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ARTHROPOD MANAGEMENT

Development of a New Whitefly Trap

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INTERPRETATIVE SUMMARY

We have developed a new whitefly trap that is easy to use, washable, reusable, and inexpensive to make. Trap catches can be counted against dark background without the aide of microscope as suggested for counting adults on yellow sticky card traps. It can be used by farm advisers or extension agents for assessing daily or weekly adult whitefly density in a cotton field or adult population changes in a specific period without saturation. It can be complementary to leaf-turn adult counts for decision making for initiating pesticide application. It can also be used to research the dispersal pattern of whitefly adults in a cotton field or between cotton and other crops in fields or greenhouses. The trap has been named *CC trap* and is pending for a patent. The trap can be used as an alternative to yellow sticky card traps, which is not reusable and difficult to handle because of its stickiness. Research is in progress to use the traps in greenhouses to capture adult whiteflies without reducing the parasites released to control whitefly nymphs.

ABSTRACT

The CC trap was designed to capture whitefly (*Bemisia* spp.) adults for survey, monitoring, and sampling in the field and in the greenhouse. The trap design was based on whitefly adult behavioral attraction to yellow color, flight orientation to sky light when leaving host plants, and walking to shade when landing on a new host for feeding and egg laying. The trap does not use sticky materials or bait. It can be placed in greenhouses or fields for extended periods without saturation catches of whitefly adults. The trap does not catch many other insect types and avoids dust contamination. It is washable, reusable, inexpensive, and easy to use. Whiteflies caught can be counted against a dark background without the aid of a microscope. It may also have potential for supplementary adult whitefly control in greenhouses where parasites are released for the control of whitefly nymphs since it does not catch many *Eretmocerus* spp. parasites. The trap can also be used as a research tool for studying whitefly activity in the field.

Whiteflies are serious economic pests worldwide (Basu, 1995; Byrne et al., 1990). Economic losses caused by silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, have been significant. In 3 years (May 1991–April 1994), losses in the Imperial Valley of California approached 1 billion dollars (Birdsall et al., 1995). Yellow sticky card traps have been widely used for monitoring of whitefly adult activity in the field (e.g., Natwick et al., 1995). They have also been used to trap whitefly adults in greenhouses but conflict with objectives where parasites are released to control whitefly nymphs. There are several disadvantages in using yellow sticky card traps: (i) they are difficult to handle because of the sticky material, (ii) trap surfaces may be rendered ineffective when covered with dust, (iii) sticky surfaces usually catch other insect species in addition to the target whitefly adults, (iv) sticky surfaces are easily saturated with whitefly adults under high population densities, (v) sticky card traps are not reusable without re-coating, (vi) sticky card traps catch whitefly parasites released in greenhouses for control of nymphs, and (vii) a microscope is needed to aid in counting the adult catches.

In a study of adult silverleaf whitefly behavior (Chu et al., 1995), we observed that when adults landed on lighted upper leaf surfaces, they walked to shaded lower leaf surfaces for feeding and egg laying. When they left a host, they flew toward the skylight. Whitefly attraction to yellow was documented as early as 1921 (Lloyd, 1921) and subsequently confirmed by other scientists (Mound,

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1962). Because of the urgent need for whitefly sampling methods, we used the observed whitefly behavioral patterns described, to develop a whitefly adult trap (CC trap) that could be a viable alternative that avoids many of the disadvantages of yellow sticky card traps. We report here the results of our studies on trap development and evaluation as a survey, monitoring, and research tool in the field and under greenhouse conditions. All studies were conducted at the USDA-ARS, Irrigated Desert Research Station, Brawley, CA, in 1996.

