Efficacy of Fumigants Against Psocids, and Other Management Tactics

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Background

Psocids, which are also called booklice or barklice, are secondary pests in grain storages, grain processing facilities, and product warehouses.

They cause quality reduction and weight loss, and can be a health (allergens) and safety (slippery floors) hazard.

Before the early 1990s, psocids were not considered serious pests of stored products, but, in some countries such as Australia, they have since become the most frequently encountered storage pest in some areas.

Background

There have been increased industry complaints/ questions in the U.S. during the last five to ten years due to psocids, but we didn't have answers for them.

So, we started a research program to look at the psocid species involved, their biology, and ways to control them.

Background

Why are we seeing sudden psocid problems?

- Psocids have a varied response to management tactics that have been developed for beetle pests – e.g., some psocid species are resistant to residual insecticides and the fumigant phosphine, while others are not

- Markets increasingly view psocids as contaminants

Background

Most psocid pests of stored products are from the genus *Liposcelis*

7 species of *Liposcelis* (*bostrychophila, brunnea*, *corrodens*, *decolor*, *entomophila*, and *paeta*) and 1 species of *Lepinotus* (*reticulatus*) that are pests of stored products have been reported from the U.S.

Psocids are small, soft-bodied insects often only 1 mm in length. Eggs hatch into nymphs, which look like small adults. Some species are parthenogenetic.

Topics

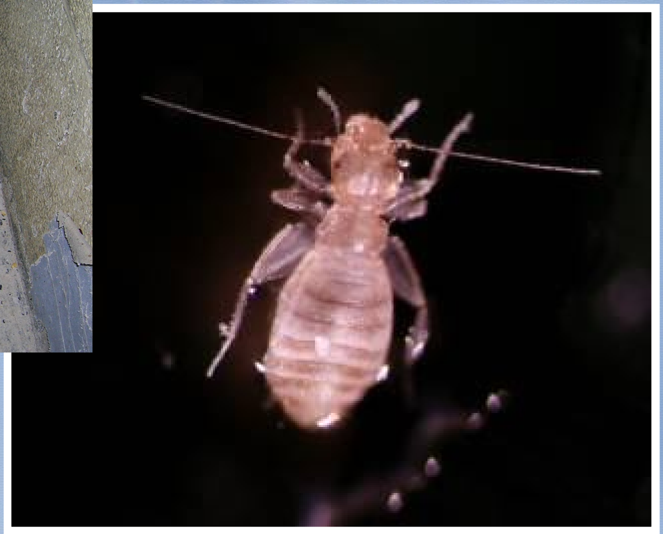
1) Species of psocids found in grain storages and processing facilities in Kansas

2) Biology of some psocid species

3) Efficacy of control technologies for psocids, including SF

Preliminary distribution studies in 2004

In studies at a flour mill, a grain elevator, and farm bins in Manhattan, we found the species *Liposcelis entomophila* and *L. decolor* – >90% of the psocids were *L. entomophila* at each site.



Liposcelis entomophila

Liposcelis decolor

Preliminary distribution studies in 2004

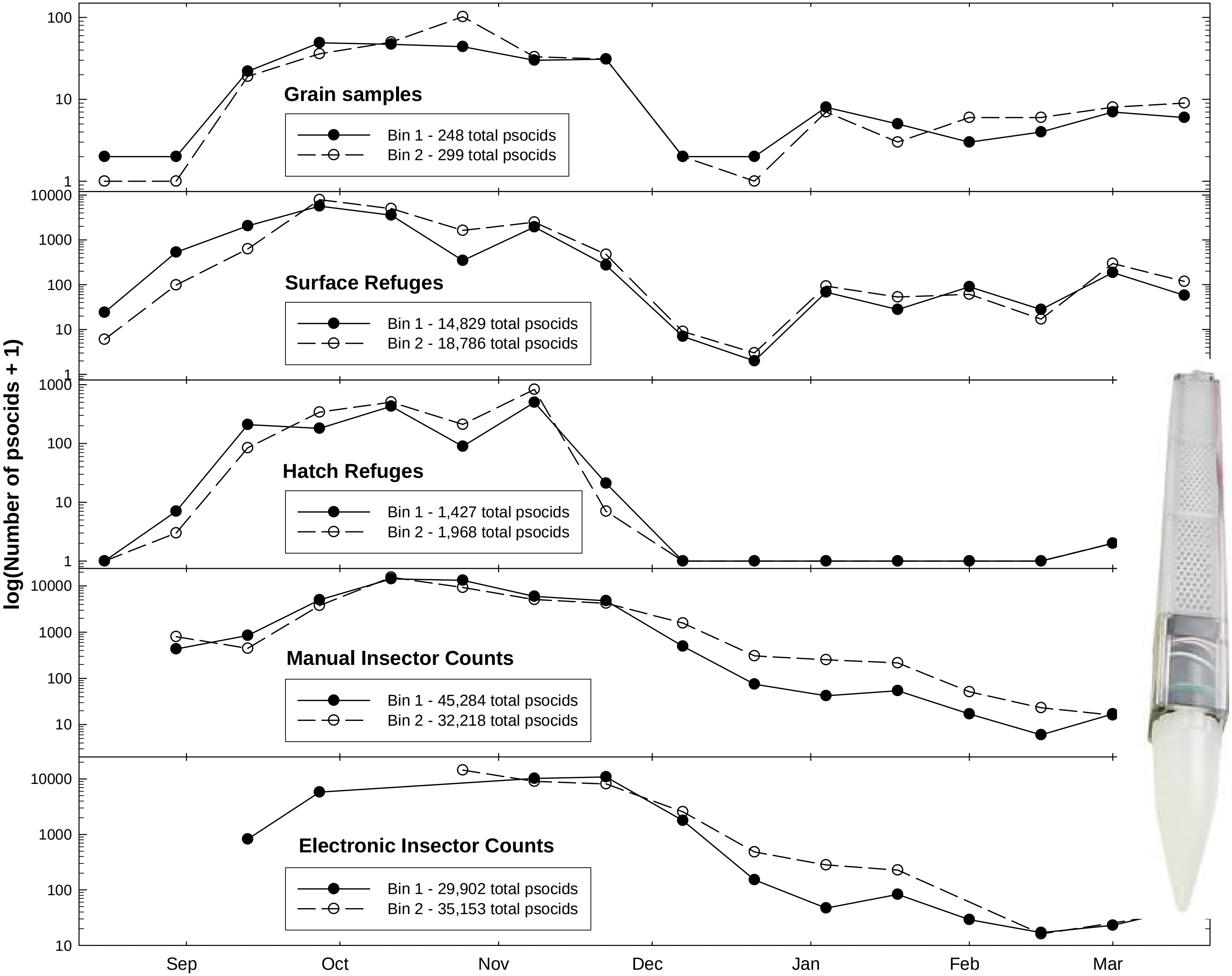
In steel bins of wheat at another site, *Liposcelis entomophila* was again predominant, with *Lepinotus reticulatus* also present.

