Relationship of Bioassay Results to Field Performance of Neonicotinoids Against *Bemisia tabaci*

Steve Castle, USDA-ARS, Phoenix

- *Bemisia tabaci* -- global pest and resistance recidivist
- Neonicotinoid resistance – examples
- Systemic uptake bioassays
- Resistance monitoring in the Southwest – laboratory vs. field

A Reputation Established – *Bemisia tabaci* in the Sudan Gezira

CROP PROTECTION (1983) 2(3), 273-287

Cotton-insect control in the Sudan Gezira: analysis of a crisis

K. G. Eveleens*

CROP PROTECTION (1985) 4(2), 161-176

Sudanese cotton and the whitefly: a case study of the emergence of a new primary pest

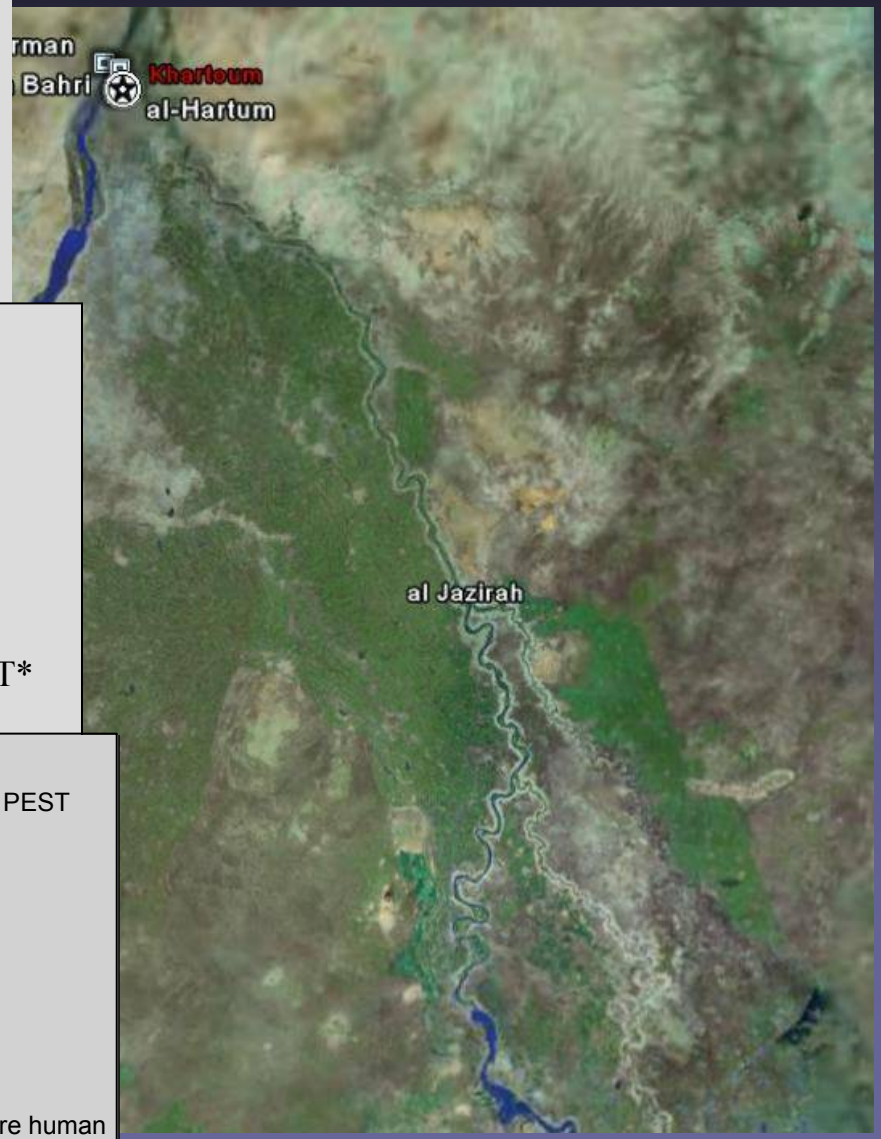
V. DITTRICH*, S. O. HASSAN**, and G. H. ERNST*

13. RESISTANCE AND HORMOLIGOSIS AS DRIVING FORCES BEHIND PEST OUTBREAKS

V. Dittrich
Agrochemicals Division, Ciba-Geigy Ltd, Basel, Switzerland

INTRODUCTION

Primary pests appear in each season in most important crops and require human



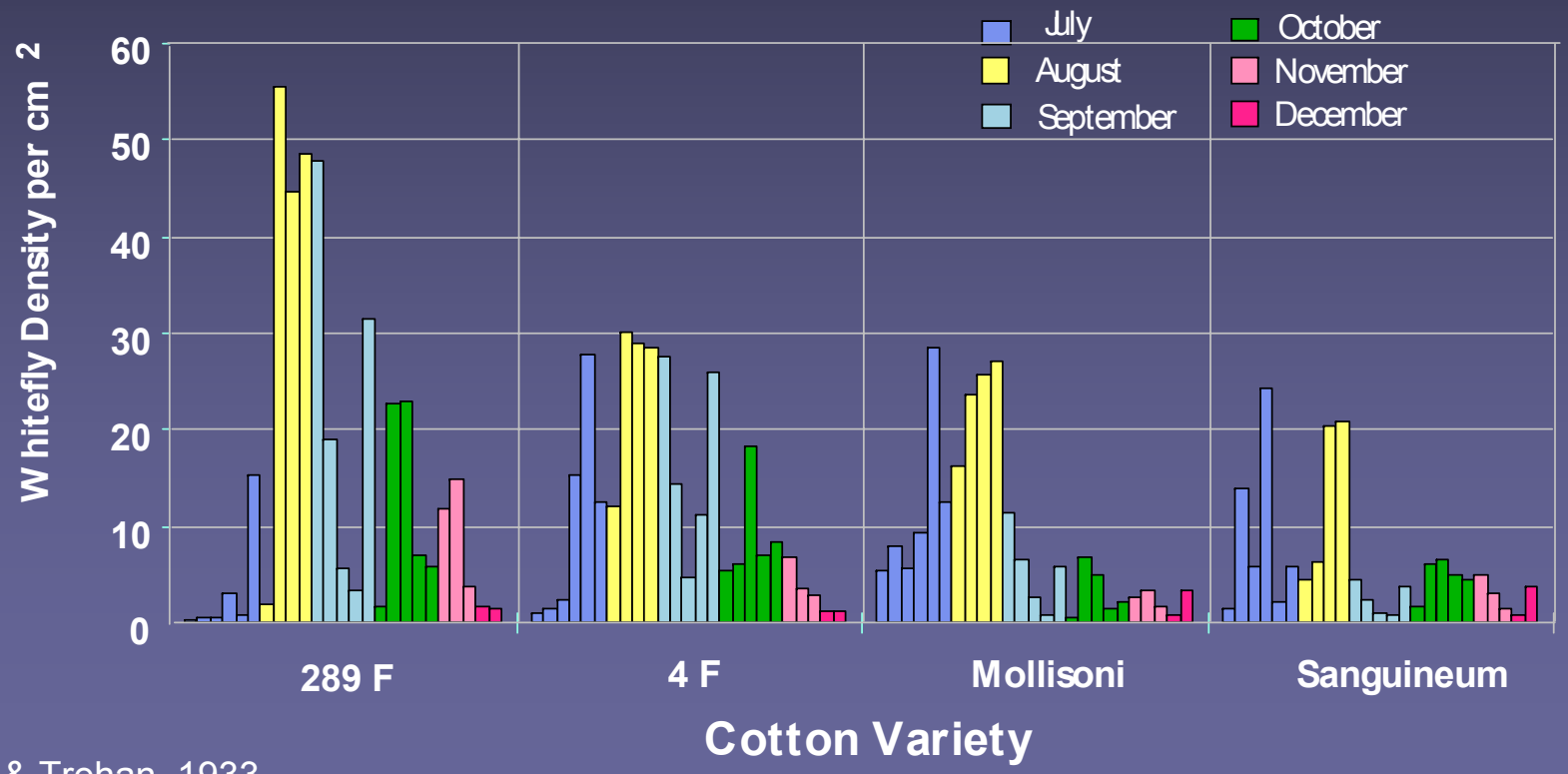
Global Resistance in *B. tabaci* Across Insecticide Classes

Location	OPs	Carbamates	Pyrethroids	Cyclodienes	IGRs	Neonicotinoids
USA	XXX		XXX	X		XX
Sudan	XXX	X	X			
Turkey	XXX	X				
Cyprus	X		X			
Israel	XX	XX	XX		XXX	XX
Pakistan	XX		XXX	X		
Guatemala	XXX	X				XX
Nicaragua	XXX	XXX	XXX			
Belize	XX		XX			
Spain	XX					XXX

Early Outbreaks of *B. tabaci* – India ca. 1920s

"In case of severe infestation of the cotton leaves not even a millimetre of leaf space is free from some stage of the pest"

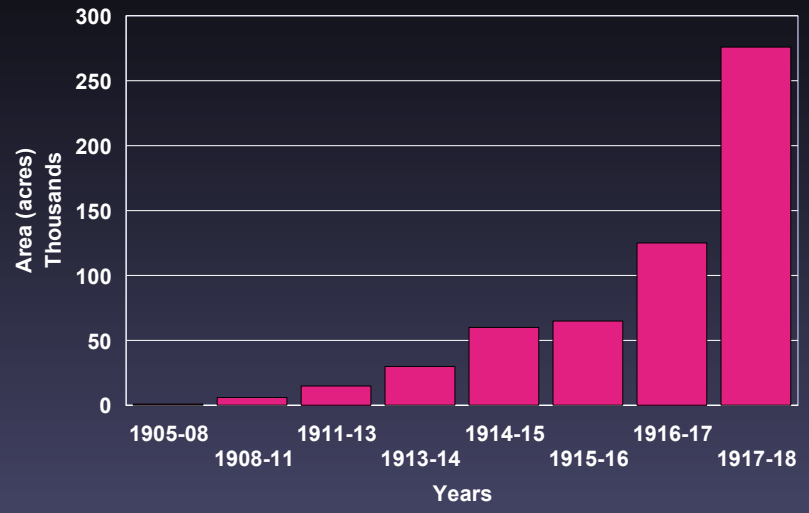
R.B.C.S Misra & K.S. Lamba, 1929. Bull. No. 196, Agricultural Research Institute, Pusa, India



After Hussain & Trehan, 1933

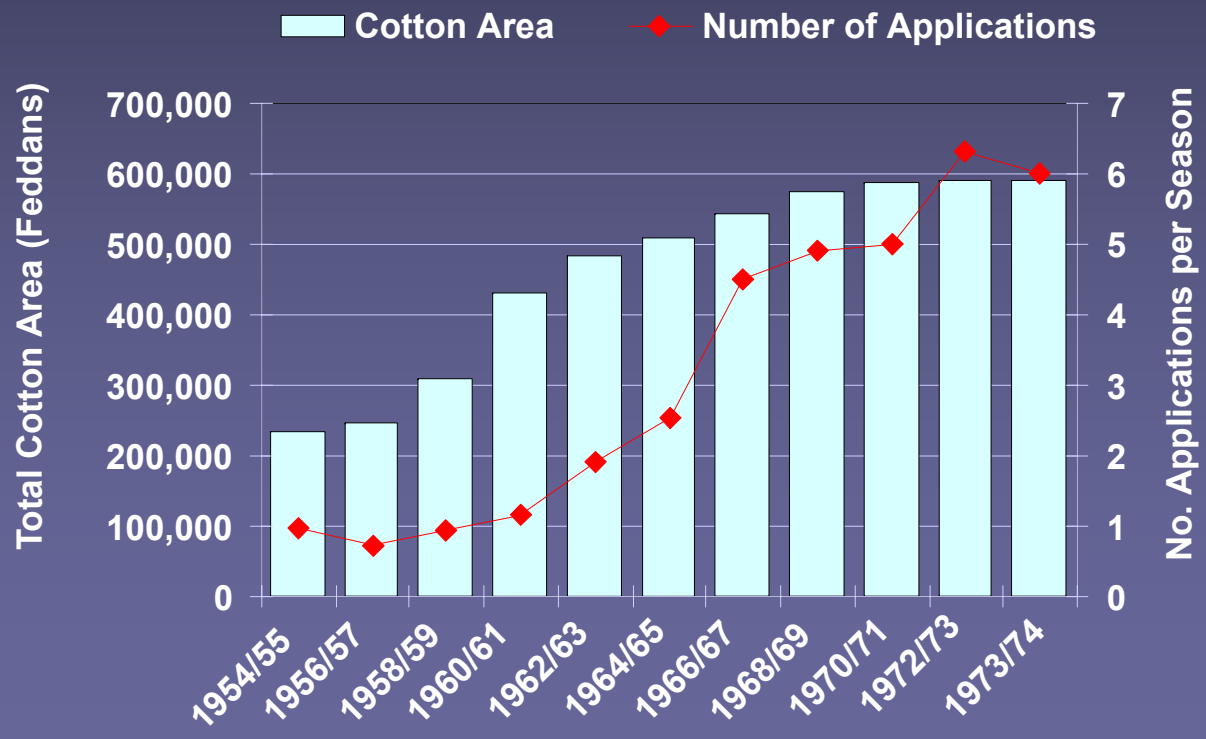
The Role of Agricultural Intensification in Outbreaks of *B. tabaci*

