.4%. average for November was 23.2%, December 40.3% and for the season was 27.5%. In the second season, the highest level of parasitism reached was 48.2%, the average for November was 9.3%, December and the season's average was 27.2%. *E. lutea* delayed the insecticidal applications against the whiteflies during November in both seasons and kept them low during December so that no insecticidal interference was needed. The parasitoid secured saving of 29% of the sprays that should have been applied in the first season, and 50% in the second season. This was roughly estimated as three million US dollars directly saved resources in both seasons, besides the indirect benefit of improving the grade of the cotton fibre, due to reduction of the immature stages of the whiteflies. Four insecticide mixtures, of the 12 applied in the two seasons, reduced parasitism by 3%-45%. The rest did not interfere with the incidence of parasitism.

INTRODUCTION

The whitefly (*Bemisia tabaci*) is one of the economically serious pests attacking cotton in the Sudan. It damages the cotton plants directly through feeding, inducing in-eversible physiological disorders in the plants (De Barro, 1995), indirectly by depositing honeydew on leaves and lint, and by transmitting viruses (Lenteren *et al* (1997). The estimated annual crop damage by B. *tabaci* in the United State of America exceeded one-half billion dollars (Perring *et al*.,1993) and in the Sudan., 35% of the total cost of cotton production goes to purchasing pesticides (Mohamed *et al*, 2002), half of which is usually used for *B. tabaci* control.

Encarsia is a large genus of the chalcidoid family Aphelinidae، Worldwide, 280 *Encarsia* species were identified (Polaszek *et al*، (1999), 110 species are known as common parasitoids of whiteflies (Babcock and Heraty, 2000) and a number of them have been used successfully in biological control programmes. In the Sudan, two species parasitising whitefly have been reported, namely *E. lutea* Masi and *Encarsia* sp. (Schmutterer, 1969). The former is the most predominant and widely spread, and the latter, not yet identified, is scarce and negligibly distributed.

E. lutea females lay eggs on or into their host nymph with their ovipositors. Eggs hatch in or on the host. The larva goes through several stages, eventually consuming the host entirely and killing it The pupal stage follows and the adult (one per host) leaves the host by chewing a hole, often circular, in its cuticle. Hosts are also killed as a result of feeding by the adult parasitoid, which stabs the nymph, in which no egg is deposited, with its ovipositor and licks the hemolymph. The honeydew secretion of the whitefly is another important source of energy and nutrient for the adult parasitoid. Many Encarsia females control the sex of the laid eggs. Fertilized eggs develop as females and unfertilized ones develop into males (Hoddle *et al*, 1998a).

Since the early report of Gameel (1969) on the interaction of DDT, dimethoate, and DDT + dimethoate on *E. lutea* and B. *tabaci on* cotton grown in small scale trials in the Gezira Research Field (Sudan), nothing was added in this regard. Gameel (1969) reported that the parasitoid was more affected by DDT and DDT + dimethoate than by dimethoate alone. According to Hoddle *et al*. (1998b), authors reported in more than 70 published articles on the parasitism of *Encarsia* species on the greenhouse whitefly, *Trialcurodes vaporariorum* Westwood, and demonstrated the effects of more than 100 different insecticides on it (Ledieu, 1979; Oomen *et al*., 1994). It was reported that he insecticidal soap (Puritch *et al*, 1982), buprofezin (Gerling and Sinai، (1994) azadirachtin (Feldhege and Schmutterer، 1993) abamectin (Zchori-Fein *et al* (1994) and resmethrin (Oébome, 1981) are selective and safe materials to *Encarsia* species and can be used in combination with the parasitoid.

The objectives of this study were to determine the parasitism efficiency of *E. lutea* on B. *tahaci* infesting cotton crop in NHAS (Lat. 15^0 N and Long. 35^0 E), Sudan, and to elucidate its interaction with the insecticides applied against the insect pests of cotton.

