#10101 Zeta-cypermethrin

Proc. Fla. Hort Soc. 2008
Paper No. C-15
Citus Section

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EVALUATION OF LOW VOLUME APPLICATION TECHNOLOGIES FOR ASIAN CITRUS PSYLLID (*DIAPHORINA CITRI* KUWAYAMA) CONTROL: INITIAL RESULTS

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Additional index words. Cold fogger, Proptec sprayer, Micronair nozzles, Huanlongbing, Citrus Greening

Abstract. **The occurrence of citrus greening (huanglongbing) disease in Florida mandates the effective control of the insect vector, Asian citrus psyllid (*Diaphorina citri* Kuwayama). Anecdotal evidence suggests that reducing psyllid populations via insecticide application may slow the rate of disease spread. Due to its speed and low cost, growers have experimented with low volume application technology for controlling psyllids. The overall objective of this study was to evaluate ultra low volume (ULV, fogging) applicators for control of *D. citri*. Efficacy with ULV technologies was equivalent to that with standard airblast applications. The duration of efficacy was much longer if a dormant winter spray was applied rather than a spray after spring flush. Pyrethroid, organophospate and insect growth regulator insecticides were effective against *D. citri* when applied as ULV sprays. Although fogging applications are effective, several pesticides known to be effective for psyllid control are currently not registered for application with ULV equipment. More research and appropriate regulatory changes to labels will be needed before fogging should be implemented commercially.**

Footnotes

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The Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae), is one of the most important worldwide pests of citrus. It causes both direct and indirect damage by feeding on plant sugars and reducing leaf area. Psyllids also vector three phloem-restricted bacteria in the genus *Candidatus* Liberibactor , which cause citrus greening (huanglongbing) the most serious disease of citrus worldwide (Halbert and Manjunath, 2004; Bové, 2006). Citrus greening was confirmed in Florida in 2005 and has become established throughout the state. Infected citrus trees initially exhibit symptoms of leaf mottling and chlorosis (Bové, 2006). Diseased trees produce less fruit which are misshapen, bitter-tasting, and unmarketable (Bové, 2006). Subsequently, plants become stunted and begin dying from branch tips downward potentially resulting in death of entire trees. The Florida citrus industry, with annual estimated earnings of $1.1 billion, is potentially doomed if the 'greening' disease is not controlled. Given its firm establishment throughout commercial citrus in Florida, eradication of *D. citri* is impossible and current efforts are focused on stringent management (Rogers et al., 2008; Srinivasan et al., 2008). It is believed that this may slow the spread of greening disease throughout Florida and to other citrus growing states in the U.S. where this disease has not yet invaded (Louisianna, Texas, Arizona, and California). Currently, soil-applied systemic and foliar insecticides are the only means of controlling *D. citri* and thus, managing disease spread (Rogers et al., 2008).

The use of ultra low volume (ULV) sprays or 'fogging' of insecticides for control of *D. citri* has recently gained substantial interest among Florida citrus growers. The potential advantages of ULV applications compared with standard airblast applications are ease of transporting equipment, shorter application time and reduced cost per application. Given that psyllid management requires a multitude of sprays compared to recent Florida citrus production spray programs, a rapid and inexpensive deployment protocol is highly desirable. ULV sprays can be delivered with various types of applicators and typical spray volume can be 2 gallons per acre (18.7 L per ha) or less. Depending on the type of ULV applicator, application speed can reach 10 miles (1.6 km) per hour. ULV sprays concentrate active ingredient per droplet and increase the number of droplets applied per leaf surface compared with standard airblast sprays of 100 or more gallons per acre (>935 L per ha). A disadvantage of fogging is that applications need to be made during night and early morning hours to minimize the potential of wind drift.

The overall objective of this study was to evaluate ultra low volume applicators for control of *D. citri*. The specific objectives were to compare: 1) various fogging technologies with standard airblast applications, 2) application efficacy at different times of the season (dormant winter spray versus after onset spring flush), and 3) efficacies of various insecticide modes of action.