Lepinotus reticulatus

Temporospatial distribution studies in 2005 and 2006

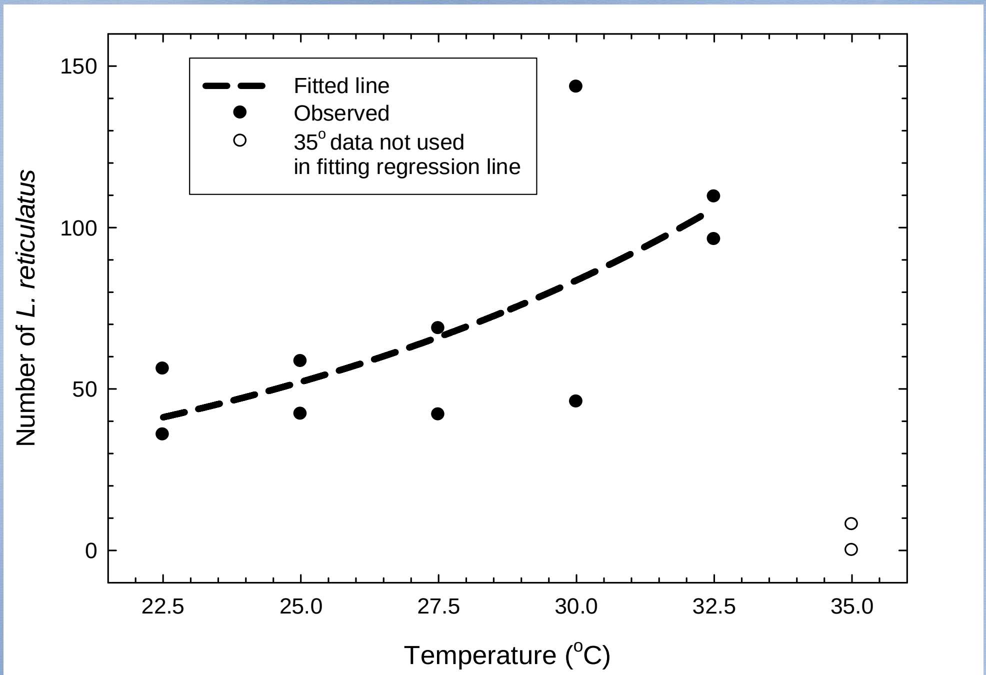
We conducted more extensive sampling in two steel bins of wheat at our GMPRC facility. The only psocid species found in the bins were *Liposcelis entomophila* in 2005 and *Liposcelis decolor* in 2006.

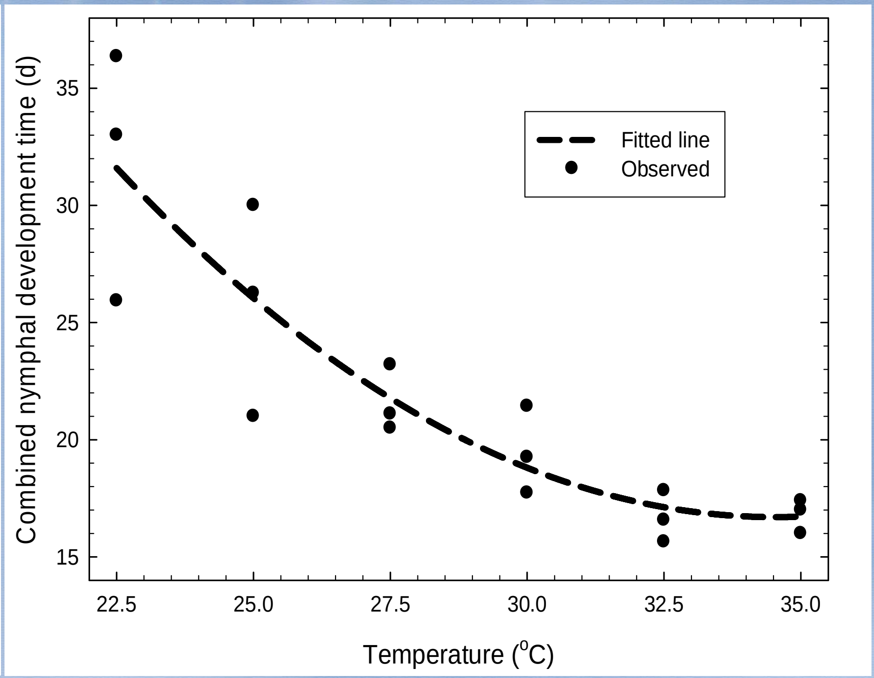
2005 Psocid trends – 115,059 psocids collected



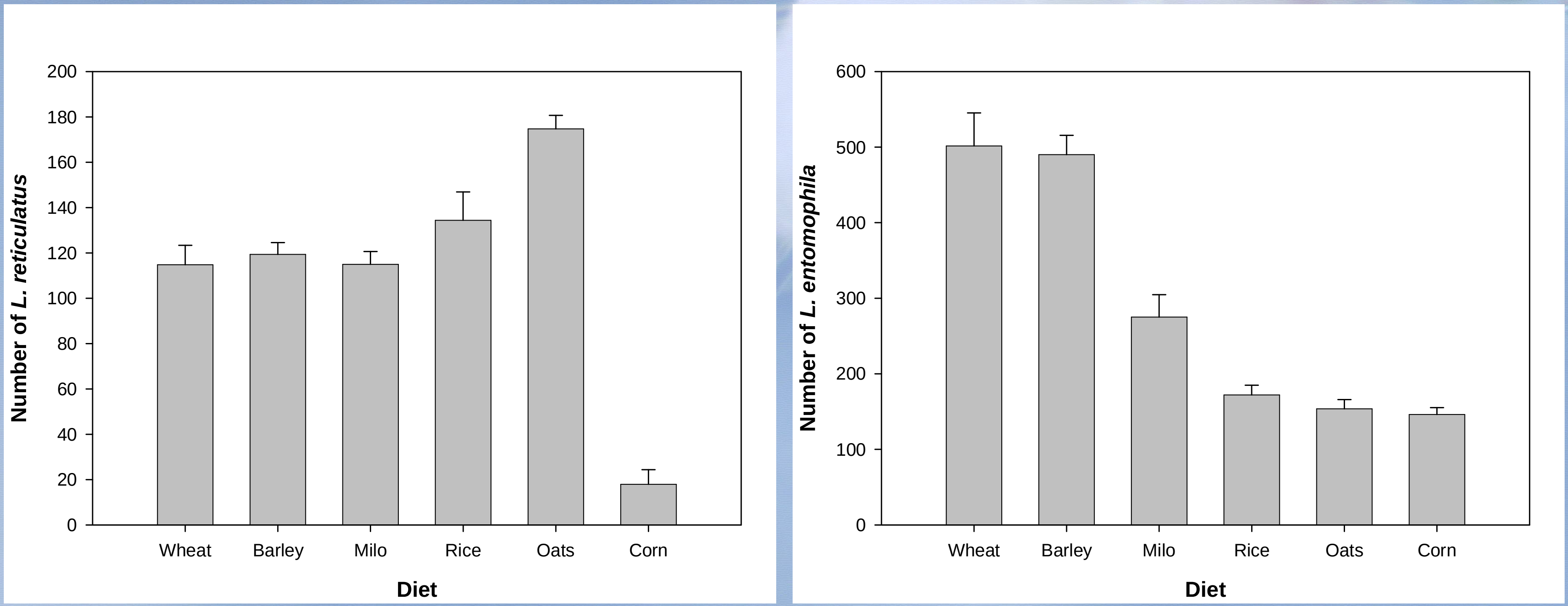
Population growth and development at constant temperatures and relative humidities

- Five adult females placed in 5 grams of diet for 46 days.
- No live *L. reticulatus* were found at 32, 43, or 55% RH.
- Number of L. reticulatus produced increased as temperature increased, except at 35°C.
- Development time decreased with increasing temperature.



