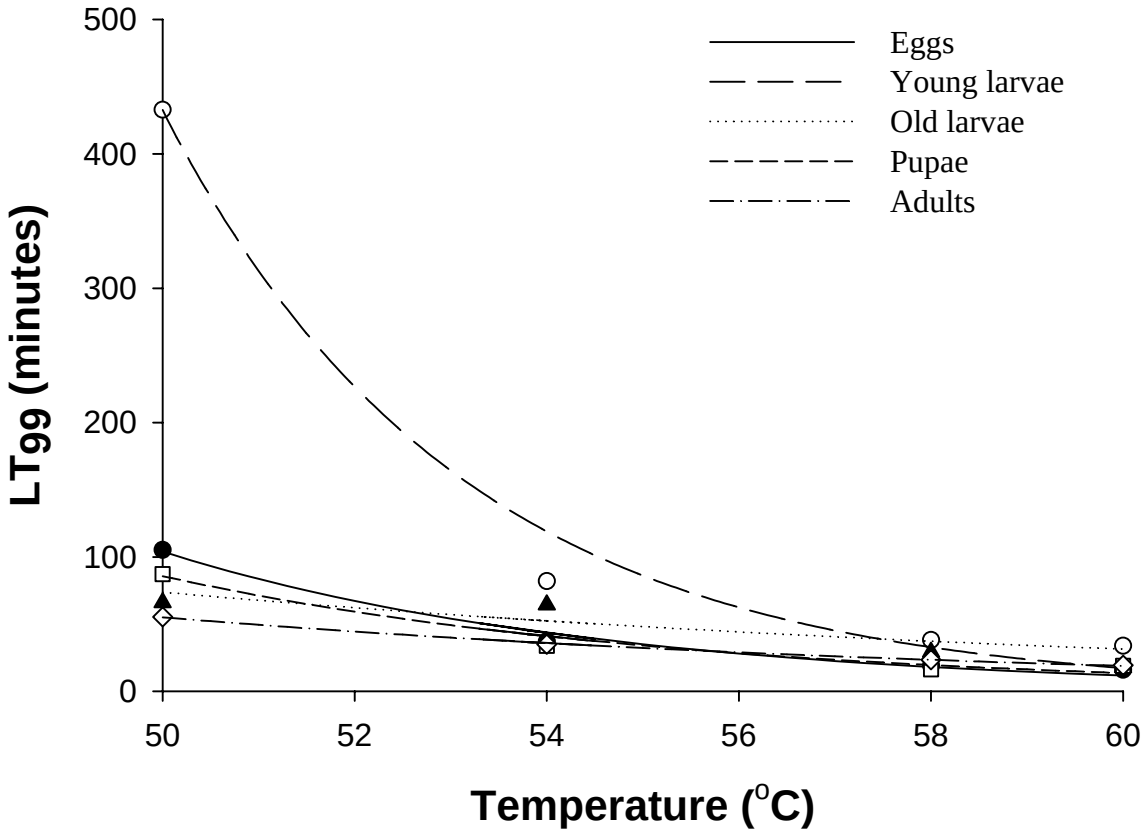
Evaluating Heat Treatment Effectiveness

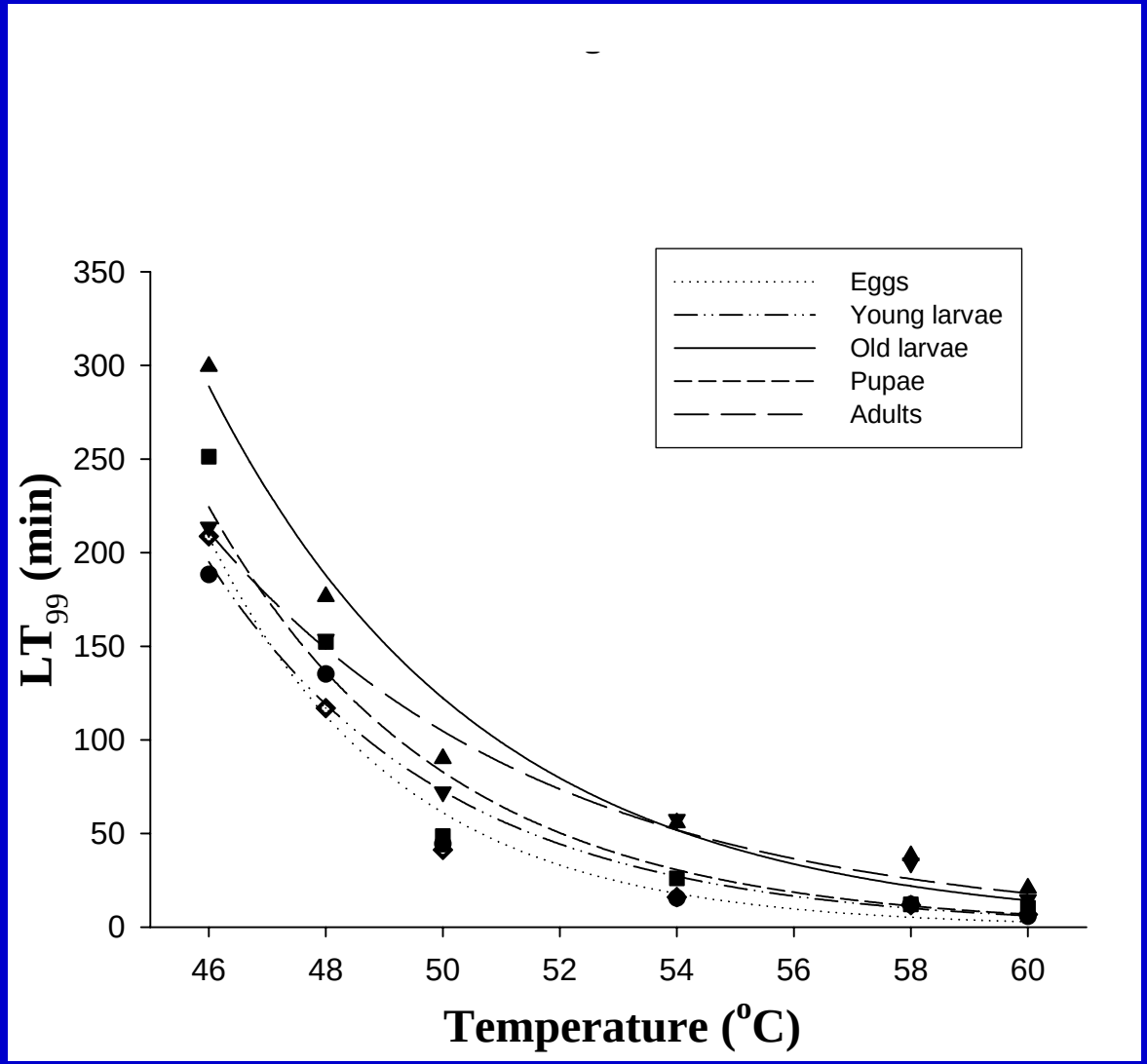
Bh. Subramanyam (Subi)
Department of Grain Science and Industry
Kansas State University
Manhattan, KS 66506
Tel: 785-532-4092
Fax: 785-532-7010
E-mail: bhs@wheat.ksu.edu