MATERIALS AND METHODS

Description of the CC Trap

Initially, the CC trap consisted of two components (Fig. 1). The trap top (component a) is an 11.2 cm high, 350 mL crystal clear plastic drinking cup (Comet Products, Inc., Chelmsford, MA). The open cup end fits into a yellow plastic base (component c) with a cylinder shape outside and hollow cone inside surface. The trap base is 4.1 cm high with bottom opening diameters of 7.9 cm outside and 7.1 cm inside; the top opening of the trap base has a 5.2 cm outside diameter and 4.8 cm inside diameter. A third trap component was added after preliminary trap evaluations. The additional component, a circular clear plastic deflector plate with a diameter of 6 cm (component b), was mounted over the top trap base opening and was supported by four 3.7 cm long plastic legs. The gap between the trap base top opening and the plate is 1.5 cm. The hollow cone trap base openings allow insect entrance and the deflector plate prevents trapped adults from escaping. The trap base can hold approximately 46000 whitefly adults.

Comparison of Initially Designed CC Traps (without Trap Base Top Opening Deflector Plate) with Yellow Sticky Card Traps - Preliminary Evaluations

The yellow sticky card traps used for comparison with CC traps were 7.6 by 12.7 cm in size with 92 cm^2 sticky surfaces. The sticky surface was exposed face downward in test fields. The CC traps in the field were hung on wooden stakes and placed 15 to 20 cm into the crop canopy. The yellow sticky traps were clamped on wooden stakes

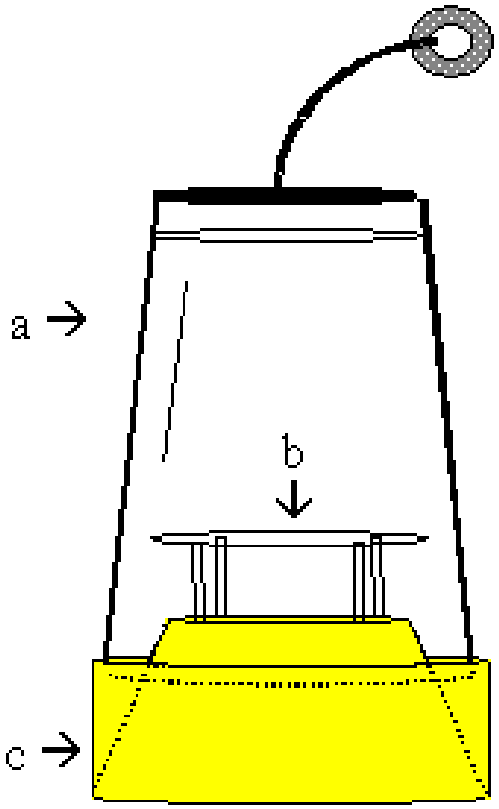

Fig. 1. Description of a new whitefly CC) trap (*a*) trap top, (*b*) deflector plate, and (*c*) trap base.

and were placed at the same height as the CC traps. Adults caught in CC traps in experiment 1 and all subsequent experiments were poured from the traps, after being subjected to subfreezing temperatures, and counted against a dark background. Adults caught with the yellow sticky card traps were counted directly on the sticky surface with the aid of a microscope. Times required to count the whitefly catches were recorded.

Experiment 1 comparing CC trap and yellow sticky card trap efficacy was conducted in an unknown density of whitefly infested kenaf (*Hibiscus cannabinus* L.) parasite refugia. Traps were placed in the field on 26 July and again on 21 August and exposed for 1, 2, 3, 4, or 5 days. Each treatment (trap) was replicated four times. Experiment 2 comparing CC trap and yellow sticky card trap performance at three levels of whitefly adult densities: high (untreated collard, *Brassica oleracea* var. *acephala*), medium (untreated cotton, *Gossypium hirsutum* L., cv. Deltapine [DPL] 5461), and low (insecticide-treated cotton). Treatments (traps) were replicated six times at each whitefly

density. Traps were exposed for 24 h from 10 to 11 June.