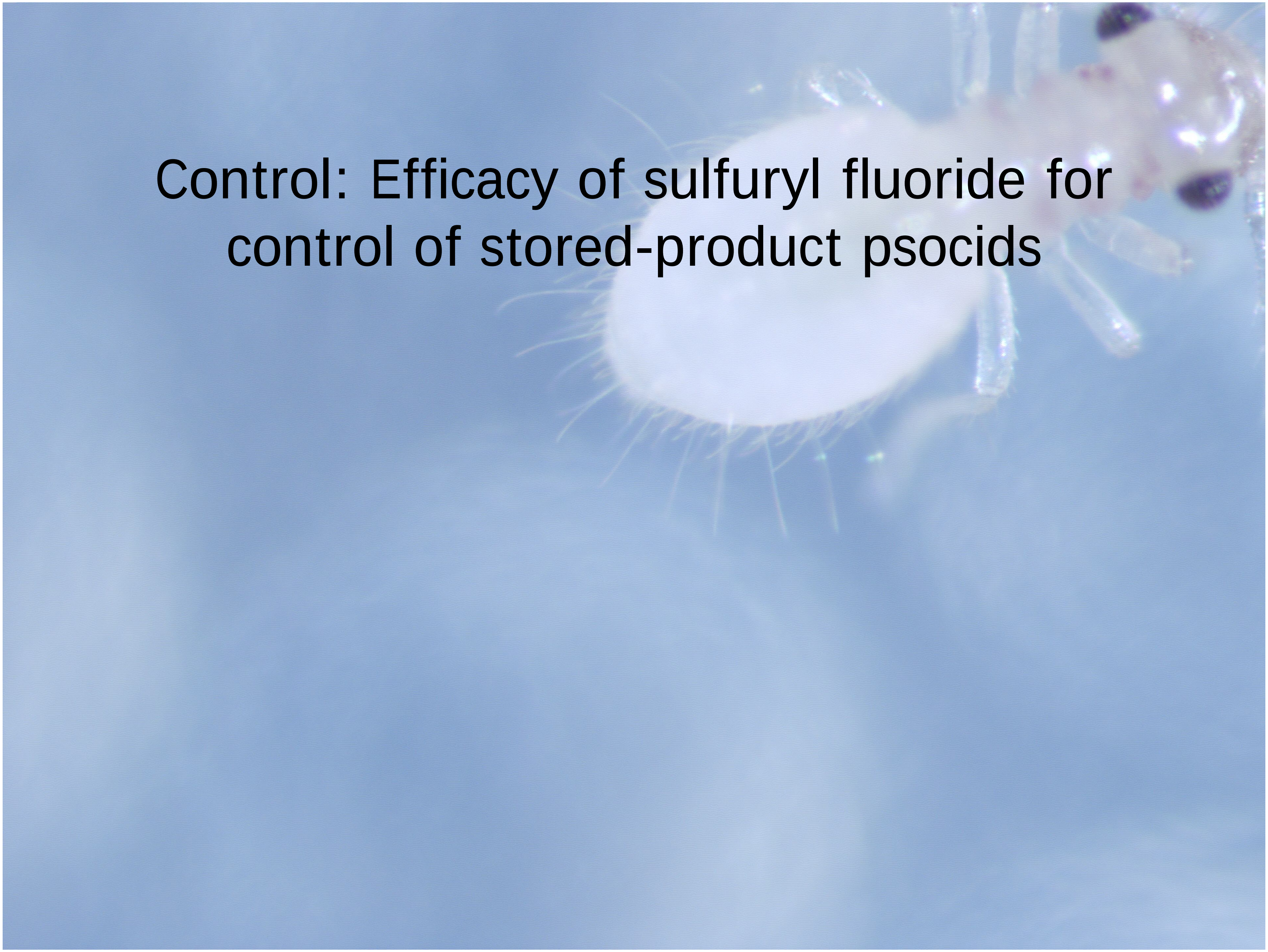


Development of *Lepinotus reticulatus* and *Liposcelis entomophila* on various grains



Five females in five grams of cracked grain for 32 days at 30°C and 75% RH.

Control: Efficacy of sulfuryl fluoride for control of stored-product psocids



Control: Efficacy of sulfuryl fluoride for control of stored-product psocids

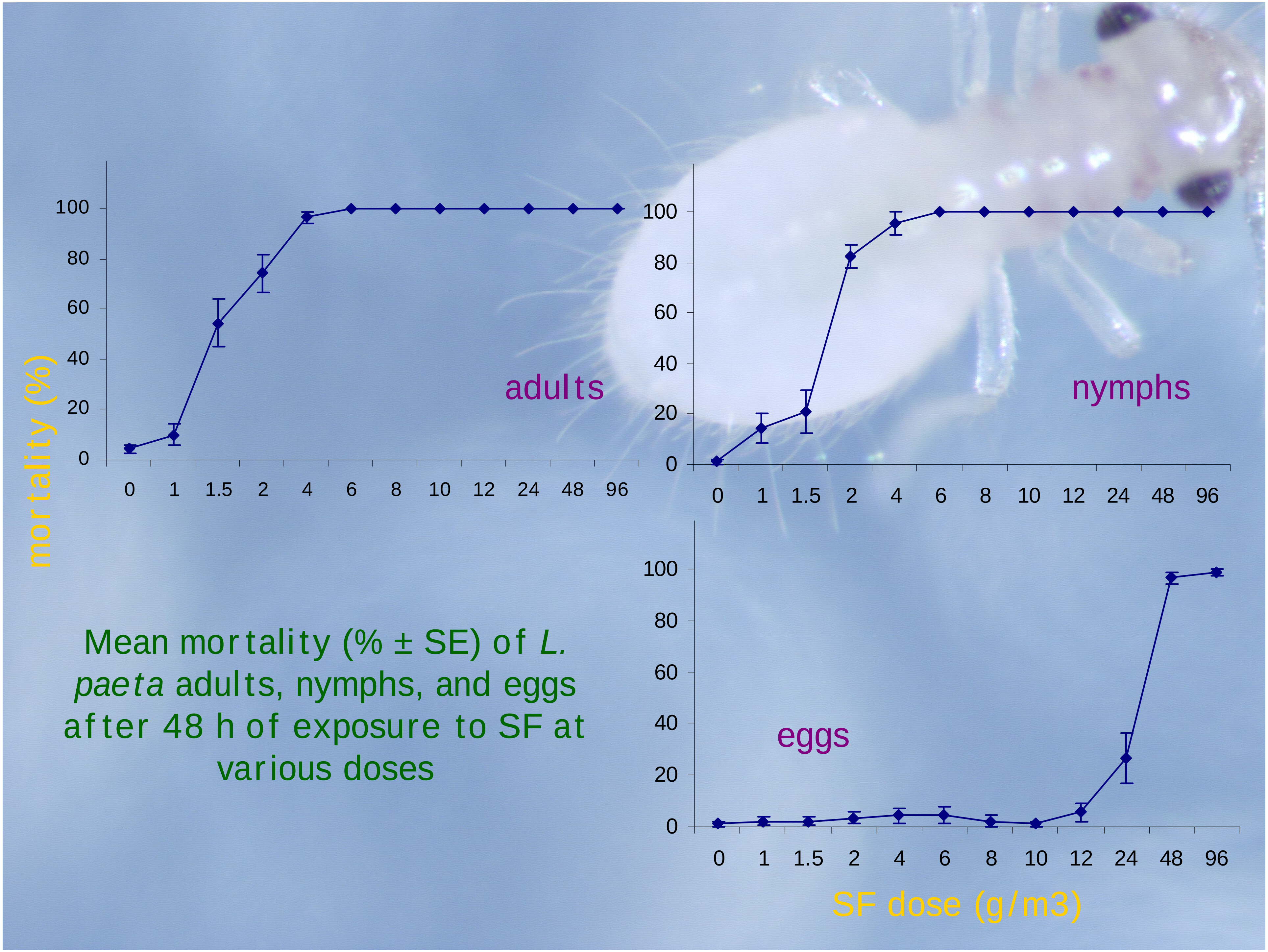
- Psocids have been shown to be tolerant to several insecticides at doses that are usually effective against other stored-product insects, such as:
  - Phosphine (especially in the egg stage)
  - OPs (such as chlorpyriphos-methyl and pirimiphos-methyl)
  - Pyrethrum and synthetic pyrethroids
  - IGRs
- Newer insecticides, such as spinosad, are ineffective against several psocid species
- There are no data published on efficacy of SF for control of psocids