MATERIALS AND METHODS

The study was conducted during seasons 2001/02 and 2002/03 in Rataja Block of NHAS. The cotton area of the block was grouped Into six sectors (treatments) in the first season, and into seven sectors in the second season. Each sector comprised three plots (replicates), 36 ha each, and were arranged in RCB design. Cotton variety Barac (67) B was, sown during the first to the third week of July in both seasons. The spacing was 80 cm between rows and 50 cm between holes؛ three plants were left per hole. The seed borne bacterial blight was catered for by dressing seeds with 2+1 ml per kg of Quinolate + Apron، respectively. Weeds were controlled by the application of 2.9 litres + 0.6 kg per ha of Stomp plus Diuron, respectively, as pre-emergence herbicides, supplemented by one hand weeding four weeks after germination. Fertilizer was applied at 190 kg N per ha, five weeks after sowing. Irrigation was done at two-week intervals.

Assessment of the insect pests was done 28 times at 3-day intervals each season according to the current methods of the Agricultural

Research Corporation, Sudan. Parasitism was evaluated microscopically 18 times in each season at 7-day intervals by checking the parasitoid larvae or pupae inside the whitefly nymphs. For that, 25 random leaves were detached from five random plants per plot per count and taken in polythene bags to the laboratory where they were examined under a binocular microscope for parasitised and unparasitised nymphs. The results were presented as percentage of parasitism and number of parasitied nymphs per leaf. The total number of the whiteflies, which would have occurred per leaf in the absence of parasitism, was calculated by adding the sampled numbers of the whitefly adults to the number of the parasitized nymphs per leaf, at the same date of count.

Insecticides

Season 2001/02

Sector 1 was sprayed on 10 November 2001 with fenpropathrin(1)+ carbusulfan(1) against the whitefly, aphid and jassid and on 27 November with endosulfan(1) + amitraz(1) against the whitefly and sublevel of aphid. Sector 2 was sprayed on 10 November with fenpropathrin(2)+ carbusulfan(1), at threshold of the whitefly and aphid and sublevel of jassid and on 22 November with endosulfan(2) + isoxathion(1) against the whitefly and aphid. Sector 3 was sprayed on 22 November with pyriproxyfen(1) /fenpropathrin(2) + benfuracarb(1) against aphid and jassid and on 9 December with the same mixture against sublevel of whitefly. Sector 4 was sprayed on 22 November with pyriproxyfen(1) / fenpropathrin(2) + oxydemeton(1) against aphid and jassid and on 9 December using the same mixture against sublevel of whitefly. Sector 5 was sprayed on 10 November with endosulfan(3) + chlorfenvinphos(1) at threshold of whitefly and sublevel of aphid and on 27 November with endosulfan(3) + amitraz(1) against the whitefly and aphid. Sector 6 was sprayed on 10 November with endosulfan(1) + chlorfenvinphos(1) against the whitefly aphid and jassid and on 27 November with endosulfan(3) + amitraz(1) at threshold of the whitefly and aphid and sub-threshold of jassid.

Season 2002/03

Sector I was sprayed on 6 November with endosulfan(3)+ Chlorfenvinphos(1) against the whitefly and on 22 November with Diafenthiuron(1) + profenfos(1) at threshold of the whitefly and sub threshold of aphid. Sector 2 was sprayed on 18 November with biphenthrin(1) + oxydemeton(1) against the whitefly, aphid and jassid and on 13 December with endosulfan(3) + amitraz(1) against aphid and sublevel of the whitefly. Sector 3 was sprayed once on 6 November with diafenthiuron(2) + profenfos(2) at threshold of the whitefly, aphid African bollworm. Sector 4 was sprayed once on 6 November diafenthiuron(1) + profenfos(1) against the whitefly. Sector 5 was spray once on 24 November with amitraz(2) + endosulfan(3) against aphid jassid and sublevel of the whitefly. Sector 6 was sprayed once on November with endosulfan(3)+ amitraz(1) against the whitefly, and aphid Sector 7 was sprayed once on 14 NoVember with diafenthiuront(1) + profenfos(1) against the whitefly.