Materials and Methods

Experiment 1. The objective of this experiment was to compare three types of ULV applications versus an airblast positive control application delivered on 15-16 Feb., 2008 prior to the onset of spring flush. All applications deployed 1 pint per acre (1.2 L per ha) of a formulated synthetic pyrethroid. The treatments compared were: 1) London cold fogger (Model 18 20, London Foggers, Long Lake, MN) at 1 pt per acre (1.2 L per ha, no carrier), 2) London cold fogger at 2 gallons per acre (GPA) (18.7 L per ha), 3) Mist blower with Micronair (Bromyard, Herefordshire) nozzles at 2 GPA (18.7 L per ha), 4) standard airblast at 100 GPA (935 L per ha), and 5) untreated control. Treatments 1 and 2 were applied at approximately 10 miles per hour (MPH) (16 km per hr), whereas treatments 3 and 4 were applied at 3 MPH(4.8 km per hr). Treatments were applied to 10 acre (4 ha) replicate plots of sweet orange [(*Citus sinensis* [L.Osbeck]) arranged in a randomized complete block design with three replicates. Treatments were evaluated weekly by monitoring adult psyllid activity with Pherocon AM (Trécé, Adair, OK) yellow sticky traps (8 per 10 acre (4 ha) replicate plot). Traps were hung vertically on the edge of trees, approximate 5 ft (1.5 m) above ground level. Traps were deployed at least 65 ft (20 m) apart in each block. In addition, leaf flush was sampled for psyllid eggs and nymphs. On each sampling date, five terminal flush samples were collected from the interior portions of 8 trees within each replicate plot. Flush samples from each plot were placed in 70 % alcohol and transferred to the laboratory for inspection. Flush samples from each plot were carefully examined using a stereomicroscope. All psyllid eggs and nymphs were counted.

Experiment 2. The objective of this experiment was to compare two types of ULV applications versus an airblast control application delivered on 11 April, 2008 during the spring flush. In this case, no application was made prior to the onset of flush during the dormant winter period as was done in Experiment 1. All applications deployed a synthetic pyrethroid insecticide at the label rate of 4.3 oz / acre (314 ml per ha). The treatments compared were: 1) London cold fogger at 1 pint (1.2 L, Proptec ULV sprayer (Proptec, Bath, MI) at 2 GPA (18.7 L per ha), and 3) standard airblast at 100 GPA (935 L per ha). Treatments were applied to 11 acre (4.4 ha) replicate plots of sweet orange arranged in a randomized complete block design with three replicates. Treatments were evaluated weekly by monitoring adult psyllid activity with Pherocon AM yellow sticky traps (6 per 11 acre (4.4 ha) replicate plot). Traps were hung vertically on the edge of trees, approximate 5 ft (1.5 m) above ground level. Traps were deployed at least 65 ft (20 m) apart in each block. In addition, leaf flush was sampled for psyllid eggs and nymphs. On each sampling date, five terminal flush samples were collected from the interior portions of 6 trees within each replicate plot. Flush samples from each plot were placed in 70 % alcohol and transferred to the laboratory for inspection. Flush samples from each plot were carefully examined using a stereomicroscope. All psyllid eggs and nymphs were counted.

Experiment 3. The objective of this experiment was to compare the efficacy of three insecticides of different modes of action when applied by a London cold fogger. The treatments compared were: 1) synthetic pyrethoid (1 pt /per acre; 1.2 L per ha), 2) organophosphate (4 oz per acre; 292ml per ha), 3) insect growth regulator (0.31 lbs a.i. per acre = 347 g per ha), and 4) untreated control. Treatments were applied to 0.4 acre (0.16 ha) plots of sweet orange arranged in a randomized complete block design with 4 replicates. Treatments were evaluated weekly by monitoring adult psyllid activity with Pherocon AM yellow sticky traps and by examining 40 flush shoots per plot as described above.

Results and Discussion

Control of both adult (Fig. 1 A) and immature (Fig. 1B) psyllids was equivalent with ULV and standard airblast applications of a broad-spectrum pyrethroid insecticide that was applied mid February prior to the spring flush. Significantly ($P < 0.05$) more adult *D. citri* were captured in control plots than in any of the treatment plots; however, there was not significant ($P > 0.05$) difference between the four insecticide treatments. Likewise, significantly more ($P < 0.05$) eggs and nymphs were found in control plots than in the treatment plots; no immature stages could be found in any of the treatment plots. ULV application of the pyrethroid without carrier at 1 pt per acre (1.2 L per ha) of material was equivalent to a more diluted application at 2 GPA (18 L per ha).