Control: Efficacy of sulfuryl fluoride for control of stored-product psocids

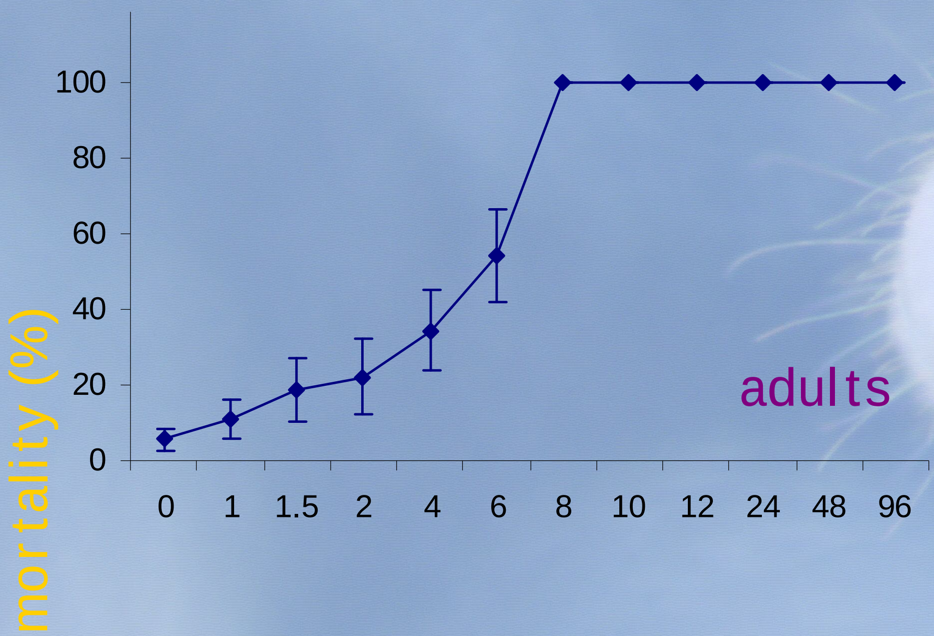
- Five bioassays were conducted between June and December 2008 in the laboratory at 27.5°C and 70% RH
- Twelve doses were assessed: 0 (control), 1, 1.5, 2, 4, 6, 8, 10, 12, 24, 48, 96 g/m3; maximum target concentration is 173 g/m3
- Large jars were used as the experimental chambers (three jars/dose)
- Vials containing 10 psocid eggs, nymphs, or adults were placed in each jar; there were three vials for each species/life stage combination

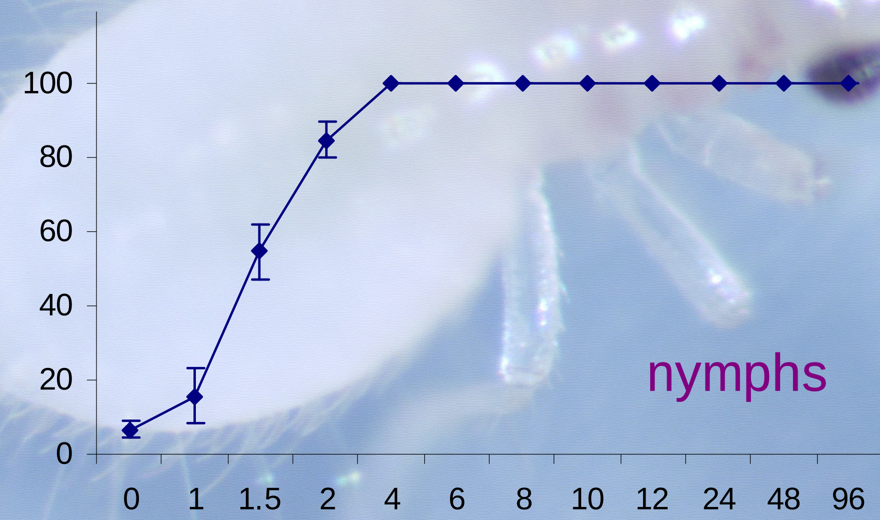
Control: Efficacy of sulfuryl fluoride for control of stored-product psocids

- After the introduction of the gas in the jars, gas concentration was measured by gas chromatography
- The jars were opened after 48 h, and the vials were transferred to the lab
- Mortality was measured after 8 d at 30°C and 70% RH

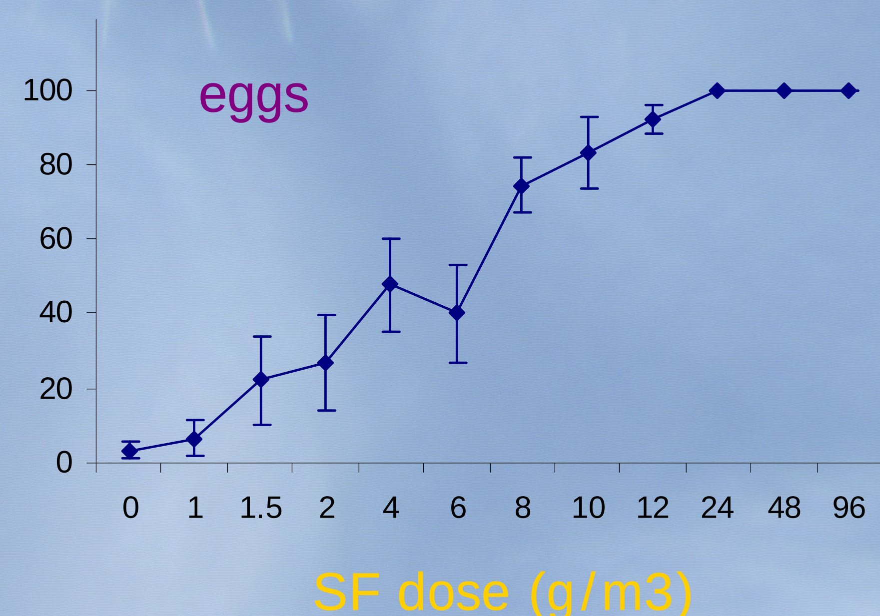


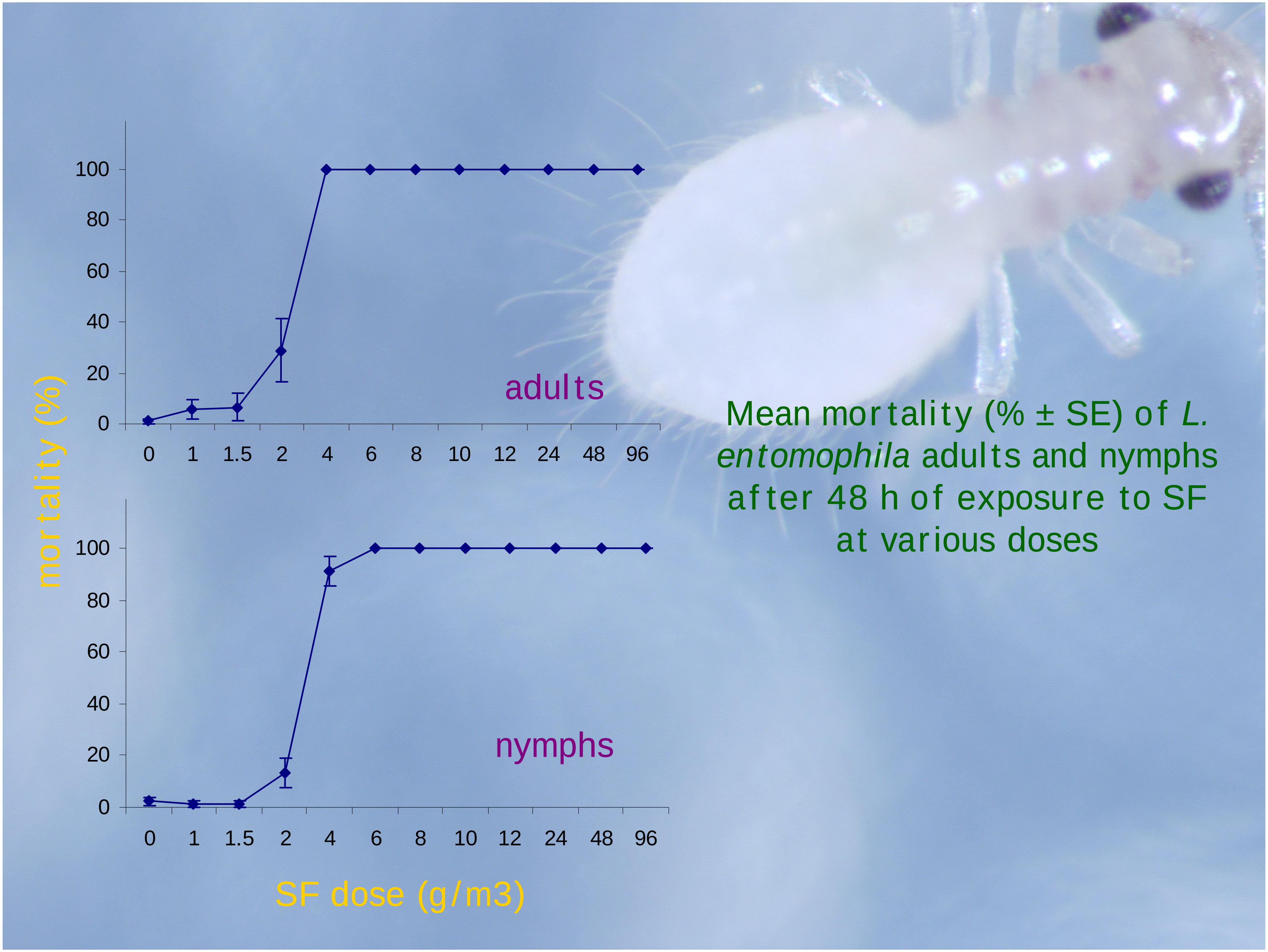
Mean mortality (% ± SE) of *L. paeta* adults, nymphs, and eggs after 48 h of exposure to SF at various doses

