Diaphorina citri management

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Fundecitrus
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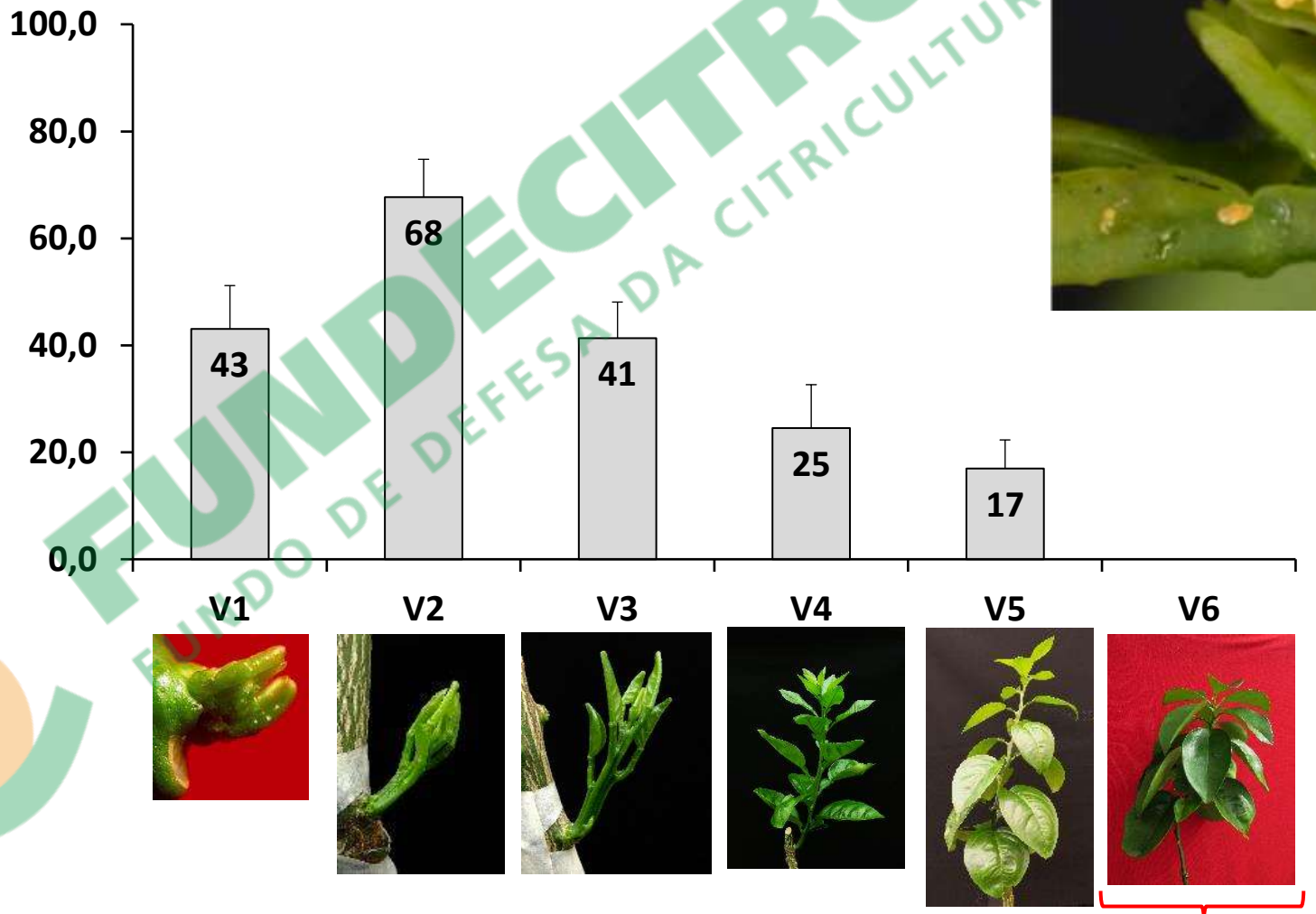
Summary

- ✓ Ecology
- ✓ Monitoring
- ✓ Chemical control
- ✓ Biological control
- ✓ Physical and cultural control