As observed in the experiment in which treatments were applied prior to spring flush, both adult (Fig. 2A) and immature (Fig. 2B) psyllid suppression was equivalent with ULV and standard airblast applications applied during active spring flush in early April. There were no significant ($P > 0.05$) differences in the mean number of adults captured per trap or nymphs counted per flush between the three treatments over the course of this experiment. Surprisingly, captures of adults were not reduced 7 days after application of treatments (Fig. 2A). However, all three treatments reduced numbers of immature psyllids to nearly zero per flush for two weeks following application (Fig. 2B).

Although ULV treatments were equivalent in efficacy to airblast applications in both experiments, applications of a pyrethroid insecticide made during the dormant period in February prior to spring flush yielded longer-lived control than applications made after the onset of spring flush in April. The dormant applications resulted in over 5 weeks of psyllid population suppression, while an application after the onset of flush resulted in only 2 weeks of control. Dormant applications are highly recommended for effective psyllid control because overwintering populations of adults are knocked down before they can increase on new flush which is required for reproduction (Rogers et al., 2008).

ULV applications of organophosphate and pyrethroid insecticides significantly ($P < 0.05$) reduced populations of adult psyllids, as measured by captures on sticky traps, compared with untreated control plots (Fig. 3A). Adult populations were not affected by ULV treatment with the insect growth regulator (Fig. 3A). However, ULV application with all three modes of action significantly ($P < 0.05$) reduced the number of live psyllid nymphs counted per flush compared with untreated control plots (Fig. 3B). These data suggest that insecticides of at least three different modes of action have potential utility with ULV applications. Rotating chemistries will be essential for managing resistance development if ULV sprays or fogging is labeled for use in citrus with these products. Given that the IGR did not affect adult populations, it will likely be most effective to rotate that chemistry in only after an initial application of either a pyrethroid or OP prior to spring flush in order to knock down adult populations. Further evaluation of other modes of action such as neonicotinoids and carbamates should be conducted to add to the potential list of tools that might eventually be available for ULV application.

Although these data show that fogging applications are effective, several pesticides known to be effective for psyllid control are currently not registered for application with ULV equipment. More research and appropriate regulatory changes to labels will be needed before fogging should be implemented commercially.

Literature Cited

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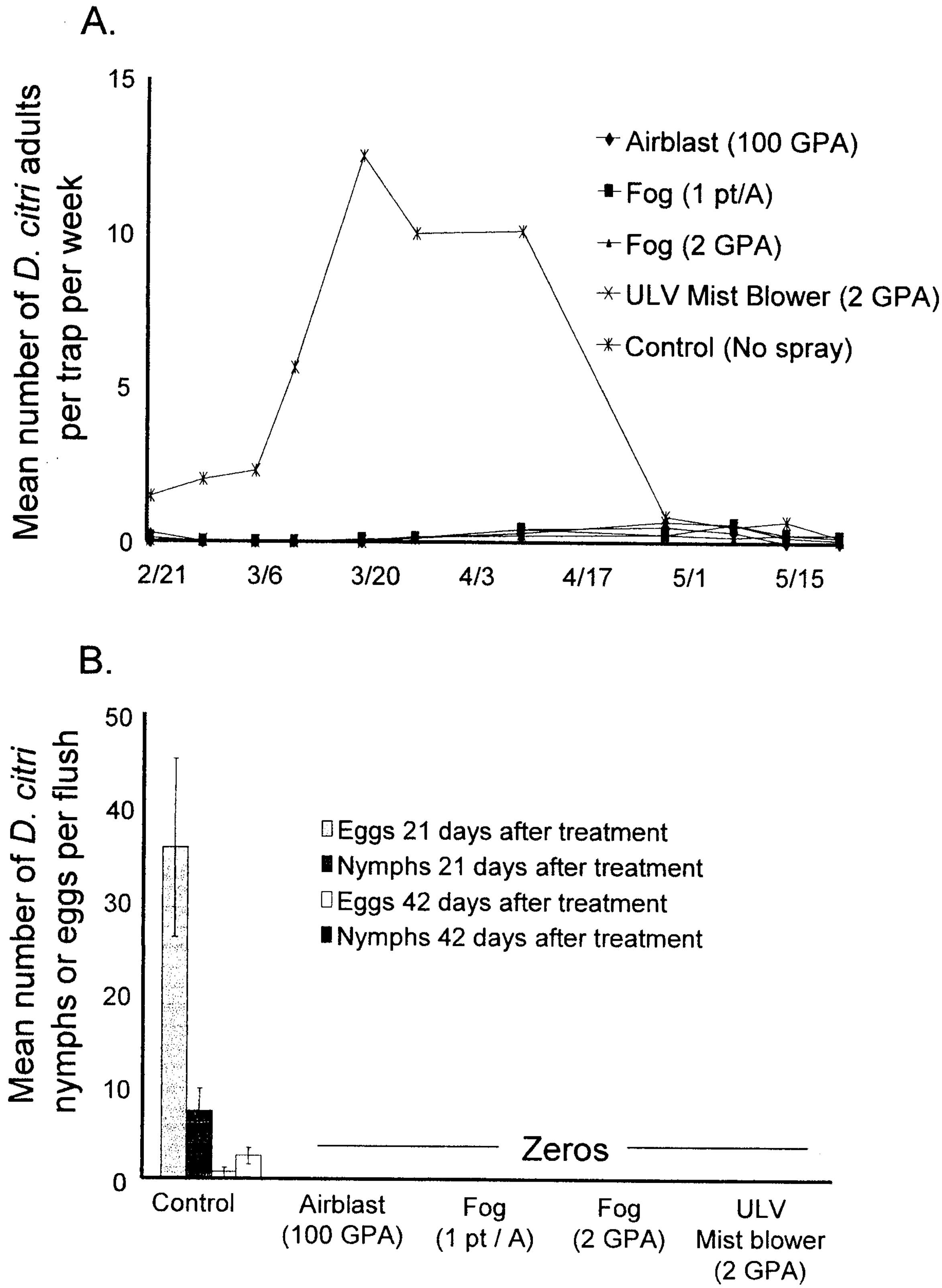
Figure Legend