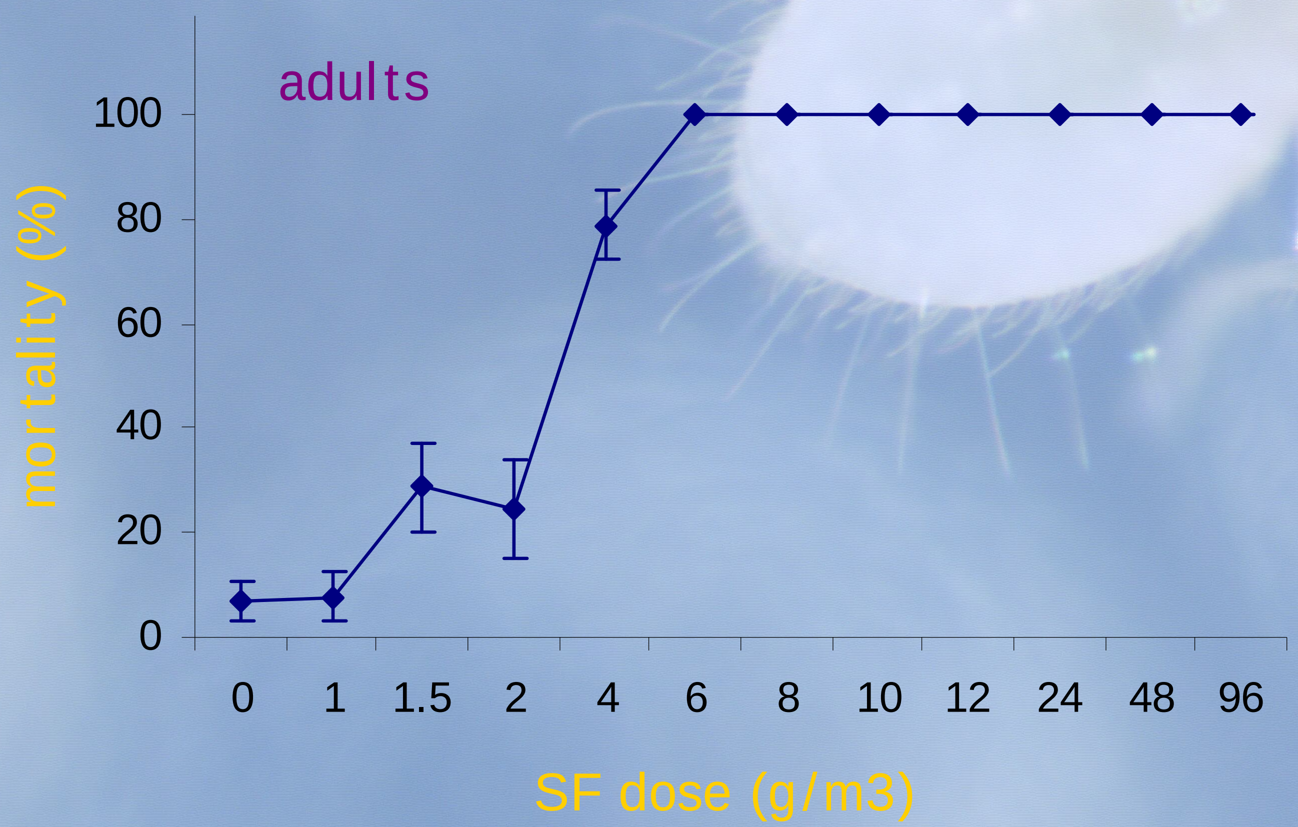




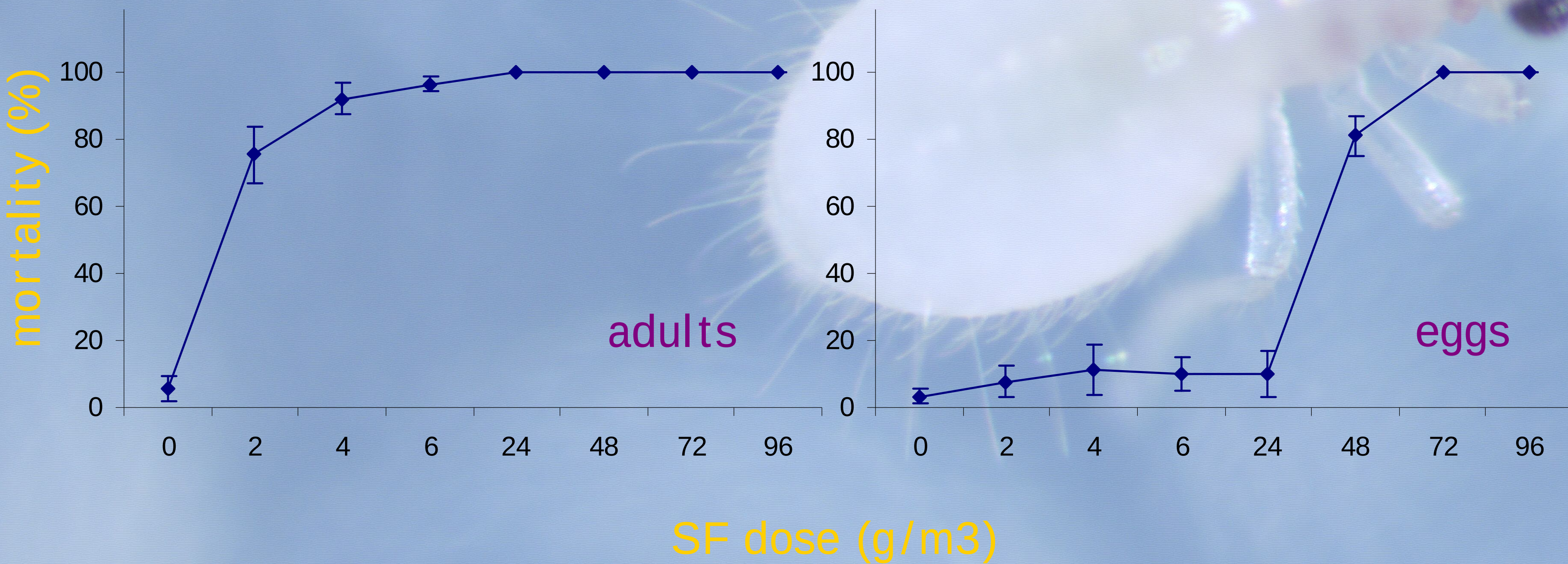
Mean mortality (% ± SE) of *L. reticulatus* adults, nymphs, and eggs after 48 h of exposure to SF at various doses




mortality (%)
100
80
60
40
20
0
0 1 1.5 2 4 6 8 10 12 24 48 96
adults
nymphs
SF dose (g/m3)
Mean mortality (% ± SE) of *L. entomophila* adults and nymphs after 48 h of exposure to SF at various doses