May 15, 2004 Heat Treatment Workshop

Insect Species Vary in Their Susceptibility to Heat

- Red flour beetle
- Newly hatched larvae are heat tolerant





- Confused flour beetle
- Old larvae are heat tolerant

Effect of Humidity on Mortality of Red Flour Beetle Adults

(KSU Pilot Flour Mill, Steam Heat Treatment, March 17-20, 2000)

Exposure time (hours)	Temp. range (°C)	Hours to reach 50°C	Hours above 50°C	% RH	% Mortality
24	22.1-42.0	0.0	0.0	71.7	0.0
	22.1-42.0	0.0	0.0	58.6	0.0
	22.1-41.5	0.0	0.0	50.6	0.0
No Glycerol	22.1-41.5	0.0	0.0	30.7	1.7
G. Chamber	27.5-28.3	0.0	0.0	36.2	1.7
47	22.1-51.8	43.0	4.0	70.5	100.0
	22.1-51.8	43.0	4.0	57.5	100.0
	22.1-50.7	44.5	2.5	49.3	100.0
No Glycerol	22.1-51.2	44.0	3.0	26.2	100.0
G. Chamber	27.5-28.7	0.0	0.0	37.1	0.0

Effect of Humidity on Mortality of Red Flour Beetle Adults
(KSU Pilot Flour Mill, Steam Heat Treatment, March 17-20, 2000)

Temperature = 50.1-52.4°C; Growth chamber = 27.5°C

% RH, Range	20 Minutes	30 Minutes	50 Minutes
53.6-63.1	0.0	29.0 b	100.0
46.1-49.3	0.0	93.8 a	100.0
31.6-48.1	0.0	97.5 a	100.0
20.4-20.5 No Glycerol	0.0	95.0 a	100.0
32.4-38.1 Chamber	0.0	0.0 c	0.0

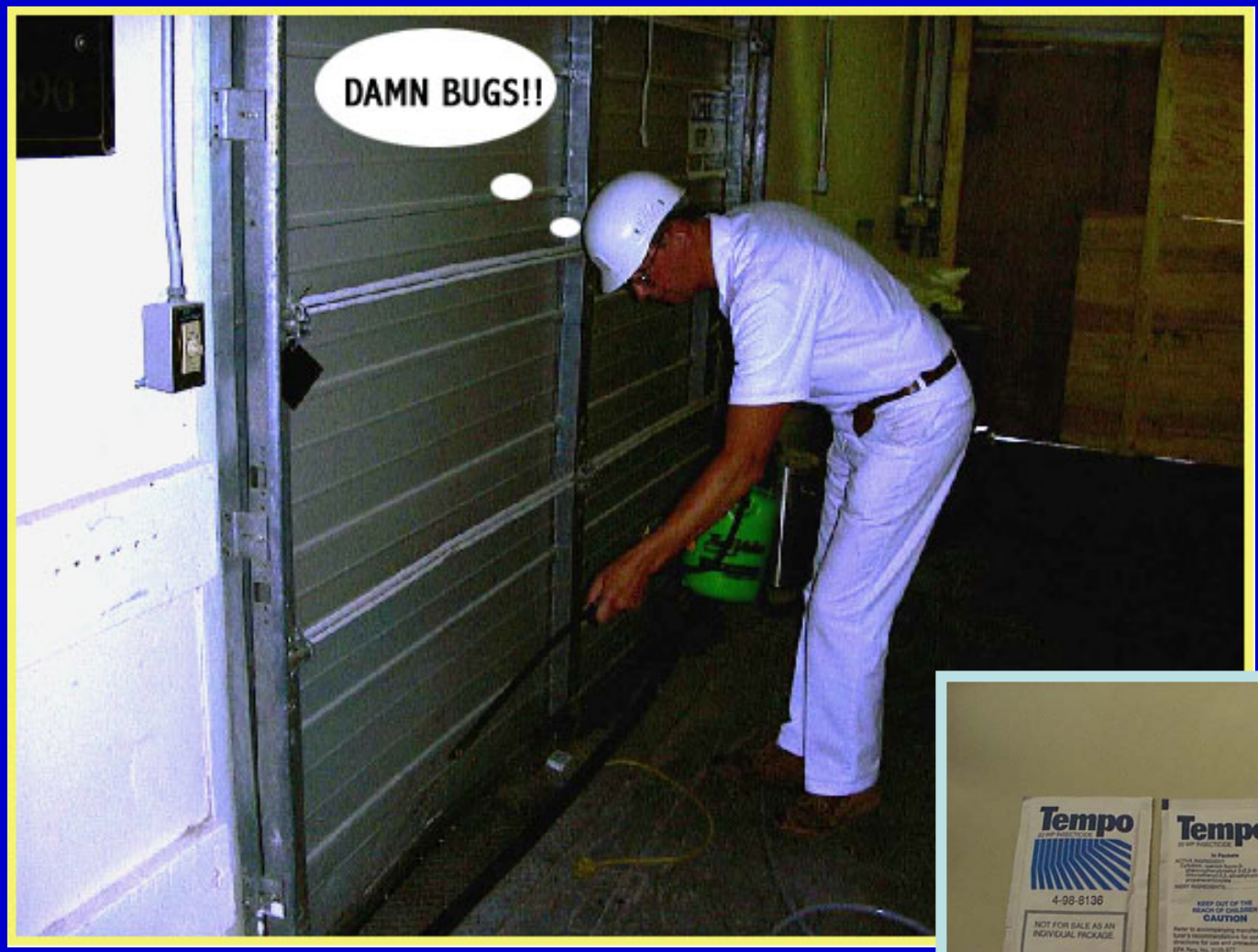
For each time and treatment combination, n = 3.