Insecticides, at their recommended dosage rates, were applied with a Turbo-Crock aircraft fitted with 10 micronairs (AU-5000), at swath width of 28 m and water spray volume of 21 litres per ha. The application of insecticides was done in a selective manner, i.e. only when certain pest(s) in a certain treatment reaches the economic threshold level (ETL). The ETL practiced against the whiteflies in the Sudan is more than five adults per leaf. Mixtures of insecticides are usually used to cater for more than one pest.

RESULTS AND DISCUSSION

The parasitoid started to appear in both seasons from the first week of November and increased in number towards the end of the season. The appearance of the parasitoid coincided with a population of two whitefly adults per leaf, and its increase had shown density dependence with the t numbers at a significant positive correlation ($P \leq 0.05$, r =.(0.97). There results agree with those of Varley (1957) who stated that the interaction between the whitefly and its nymphal parasite *E. lutea* is an example of typical density dependence.

Parasitism in season 2001/02, as the sector's averages show (Table1) started to appear from the 4th of November at 17.9% and to appear progressively increased towards mid-December, reaching 41.9%. This increasing trend was slightly disturbed by the insecticidal treatments carried on 10 November in sectors 1,2,5 and 6, with the mixtures fenpropathrin(1) +carbusulfan(1) ,fenpropathrin(2) +carbusulfan(1) ,endosulfan(3)+ chlorfenvinphos(1) andendosulfan(1) + chlorfenvinphos(1), respectively. They reduced parasitism by 15%, 45%, 15%, and 3%, respectively، compared with the pre application rates. The other eight mixtures did not interfere with parasitism.

The highest numbers of the immature whiteflies destroyed by *E. lutea* was 45.4% . The average parasitism for November was 23.2%, for December was 40.3% and for the whole season was 27.5% (Table 1).

Table 1. Percentage of parasitised whitefly nymphs with *E. lutea* at different sectors and sampling dates season 2001 / 2002.

Sector	Date of count									Average parasitism during		
	23.10.2001	4.11	8.11	12.11	21.11	24.11	29.11	7.12	11.12.2001	Nov.	Dec.	Season
1	0.0	14.7	20.6↓	17.4	18.8	29.1↓	34.8	40.2	41.4	22.5	40.7	27.1
2	0.0	14.7	21.7↓	12.0	22.6↓	31.7	33.9	39.6	45.4	22.8	42.5	27.7
3	0.0	18.4	17.9	17.6	19.5↓	34.3	33.4	35.7↓	42.8	22.5	39.2	26.7
4	0.0	15.0	14.6	14.9	23.2↓	31.2	34.9	40.0↓	40.8	24.4	40.4	28.4
5	0.0	17.3	17.0↓	14.5	18.7	36.8↓	36.3	38.9	42.3	23.4	40.6	27.7
6	0.0	14.2	15.6↓	15.2	17.5	31.5↓	39.1	38.7	38.6	23.4	38.6	27.2
Mean	0.0	17.9	18.1	15.3	20.1	32.4	35.4	38.9	41.9	23.2	40.3	27.5
SE±		4.8	4.4	4.0	3.2	4.5	3.5	3.6	2.6	1.4	2.4	1.2
C.V(%)		32.9	29.9	32.0	19.8	17.1	12.0	11.4	7.7	7.4	7.4	5.4

↓ = Insecticidal spray.

In season 2002/03, parasitism followed the same pattern of appearance and increased as in the previous season (Table 2). Parasitism appeared on the 3rd of November at 3.7%, as the averages for the seven sectors show, and increased to 47.2% towards the end of December. The highest level of parasitism reached in the season was 48.2%. The average for November was 9.3%, December 41.5%, and for season was 27.2%. In contrast, parasitism in the Gezira (central Sudan), starts from September (at 6%), increases to the maximum towards November (30%) and gradually decreases afterwards (Gameel, 1969).

Table2. Percentage of parasitised whitefly nymphs with *E. lutea* at different sectors and sampling dates season 2002 /2003.