Increase in cotton acreage in India

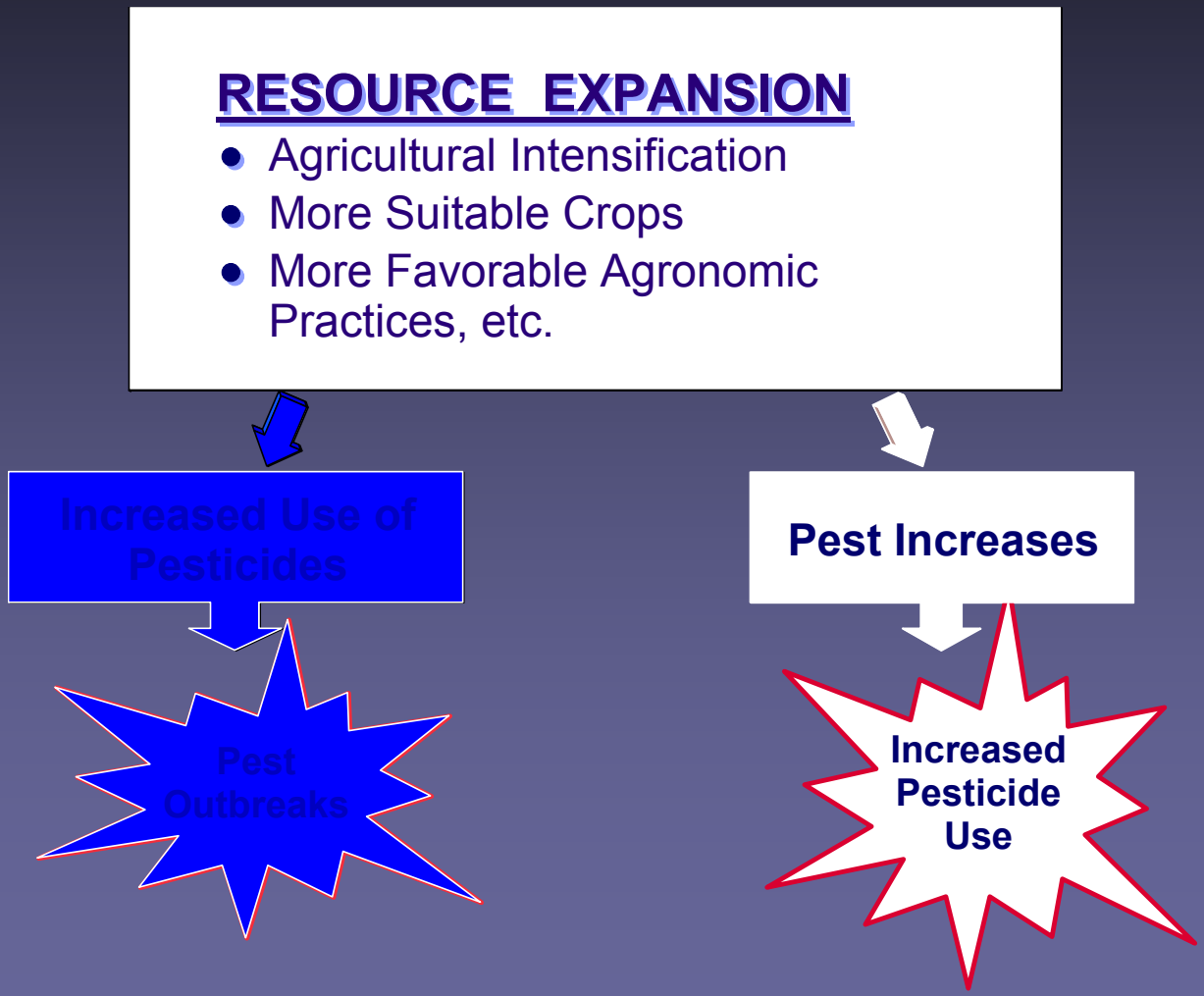


The total crop reached 1,000,000 acres by 1925… (Roberts, 1930)

Sudan Gezira: Increased cotton area, Increased number of insecticide applications



Competing Models of Pest Outbreaks

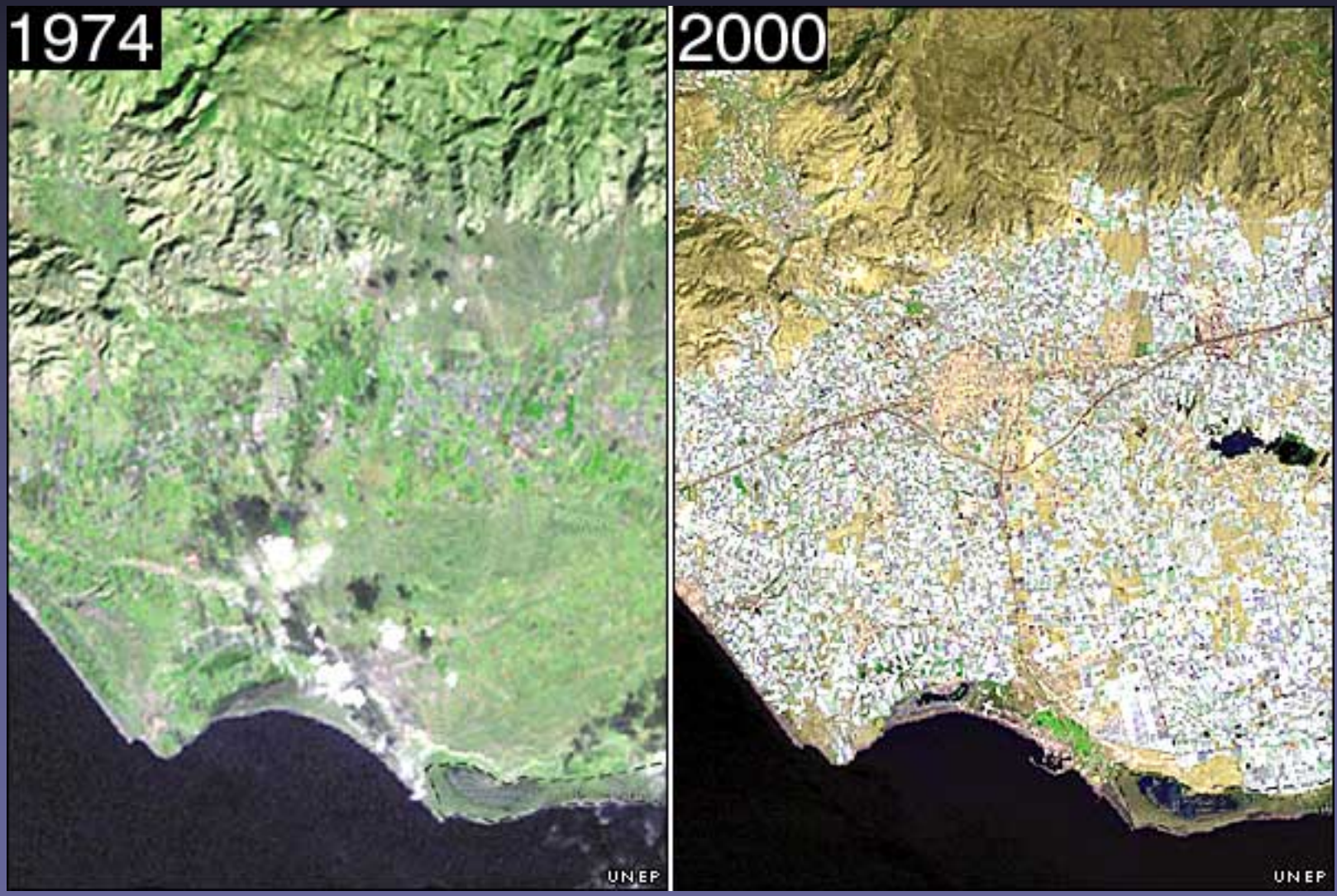


Examples of Neonicotinoid Resistance in *B. tabaci*

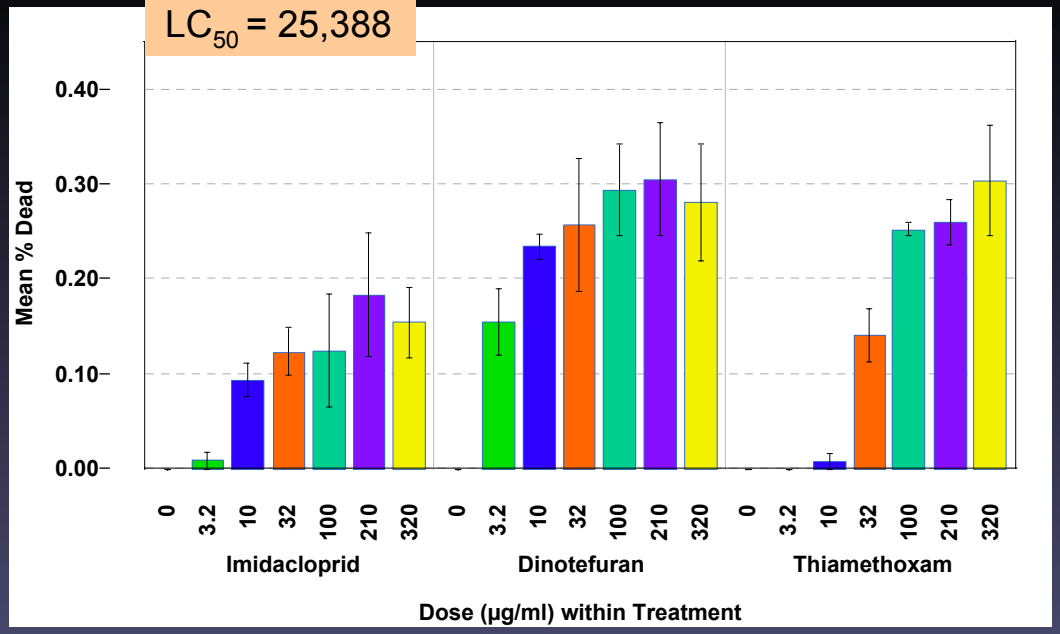
- Almeria, Spain
- Israel
- Guatemala
- Arizona