Flush shoot

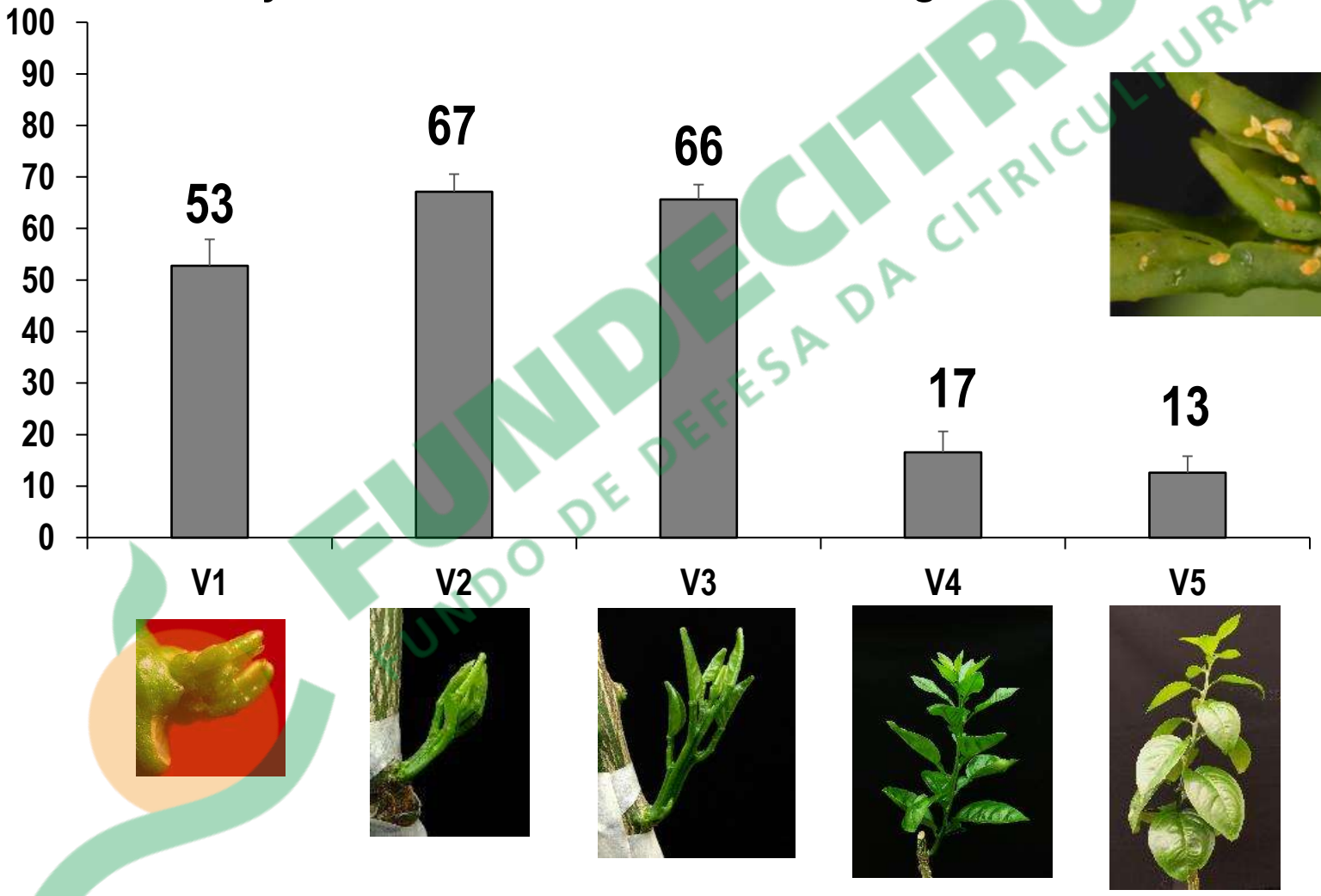
✓ Number of eggs/flush shoot



Cifuentes-Arenas et al, 2018

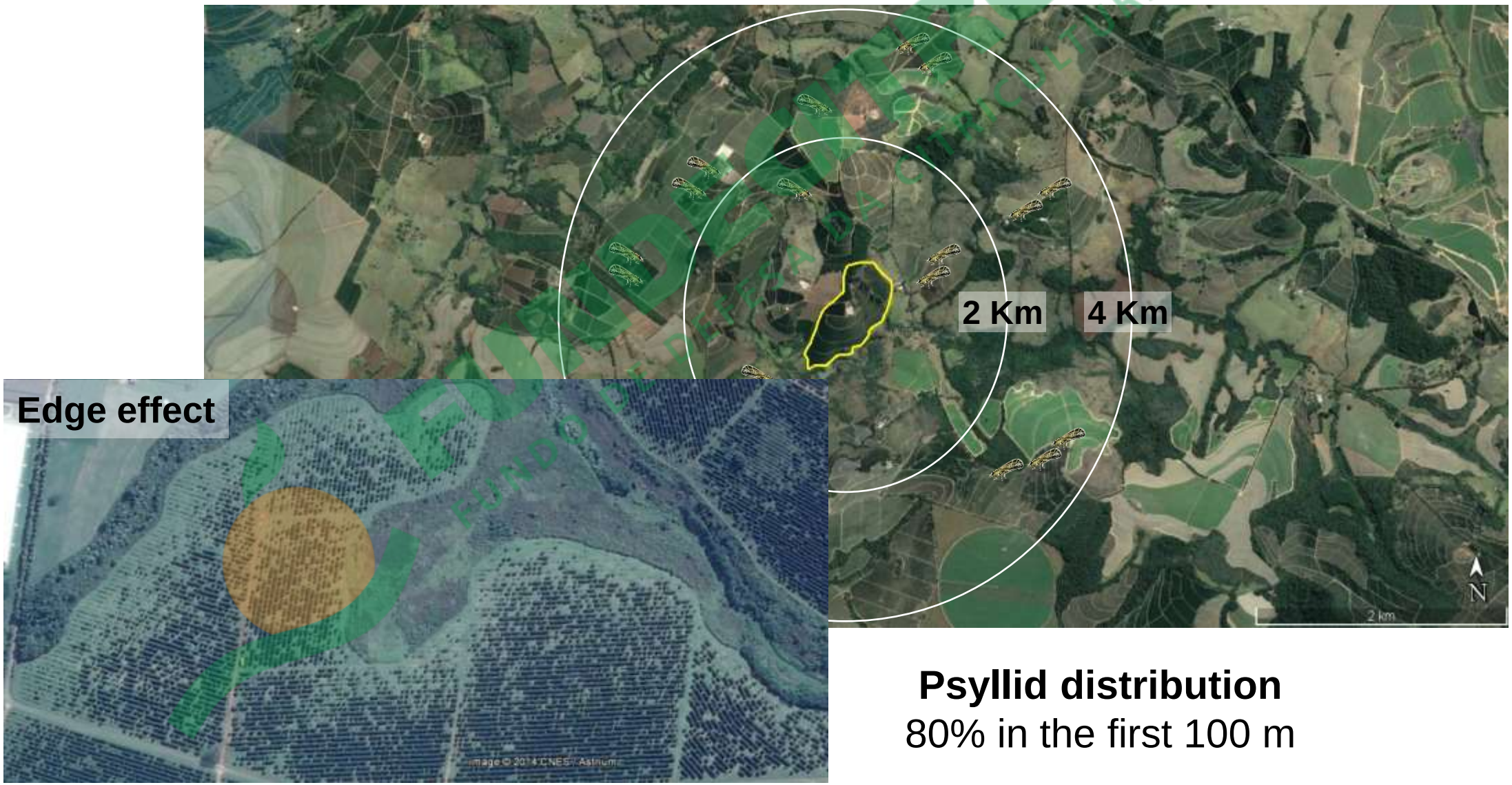
Flush shoot

✓ Total viability of *D. citri* on flush shoot stages



Cifuentes-Arenas et al, 2018

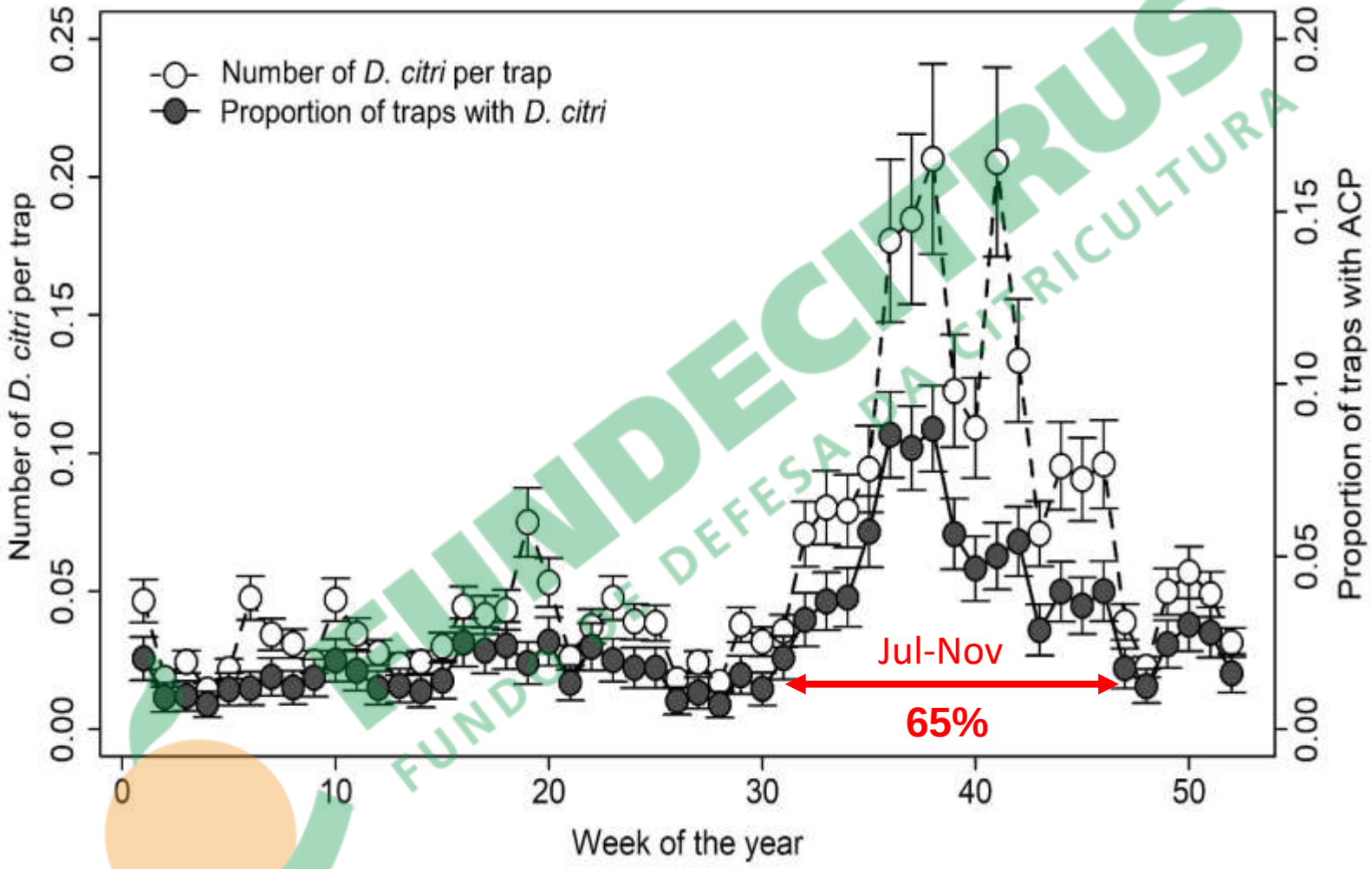
Psyllid migration from abandoned groves and dooryards to commercial groves

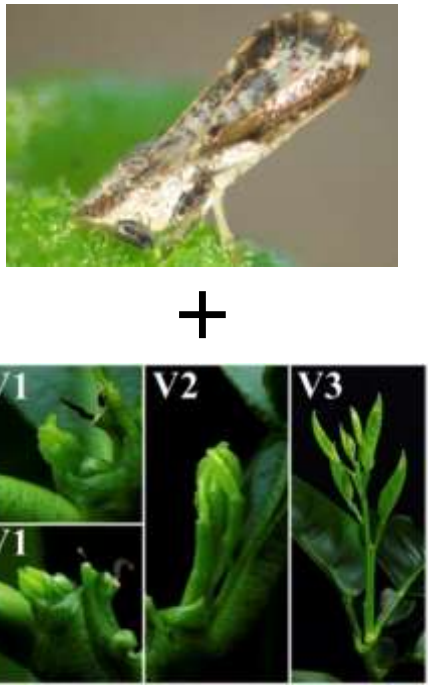


Psyllid distribution

80% in the first 100 m

D. citri dispersal in São Paulo state





High risk of HLB dissemination

- Maximum and minimum temperature and rainfall (3 weeks prior) were associated with new citrus flush production, which itself was positively related to *D. citri* dispersal.
- Low relative air humidity was associated with *D. citri* dispersal.

Zorzenon, 2019

Psyllid management

Psyllid monitoring

Sustainable measures

Internal actions

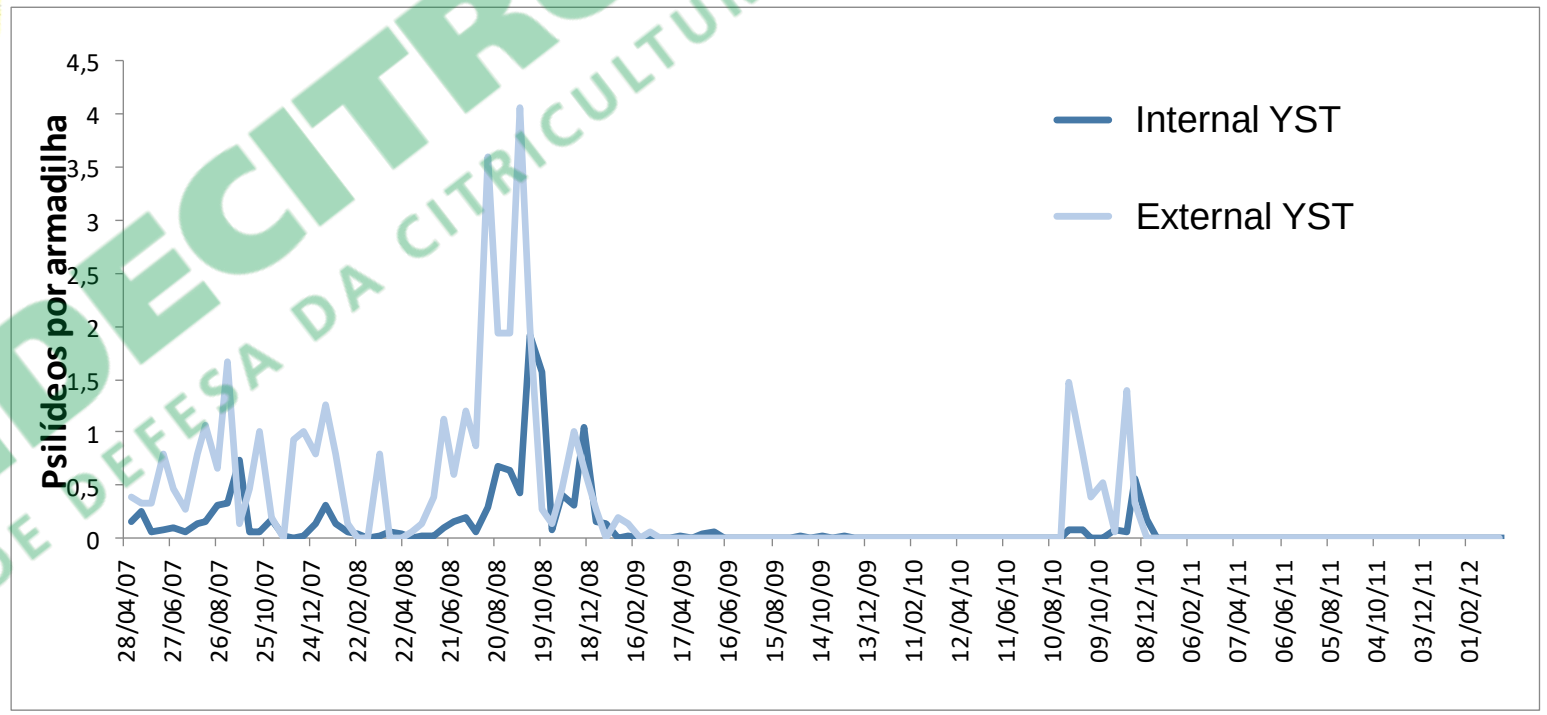
External actions

Chemical control

Eradication or replacement of psyllid hosts

Release of *Tamarixia radiata*

Psyllid monitoring



- ✓ Yellow Stick trap (YST) detects **30 times more** psyllids than visual inspection
- ✓ Install **YST mainly at the edges** of the blocks located in the farm perimeter