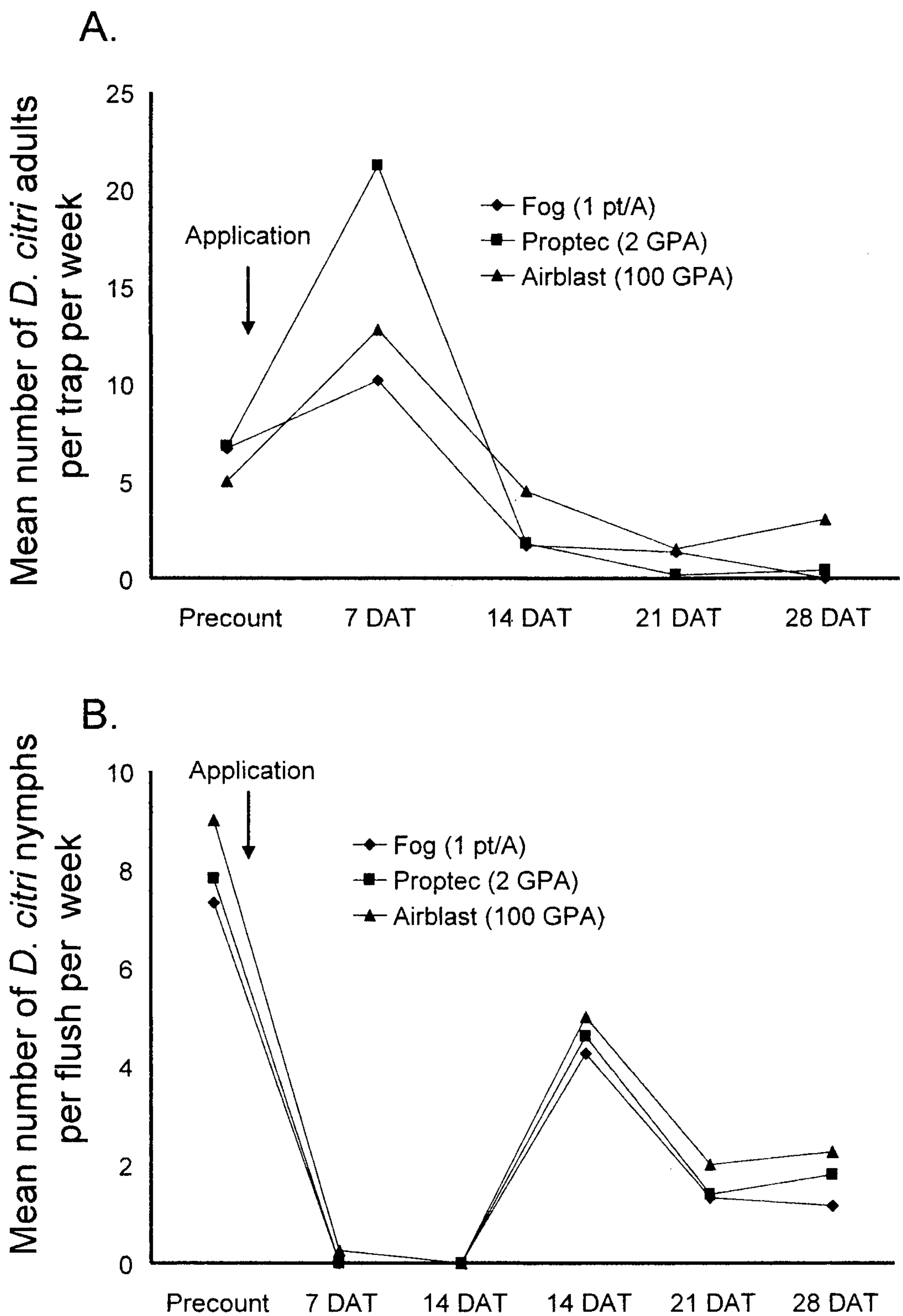
Fig. 1. Mean (n = 24) number of *Diaphorina citri* adults per sticky trap per week (A) and nymphs or eggs per flush (B) in plots treated with various ULV applications versus