Protected Agriculture in Southern Spain and North Africa

Resource Expansion in Almeria

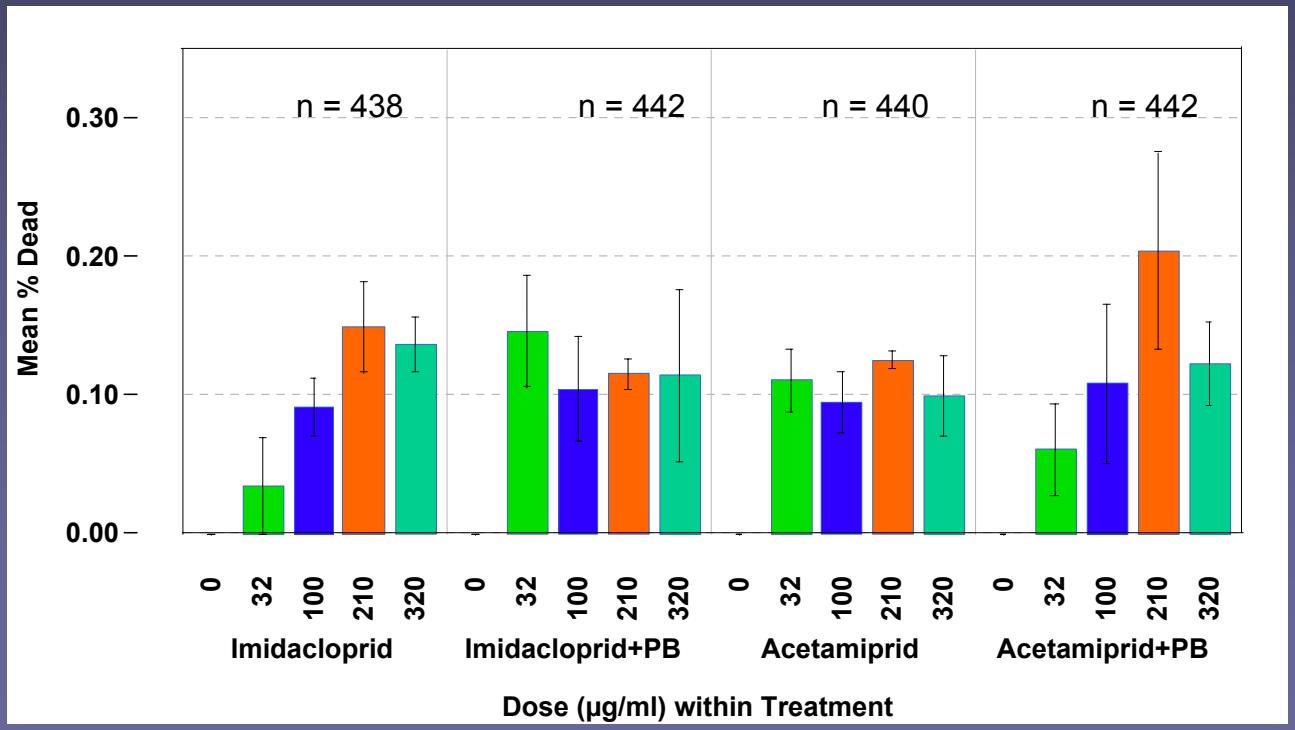


Bioassay Results on Biotype Q held in UC Riverside Quarantine

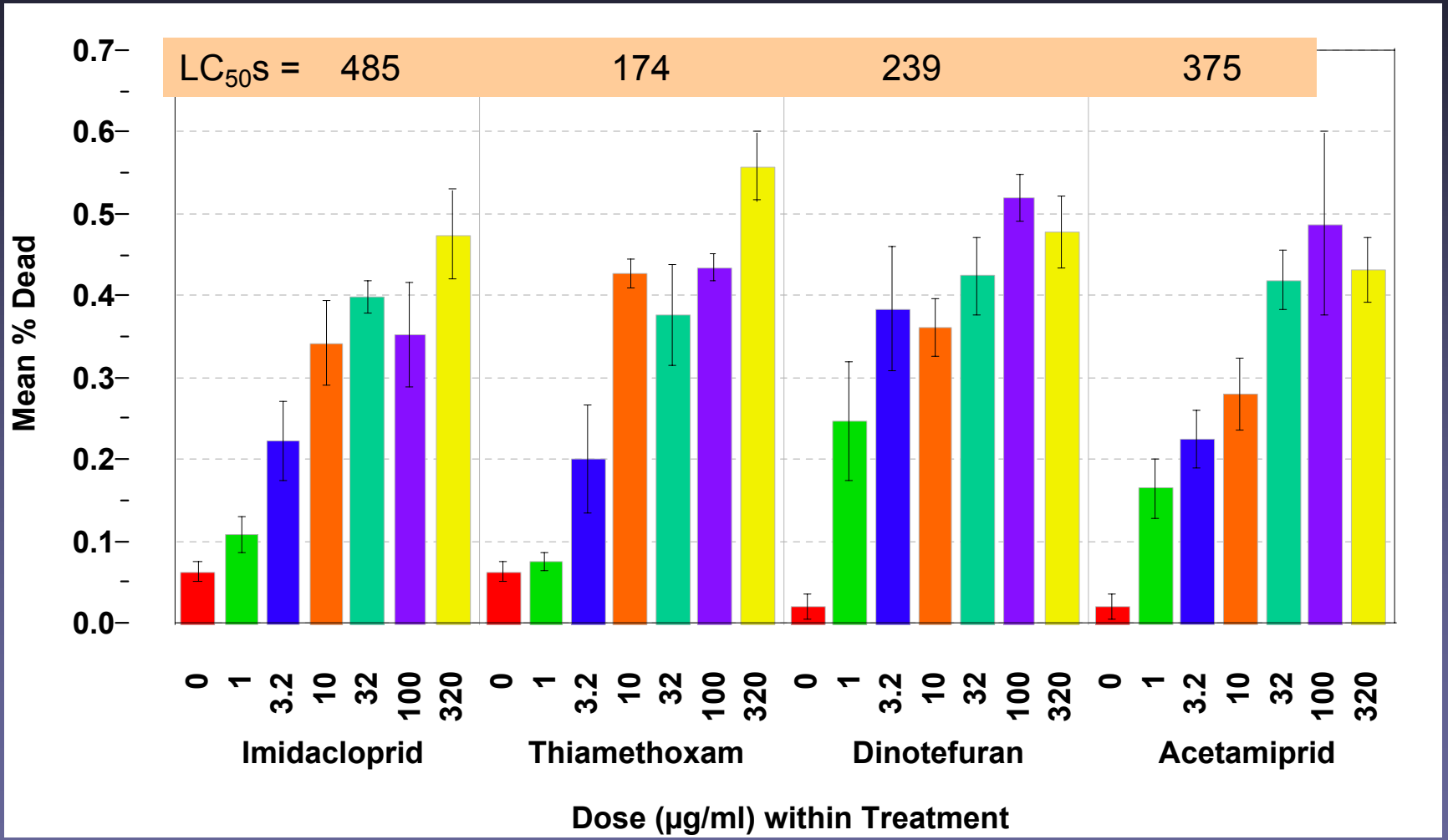


June 2004

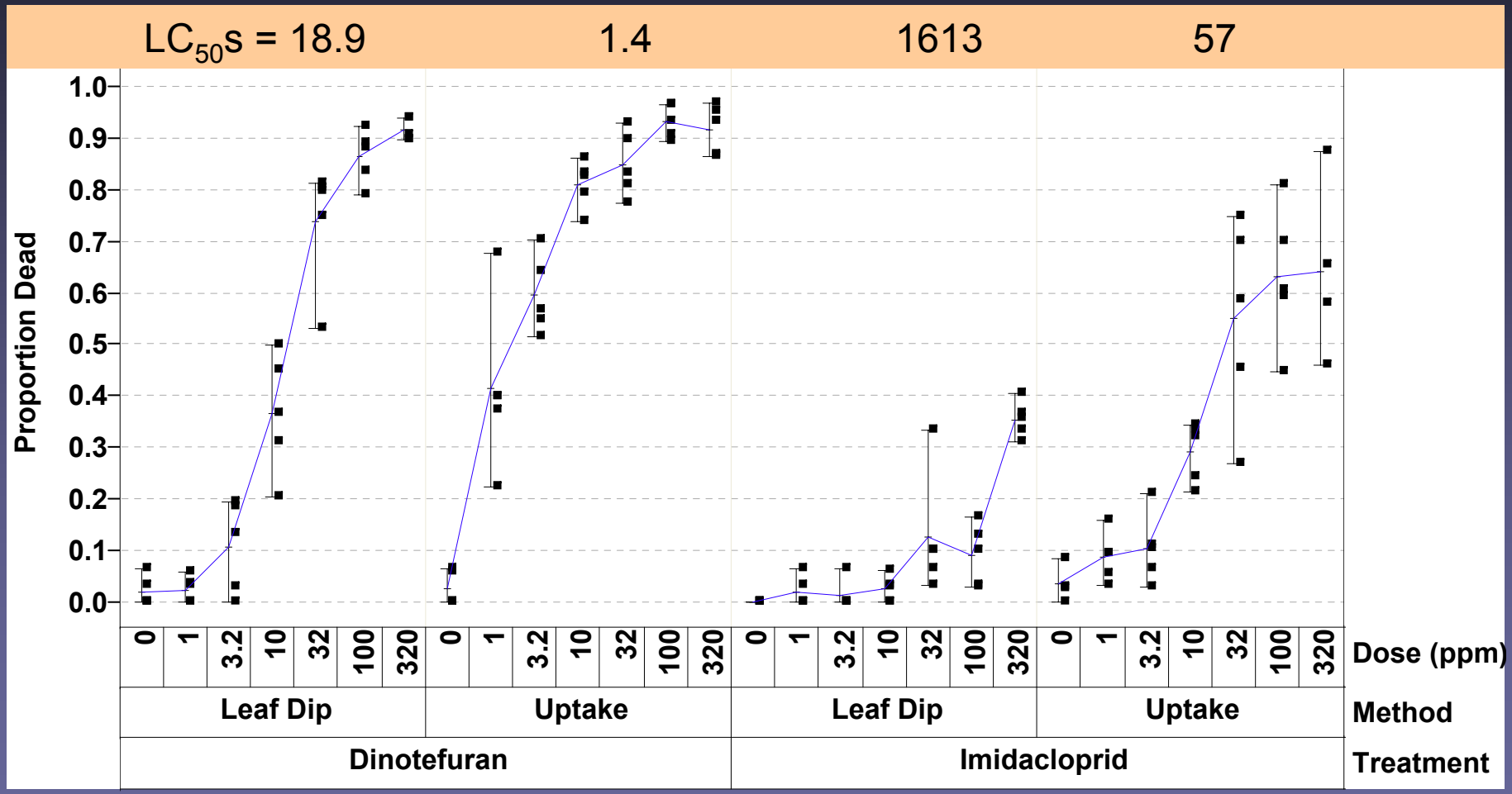
April 2004



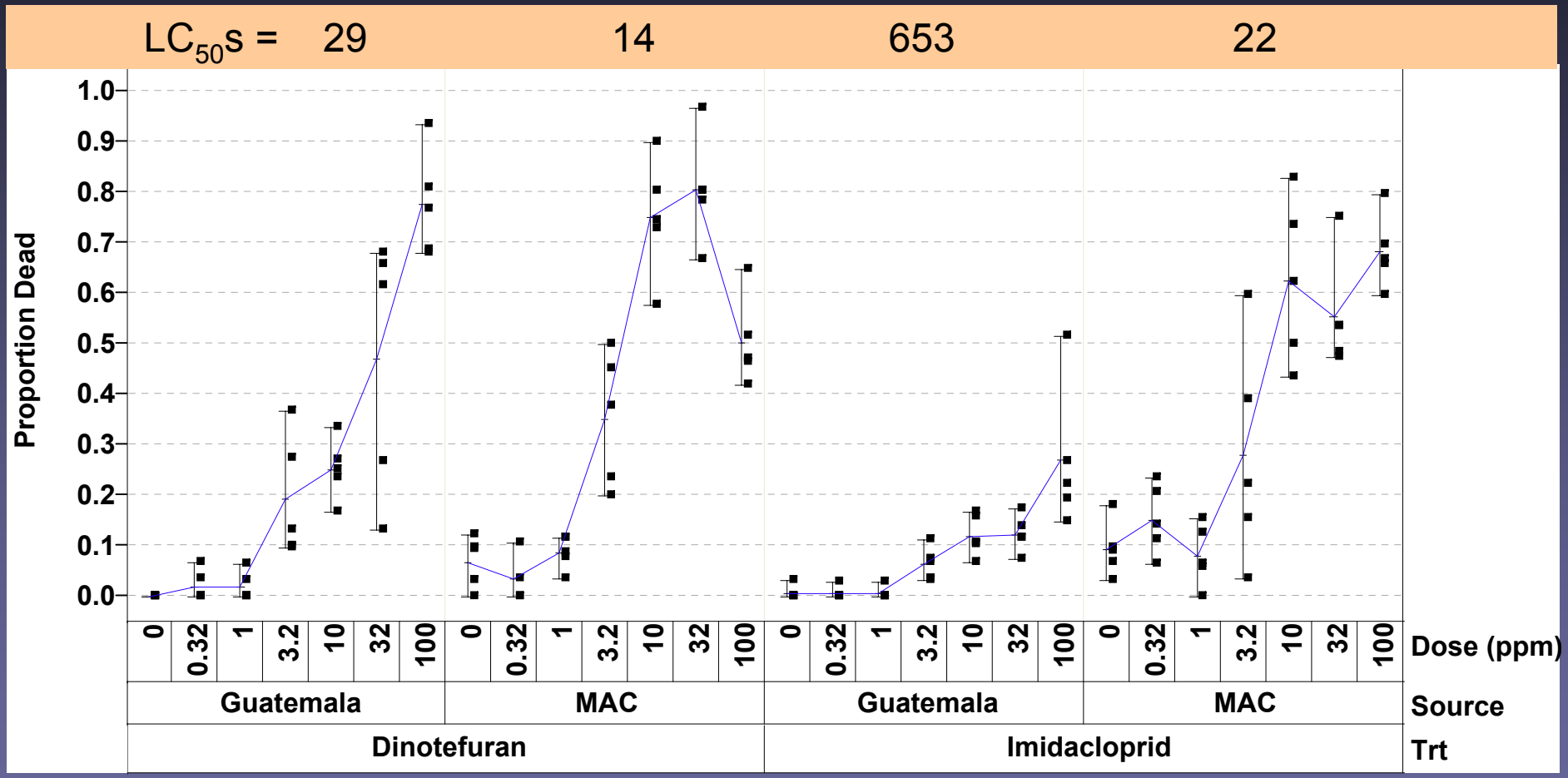
Biotype Q from Almeria



Bioassay Results on Biotype B from Guatemala



Comparison of Biotype B Whiteflies from Guatemala and Arizona to Two Neonicotinoids



Resistance and Cross-Resistance Patterns in Israel

INSECTICIDE RESISTANCE AND RESISTANCE MANAGEMENT

Dynamics of Resistance to the Neonicotinoids Acetamiprid and Thiamethoxam in *Bemisia tabaci* (Homoptera: Aleyrodidae)

A. RAMI HOROWITZ,[1] SVETLANA KONTSEDALOV,[2] AND ISAAC ISHAAYA[2]

J. Econ. Entomol. 97(6): 2051–2056 (2004)

ABSTRACT The dynamics of resistance in the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), to the neonicotinoids acetamiprid and thiamethoxam was studied extensively in cotton fields in Israel during the cotton-growing seasons 1999–2003. Whitefly strains were collected in early and late seasons mainly in three locations in northern, central, and southern Israel. The whiteflies were assayed under laboratory conditions for susceptibility to neonicotinoids, as part of the Israeli cotton insecticide resistance management strategy. Selections to both acetamiprid and thiamethoxam and cross-resistance between them also were conducted in the laboratory. Although no appreciable resistance to acetamiprid was observed up to 2001, a slight increase of approximately five-fold resistance was detected during 2002 and 2003. However, from 2001 to 2003 thiamethoxam resistance increased >100-fold in the Ayalon Valley and Carmel Coast cotton fields. In cross-resistance assays with both neonicotinoids, the strain that had been selected with thiamethoxam for 12 generations demonstrated almost no cross-resistance to acetamiprid, whereas the acetamiprid-selected strain exhibited high cross-resistance of >500-fold to thiamethoxam.

KEY WORDS *Bemisia tabaci*, neonicotinoids, cross-resistance, acetamiprid, thiamethoxam

Bemisia tabaci (Gennadius) is an important worldwide insect pest in many crops (Byrne and Bellows 1991). Reasons for expansion of *B. tabaci* populations in range and importance are not clear, but they may include agronomic and pesticide-related factors, coupled with the occurrence of new biotypes having distinct biochemical and host range characteristics (Costa and Brown 1991, Perring 2001).

Although some natural biological control has been achieved, the use of insecticides is still considered the primary strategy used to control whiteflies in cotton fields (Horowitz and Ishaaya 1996). Consequently, management of whitefly populations in cotton has been largely dependant on the availability of a diversity of effective insecticides (Li et al. 2001).