Bassanezi et al 2012

Miranda et al 2017

Psyllid monitoring

✓ Pheromone

(Fundecitrus, Esalq and UC-Davis)

- Identification of molecules
- Laboratory and field assessment

Analyses of extract in CG-MS

Compound dispenser

Field experiments

SCIENTIFIC REPORTS

OPEN

Putative sex pheromone of the Asian citrus psyllid, *Diaphorina citri*, breaks down into an attractant

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Odimar Z. Zanardi[1], Haroldo X. L. Volpe[1], Arodi P. Favaris[2], Weliton D. Silva[2], Rejane A. G. Luvizotto[1], Rodrigo F. Magnani[1], Victoria Esperança[1], Jennifer Y. Delfino[1], Renato de Freitas[1], Marcelo P. Miranda[1], José Roberto P. Parra[2], José Mauricio S. Bento[2] & Walter S. Leal[3]

Under laboratory conditions, mating activity in Asian citrus psyllid (ACP) started 4 days after emergence, peaked at day 7, and showed a clear window of activity starting 8 h into the photophase and extending through the first hour of the scotophase. We confirmed that ACP males are attracted to emanations from conspecific females. Traps loaded with a candidate compound enriched with female extract, lignoceryl acetate (24Ac), at various doses were active only after being deployed for several weeks in the field, suggesting that a degradation product, not the test compound, was the active ingredient(s). Lignocerol, a possible product of 24Ac degradation, was not active, whereas acetic acid, another possible degradation product, was found in the airborne volatile collections from lures matured under field conditions and detected in higher amounts in volatiles collected from females at the peak of mating activity than in male samples. Acetic acid elicited dose-dependent electroantennographic responses and attracted ACP males, but not females, in Y-type and 4-way olfactometers. Field tests showed that acetic acid-baited traps captured significantly more males than control traps. Surprisingly, captures of females in acetic acid-baited traps were also higher than in control traps, possibly because of physical stimuli emitted by captured males.

The Huanglongbing (HLB), also known as citrus greening, is one of the most devastating problems in agriculture worldwide, particularly for the citrus industry[1] given that, once infected, trees must be eradicated. In Brazil, as many as 46.2 million citrus trees (representing 26% of the currently planted trees) have been eradicated since the detection of HLB in 2004[2]. In Florida, HLB has caused severe losses to the citrus industry. Because of HLB and hurricane Irma, this year's production is forecast to be 68.7 million boxes of oranges, as compared to 96.9 million boxes produced in 2014-2015[3]. HLB is caused by endogenous, phloem-restricted bacteria of the genus *Candidatus* Liberibacter spp., which are transmitted from tree to tree by the Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera: Liviidae) in Asia and America and the African citrus psyllid, *Trioza erytreae* (Del Guercio) (Hemiptera: Triozidae) in Africa[1]. Two other psyllid species have been implicated without actual transmission tests[4]. Thus, the Asian citrus psyllid (ACP), which led to HLB being widespread in China, Brazil, and the United States[4], is today's most serious threat to the citrus industry. In places like Arizona and California where ACP is present, but the disease apparently has not been established, the emphasis is on early detection, eradication, and limiting the spread of the disease[4], whereas in other areas like in Florida, where HLB is widespread[4], monitoring ACP populations is essential to avoid reinfection after eradication of infected plants. Currently, colored sticky traps are widely used for *D. citri* detection and population monitoring in field studies[5]. Efficient lures are sorely needed for sticky traps, particularly for early ACP detection; otherwise, farmers have to resort to regular sprays to avoid infection given that infected insects from gardens and noncommercial areas migrate to citrus farms[6]. Pheromones and other semiochemicals have been widely used in agriculture and medical entomology

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Chemical control

- ✓ **Nursery** (1- 5 days before planting)

  Systemic insecticides (drench application)

- ✓ **New planting (0-3 years)**

  Spray + systemic (Drench and trunk)

- ✓ **Adult planting (>3 years)**

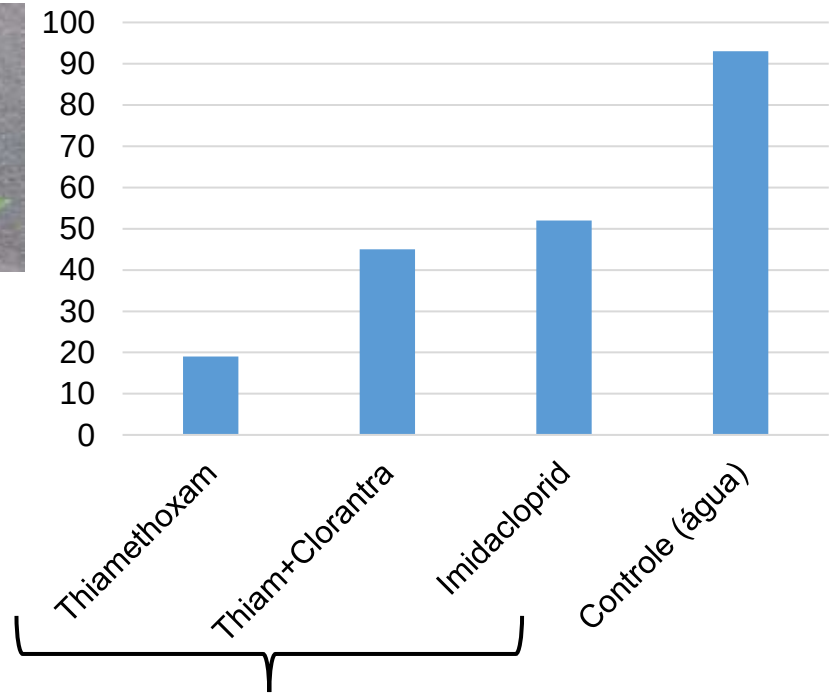
  Spray application

Systemic insecticides

D. citri rearing on diseased plants (CLas+)

Inoculation (5 psyllids/plant): flush shoot (V3) and temperature (25±2ºC)

% positive plants (Clas+) 12 months after inoculation



Carmo-Sousa et al 2020

GUIA DE CONTROLE QUÍMICO

PSILÍDEO, CANCRO CÍTRICO E PINTA PRETA

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Atualizado em Fev/2020©

IDADE DO POMAR (ANOS)

DOENÇA/PRAGA	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	> 14
PSILÍDEO	Inseticida sistêmico (*drench* e tronco) + inseticida foliar			Inseticida foliar											
	Sistêmico: aplicar 3 a 4 vezes/ano Foliar: aplicar em intervalo de 7 a 14 dias por todo ano			Aplicar a cada 14 a 28 dias por todo ano											
	Inseticida sistêmico – *Tabela 1* Inseticida foliar – *Tabela 2*			Dose do inseticida foliar *(Tabela 2)*											
	Sistêmico: *drench* 100 a 500 mL/planta Foliar: 25 a 40 mL de calda/m³ de copa com velocidade de 6 a 7 km/h			Volume de 25 a 40 mL de calda/m³ de copa Velocidade de aplicação de 6 a 7 km/h com turbo-pulverizador											
	• As aplicações de inseticidas sistêmicos devem ocorrer no início dos fluxos vegetativos (entumescimento das gemas). Normalmente, no início da primavera e no início e final do verão • O uso de inseticidas sistêmicos não exclui a necessidade de pulverizações com inseticidas foliares • Aplicações mais frequentes de inseticidas foliares devem ser feitas durante o fluxo vegetativo e em talhões de borda ou com maior ocorrência de psilídeos e HLB														
CANCRO CÍTRICO	Cobre fixo (hidróxido de cobre, oxicloreto de cobre e óxido cuproso) *(Tabela 3)*														
	Aplicar a cada 14 ou 21 dias ou quando houver brotações, normalmente de setembro a abril			Aplicar a cada 14 ou 21 dias a partir da florada principal por até 120 dias, em geral de setembro a janeiro (até os frutos atingirem 50 mm de diâmetro) Após este período, reaplicar quando houver fluxos vegetativos, normalmente até abril. Em pomares com floradas extemporâneas as aplicações devem ocorrer regularmente a cada 14 ou 21 dias após a florada principal até março ou abril										
	Intervalo 21 dias: 40 mg de cobre metálico/m³ de copa até atingir 1 kg de cobre metálico/ha Intervalo 14 dias: 30 mg de cobre metálico/m³ de copa até atingir 0,7 kg de cobre metálico/ha														
	Volume de 40 a 70 mL de calda/m³ de copa Velocidade de aplicação de 4,5 a 5,5 km/h, com turbo-pulverizador														
	• Utilizar os maiores volumes de calda e menores intervalos de aplicação de cobre em pomares jovens de até 5 anos, em variedades mais suscetíveis e/ou pomares destinados à produção de fruta de mesa • Aplicações de cobre de maio a agosto normalmente são dispensáveis pela baixa precipitação pluviométrica, temperaturas amenas e ausência ou baixa quantidade de tecido vegetal jovem suscetível														
PINTA PRETA	Na maioria dos pomares nessa faixa etária não é requerida pulverização. Se os sintomas aparecerem, deve-se adotar o programa indicado para pomares com mais de 5-6 anos					Cobre fixo *(Tabela 3)* e/ou estrobilurina *(Tabela 4)*									
						Se a doença estiver presente, aplicar cobre de 21 a 28 dias, a partir da queda de pétalas até o início das chuvas intensas e frequentes, em geral de setembro a novembro. Aplicar estrobilurina de 35 a 42 dias, de novembro até o fim do período chuvoso (março/abril). Se chuvas ocorrem de maio a agosto, a aplicação de estrobilurina deve ser estendida nos pomares destinados à produção de frutas de mesa ou aqueles que serão colhidos após dezembro									
						Cobre (30 a 40 mg de cobre metálico/m³) Estrobilurina (2,8 mg i.a./m³) + óleo mineral ou vegetal (até 0,25%)									
						Volume de 70 a 100 mL de calda/m³ de copa Velocidade de aplicação de 2,5 a 4,5 km/h com turbo-pulverizador									
	• Nos pomares mais velhos, de variedades de maturação tardia ou de frutas de mesa, utilizar mais pulverizações, com o maior volume de calda e a menor velocidade de aplicação • Em áreas com pinta preta e cancro cítrico, deve-se aplicar cobre, a cada 14-21 dias, de setembro (florada) até janeiro, e estrobilurina, a cada 42 dias, de novembro até março/abril • Não é recomendado utilizar mais de duas aplicações de estrobilurina por safra, porém, quando for necessário, deve-se associar as aplicações de estrobilurinas com cobre														
DOENÇA/PRAGA	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	> 14