5th Break
OCRIM
CREMONA

Mortality of Red Flour Beetles Insulated by Whole Wheat Kernels and Flour

(KSU Pilot Flour Mill, Steam Heat Treatment, November 23-28, 1999)

Commodity	Location	Temp. range (°C)	% RH, range	% Mortality
Wheat	Top, 4"	21.7 - 40.1	32.2 - 81.4	9.5
	Middle, 14"	22.9 - 40.1	26.2 - 79.5	40.0
	Bottom, 23"	22.9 - 39.7	26.1 - 80.2	25.0
Flour	Top, 6"	19.4 - 38.8	27.9 - 76.4	4.8
	Middle, 14"	19.4 - 38.9	27.6 - 75.5	0.0
	Bottom, 22"	19.8 - 37.9	28.3 - 70.6	0.0



Apply a residual pesticide such as Tempo or diatomaceous earth

Why is sanitation alone not enough?

- Stored-product insects live for several months
- They can survive on very little food
- 50% of the facility is inaccessible for cleaning
- Insects can seek out cool spots

Remove products and fumigate to reduce risk of reinfestation

Verify that the fumigation was successful

Should equipment be opened or closed?

Open, clean, and then close

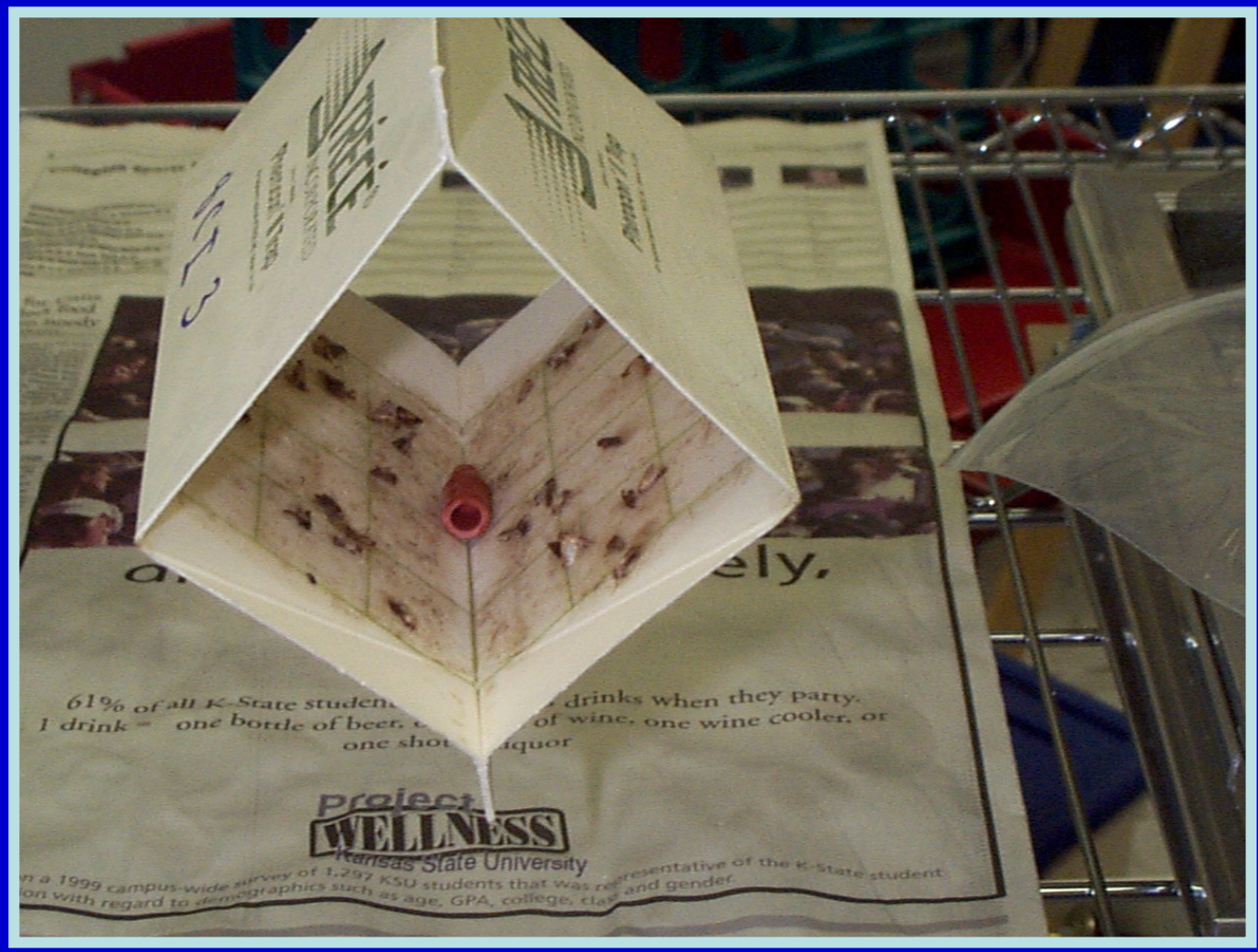
Monitoring Insects

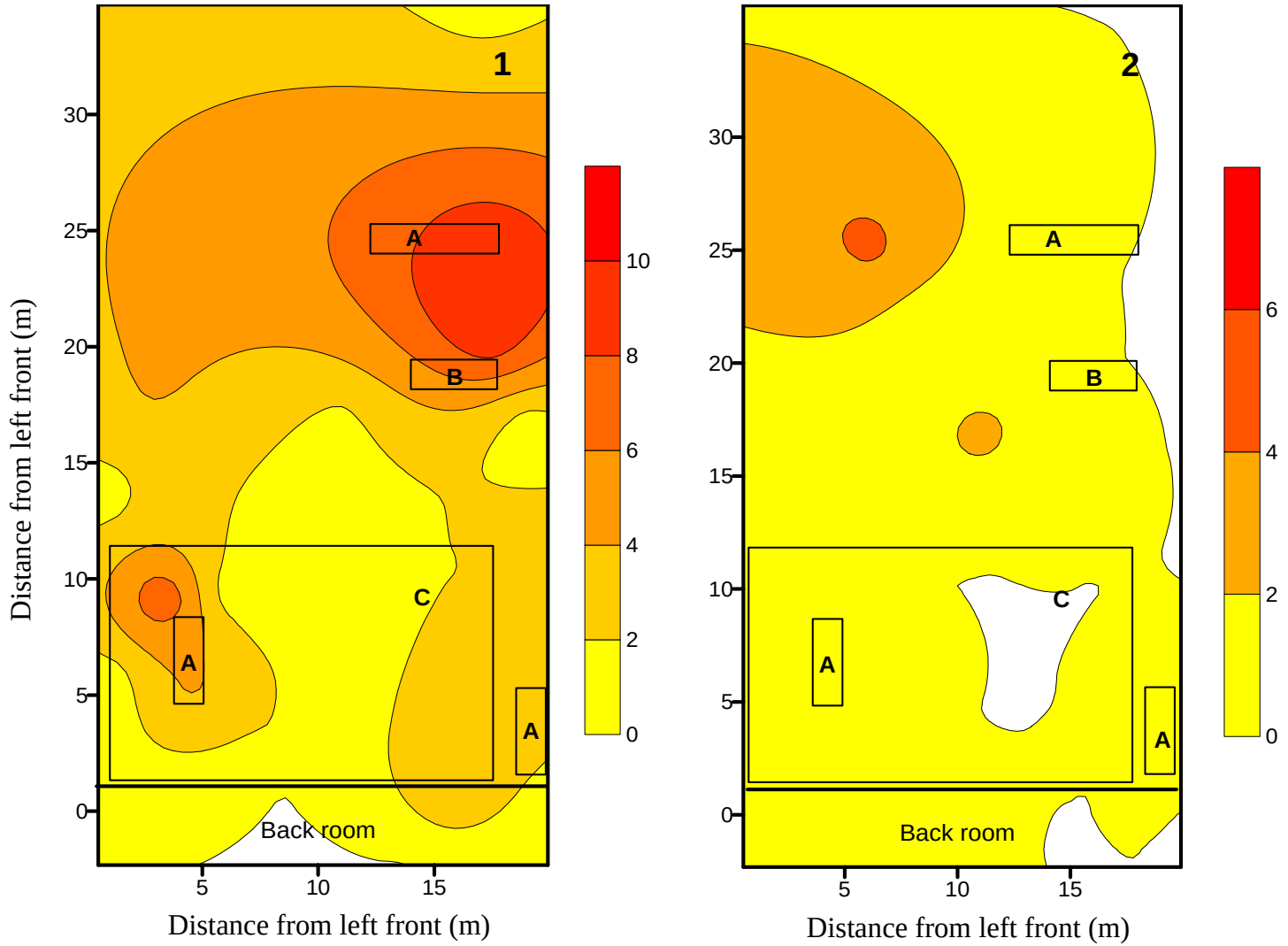
- Before heat treatment, several weeks
- After heat treatment, several weeks
- Identify species of importance
- Degree of suppression
- Duration of suppression
- Use traps or take samples of products before and after heat treatment
- Results vary depending on whether traps or products were used