Chemical control is an essential component of crop protection in modern agriculture, although overreliance on insecticides has resulted in resistance problems, ecological disturbances, and higher costs to the growers. In many cropping systems, repeated spray applications intended to control *B. tabaci* often resulted in overuse of these insecticides. As a result, whitefly populations developed resistance to numerous conventional insecticides throughout the world (Dittrich et al. 1990, Denholm et al. 1996, Horowitz and Ishaaya 1996, Palumbo et al. 2001).

The need for a greater diversity of compounds effective against whiteflies is being met by the introduction of several insecticides with new modes of action, which are less affected by existing resistance mechanisms (Denholm et al. 1998). Neonicotinoid insecticides (e.g., imidacloprid, acetamiprid, nitenpyram, and thiamethoxam) are generally systemic in plants, and act on acetylcholine receptors in the insect central nervous system. The use of neonicotinoid insecticides against whiteflies and other sucking pests is increasing rapidly. Neonicotinoid overuse, coupled with a strong risk of cross-resistance between these chemicals, threatens the effectiveness of the group as a whole (Cahill and Denholm 1999, Li et al. 2001).

Resistance to imidacloprid has already been reported in *B. tabaci* from greenhouses in southern Spain (Cahill et al. 1996, Elbert and Nauen 2000, Rauch and Nauen 2003) and in a strain from the United States placed under strong and prolonged selection pressure in the laboratory (Prabhaker et al. 1997). In addition, 3 yr of acetamiprid use in Israeli greenhouses resulted in 5–10-fold tolerance of *B. tabaci* to this compound; however, acetamiprid remained highly effective in cotton fields (Horowitz et al. 1999a).

This article reports on the dynamics of resistance of two neonicotinoids, acetamiprid, which has been used annually in cotton fields since 1996, and thiamethoxam, which has not been used at all in cotton in Israel. Whitefly selections to both insecticides was done under laboratory conditions and used for cross-resistance studies.

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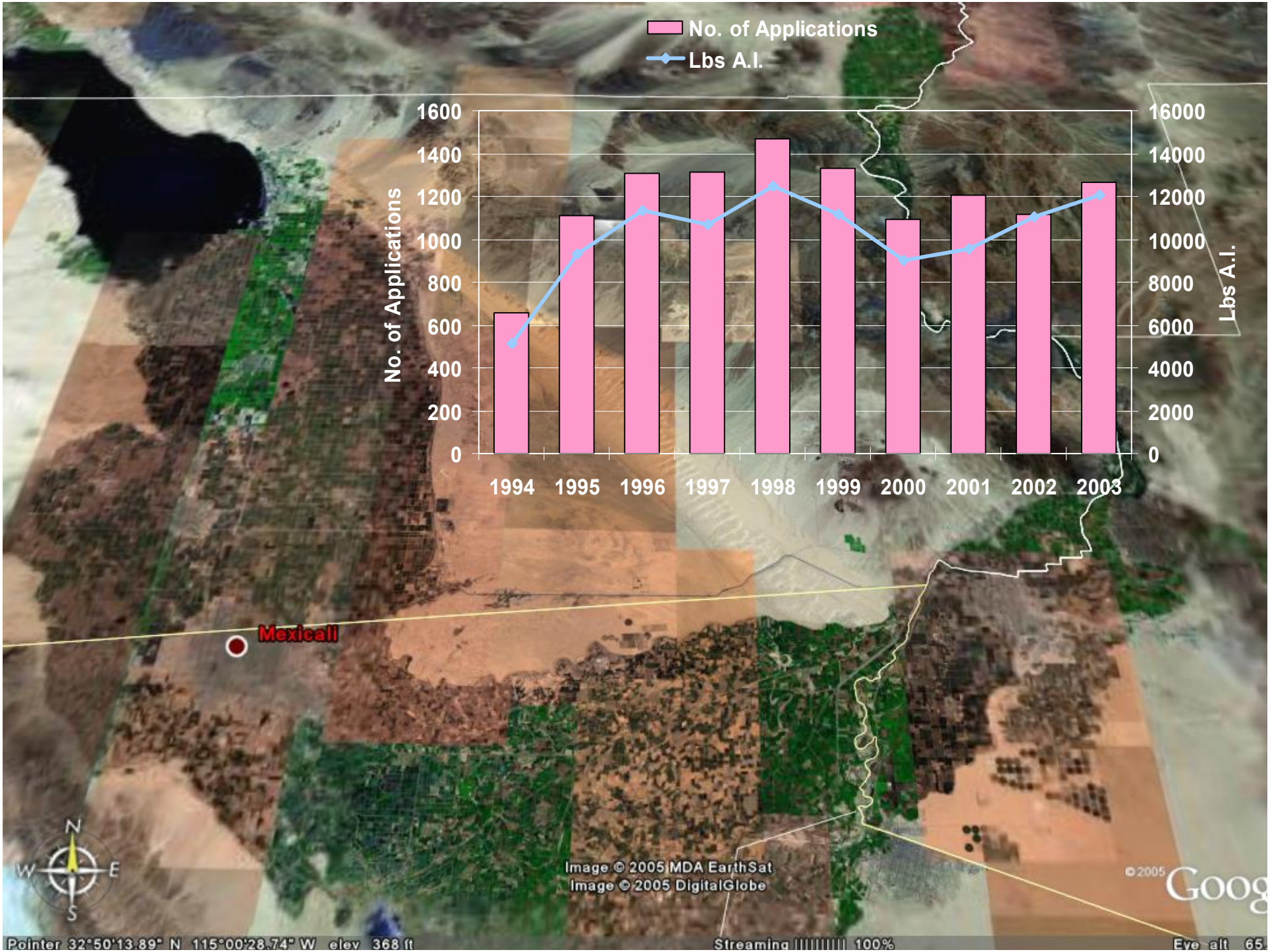
	Acetamiprid			Thiamethoxam	
Location	LC_{50}	RR		LC_{50}	RR
Lab Susc.	2	---		2	---
Ayalon (early)	3	1.5		223	106
Ayalon (late)	5	2.5		208	104
Carmel (early)	4	2		279	140
Carmel (late)	4	2		474	237
W. Negev (early)	3	1.4		22	11
W. Negev (late)	2	1		95	48

Strain	Gen	LC_{50}	RR
Acetamiprid-selected	15	219	72
Thiamethoxam-selected	12	1178	675

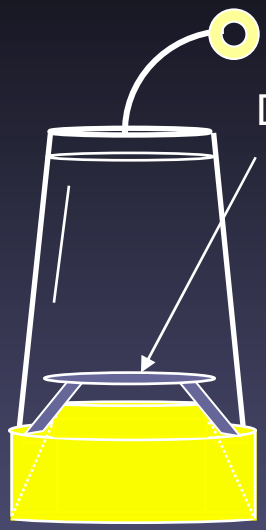
Tested with Thiamethoxam

Tested with Imidacloprid

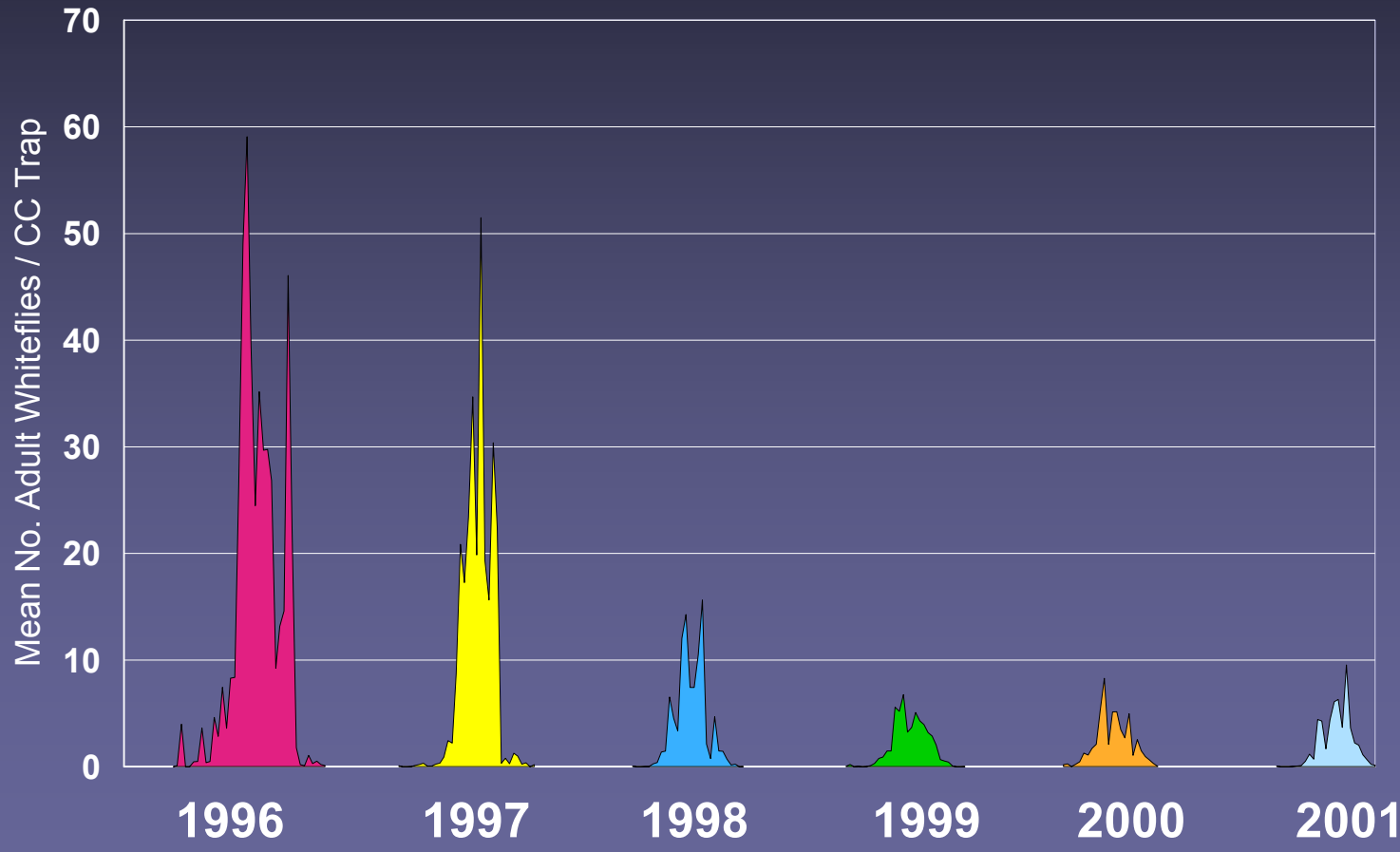
Strain	Gen	LC_{50}	RR
Acetamiprid-selected	15	1108	142
Thiamethoxam-selected	12	8	4


No. of Applications
Lbs A.I.
No. of Applications
Lbs A.I.
1600
1400
1200
1000
800
600
400
200
0
16000
14000
12000
10000
8000
6000
4000
2000
0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Mexicali
Image © 2005 MDA EarthSat
Image © 2005 DigitalGlobe
© 2005 Goog
Pointer 32°50'13.89" N 115°00'28.74" W elev 368 ft
Streaming 100%
Eye alt 65