Este guia foi elaborado para servir de referência para a prevenção e controle da psilídeo, cancro cítrico e pinta preta. É necessário consultar sempre a bula do produto e a bula PIC antes de utilizar qualquer defensivo químico. A bula PIC passa por revisões periódicas, a versão atualizada encontra-se em www.fundecitrus.com.br/bulapic.

TABELA 1 - INSETICIDAS APLICADOS VIA *DRENCH* OU TRONCO

Inseticida		Dose/planta*	Período residual no campo	Modo de ação
Princípio ativo	Formulação			
Imidacloprid	200 SC	3,5 mL/metro de altura de planta	50 – 70 dias	Agonistas de receptores nicotínicos da acetilcolina
Imidacloprid	200 SL	1 mL/cm de diâmetro de tronco		
Thiamethoxam	250 WG	1,25 g/metro de altura de planta		
Thiamethoxam + Clorantraniliprole	200 + 100 SC	1–1,5 mL/metro de altura de planta		Agonistas de receptores nicotínicos da acetilcolina + Moduladores e receptores de rianodina

*Dose de produto comercial/planta

TABELA 2 - INSETICIDAS APLICADOS VIA PULVERIZAÇÃO

Inseticida		Dose/2000 L*	Período residual no campo**	Modo de ação
Princípio ativo	Formulação			
Imidacloprid	200 SC	0,4 – 0,5 L	7 a 10 dias	Agonistas de receptores nicotínicos da acetilcolina
Thiamethoxam	250 WG	0,2 kg	7 a 14 dias	
Zeta-cipermetrina	350 EC	0,2 L	7 dias	Moduladores de canais de sódio
Bifentrina	100 EC	0,2 – 0,4 L	7 a 14 dias	
Beta-ciflutrina	50 EC	0,15 – 0,25 L	7 a 10 dias	
Fenpropatrina	300 EC	0,15 – 0,3 L	7 a 10 dias	
Etofenprox	300 EC	0,5 L	Somente ação tópica	
Fosmete	500 WP	0,5 – 1 Kg	5 a 14 dias	Inibidores de acetilcolinesterase
Clorpirifós de Formetanato	500 SP	0,5 Kg	5 a 10 dias	
Malathion	1000 EC	1,5 – 3 L	1 a 3 dias	
Spirotetramat	250 WG	0,2 – 0,25 Kg	7 dias	Ativadores alostéricos de receptores nicotínicos da acetilcolina
Afidopiropenotrina + Tefluthrin	75 SC	0,4 – 0,5 L	7 a 14 dias	Moduladores de canais de sódio + Inibidor da síntese de quitina
Clorantraniliprole + Abamectina	45 + 18 SC	0,2 – 0,4 L	Somente ação tópica	Moduladores dos receptores de Rianodina + Moduladores alostéricos de canais de cloro mediados pelo glutamato
Buprofezin***	250 WP	0,3 kg	5 a 7 dias	Inibidor da síntese de quitina tipo 1
Piriproxifen***	100 EC	0,125 L	5 a 7 dias	Agonista do hormônio juvenil
Diflubenzuron***	240 SC	0,5 L	5 a 7 dias	Inibidor da síntese de quitina tipo 0

*Dose de produto comercial/2000L ; **Mortalidade ≥ 80%; *** Controle somente de ninfas
Ação tópica = pulverização sobre o inseto

TABELA 3 - COBRE

Tipo de cobre	Produto comercial	Cobre metálico (%)
Hidróxido de cobre	Aupe	35
	Cantact	45
	Effect	45
	Garant	45
	Garant BR	45
	Garra 450 WP	45
	Kentan 40WG	40
	Kocide WDG Bioactive	35
	Supera	35
	Tutor	45
Oxicloreto de cobre	Agrinose	35
	Cobox	50
	Cobox DF	50
	Cobre Fersol	50
	Copsuper	35
	Cupravit Azul BR	35
	Cupravit Verde	50
	Cuprital 700	70
	Cuprogarb 350	35
	Cuprogarb 500	50
	Cuputan 500 PM	50
	Difere	35
	Fanavid 85	50
	Fanavid Flowable	40
	Fungitol Azul	35
	Fungitol Verde	50
	Funguran Verde	50
	Neoram 37,5 WG	38
	Ramexame 850 PM	50
	Reconil	35
	Recop	50
	Status	35
Óxido Cuproso	Cobre Ator BR	50
	Redshield 750	75

TABELA 4 - ESTROBILURINA E ÓLEO

Grupo químico	Ingrediente ativo (i.a.)	Produto comercial	Dose
Estrobilurina	Azoxistrobina	Vantigo 500 WG	2,8 mg i.a./m³ de copa ou 3,8 g i.a./100 L
	Piraclostrobina	Comet 250 CE	
	Trifloxistrobina	Flint 500 WG	
Óleo	Vegetal ou mineral	Consultar Lista PIC	até 0,25%

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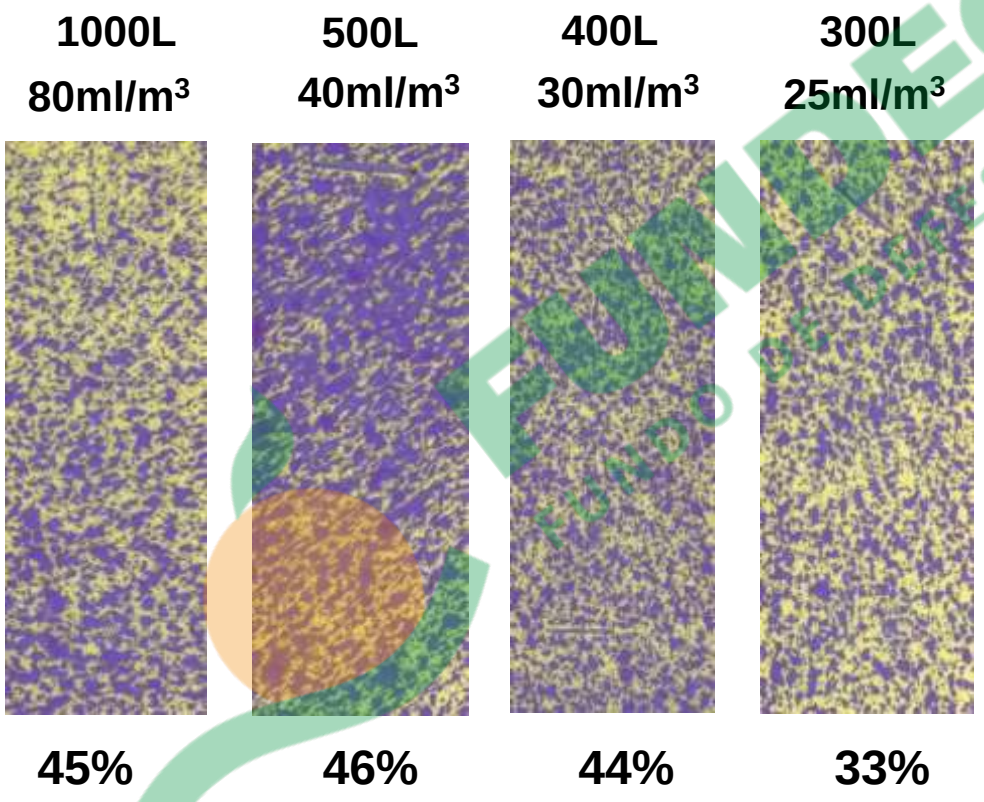
Spray volume

✓ **25 – 40 ml** spray mixture/m^3 of tree canopy was efficient (psyllid mortality ≥80%)

Spray coverage (%)