Mean mortality (% ± SE) of *L. bostrychophila* adults after 48 h of exposure to SF at various doses



Mean mortality (% ± SE) of *L. decolor* adults and eggs after 48 h of exposure to SF at various doses

Dose to 100% kill of psocids after 48 h of exposure to SF

Dose (g/m^3)	Egg	Nymph	Adult
Lepinotus reticulatus	24	4	8
Liposcelis bostrychophila	-	-	6
Liposcelis decolor	72	-	24
Liposcelis entomophila	-	6	4
Liposcelis paeta	96	6	6

SF for Psocid Control

- SF was effective for control of all psocid species tested
- Despite variations in susceptibility, there was complete mortality of nymphs and adults of the species tested between 4 and 24 g/m3
- Eggs were much more tolerant than adults or nymphs; complete mortality occurred between 24 and 96 g/m3
- SF looks like a useful tool for control of psocids

Control Technologies: Heat

Heat is used to disinfest some flour mills, so we wanted to determine susceptibility of psocids to heat

We determined how long it takes to kill adult psocids at different temperatures

95% FL (hours) at:	Temperature (°C)	*Lepinotus reticulatus*	*Liposcelis entomophila*
LT_{95}	37.5	90.92 (93.00-102.35)	111.43 (100.19-126.88)
	40.0	13.83 (12.59-15.56)	43.52 (39.90-48.23)
	42.5	3.84 (3.50-4.36)	9.06 (6.96-15.68)
	45.0	0.70 (0.67-0.74)	5.51 (5.16-5.95)
	47.5	0.66 (0.63-0.70)	1.89 (1.81-1.99)

Psocids appear to be very susceptible to heat

Control Technologies: Insecticides

Surface Insecticides

We looked at efficacy of surface insecticides for control of psocids

These insecticides are used to treat surfaces and cracks and crevices at flour mills and other food facilities

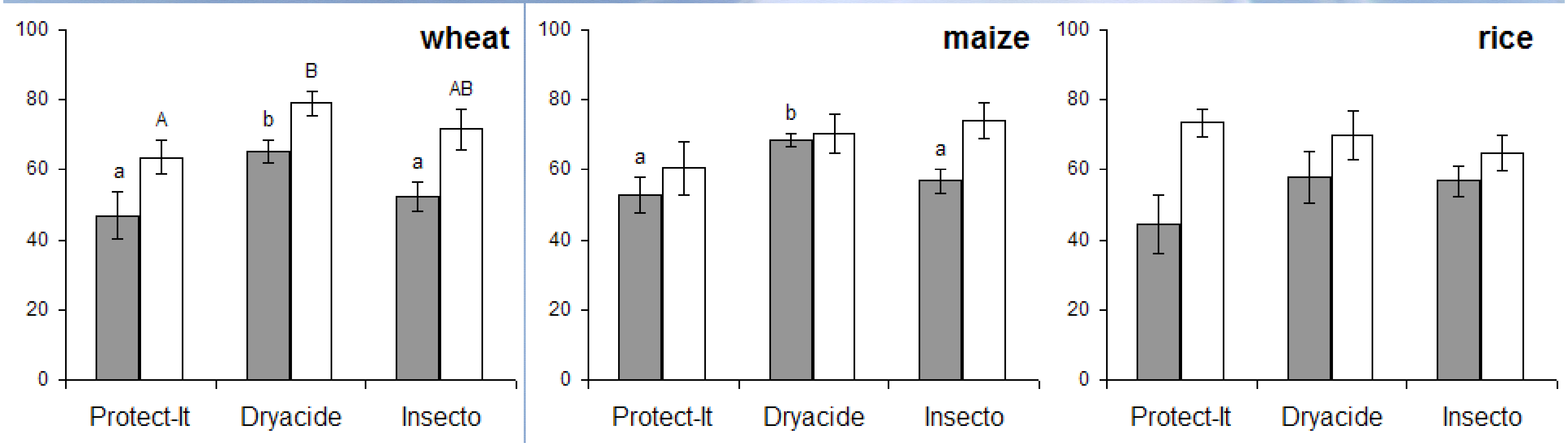
Chlorfenapyr and β-cyfluthrin provided efficient control of *Liposcelis bostrychophila* and *L. entomophila* at the label rates, unlike pyrethrin

Insecticide	*Liposcelis* species	LT_{95} (95% FL) [hours]
β-Cyfluthrin	*entomophila*	12.5 (11.7-13.6)
	bostrychophila	15.3 (14.6-16.2)
Chlorfenapyr	*entomophila*	5.1 (4.9-5.4)
	bostrychophila	7.7 (6.9-9.1)
Pyrethrin	*entomophila*	102.1 (94.6-112.5)
	bostrychophila	195.8 (158.3-280.1)

Chlorfenapyr is derived from a class of microbially-produced compounds known as halogenated pyrroles; β-Cyfluthrin is a synthetic pyrethroid

Diatomaceous earth (DE) for psocid control

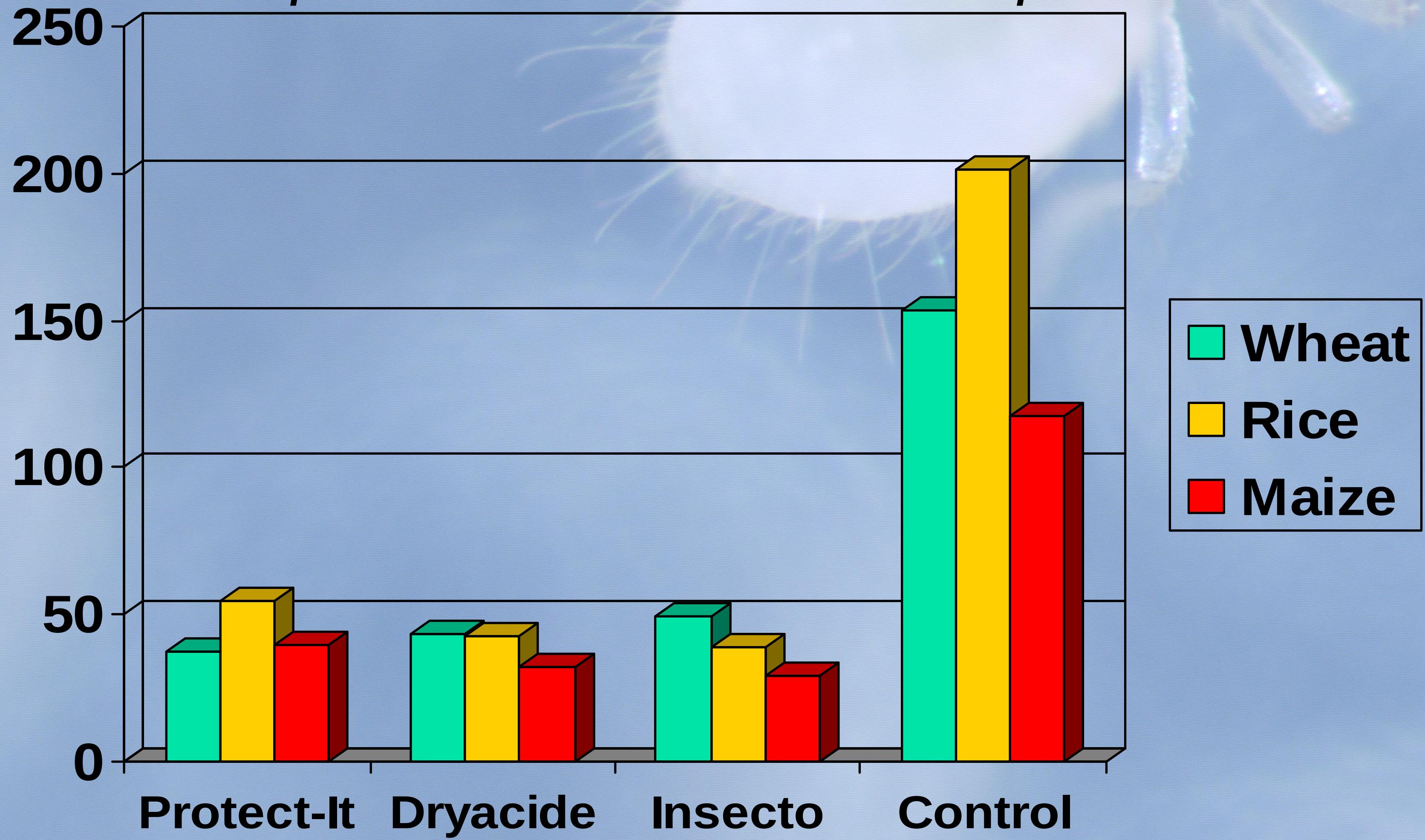
Mean % mortality of *Liposcelis entomophila* adults after 7 and 14 days exposure to three DE's was 45-80%