Monitoring Insects: Traps for Beetles

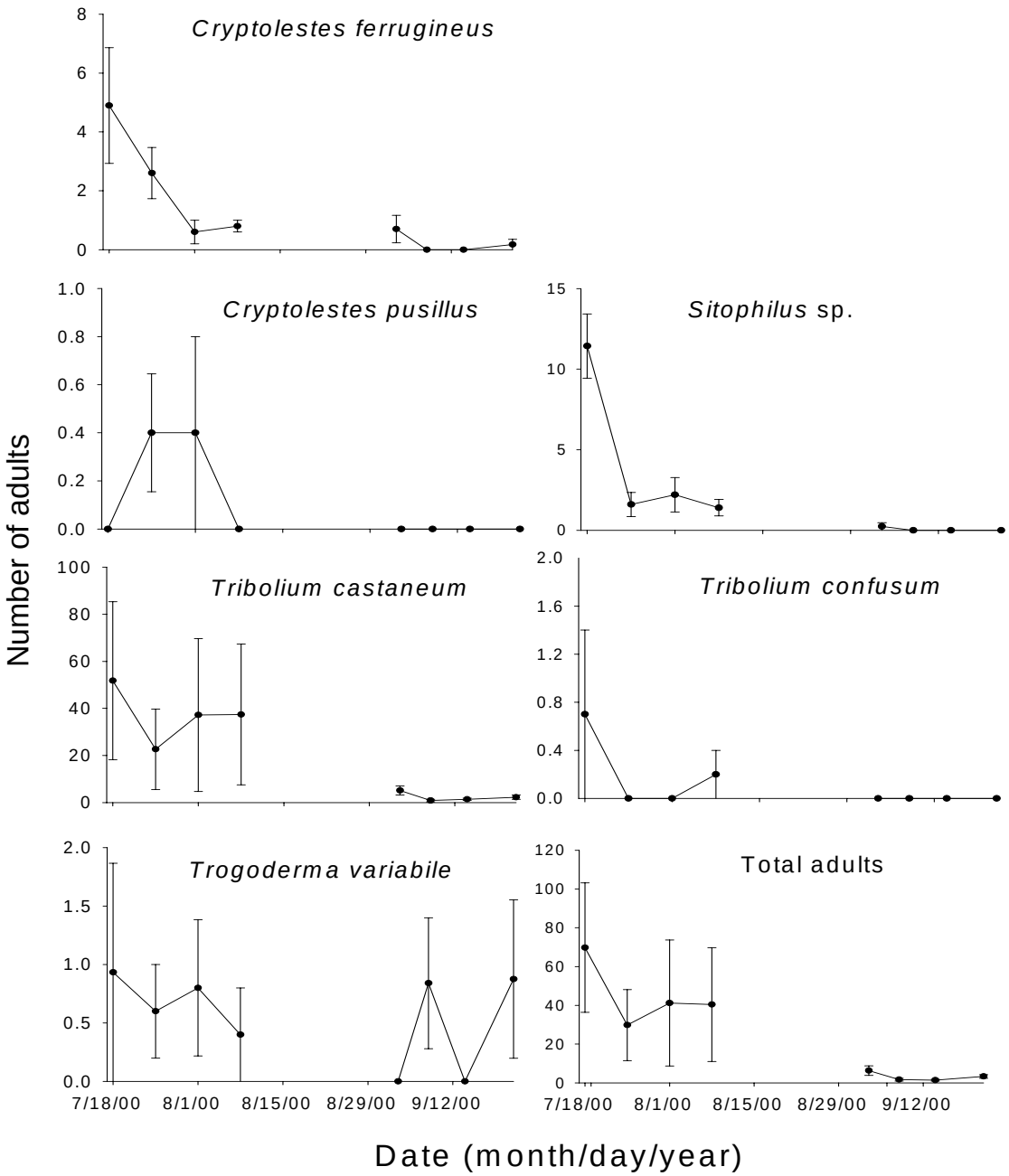
Flit-Trak Traps

Pherocon II traps for moths





A=Wild bird food B=Small animal food C=Cat and dog food

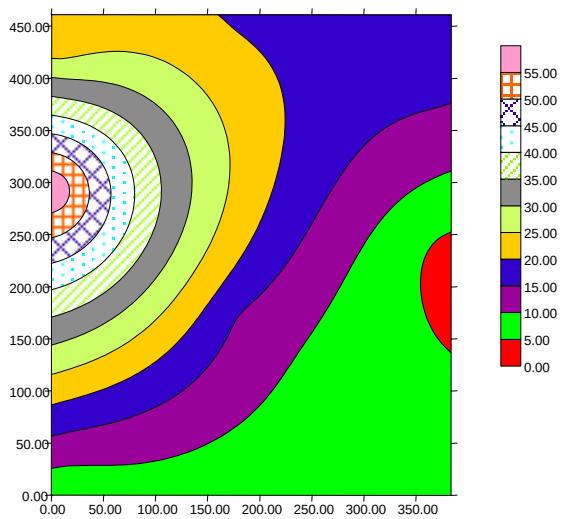


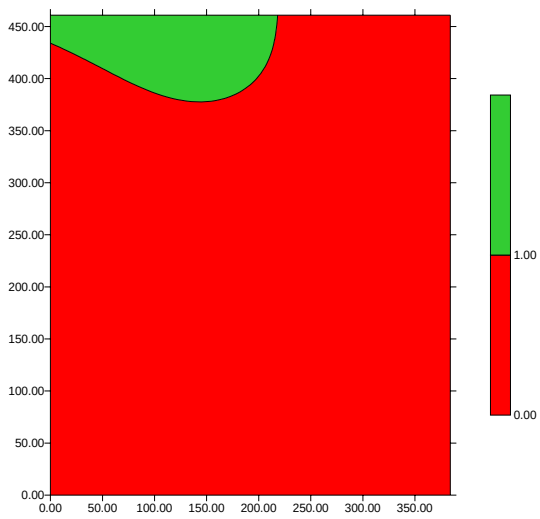
Changes in mean number of insects captured in traps