standard airblast applied prior to the onset of spring flush during the winter dormant period (15-16th Feb). Vertical lines represent ± 1 SE.

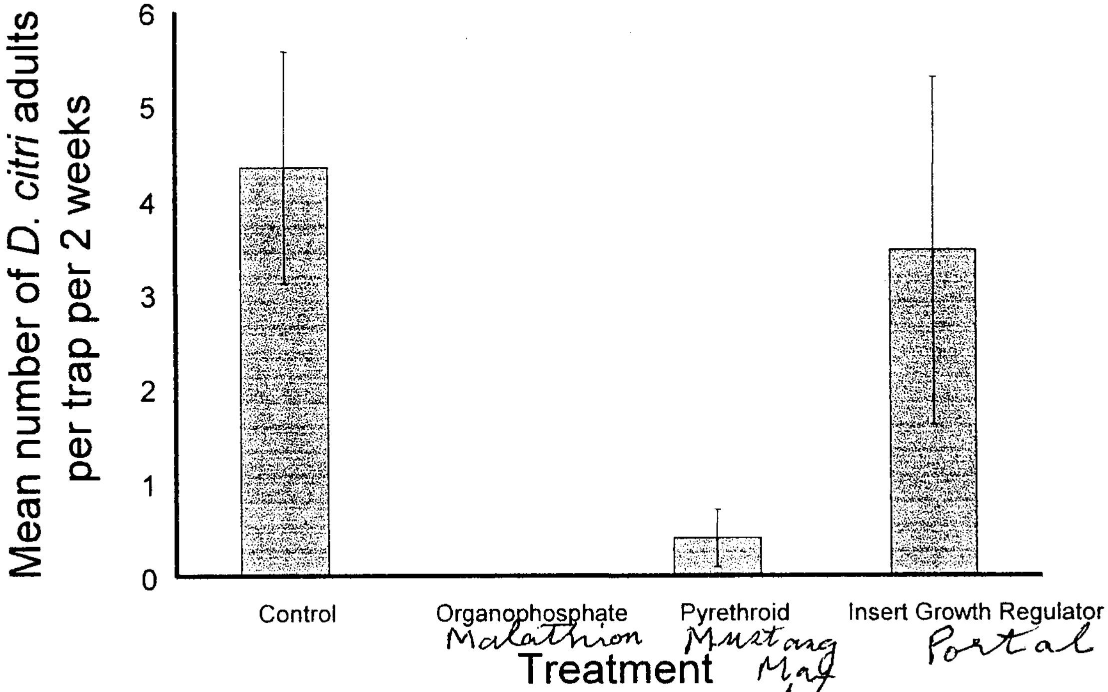
Fig. 2. Mean (n = 18)number of *Diaphorina citri* adults per sticky trap per week (A) and nymphs per flush per week (B) in plots treated with various ULV applications versus standard airblast applied during the spring flush period (11th April).

Fig. 3. Mean (n = 24)number of *Diaphorina citri* adults per sticky trap (A) and nymphs per flush (B) over a 2 week period in plots treated with either organophosphate, pyrethroid, or insect growth regulator insecticides applied by London fogger compared with untreated control plots. Vertical lines represent ± 1 SE.