Mean % mortality of *Lepinotus reticulatus* adults after 7 and 14 days exposure to three DE's was 30-93%

Mean % mortality of *Liposcelis decolor* adults after 7 and 14 days exposure to three DE's was 30-47%

Number of progeny produced by ten *Liposcelis entomophila* females after 30 days exposure to three DE's was about 25% of that in controls; results were similar for *Leptinotus reticulatus* and *Liposcelis decolor*



Diatomaceous earth (DE) for psocid control

- All DE’s resulted in a 75% reduction in population levels of three psocid species in wheat, rice, and corn
- DE’s alone will not be suitable for psocid control in grain
- Psocids were expected to be susceptible to DE’s because they are soft-bodied insects; DE’s work through dessication
- Psocids have an unusal cuticular lipid composition which may help them slough off fungal pathogens and dusts; this may help explain psocid tolerance to DE

Registered grain insecticides

In a study of all insecticides registered in the U.S. for corn, rice, and wheat (except the insect growth regulator methoprene), the organophosphorus insecticides chlorpyriphos-methyl + deltamethrin (Storicide II) and pirimiphos-methyl (Actellic) were the most effective for all psocid species tested. Efficacy of spinosad and pyrethrum was dependent on psocid species and commodity.

All insecticides were tested at their label rates for the three crops.

Mean % mortality of *Lepinotus reticulatus* adults after 7 and 14 d of exposure and mean progeny production after 30 d of exposure in treated and untreated commodities

Commodity	Treatment	Exposure (d)		
		7 (mortality)	14 (mortality)	30 (progeny)
Wheat	chlorpyriphos-methyl + deltamethrin	100.0 ± 0.0a	100.0 ± 0.0a	0.2 ± 0.2a
	spinosad	94.4 ± 4.5a	96.7 ± 2.4a	0.0 ± 0.0a
	pyrethrum	41.1 ± 14.2b	65.7 ± 13.5b	11.6 ± 6.3b
	control	10.0 ± 5.3c	21.1 ± 7.4	60.8 ± 11.7c
Rice	chlorpyriphos-methyl + deltamethrin	100.0 ± 0.0a	100.0 ± 0.0a	1.6 ± 1.0a
	spinosad	80.0 ± 9.4b	71.1 ± 13.0b	3.3 ± 1.0a
	pyrethrum	23.4 ± 6.0c	14.3 ± 8.8c	91.1 ± 13.9b
	control	6.8 ± 2.4d	15.5 ± 4.1c	115.6 ± 13.5b
Maize	pirimiphos-methyl	100.0 ± 0.0a	100.0 ± 0.0a	0.0 ± 0.0a
	spinosad	94.5 ± 3.8a	100.0 ± 0.0a	0.1 ± 0.1a
	pyrethrum	57.8 ± 11.2b	86.7 ± 5.8b	0.2 ± 0.2a
	control	34.4 ± 11.4b	61.1 ± 11.9c	29.7 ± 8.3b

Mean % mortality of *Liposcelis entomophila* adults after 7 and 14 d of exposure and mean progeny production after 30 d of exposure in treated and untreated commodities

Commodity	Treatment	Exposure (d)		
		7 (mortality)	14 (mortality)	30 (progeny)
Wheat	chlorpyriphos-methyl + deltamethrin	100.0 ± 0.0a	100.0 ± 0.0a	0.2 ± 0.1a
	spinosad	61.2 ± 14.0b	84.4 ± 7.8b	7.7 ± 5.9ab
	pyrethrum	47.8 ± 13.1b	55.6 ± 11.8c	26.4 ± 9.0b
	control	5.6 ± 2.9c	13.3 ± 4.7d	84.0 ± 21.5c
Rice	chlorpyriphos-methyl + deltamethrin	95.6 ± 4.4a	100.0 ± 0.0a	0.0 ± 0.0a
	spinosad	52.2 ± 10.2b	52.3 ± 4.6b	6.1 ± 1.9b
	pyrethrum	8.9 ± 3.5c	16.7 ± 5.8c	82.1 ± 17.6c
	control	3.3 ± 2.6c	10.0 ± 4.7c	81.9 ± 9.5c
Maize	pirimiphos-methyl	100.0 ± 0.0a	100.0 ± 0.0a	0.0 ± 0.0a
	spinosad	90.0 ± 4.4b	98.9 ± 1.1a	0.3 ± 0.2a
	pyrethrum	17.8 ± 7.6c	60.0 ± 12.5b	8.5 ± 1.6b
	control	15.6 ± 6.9c	14.4 ± 4.1c	65.5 ± 14.1c

Mean % mortality of *Liposcelis bostrychophila* adults after 7 and 14 d of exposure and mean progeny production after 30 d of exposure in treated and untreated commodities

Commodity	Treatment	Exposure (d)		
		7 (mortality)	14 (mortality)	30 (progeny)
Wheat	chlorpyriphos-methyl + deltamethrin	97.8 ± 1.4a	98.9 ± 1.1a	0.7 ± 0.6a
	spinosad	74.5 ± 13.5b	75.6 ± 10.2b	42.3 ± 18.0b
	pyrethrum	17.8 ± 5.9c	30.0 ± 11.1c	52.0 ± 21.0b
	control	3.3 ± 1.7d	6.8 ± 3.3d	161.8 ± 21.1c
Rice	chlorpyriphos-methyl + deltamethrin	93.3 ± 6.7a	100.0 ± 0.0a	0.3 ± 0.3a
	spinosad	48.9 ± 11.6b	45.7 ± 10.1b	106.9 ± 14.3b
	pyrethrum	23.3 ± 9.7bc	26.5 ± 9.6bc	134.5 ± 19.3b
	control	8.9 ± 4.5c	9.7 ± 2.4c	298.5 ± 49.0c
Maize	pirimiphos-methyl	100.0 ± 0.0a	100.0 ± 0.0a	0.0 ± 0.0a
	spinosad	71.1 ± 12.6b	76.4 ± 7.7b	10.9 ± 6.8b
	pyrethrum	18.9 ± 5.1c	23.3 ± 7.8c	1.9 ± 0.4ab
	control	8.9 ± 2.6c	13.5 ± 5.3c	82.7 ± 16.0c

Mean % mortality of *Liposcelis paeta* adults after 7 and 14 d of exposure and mean progeny production after 30 d of exposure in treated and untreated commodities