Sector	Date of count										Average parasitism %		
	30.10.02	3.11	8.11	16.11	24.11	1.12	10.12	19.12	26.12	30.12.02	Nov.	Dec.	Season
1	0.0	3.7↓	11.6	6.8↓	16.0	40.5	35.3	41.8 a	45.3	46.2	9.5	41.8	27.5
2	0.0	2.9	6.2	5.9↓	15.2	44.6	33.3↓	42.1 a	46.9	47.6	7.6	42.9	27.2
3	0.0	3.2↓	8.6	7.1	19.6	40.9	33.0	41.8 a	46.3	48.2	9.6	42.0	27.6
4	0.0	3.7↓	11.6	6.7	17.8	41.9	33.3	43.5 a	46.3	48.0	9.9	42.6	28.1
5	0.0	2.7	5.1	5.4	19.5↓	40.2	27.1	37.7 bc	45.6	45.4	8.1	39.2	25.4
6	0.0	4.5	13.3	7.3↓	17.1	39.4	33.2	34.3 c	46.4	47.4	10.5	40.2	27.0
7	0.0	5.0	10.1↓	7.1	18.6	39.8	33.0	40.7 ab	47.2	47.5	10.2	41.6	27.7
Mean	0.0	3.7	9.5	6.6	17.7	41.0	32.6	40.3	46.3	47.2	9.3	41.5	27.2
SE±		0.3	0.5	0.2	0.3	0.5	0.2	2.1	2.0	1.5	1.3	1.9	1.2
C.V(%)		17.9	18.5	9.1	9.8	9.9	5.3	6.4	5.3	3.9	16.4	5.7	5.3

Means within a column followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.
↓ = insecticidal spray.

In spite of the comparatively low parasitism recorded during November for both seasons (23.2% and 9.3%) that proved to be insufficient in keeping the whitefly populations below the ETL, it delayed reaching the ETL and sprays during that month. As parasitism increased to 40.3% and %41.5during December of season 2001/02 and 2002/03, respectively، the whitefly populations were kept at low level and no sprays were needed. These results agree with those of several authors (Parrella *et al* 1991،) ؛Hoddle *et al*, 1996) who stated that *Bemisia* infesting poinsettia was kept at low densities by different *Encarsia* spp.

With regards to the interaction of parasitism with the insecticidal sprays as, e.g. in sector one of season 2002/03 (Fig. 1): Virtually, two sprays were applied against the whiteflies at threshold level in this sector. The first spray was carried out on the 6th of November 2002 at 5.2 adults per leaf and the second was after 12 days at 4.7 adults. Three weeks later (10 December), the sampled numbers of the whitefly adults were below the ETL (3.4 / leaf). However, when we add the 1.9 parasitized nymphs، counted at the same date per leaf, which would have developed into adults if no parasitism occurred, the total would have reached the ETL، 5.3 adults/leaf. A spray should have been conducted then. But it was not. Hence, the parasite saved one spray (on 10 December). On 26 December، the sampled whitefly adults counted 3.1/ leaf, and the parasitized nymphs registered

2.6/1eaf. Accordingly, the total number would have again reached the ETL, 5.6 per leaf, if no parasitism occurred, and another spray should have been conducted. Therefore, *E. lutea* saved another spray on 26 December. Applying this analysis for sectors 2-6 of season 2001/02, and the seven sectors of season 2002/03, it was found that of the 14 insecticidal treatments that should have been carried out against the whitefly in season 2001/02, ten were executed, and four (29%) were saved by the parasite. In season 2002/03, the parasite showed better efficiency and saved eight sprays (50%) of the total 16 that should have been carried out. The average reduction of sprays due to *E. lutea* of both seasons was 39.5% (Table 3).

The analysis of pesticide cost for season 2002/03 showed that one spray per ha (price of products + cost of application), with the commonly used mixture against the whitefly diafenthiuron + profenfos, was 43.1 US$. The cotton area of NHAS grown in 2001/02 season was 17220 ha and in 2002/03 season was 16170 ha, and the average number of sprays was 3.28 and 2.52, respectively, Calculating the saved sprays by *E. Lutia* (%39.5) of the above average sprays in season 2001/02 and 2002/03, it