Decline in *B. tabaci* numbers in the Imperial Valley as determined by CC traps



C.C. Chu et al.
2005

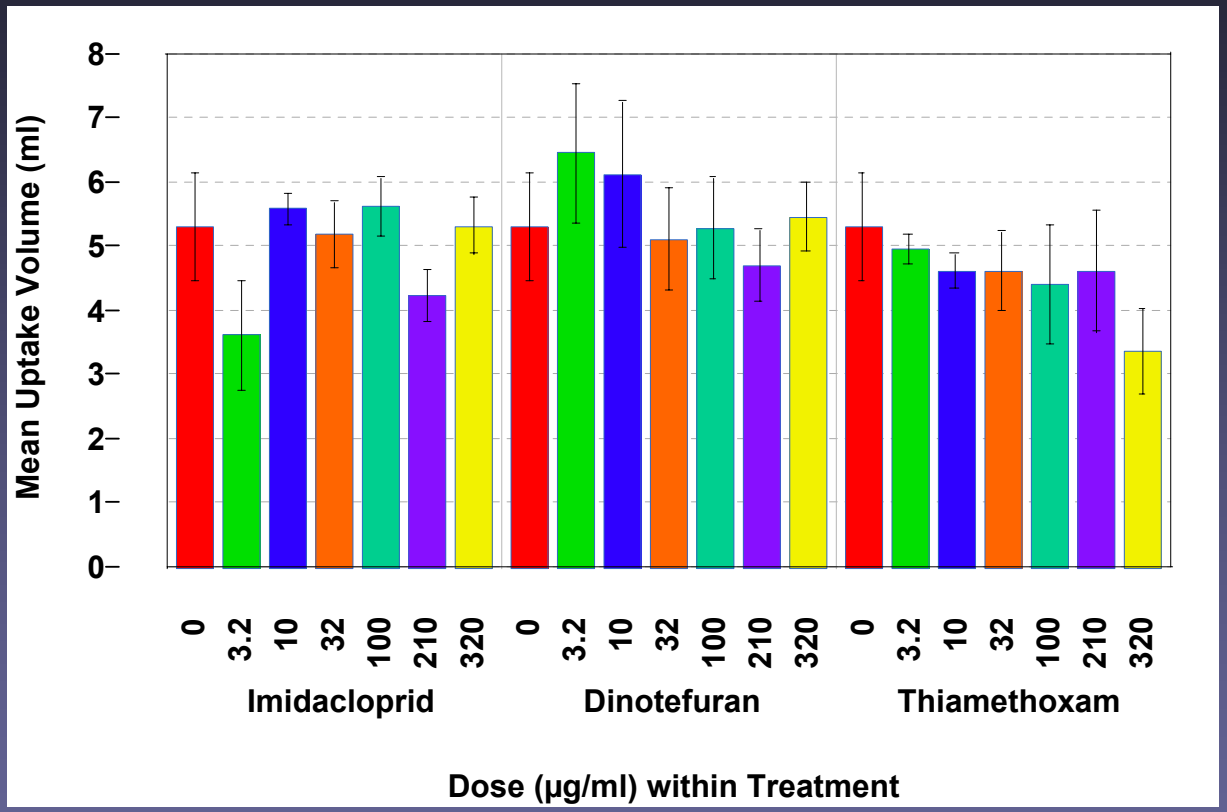


Cauliflower in Imperial Valley – Late September 2005

Systemic Uptake Bioassay Procedure

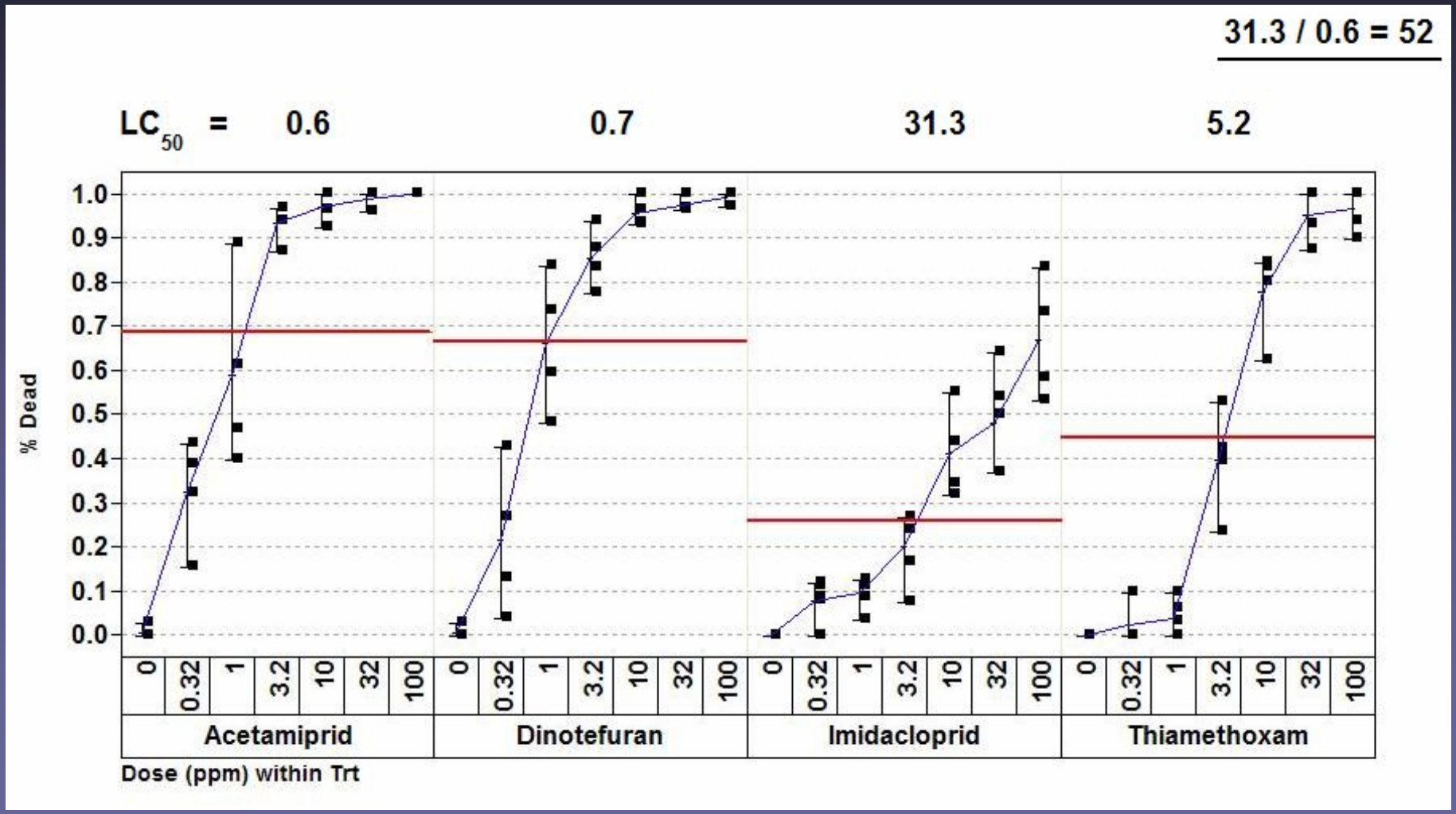
Systemic Uptake Bioassay Procedure

Uptake Volumes Measured for Each Systemic Uptake Bioassay



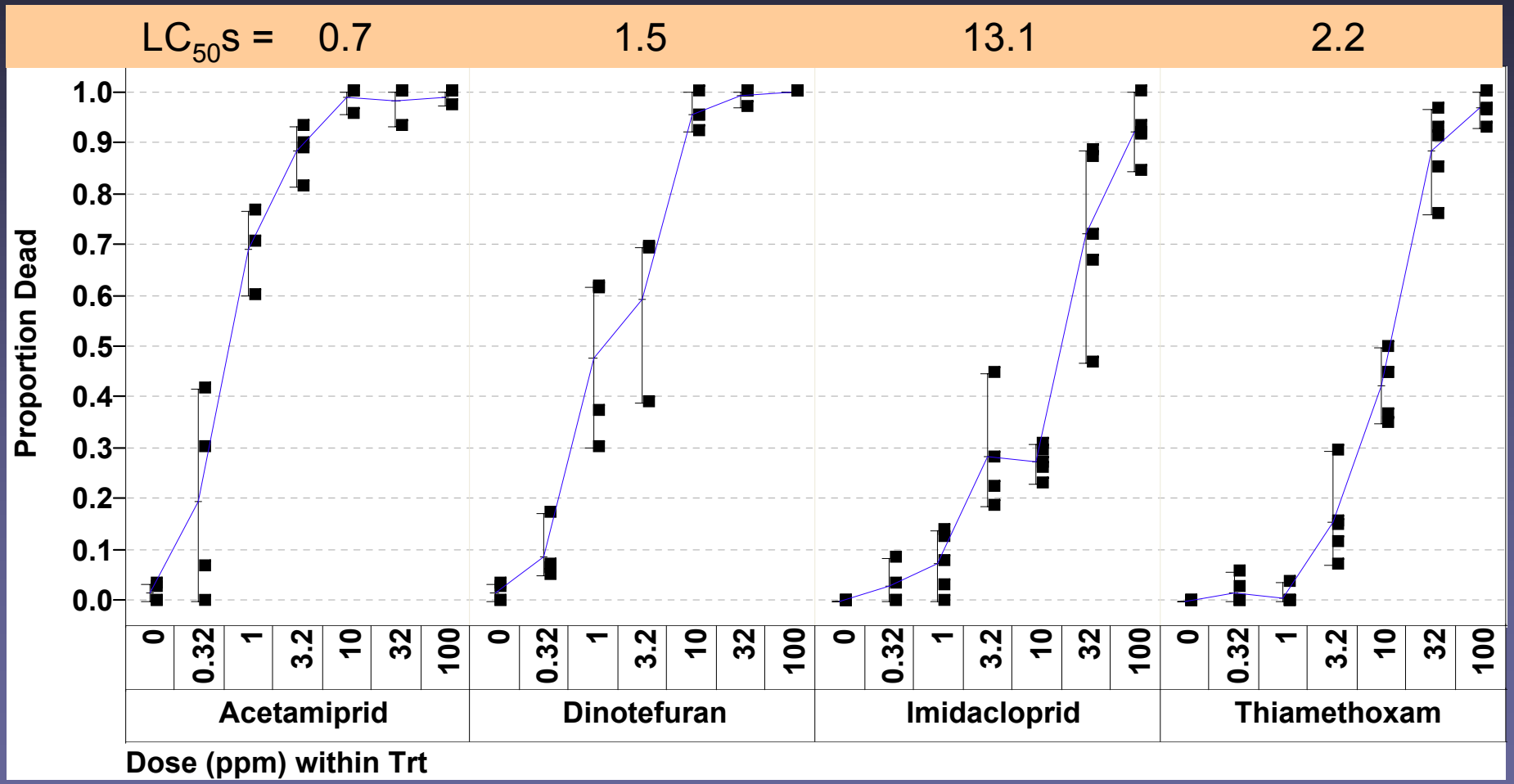
Leaf burn after 24 h uptake of 320 ppm imidacloprid