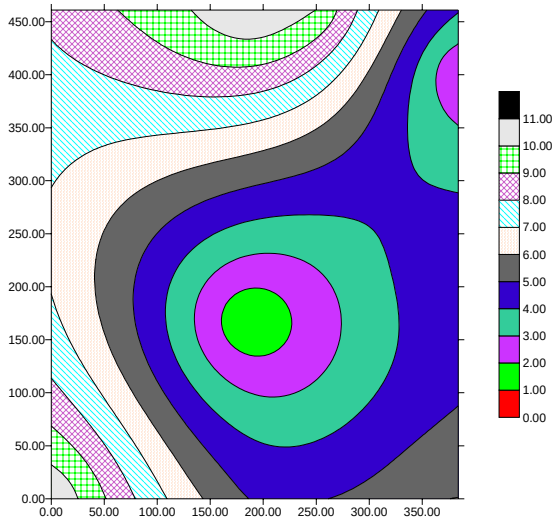
July 21-28, 1999

August 18-27, 1999

November 9-18, 1999





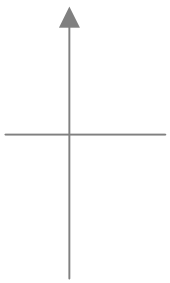


Before heat trt 1

After heat trt 1

Before heat trt 2

N

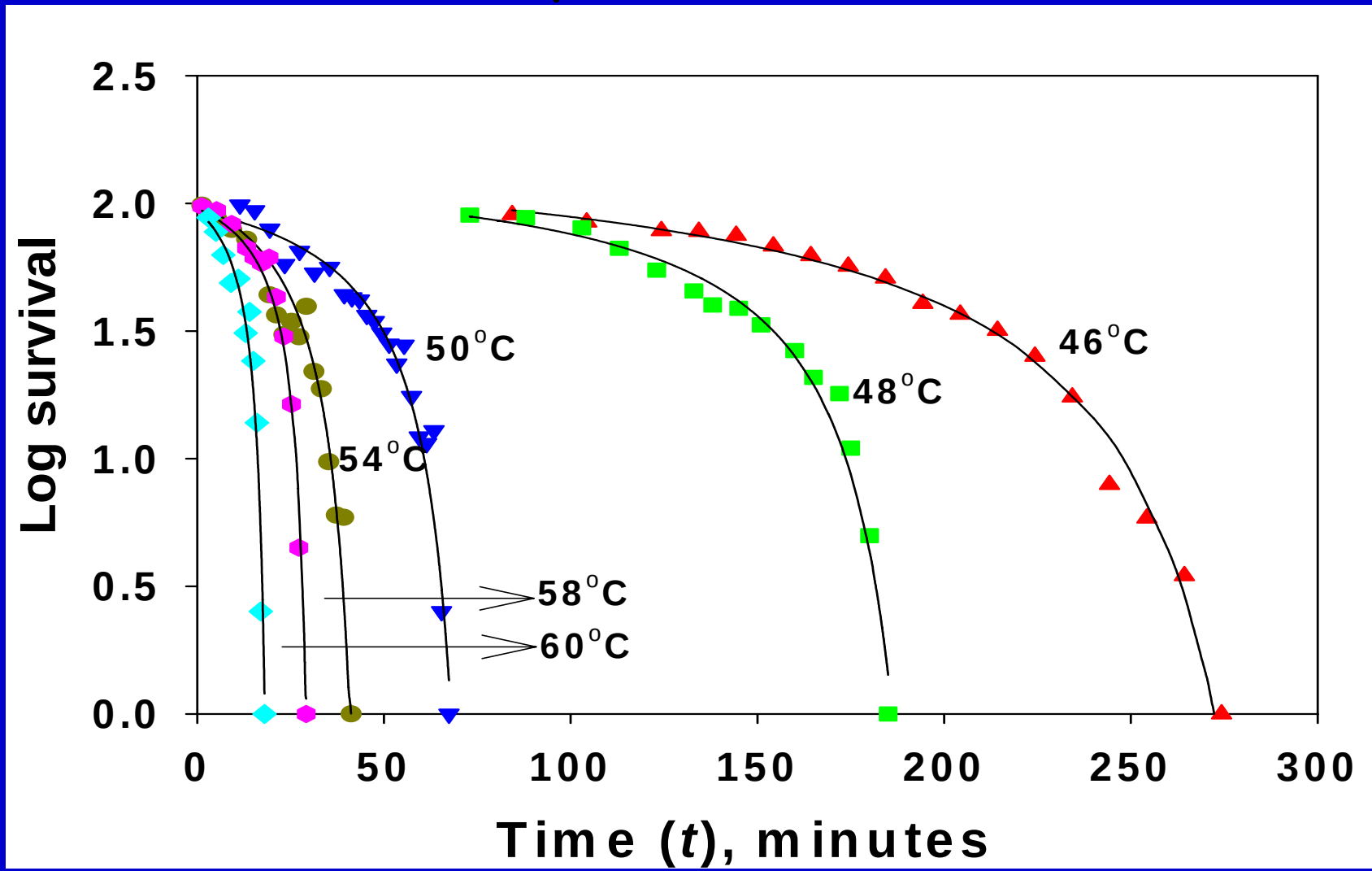


KSU Pilot Flour Mill, mill floor - 1

Predictive Models

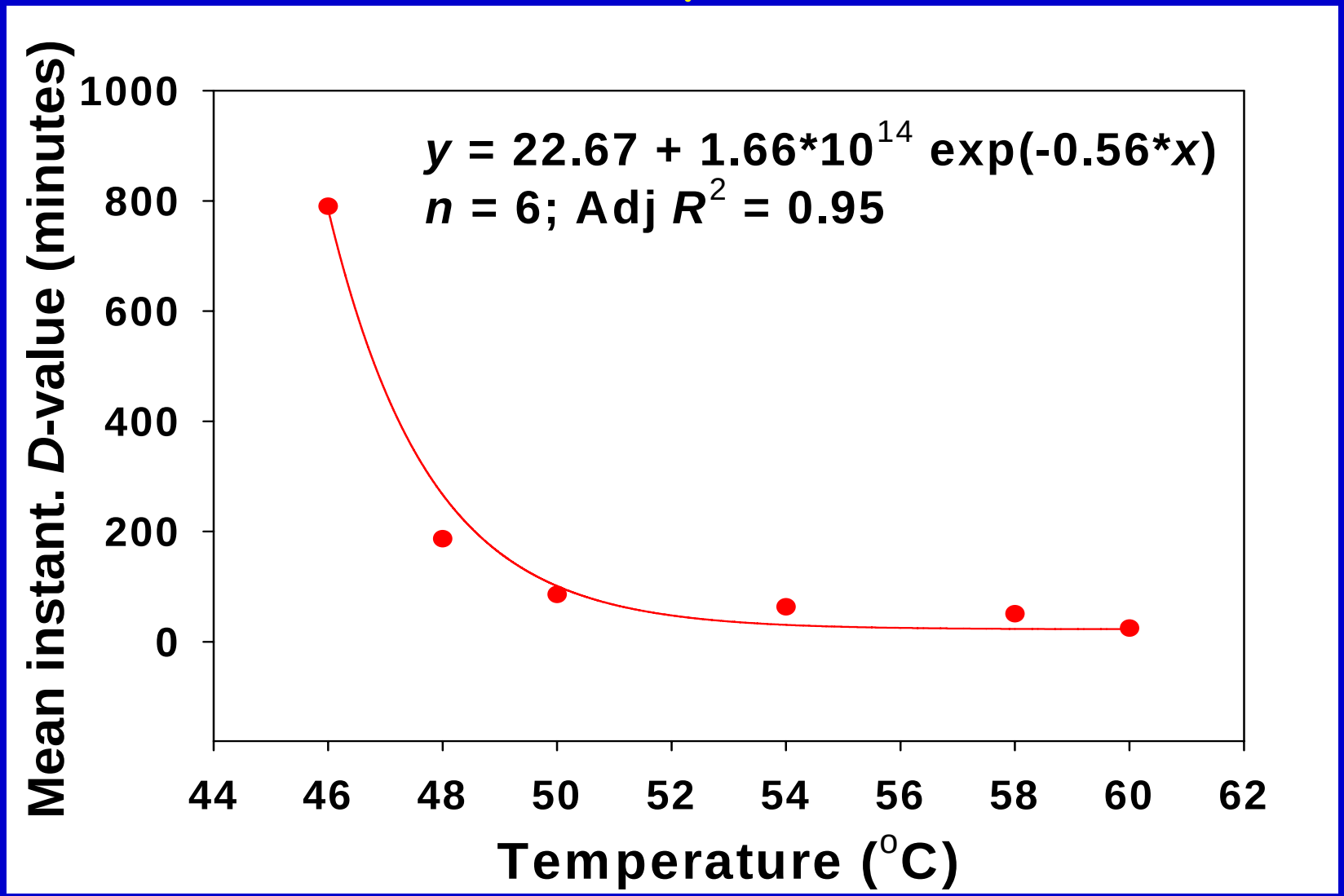
- Need to generate data at constant temperatures in the laboratory