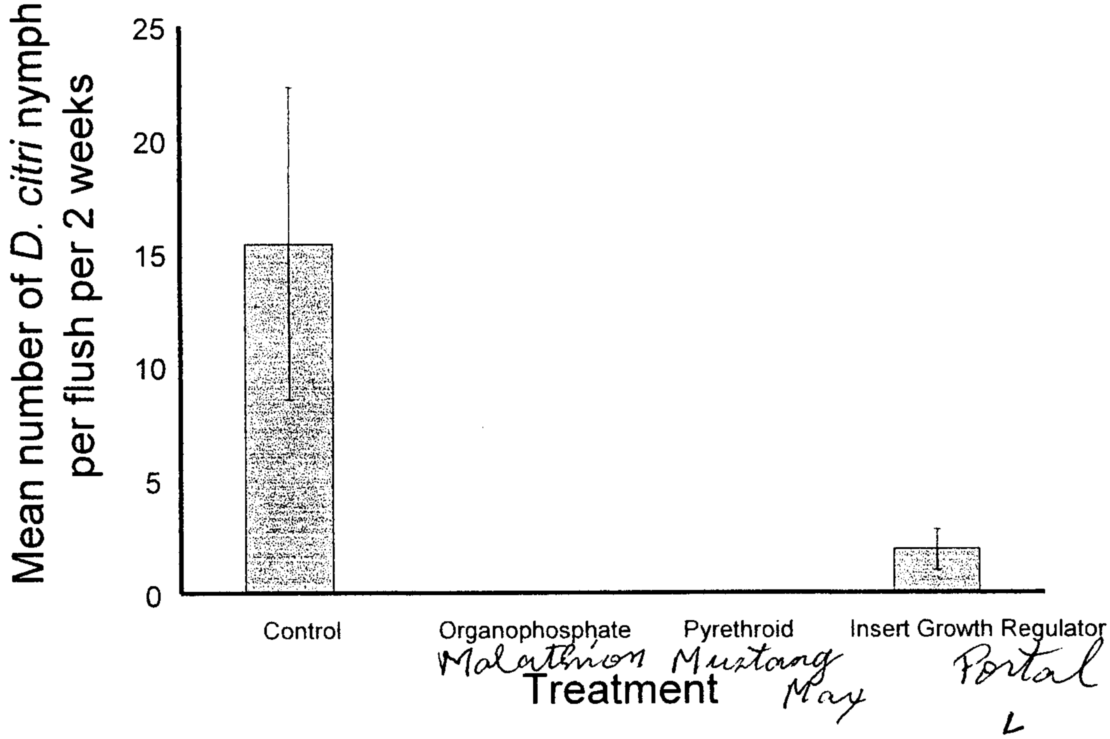

A.
Mean number of D. citri adults per trap per week
15
10
5
0
Airblast (100 GPA)
Fog (1 pt/A)
Fog (2 GPA)
ULV Mist Blower (2 GPA)
Control (No spray)
2/21
3/6
3/20
4/3
4/17
5/1
5/15
B.
Mean number of D. citri nymphs or eggs per flush
50
40
30
20
10
0
Eggs 21 days after treatment
Nymphs 21 days after treatment
Eggs 42 days after treatment
Nymphs 42 days after treatment
Zeros
Control
Airblast (100 GPA)
Fog (1 pt / A)
Fog (2 GPA)
ULV Mist blower (2 GPA)


A.
Mean number of D. citri adults per trap per week
25
20
15
10
5
0
Application
Fog (1 pt/A)
Proptec (2 GPA)
Airblast (100 GPA)
Precount
7 DAT
14 DAT
21 DAT
28 DAT
B.
Mean number of D. citri nymphs per flush per week
10
8
6
4
2
0
Application
Fog (1 pt/A)
Proptec (2 GPA)
Airblast (100 GPA)
Precount
7 DAT
14 DAT
14 DAT
21 DAT
28 DAT

A.


Mean number of D. citri adults per trap per 2 weeks
6
5
4
3
2
1
0
Control
Organophosphate
Malathion
Pyrethroid
Mustang
May
Insert Growth Regulator
Portal
Treatment
#10101

B.


Mean number of D. citri nymphs per flush per 2 weeks
25
20
15
10
5
0
Control
Organophosphate
Malathion
Pyrethroid
Mustang
May
Insert Growth Regulator
Portal
Treatment