Bioassay Results on *B. tabaci* adults collected in Imperial Valley, 1 July 2004

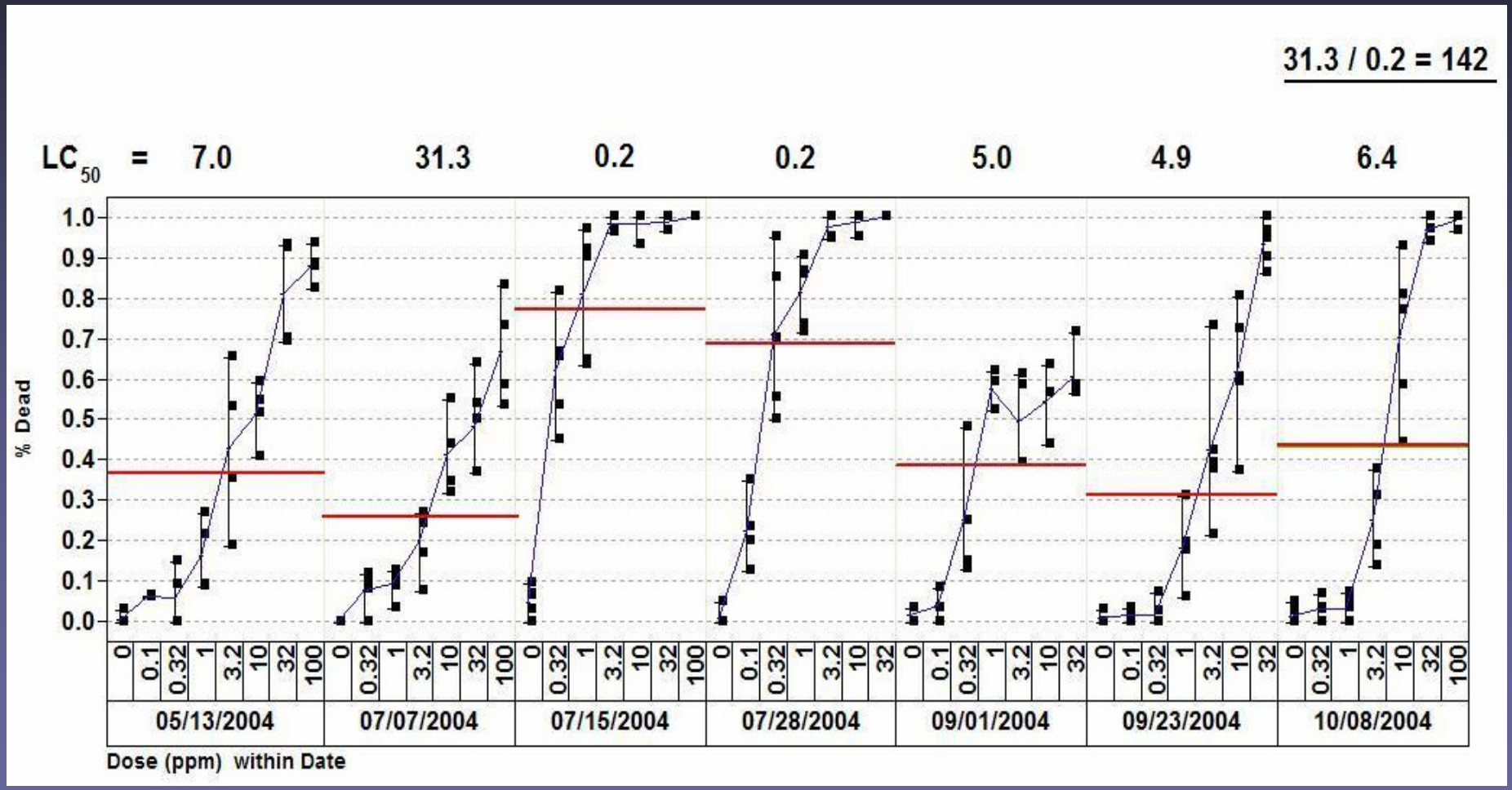


Bioassay Results on *B. tabaci* adults collected in Yuma, AZ 1 July 2004

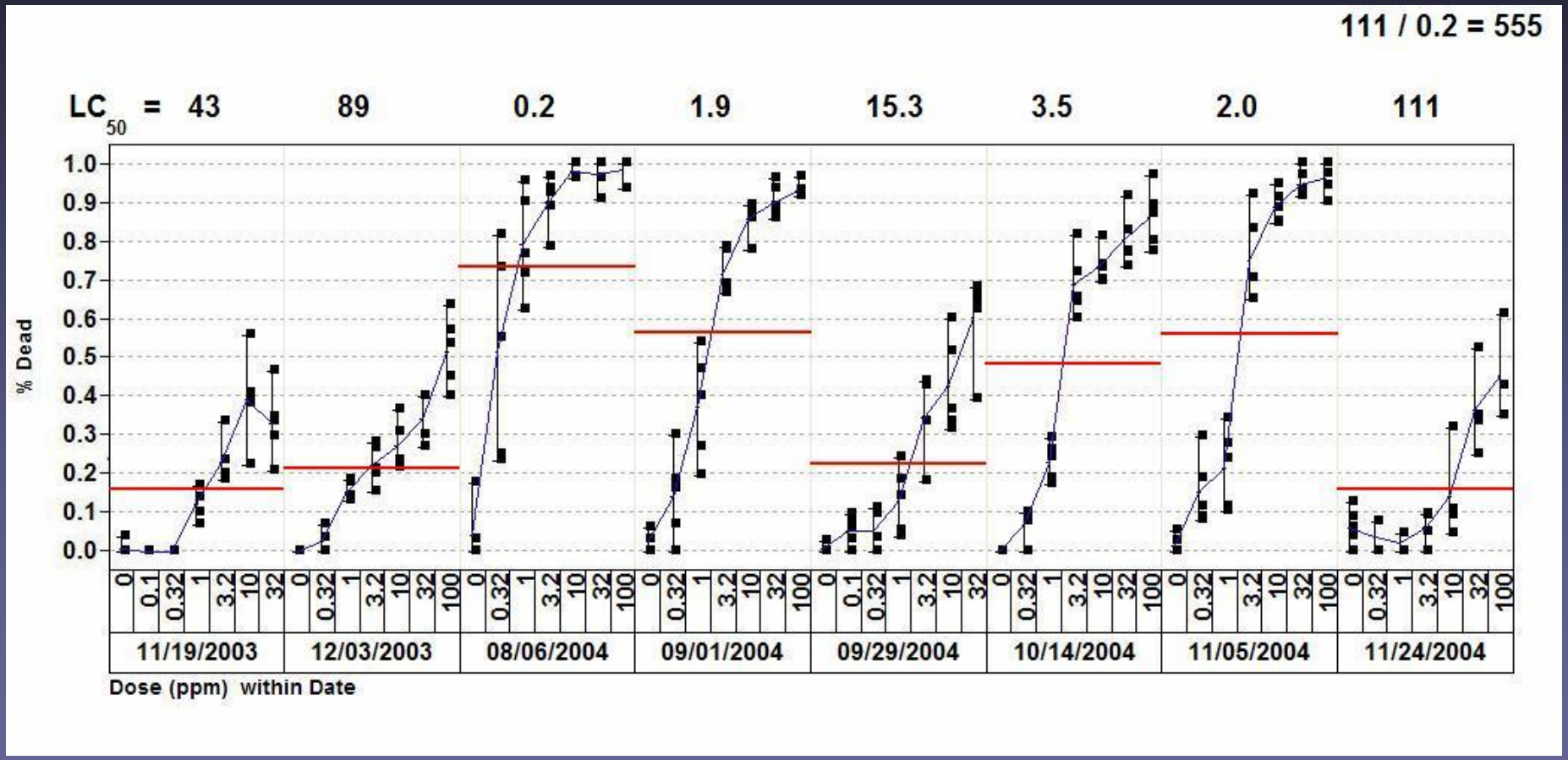
13.1 / 0.7 = 18.7



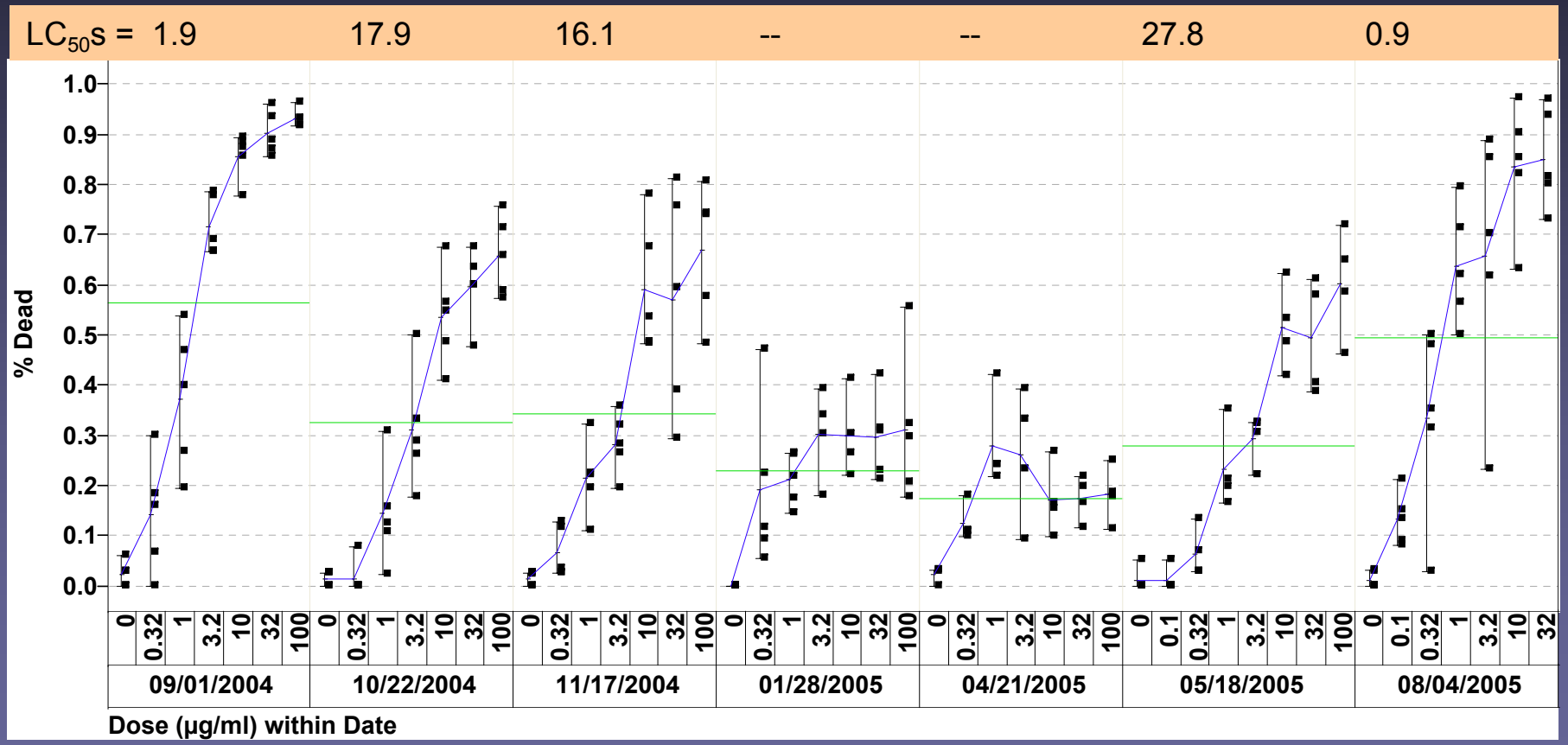
Bioassay Results for Imidacloprid on *B. tabaci* Collected in Imperial Valley



Bioassay Results for Imidacloprid on *B. tabaci* Collected at Maricopa Agricultural Center, AZ



Performance of a Mac Field Strain Following Establishment as a Greenhouse Colony Without Selection

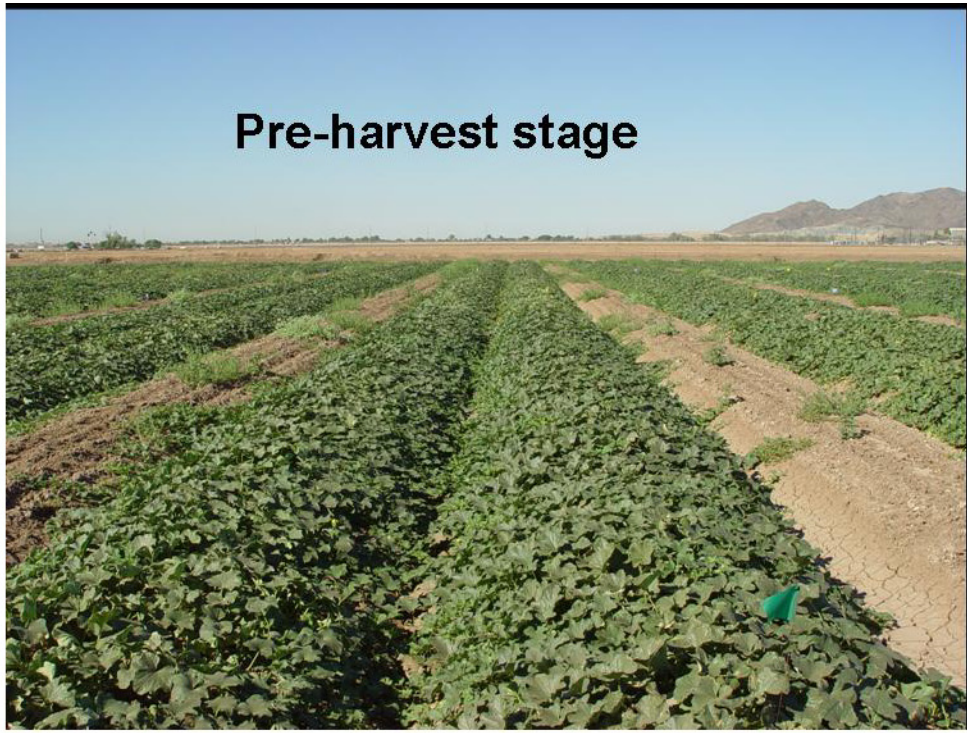


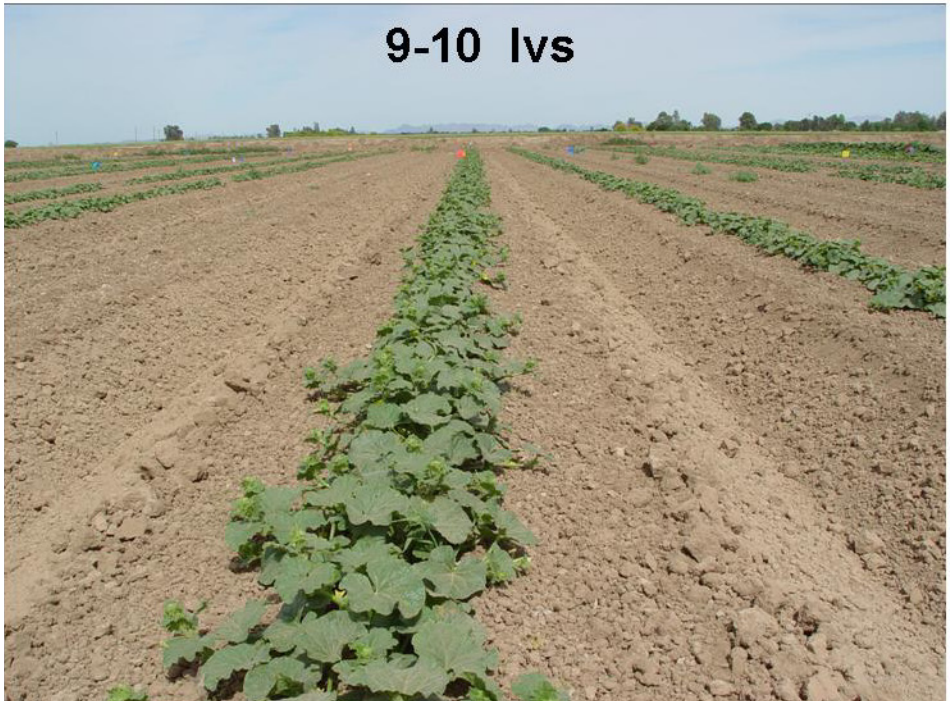
Summary of LC_{50} Ratios for *B. tabaci* Adults Collected in Imperial Valley and Maricopa

Compound	Imperial Valley	Maricopa
Acetamiprid	32	48
Dinotefuran	65	52
Imidacloprid	142	555
Thiamethoxam	10	7.5