Development of the Clear Plastic Deflector Plate Modification of the CC Trap

Following the preliminary evaluations of the CC and yellow sticky card traps, the third trap component, as described in the Material and Methods sections, was added to the CC trap to improve whitefly trap captures. Experiments 3 and 4 were conducted in a greenhouse with whitefly infested cantaloupe (*Cucumis melo* var. *cantalapensis* L.) plants. CC traps with and without the trap base top opening plate deflector were suspended about 50 cm above the plants. Traps were set in place between 0900 to 1100 hour each day for 6 days for 24 h exposures. Experiment 4 was conducted in a similar manner to compare the effect on trap catches of the height of the deflector plate above the trap base top opening. The deflector plate was placed at 2.5 or 1.5 cm above the opening. Traps were placed in the greenhouse at the same times of day for 24 h exposures on each of 4 days. Traps were retrieved and placed on white sticky papers for 24 h to determine the escape of the trapped adults.

Performance of CC Trap in Cotton Fields

Experiment 5 was conducted in the field to determine the potential of the CC trap for measuring seasonal whitefly population variations and differences in populations among cotton cultivars. There were with four cotton cultivars: DPL 5415, DPL 5461, Stoneville (ST) 474, and Louisiana (LA) 887 in a randomized complete block design. Each small plot was partially isolated from others using four skip rows to reduce whitefly adult migration between plots. Plots were six rows wide. Rows were 6 m long and spaced 1 m apart. A CC trap or yellow sticky trap was placed in the middle of plots. The traps were exposed for 24 hour periods for nine sampling days during 15 July to 12 August. Also the number of whitefly adults on 10 fifth node leaves from main stem terminals (Naranjo and Flint, 1994), in each plot were counted weekly to compare with CC trap catches. Experiment 6 was conducted in an untreated cotton field on 1 August with three replicates of each trap type to compare adult whitefly and *Eretmocerus* adult whitefly parasites captures in the CC trap with those caught in the yellow sticky card trap.

Data from all experiments were statistically analyzed using the MSTAT-C computer program (MSTAT-C, 1989).

RESULTS

Comparison of Initially Designed CC Trap (Without Trap Base Top Opening Deflector Plate) with Yellow Sticky Card Traps

Whitefly adult catches in CC traps without a trap base top opening plate deflector were significantly correlated (r = 0.693) with yellow sticky card whitefly trap catches (Table 1, Experiment 1). Significantly fewer whitefly adults were caught with CC traps than with yellow sticky card traps by a factor of about three to seven times. Accordingly, less time was required to count the CC trap catches compared to yellow sticky card traps

Table 1. Mean numbers of silverleaf whitefly adults caught and counting time for CC whitefly traps without a trap base plate deflector and yellow sticky card trap catches in a kenaf refugia (Exp. 1).

	No. adults caught per		Time (seconds) to count adults	
Days	CC trap	Yellow sticky trap	CC trap	Yellow sticky trap
1	42.6 ± 8.8 b†	140.1 ± 17.0 b	22.5 ± 2.6 b	99.6 ± 5.7 c
2	39.5 ± 11.5 b	242.9 ± 40.3 b	22.5 ± 4.3 b	137.5 ± 13.4 b
3	65.5 ± 19.8 ab	407.0 ± 97.1 a	34.9 ± 4.9 a	151.1 ± 20.3 b
4	81.1 ± 22.3 a	528.0 ± 91.6 a	37.0 ± 6.0 a	198.6 ± 20.7 a
5	81.3 ± 17.0 a	546.9 ± 99.8 a	36.0 ± 4.3 a	197.7 ± 19.7 a
Total	310.0	1864.9	152.9	784.5
F value (*P*)	4.78 (0.005)	12.62 (< 0.001)	12.64 (< 0.001)	11.53 (< 0.001)
Correlation coeff.	-	0.693***	-	0.623***

*** Significant at $P < 0.001$ ($n = 40$).

† Means (± standard error) in a column with different letters differ significantly (Student- Neuman-Keul's multiple range test, $P = 0.05$).

Table 2. Mean numbers of silverleaf whitefly adults caught and counting time required for CC whitefly traps without a trap base opening deflector and yellow sticky card traps at three levels of whitefly population (Exp. 2).