- Uses temperature to determine mortality for any given temperature-time history

Nonlinear Relationship Between Survival of Old Larvae and Exposure Time at 46-60°C



D(*T*) is reciprocal of the negative slope averaged over time

Nonlinear Relationship Between Mean *D*(*T*) and Temperature



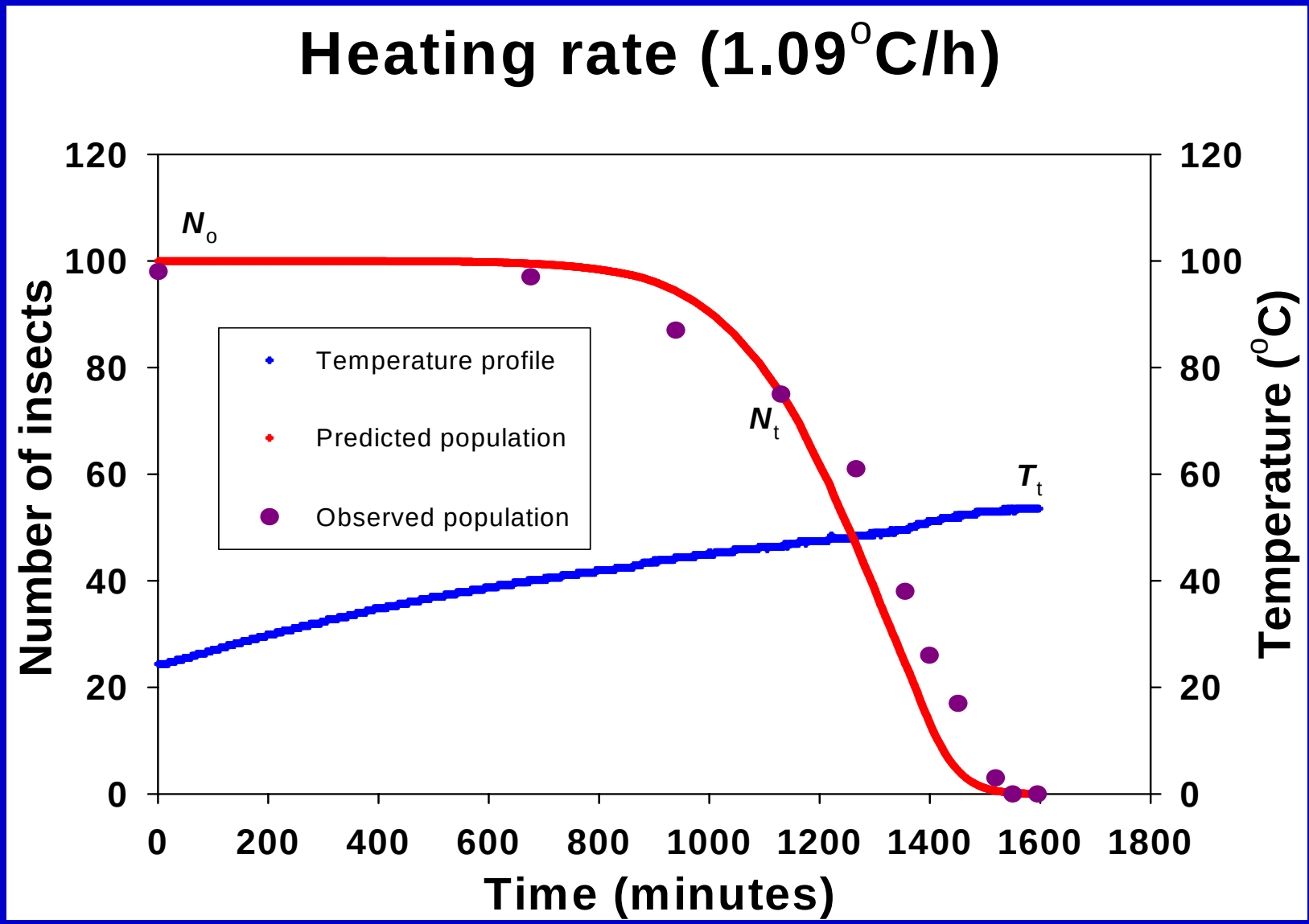
The thermal death kinetic model was derived from the following equation