✓ **Reduction**

- 52% application cost
- 70% amount of **water and insecticide/ha**
- 32% Diesel

Miranda et al 2015

Scardelato 2013

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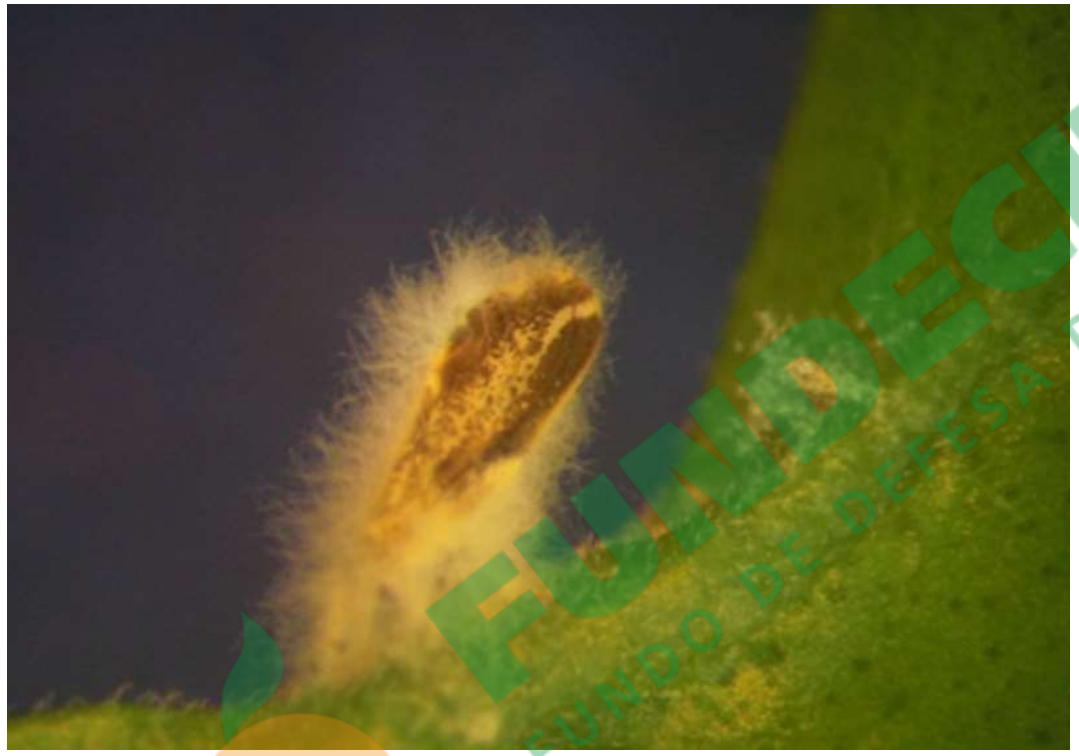
Spray volume

✓ APP **Fundecitrus Integrated Spraying System**

Bioinsecticides (entomopathogenic fungus)



Cordyceps (=Isaria) fumosorosea

- ✓ Bioinsecticides
  - *Cordyceps (=Isaria) fumosorosea*
  - *Beauveria bassiana*
  - *Metarhizium anisopliae*
  - *Hirsutella thompsonii*
  - Mixture

Bioinsecticide (entomopathogenic fungus)

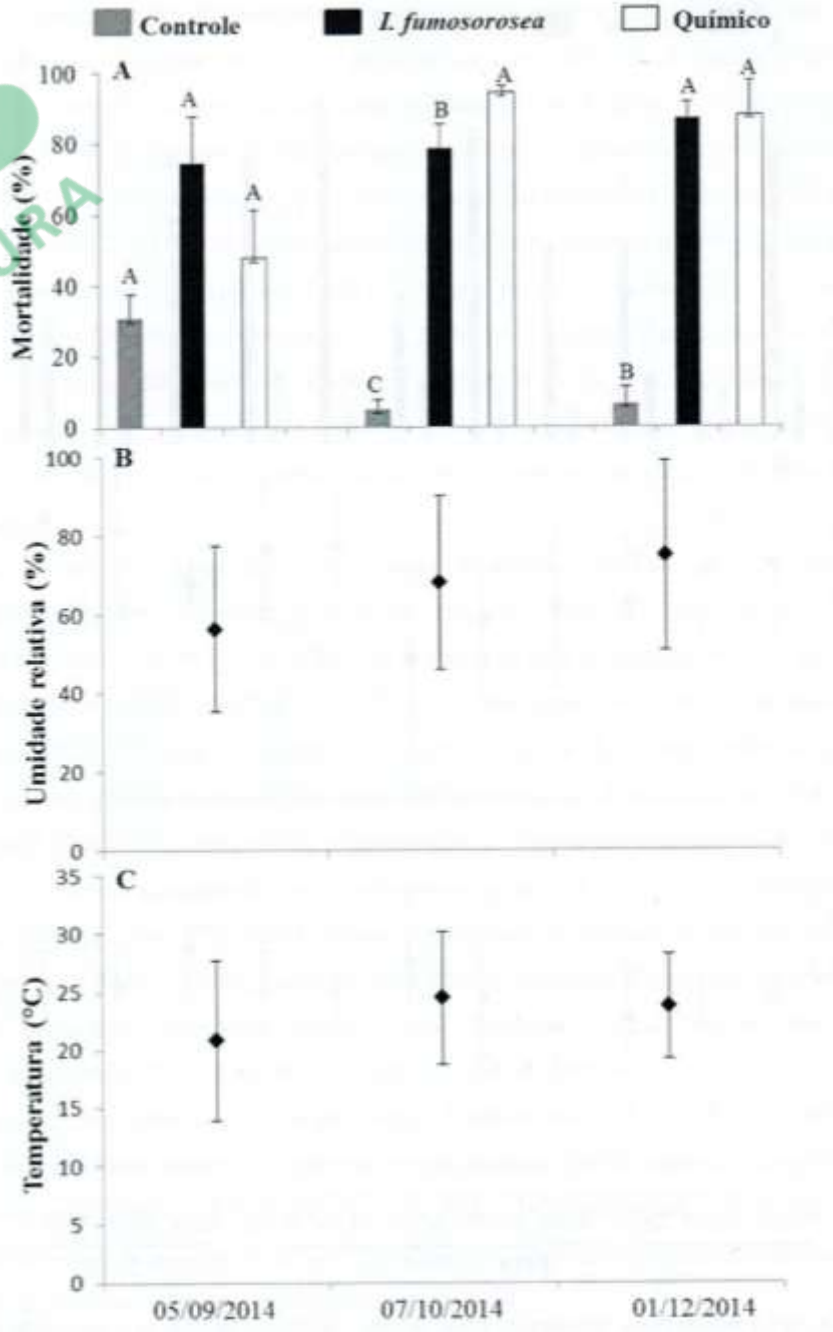
✓*Cordyceps (=Isaria) fumosorosea*

- Sustainable product (**without residue**)
- Reduces the population of other citrus pests

(e.g. leprosis mite, aphids and mealybugs)

- Compatibility with miticides and insecticides
- Reduces risk of selection of psyllids resistant to

chemical insecticides



Conseschi 2017

Tamarixia radiata

✓ **2015 - Laboratory**

Production: 100.000 parasitoids / month

Areas without chemical control (abandoned groves, backyards, urban areas)

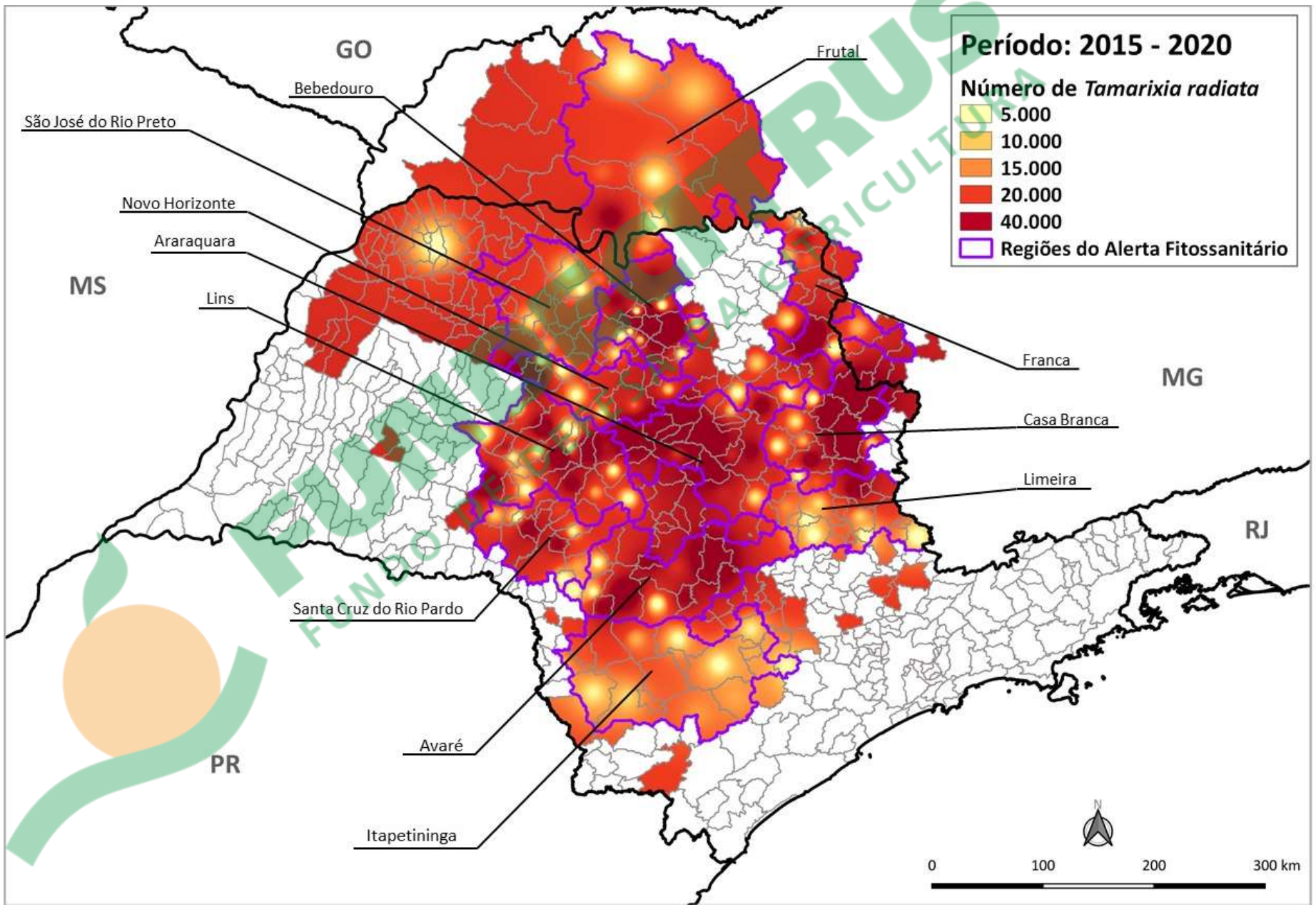
Dispersal radius of 15 m (**74% parasitism**)

60 parasitoids/point

Marin, 2019

MASTERCITRUS

Tamarixia radiata



Processed kaolin (Surround WP)

- Kaolin is a white nonabrasive fine-grained mineral that when is sprayed on the plants forms a particle film.