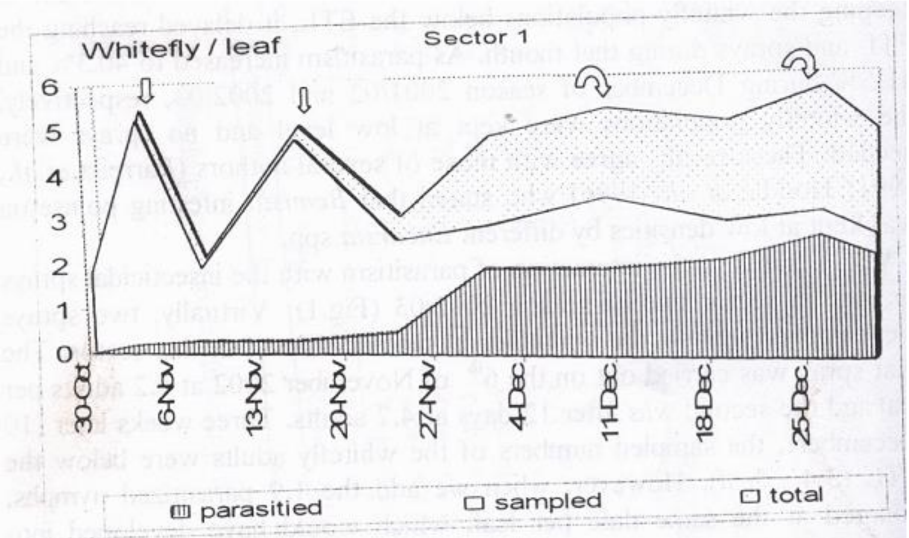

Fig. 1. The sampled, parasitised and total whitefly adults per leaf; executed sprays (⇩) and saved sprays (↷) by *E. lutea* in sector 1, season 2002/03.

Table 3. The total insecticidal treatments that should have been carried out against the whitefly, the actual executed, and the saved by *E. lutea*.

	Season 2001/02			Season 2002/03		
Sector	Total	Carried	Saved	Total	Carried	Saved
1	2	2	0	4	2	2
2	3	2	1	3	1	2
3	2	1	1	2	1	1
4	2	1	1	2	1	1
5	3	2	1	1	1	0
6	2	2	0	1	1	0
7				3	1	2
Total	14	10	4 29%	16	8	8 50%

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was found that the parasite had saved 2.14 and 1.65 sprays, respectively، i.e. in terms of money equals to:

2.14 sprays x 17220 ha x 43.1 $ = 1,588,269 $ in season 2001/02 and

1.65 sprays x 16170 ha x 43.1 $ = 1,149,930 $ in season 2002/03

Around three million US$ (2,738,199) were saved by *E. lutea* in both seasons, and the average saved for the season was 1,369,100 US.$ Moreover, by reducing the numbers of the immature whiteflies, known to produce the honeydew as the adults do, *E. lutea* indirectly improves the grade of the cotton fibre. The latter finding explains why NHAS cotton is historically known to be less sticky as compared to that of Gezira and Rahad cotton producing schemes (Sudan). In 1998/99 season, 84% of the cotton fibres produced in NHAS was classified as free of stickiness، versus 36% and 0% for Gezira and Rahad Schemes, respectively, and only 1% of NHAS cotton fibres was classified as highly sticky versus %14and 87%, respectively (Abdelatif *et al*., 2002).

No insecticide treatments applied in the second season affected parasitism, except diafenthiuron(1) +profenfos(1) applied on 14 November in sector 7. It reduced parasitism by 30% compared to the pre application rate. These results could serve as basis for future field and laboratory studies to identify selectivity of insecticides to all stages of *E. lutea*.

In conclusion, The high parasitism efficiency of *E. lutea*, during December and onwards, makes growing of the long stable varieties, such as Barakat S, known to have longer vegetative period and better price than Barac (67) B, in New Halfa region, logical. The parasite can be brought to the Gezira and Rahad Schemes for possible augmentation، introduced to wherever whitefly problems exist, in a similar way to the shipment of *E. lutea* from Gezira to the University of Florida (U.S.A) for release against *B. tabaci* on vegetable crops (Stam, 1991).

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