In Situ vs. Laboratory Bioassays

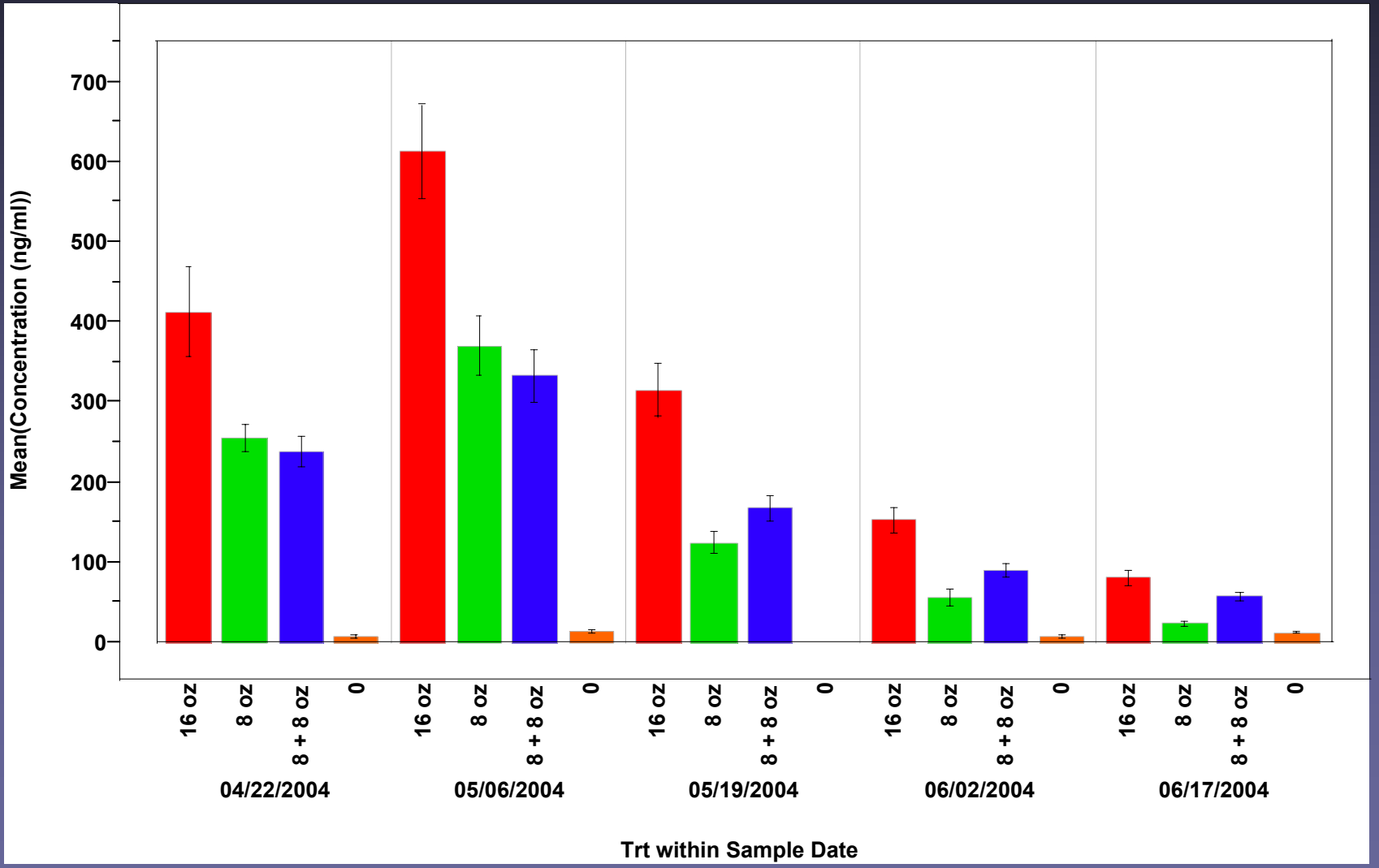

2-3 lvs

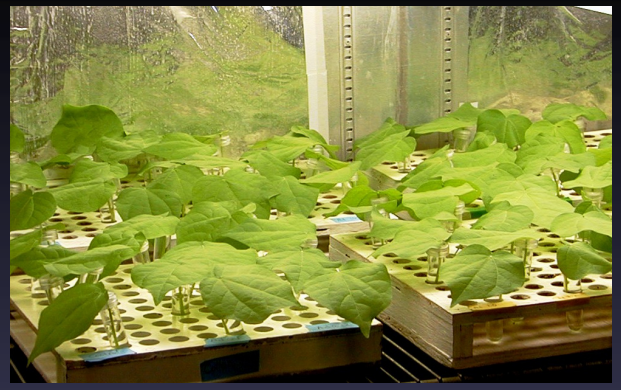

Pre-harvest stage


9-10 lvs

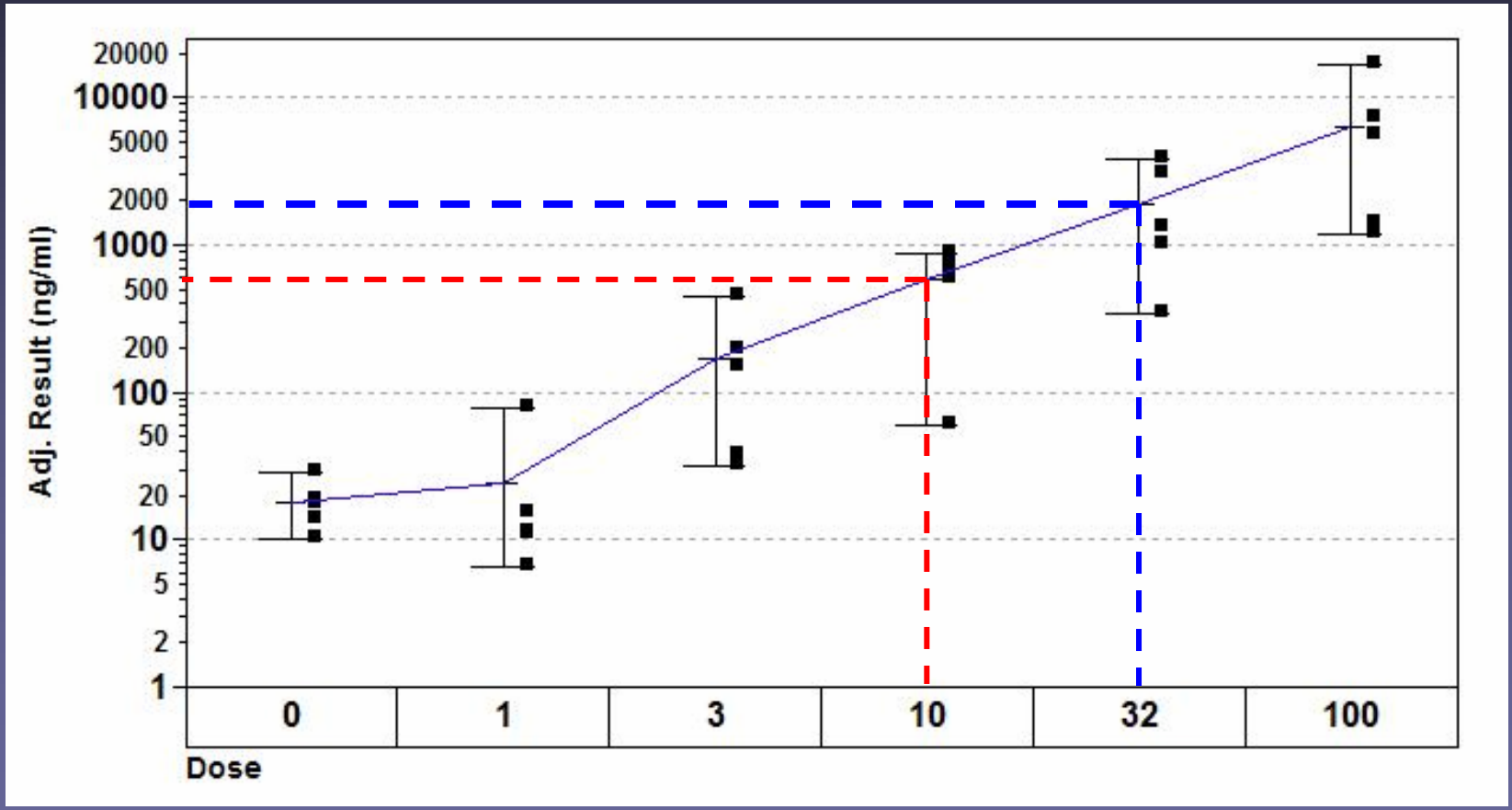

22-24 lvs

Comparison of Imidacloprid Titers in Crown Leaves in the at-Plant Treatments

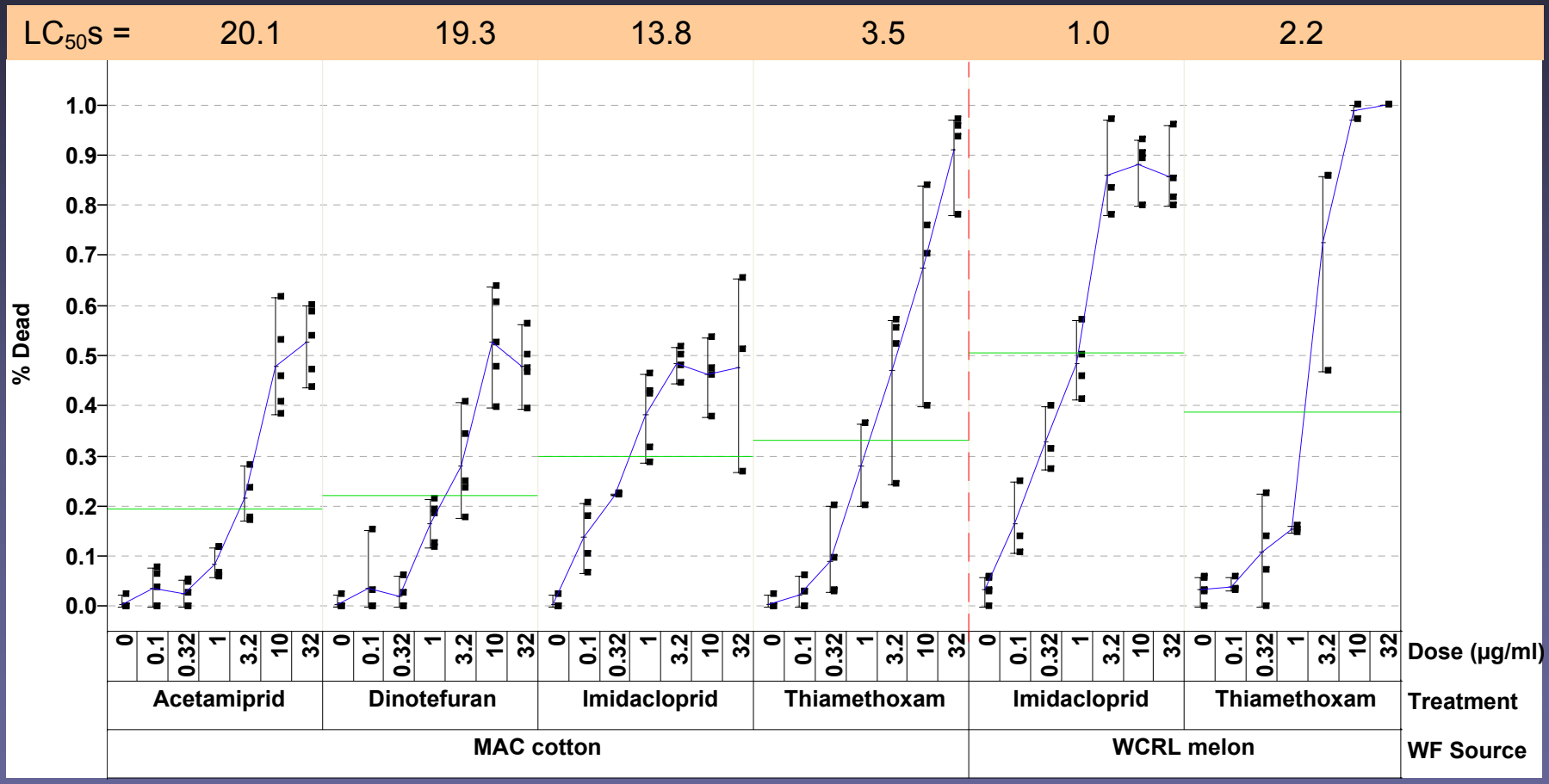




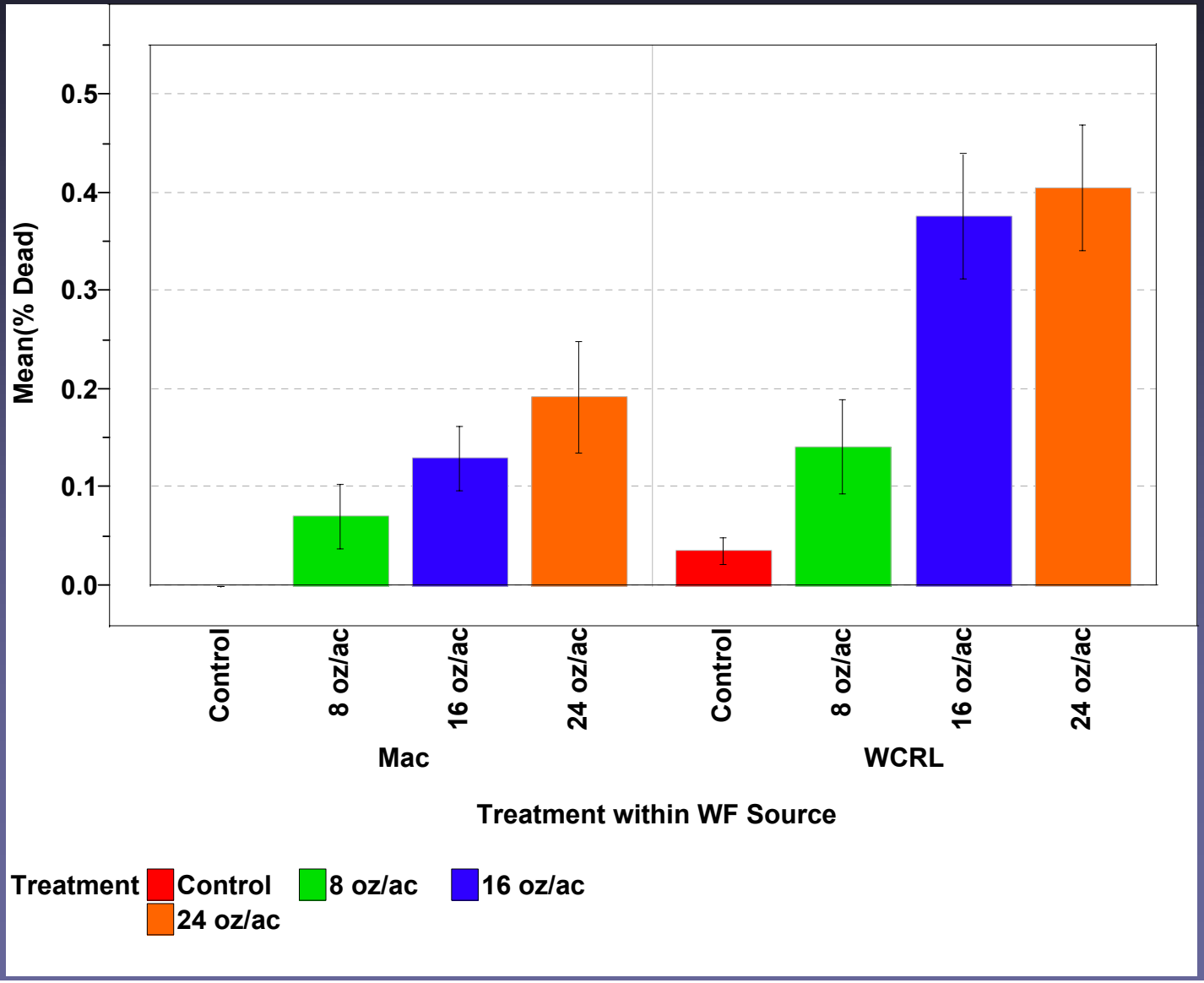
Concentration of Imidacloprid in Cotton Leaves Used in Uptake Bioassays