Glenn et al. 1999; Puterka et al. 2000

- Interfere host selection (Hemipterans)
  - Repellent
  - Feeding behavior
  - Camouflaging

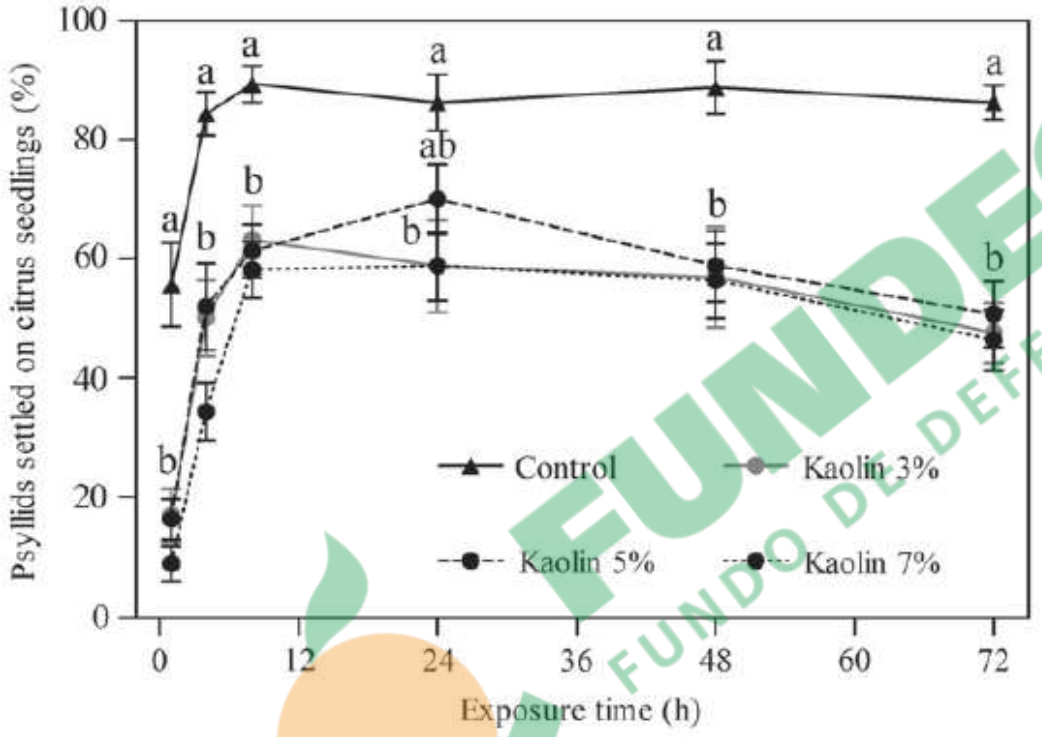
Puterka et al. 2000; Liang and Liu 2002; Tubajika et al 2012

- Reduce *D. citri* population Hall et al 2007

M.P.Miranda

Processed kaolin (Surround WP)

- Repellent effect



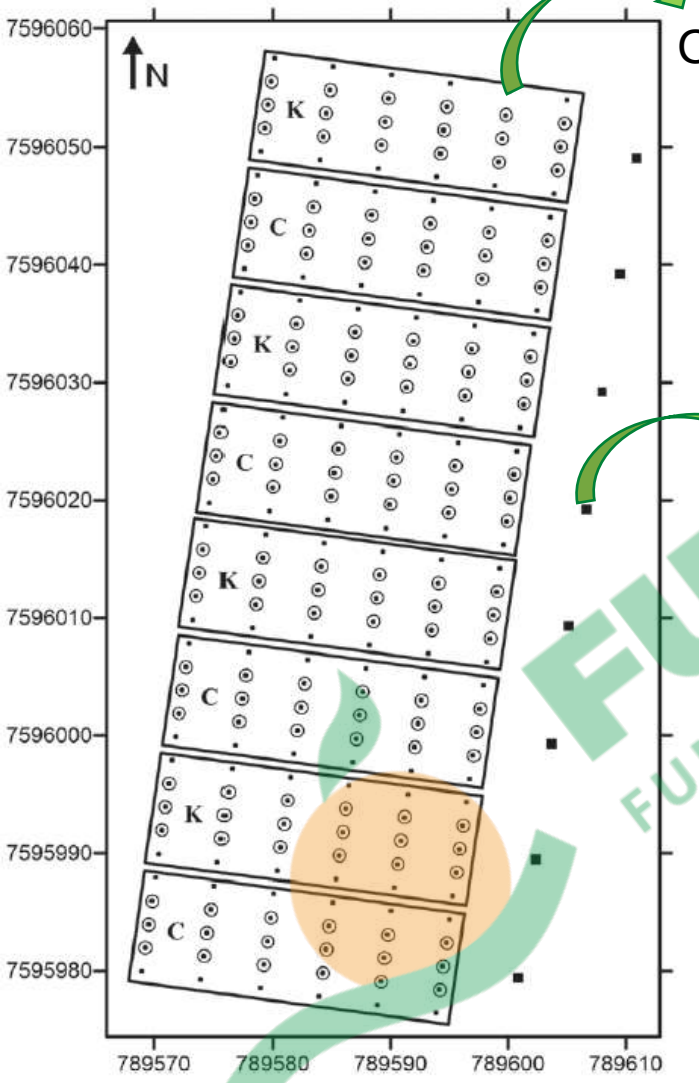
Reduces the proportion of psyllids that landed on plants by 40%

- Disrupt the probing behavior (EPG technique)

Reduces the proportion of psyllids that feed on phloem by 50%

Miranda et al 2018

Effect of kaolin (Surround WP) on *D. citri* settling and dispersal



Citrus trees

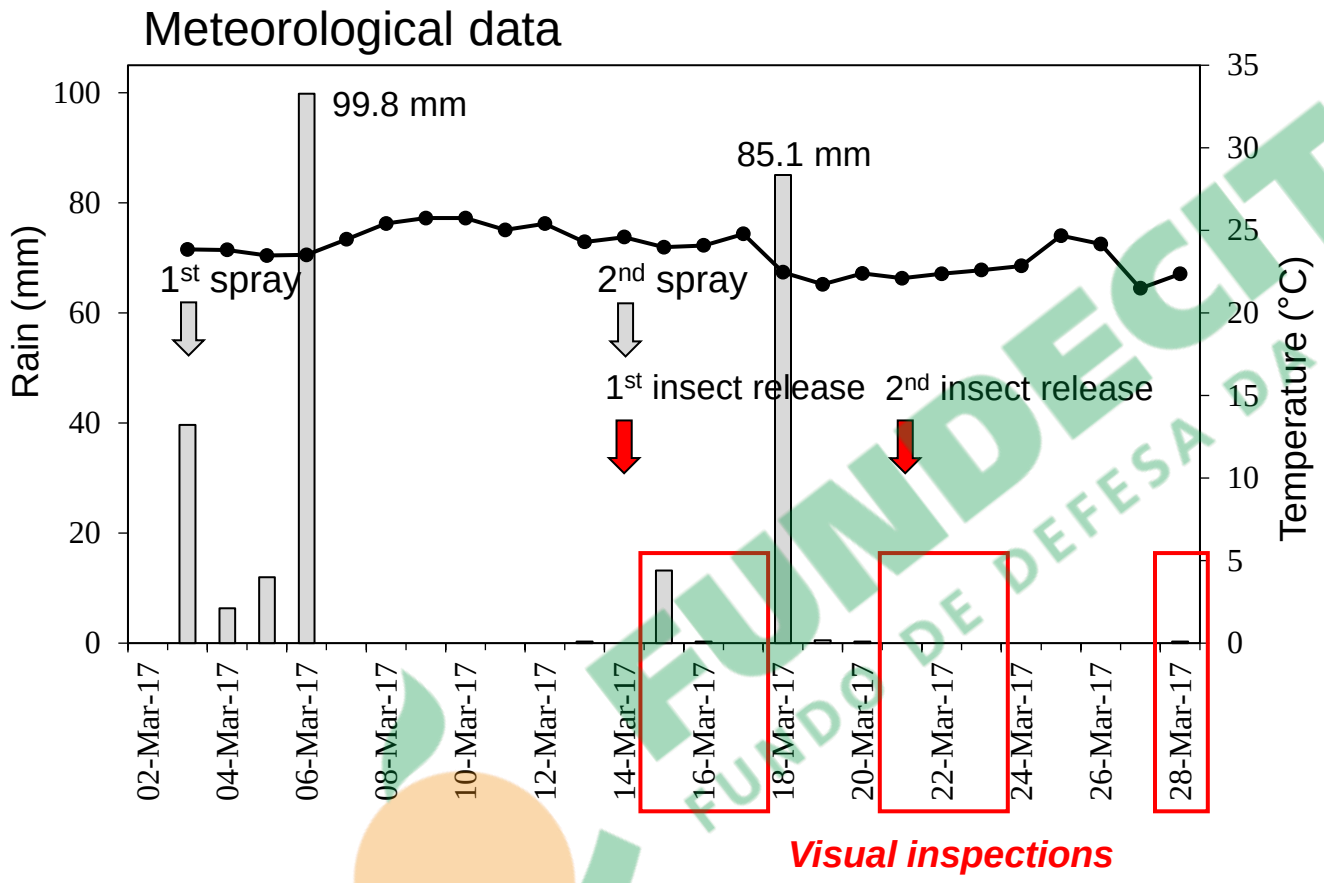
Release point (550 psyllids)
(**total 8800** insects/release)