	Adult whitefly population densities†					
	High†	Medium	Low	High	Medium	Low
Trap type Counting time (s)	Adults/trap/day					
CC	68.0 ± 16.9 b‡	31.3 ± 6.8 b	23.3 ± 3.9 a	97.7 ± 5.2 b	64.2 ± 5.0 b	61.3 ± 4.4 b
Yellow sticky card trap	438.7 ± 40.9 a	188.2 ± 20.7 a	66.3 ± 17.7 a	181.0 ± 19.6 a	157.3 ± 14.0 a	88.7 ± 9.7 a
F value (*P*)	74.5 (<0.001)	36.1 (<0.001)	2.38 (0.14)	14.2 (<0.001)	76.8 (<0.001)	15.1 (<0.001)

† High, medium and low whitefly population densities in infested collards, and untreated and insecticide treated cottons, respectively.

‡ Means (± standard error) in a column with different letters differ significantly (*t*-test, $P = 0.05$).

catches by a factor of four to six times. However, for all trapping days, 49 and 42 seconds/100 whiteflies were required for counts in CC and yellow sticky card traps, respectively. Counting of whitefly adults on the yellow sticky traps required a skilled technician with aid of a microscope. Similar results were obtained in another comparison of the two traps placed in fields with different whitefly adult population density levels (Table 2, Experiment 2).

Development of the Clear Plastic Deflector Plate Modification of the CC Trap

When the CC trap was fitted with a circular deflector plate mounted 2.5 cm above the trap base top entrance opening to prevent the escape of trapped adults, the catches were increased more than three times as compared to the CC trap without base top opening plate (Table 3, Experiment 3). Reducing the distance between the deflector plate and the insect entrance opening of the trap base increased whitefly catch further by decreasing escaping adults from 54 to 40% (Table 3, Experiment 4).

Performance of CC Trap in Cotton Fields

For experiment 5, seasonal mean whitefly adult catches in CC traps followed the same trend as adults using the leaf turn method (Table 4). However, correlations between the leaf turn method and trap catches were low. This is probably because traps reflect accumulated numbers of adults from 24 h trap exposures as opposed to the leaf turn, which is an observation count at the time of plant examination. The leaf turn method (Naranjo and

Table 3. Comparison of whitefly adult catches in CC whitefly traps with and without trap base top opening deflector plates and percent of catches remaining in the traps (Exp. 3 and 4).

	No. adults/trap-24 h	No. adults/trap-24 h	% Adults remaining after 24 h
CC trap	Exp. 3	Exp. 4	
Without plate	187.3 ± 1.1 b†	164.7 ± 15.7 a	27.7 ± 5.7 b‡
With plate 2.5 cm high	713.4 ± 1.6 a	180.3 ± 21.2 a	46.4 ± 5.4 a
With plate 1.5 cm high		236.8 ± 39.3 a	59.6 ± 6.2 a
F value (*P*)	6.81 (0.014)	2.33 (0.216)	7.59 (0.004)

† Means (± standard error) in a column with different letters differ significantly (*t*-test, $P = 0.05$).

‡ Without continuous supply of adults from plants.

Table 4. Mean seasonal numbers of silverleaf whitefly adults caught in CC whitefly traps† in relation to different whitefly adult densities on the four cotton cultivars fron 15 July to 12 Aug. 1996. (Exp. 5).

Correlation cultivar	No. adults/ leaf turn	No. adults/ trap per 24 h	Coefficient
DPL 5415	17.8 ± 1.2 b‡	63.4 ± 5.2 c	0.249**
DPL 5461	15.0 ± 1.2 c	61.3 ± 6.0 c	0.235*
ST 474	23.1 ± 1.3 a	98.7 ± 8.9 a	0.014
LA 887	22.2 ± 1.3 a	85.3 ± 6.9 b	0.034
F value (*P*)	27.34 (< 0.001)	16.53 (< 0.001)	

*, ** Significant at $P = 0.05$ and $= 0.01$, respectively. $N = 108$.

† With plate 1.5 cm above top opening of trap base.