Commodity	Treatment	Exposure (d)		
		7 (mortality)	14 (mortality)	30 (progeny)
Wheat	chlorpyriphos-methyl + deltamethrin	100.0 ± 0.0a	100.0 ± 0.0a	0.2 ± 0.1a
	spinosad	46.7 ± 7.7b	55.6 ± 11.5b	40.1 ± 12.2b
	pyrethrum	14.5 ± 6.3c	14.4 ± 4.7c	11.6 ± 2.1c
	control	7.8 ± 3.2c	5.6 ± 1.8c	93.1 ± 15.2d
Rice	chlorpyriphos-methyl + deltamethrin	98.9 ± 1.1a	100.0 ± 0.0a	0.8 ± 0.6a
	spinosad	10.0 ± 3.7b	18.8 ± 6.4b	35.0 ± 4.4b
	pyrethrum	15.7 ± 7.9b	31.1 ± 12.5b	41.3 ± 7.2b
	control	3.3 ± 1.7b	3.4 ± 1.6c	93.7 ± 12.9c
Maize	pirimiphos-methyl	97.8 ± 1.5a	100.0 ± 0.0a	0.0 ± 0.0a
	spinosad	16.7 ± 3.8b	37.8 ± 11.4bc	8.2 ± 1.8bc
	pyrethrum	10.0 ± 3.3b	18.9 ± 5.9cd	2.7 ± 1.8ab
	control	13.3 ± 3.3b	14.1 ± 4.1d	18.1 ± 6.4c

Other insecticide studies

The insect growth regulator methoprene was only partially effective for control of psocids.

Numbers of *Liposcelis bostrychophila* adults, but not nymphs, were reduced 40 days after the introduction of 10 females on methoprene-treated grain

Stage	Dose (ppm)	Wheat	Rice	Maize
Adult	0	102.6 ± 18.0a	75.8 ± 13.0a	48.2 ± 14.6a
	1	6.3 ± 1.4Ab	66.7 ± 15.3Ba	4.2 ± 0.9Ab
	5	4.2 ± 0.7b	5.8 ± 1.4b	3.1 ± 0.8b
	10	4.5 ± 0.5b	5.8 ± 0.9b	2.8 ± 0.7b
Nymph	0	48.0 ± 11.4A	21.6 ± 5.8B	9.0 ± 1.7B
	1	39.1 ± 13.9	18.2 ± 5.5	10.0 ± 2.4
	5	34.9 ± 6.7A	26.7 ± 6.7A	5.8 ± 1.7B
	10	38.2 ± 7.7A	26.3 ± 3.6A	3.5 ± 1.4B

Numbers of *Liposcelis entomophila* adults, but not nymphs (except on maize), were reduced 40 days after the introduction of 10 females on methoprene-treated grain

Stage	Dose (ppm)	Wheat	Rice	Maize
Adults	0	155.3 ± 10.8Aa	132.1 ± 10.0Aa	66.9 ± 14.6Ba
	1	40.0 ± 15.8Ab	97.0 ± 15.4Ba	17.8 ± 9.6Ab
	5	8.3 ± 0.8Ac	15.2 ± 2.7Bb	6.1 ± 0.6Ab
	10	7.5 ± 1.1c	8.8 ± 0.5b	7.2 ± 0.5b
Nymphs	0	65.6 ± 10.3A	42.0 ± 5.9AB	21.8 ± 5.1Bab
	1	80.0 ± 8.6A	44.1 ± 4.8B	26.7 ± 3.2Ba
	5	75.8 ± 8.2A	52.8 ± 6.6B	10.4 ± 4.0Cb
	10	61.8 ± 11.8A	58.8 ± 5.7A	9.8 ± 3.9Bb

Numbers of *Lepinotus reticulatus* adults, but not nymphs, were reduced 40 days after the introduction of 10 females on methoprene-treated grain

Stage	Dose (ppm)	Wheat	Rice	Maize
Adults	0	151.2 ± 7.2Aa	87.8 ± 15.4Ba	45.1 ± 5.7Ca
	1	14.7 ± 5.0Ab	93.1 ± 11.5Ba	12.3 ± 5.5Ab
	5	6.9 ± 1.8b	11.0 ± 1.8b	5.8 ± 0.9b
	10	6.1 ± 0.8b	6.0 ± 1.3b	6.1 ± 1.2b
Nymphs	0	55.8 ± 7.0A	28.8 ± 4.6Ba	16.7 ± 2.8Bab
	1	50.8 ± 9.5A	43.5 ± 3.8Aab	27.0 ± 4.7Ba
	5	56.3 ± 8.3A	51.3 ± 5.2Ab	18.2 ± 6.6Bab
	10	44.3 ± 6.0A	35.7 ± 5.3Aab	7.8 ± 2.5Bb

Numbers of *Liposcelis paeta* adults, but not nymphs (except on rice), were reduced 40 days after the introduction of 10 females on methoprene-treated grain

Stage	Dose (ppm)	Wheat	Rice	Maize
Adults	0	53.7 ± 7.1Aa	41.9 ± 4.7Aa	19.7 ± 3.1Ba
	1	8.6 ± 0.9Ab	26.3 ± 3.2Bb	6.0 ± 0.9Ab
	5	7.4 ± 0.8b	6.0 ± 1.3c	6.9 ± 0.9b
	10	7.9 ± 1.4Ab	7.1 ± 0.9Ac	3.6 ± 0.9Bb
Nymphs	0	35.9 ± 5.3A	39.4 ± 3.4Aa	14.8 ± 2.8B
	1	40.8 ± 5.9A	46.4 ± 3.7Aa	11.6 ± 2.8B
	5	29.4 ± 4.0A	24.4 ± 4.2Ab	11.9 ± 2.2B
	10	36.6 ± 8.1A	17.7 ± 2.5Bb	5.2 ± 0.7C

Numbers of *Liposcelis decolor* adults and nymphs were reduced 40 days after the introduction of 10 females on methoprene-treated grain

Stage	Dose (ppm)	Wheat	Rice	Maize
Adults	0	67.1 ± 4.8Aa	27.8 ± 4.6Ba	12.9 ± 3.3Ba
	1	15.2 ± 4.2Ab	19.4 ± 6.1Aa	3.1 ± 0.7Bb
	5	3.9 ± 0.8ABb	5.9 ± 0.9Ab	1.0 ± 0.9Bb
	10	3.7 ± 0.8ABb	5.0 ± 0.8Ab	1.4 ± 0.6Bb
Nymphs	0	32.7 ± 4.4Aa	28.3 ± 5.7ABab	14.0 ± 1.2Ba
	1	25.4 ± 3.8Bab	51.6 ± 13.2Aa	8.5 ± 1.8Cb
	5	18.4 ± 3.9Ab	27.6 ± 5.3Aab	3.7 ± 1.3Bb
	10	14.7 ± 2.3Ab	16.7 ± 2.3Ab	5.6 ± 1.0Bb

Effects of esfenvalerate aerosol on adult *Liposcelis bostrychophila*, *L. entomophila*, and *L. decolor*

- Regular aerosol treatments are being used more regularly in flour mills and warehouses as an alternative to fumigation
- Esfenvalerate aerosol treatment had no effect on mortality of any of the psocids, but did kill all beetle species tested

Overall conclusions from psocid studies

- Psocids are unique insects and often respond to control technologies differently than stored-product beetle pests, and different psocid species respond differently to control technologies
- Psocid biology is similar to that of other stored-product insect pests, except for their parthenogenesis (lack of males in some species - *Lepinotus reticulatus and Liposcelis bostrychophila;* North American stored-product pest species with males are *Liposcelis brunnea*, *L. corrodens*, *L. decolor*, *L. entomophila*, and *L. paeta*.)
- Psocids are poorly studied and much remains to be learned about their ecology and control

Collaborators:

- George Opit, formerly GMPRC, currently OSU
- Christos Athanassiou, Agricultural University of Athens, Greece
- Raul Guedes, Federal University of Viçosa, Brazil
- Kun Yan Zhu, Tom Phillips, Mahbub Hasan, and Jamie Aikins, KSU
- Frank Arthur, Paul Flinn, and Jim Campbell, GMPRC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