Visual inspection **(whole tree)**

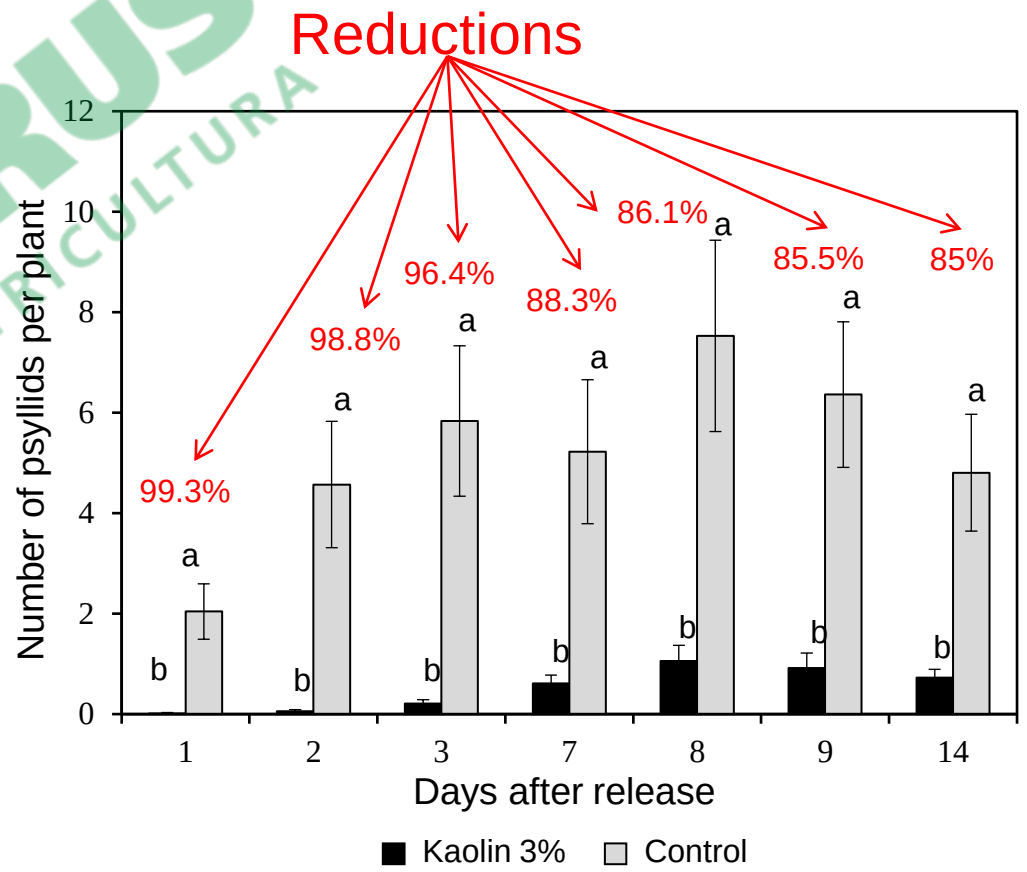
Marked psyllid with fluorescent powder

Miranda et al 2018

Effect of kaolin (Surround WP) on *D. citri* settling and dispersal



Miranda et al 2018

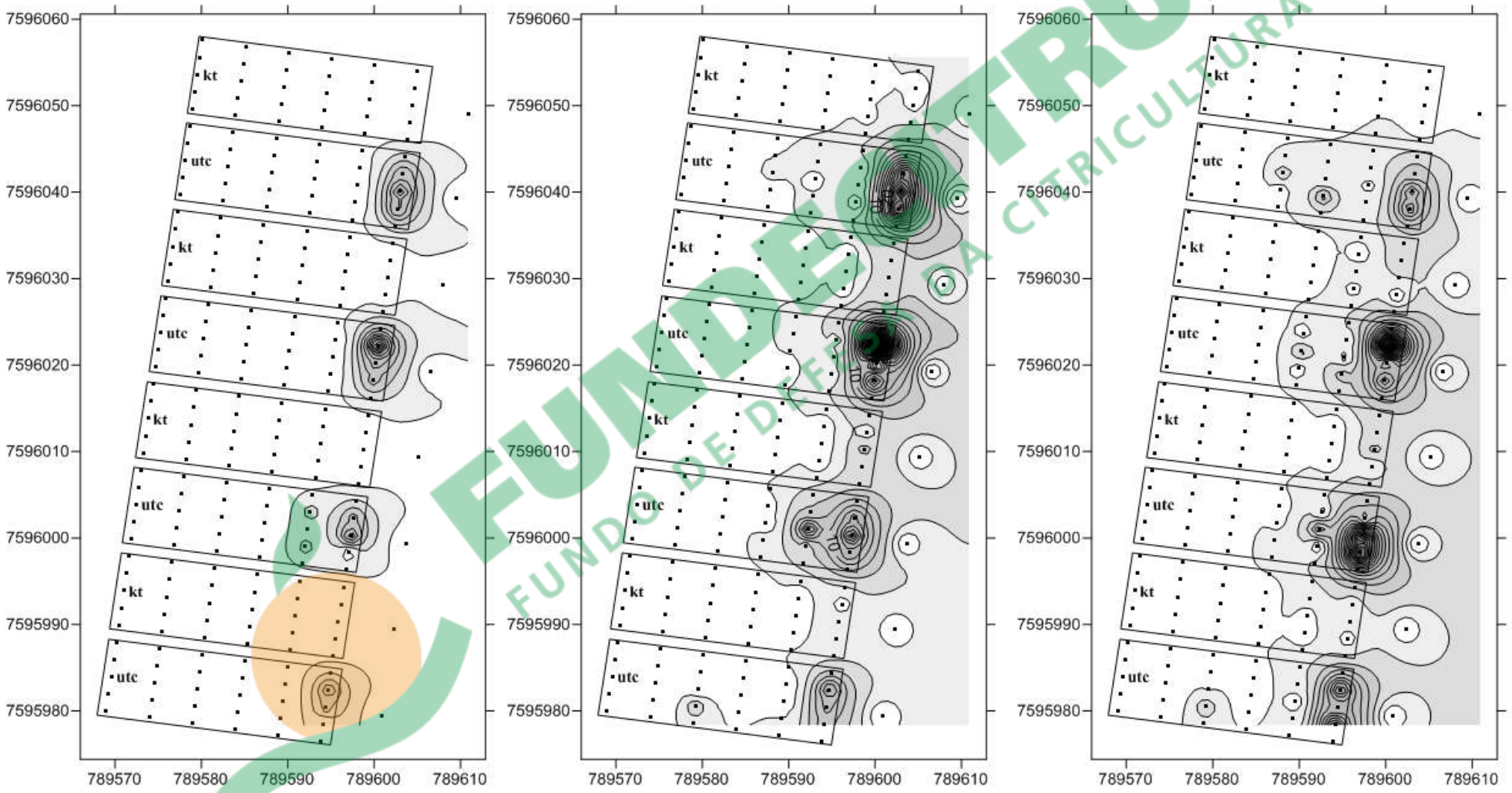


Data analysis:

- **In each time:** Quasi-Poisson GLM (count data)
  Kaolin ≠ Control ($P < 0.001$)
- **Over time:** Poisson GLMM (count data)
  Effect of treatment (**Kaolin ≠ Control**) ($P < 0.001$)
  Effect of time (increase in the number of insects landing) ($P < 0.001$)

Effect of kaolin (Surround WP) on *D. citri* settling and dispersal

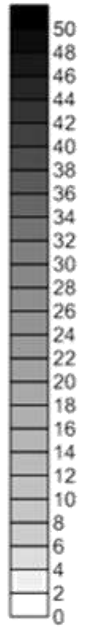
Infestation maps – edge effect



1 DAR | 7 DAR | 14 DAR

DAR (days after release)

Number of marked insects



kt = kaolin-treated
utc = untreated control

Miranda et al 2018

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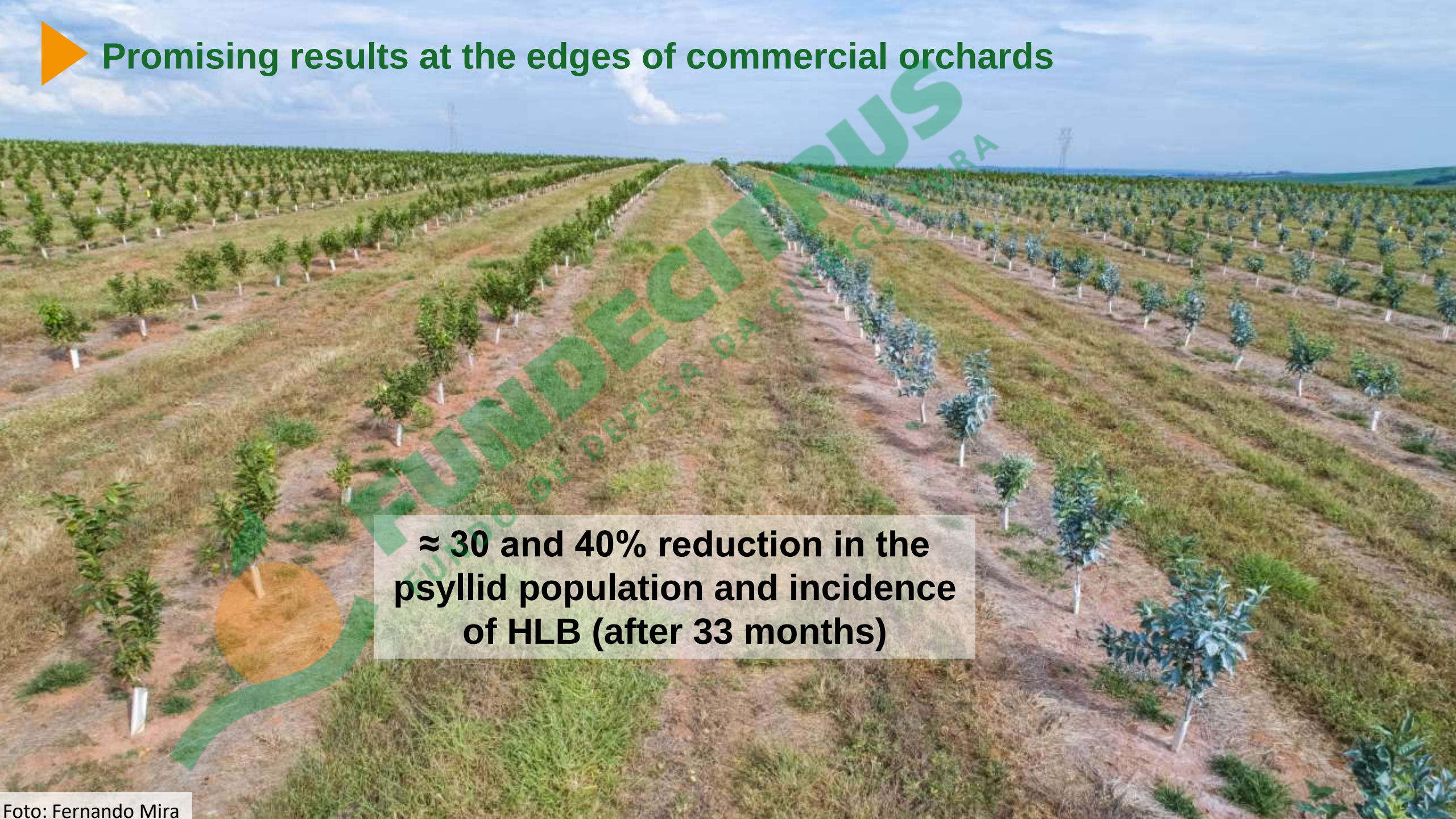
Promising results at the edges of commercial orchards