‡ Means (± standard error) in a column with different letters differ significantly (Student-Neuman-Keul's multiple range test, $P = 0.05$).

Table 5. Mean numbers of silverleaf whitefly adults and Eretmocerus parasites caught in CC and yellow sticky card traps in an untreated cotton field (Exp. 6).

	No. adults/trap per 24 h	
Trap type	**Whitefly**	**Eretmocerus spp.**
CC†	**43.7 ± 9.2 a‡**	**0.0 ± 0.0 b**
Yellow sticky card	**21.0 ± 4.7 b**	**27.0 ± 3.6 a**
***F* value (*P*)**	**17.85 (0.050)**	**56.08 (< 0.017)**

† With plate 1.5 cm above the top opening of trap base.

‡ Means (± standard error) in a column with different letters differ significantly (*t*-test, *P* = 0.05).

Flint, 1994) has been widely accepted by cotton growers in the United States as a decision-making tool to determine the need for insecticide applications for silverleaf whitefly control. From the results presented here, it appears that in some circumstances the CC trap results can be used in conjunction with the leaf-turn method. However, because of the difference in temporal sampling times between the two methods, our results suggest the need for critical studies to determine potential relationships between CC traps catches, whitefly population development, and cotton yields and quality. The CC trap may have use as a decision-making tool regarding critical action thresholds requiring control action.

In experiment 6 in an untreated (no insecticide) cotton field, the CC traps caught more whitefly adults compared with yellow sticky card traps (Table 5, Experiment 6). The CC trap did not catch whitefly parasites (*Eretmocerus* spp.). Further, CC trap catches were almost exclusively whiteflies. A similar but more extensive field test completed in September 1996 confirmed that CC traps did not catch parasites in a cotton parasite refugia field (Hoelmer et al., 1998). Similar results were also observed in greenhouse studies (K.L. Esau, USDA, APHIS/PPQ, Mission Biological Control Center, Mission, TX, 1997, personal communication; and K. Bolckmans, Biobest Biological Systems, Westerlo, Belgium, 1997, personal communication).

DISCUSSION

The CC trap is inexpensive, costing about $0.71 (U.S.) apiece to produce (7 cents for trap top cup components and 64 cents for a trap base component with a deflector plate) but can be used repeatedly as compared to $0.23 apiece for a 3 by 5 inch sticky card used only once. It does not require any bait or sticky material and is washable and easy to handle. These unique features make it easily acceptable to growers of field and greenhouse crops for use where whitefly is an economic pest. The CC trap was adopted by Imperial County Agricultural Commissioner's Office for monitoring the seasonal silverleaf whitefly population density changes. In that program it has been used in the Imperial Valley since 1996. In 1997 and 1998, the traps have been used by both Imperial and Palo Verde Valleys. Results with yellow sticky card traps exposed for more than 1 day are often unreliable because of dust and dirt coverage of the sticky material. The CC traps have not been tested with bandedwinged whiteflies (*Trialeurodes abutilonea* Haldeman), however, the two whitefly species have similar flight activity (Byrne and Bretzel, 1987). Tests under choice and no-choice conditions in 1996 and 1997 cotton fields showed that CC trap catches were significantly correlated with densities of whitefly adults estimated on leaves using leaf-turn method when leaf counts were 5.4 or more adults per leaf (Chu et al., 1998). The fact that the CC trap caught few whitefly parasites (*Eretmocerus* spp.) in the field (Hoelmer et al., 1998) suggests that it has potential for use as a supplementary control device to trap adults where parasites are released in greenhouses for control of whitefly nymphs. A test of CC trap in a greenhouse showed that the CC traps caught significant numbers of greenhouse whiteflies (*Trialeurodes vaporariorum* Westwood) (Zhu Guoren, Institute of Vegetable and Flowers, Chinese Academy of Agricultural Sciences, July 1998, personal communication). Research on the selectivity of trapping whiteflies and parasites in greenhouses is in progress, initial results are promising.

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