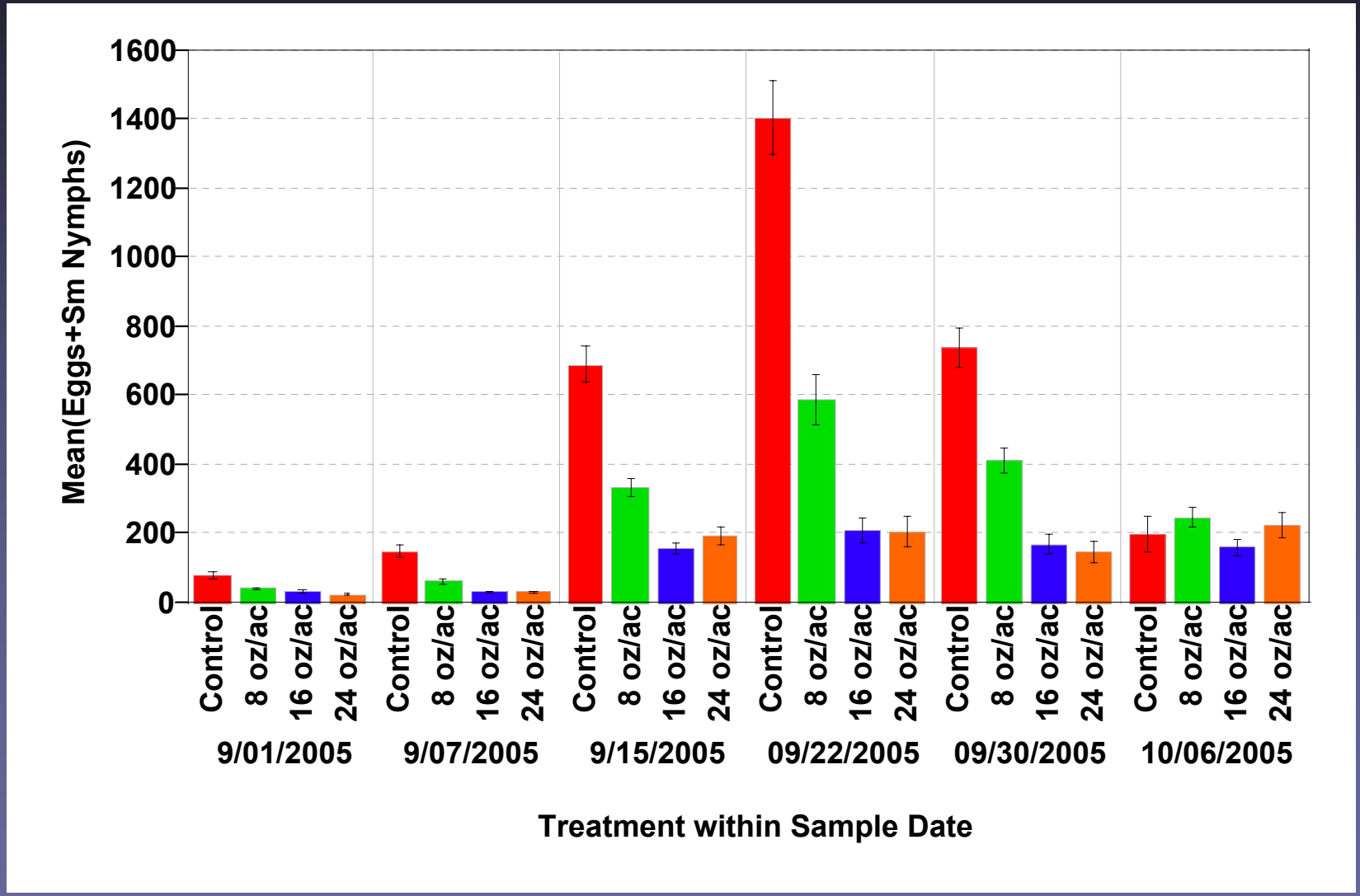
Bioassay Comparison of Adult Whiteflies Collected on Cotton at Mac vs. on Melons in Phoenix



In Situ Bioassay Results for Mac vs. Phoenix Whiteflies
(48 h exposure)



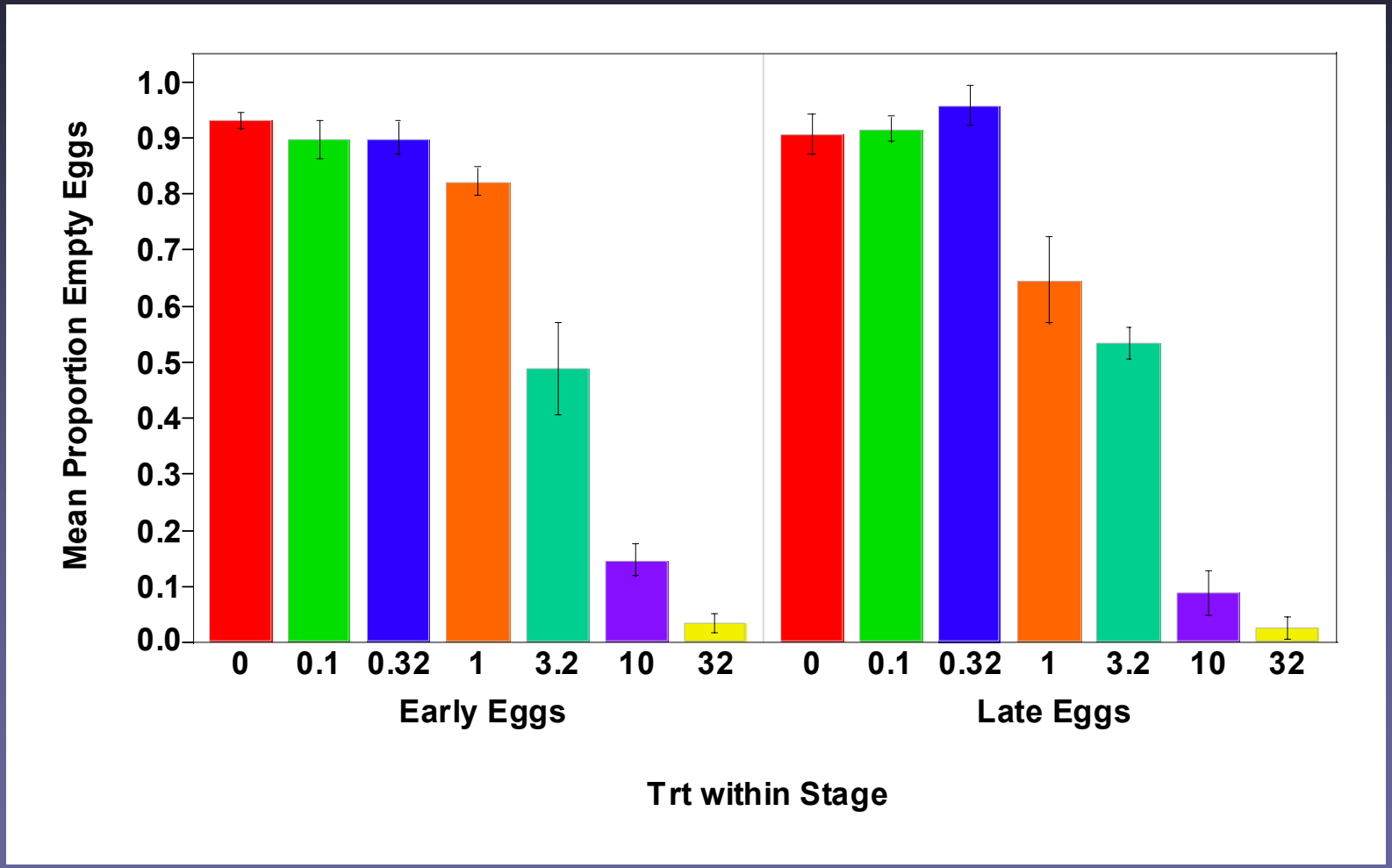
Mean Egg+Small Nymph Densities on Melon Leaves from Plants Treated at 3 Rates of Admire



Impact of Imidacloprid on Immatures

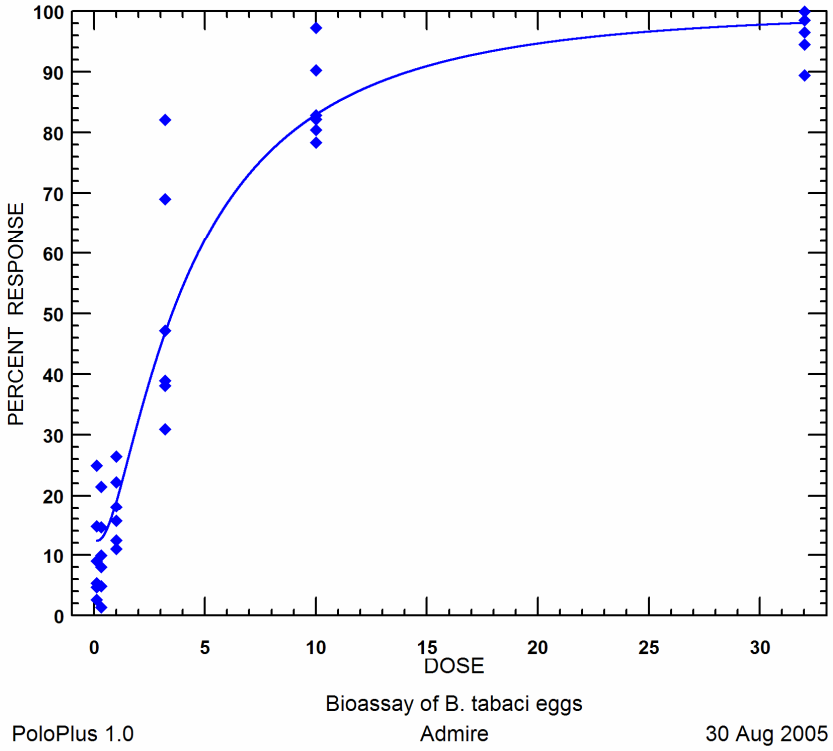
- Cotton plants grown in clean greenhouse completely free of Wfs
- First node leaf on each plant infested with 20 adults held in clip cage
- Adults removed after 1 day to produce a synchronous cohort of eggs
- Leaves randomly selected at intervals for bioassays
  - 1 day old eggs
  - 3 day old eggs
  - Settled firsts
  - 2nds
  - 3rds
  - 4th
- 24 h uptake followed by a 2 day exposure period before reading results; 8 day exposure for eggs

Proportion of Hatched Eggs According to Concentration of Imidacloprid in Uptake Solution

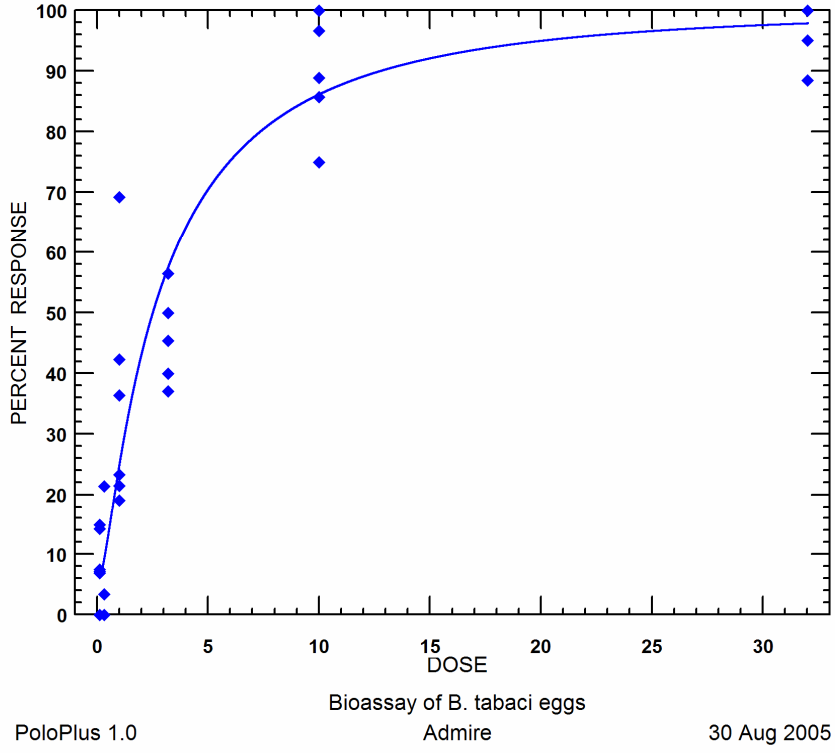


Probit Results for *B. tabaci* Eggs

1 day eggs LC_{50} = 4.1



3 day eggs LC_{50} = 2.7



Summary

- Responses of *B. tabaci* populations to various neonicotinoids are not always uniform, i.e. inconsistent expression of cross-resistance
- Results of systemic uptake bioassays are based on solution concentrations and likely exaggerate susceptibilities relative to field concentrations
- Resistance assessments based on adult *B. tabaci* only underestimate the full capacity of neonicotinoid treatments to control infestations