≈ 30 and 40% reduction in the psyllid population and incidence of HLB (after 33 months)

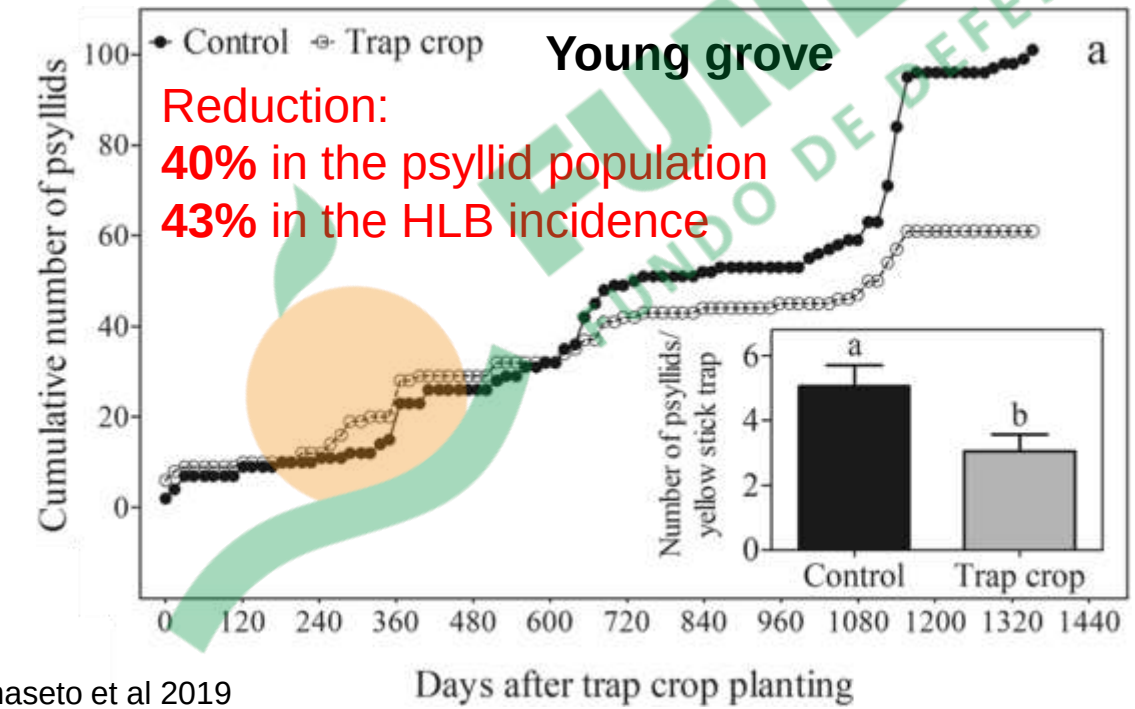
Foto: Fernando Mira

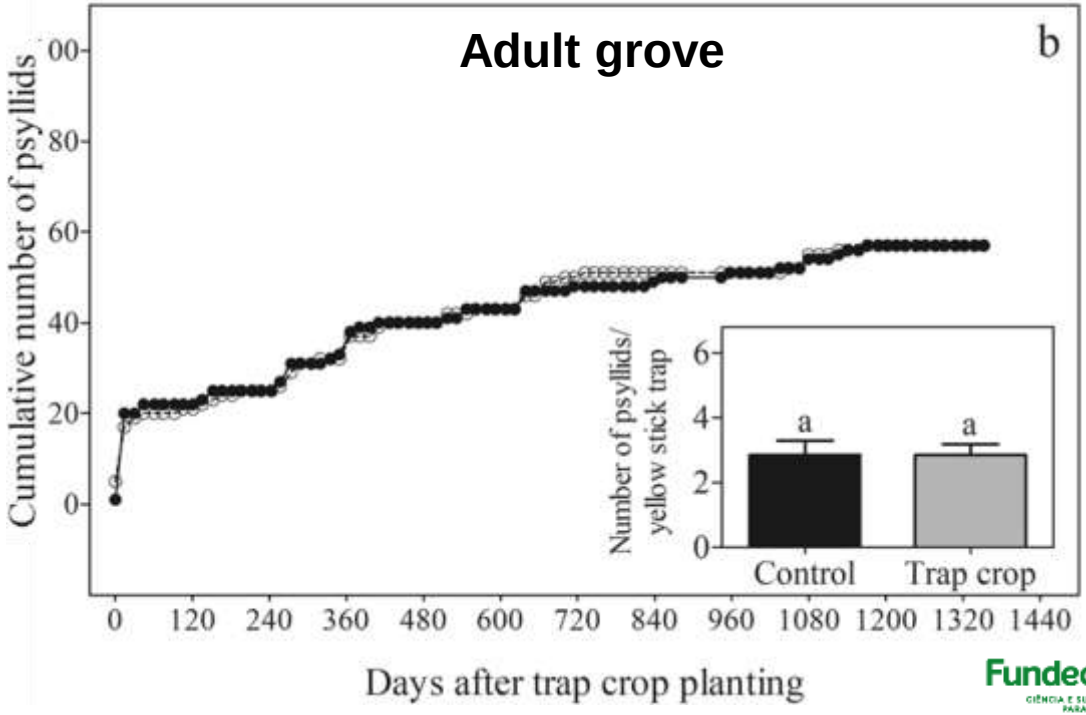
Orange jasmine as a trap crop on *D. citri*

Young grove (6 months old)

Orange jasmine treated with insecticides

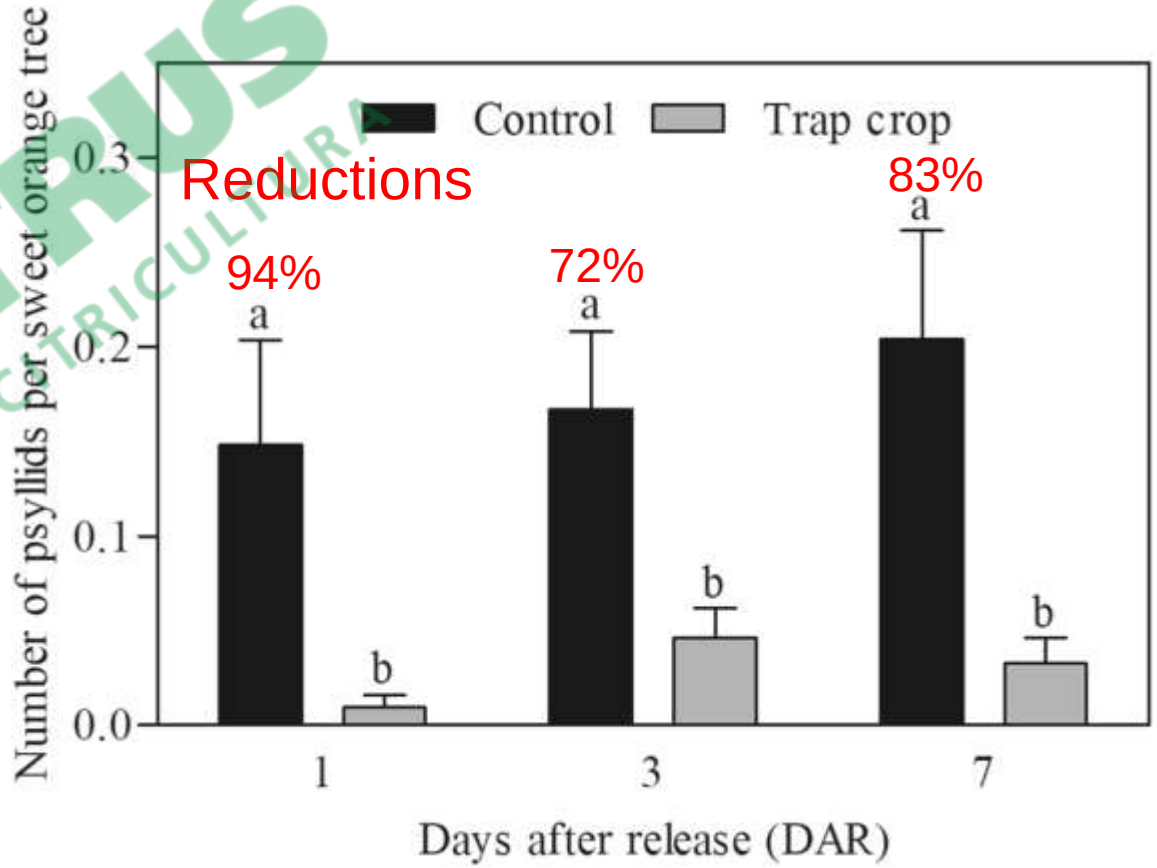
Adult grove (7 years old)





Tomaseto et al 2019

Effects of orange jasmine as a trap crop on *D. citri* settlement and dispersal



Release platform (10 m from citrus grove):
600 psyllids / plot (3,600 per release – 3 releases)
Total psyllids released: 10,800

Marked psyllid with fluorescent powder

Tomaseto et al 2019

Push-Pull and Kill strategy

Murraya or Bergera trap crop

Abandoned grove

Trap crop

Processed kaolin

Final considerations

The integration of the chemical control associated with alternative control tactics, such as biological, trap crop and processed kaolin, and the implementation of a program of external actions to reduce the dispersal of D. citri, are crucial for achieving more effective and sustainable D. citri and HLB management.

Marcelo P. Miranda

Thank you!

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