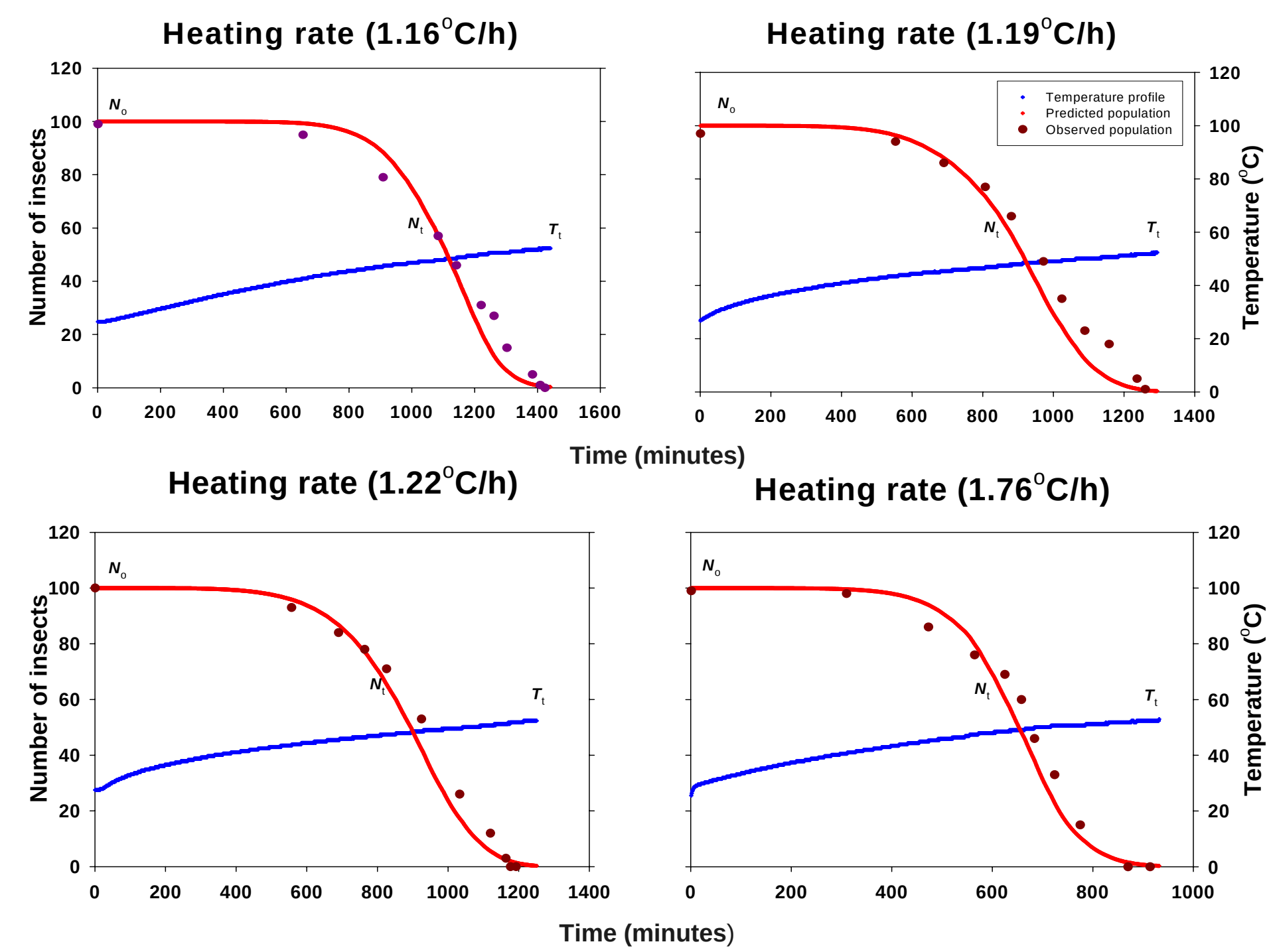
$$\log_{10}\left(\frac{N_{t-dt}}{N_t}\right) = \frac{dt}{D(T_t)}$$

where N_{t-dt} is the survival at t-dt time interval, N_t is survival at time t

$$N_t = \frac{N_0}{\sum_{10}^{t}{}_{0} \frac{\Delta t}{D(T_t)}}$$

where N_t is number of larvae at time t; N_o is the original number of insects, Δt is the incremental exposure time (0.5-min), D is the mean instantaneous D-value as a function of temperature (T), and T_t is time-dependent temperature profile


Heating rate (1.09°C/h)
Number of insects
Temperature (°C)
Time (minutes)
N_o
N_t
T_t
Temperature profile
Predicted population
Observed population
0
20
40
60
80
100
120
0
200
400
600
800
1000
1200
1400
1600
1800


Heating rate (1.16°C/h)
Heating rate (1.19°C/h)
Heating rate (1.22°C/h)
Heating rate (1.76°C/h)
Number of insects
Temperature (°C)
Time (minutes)
Time (minutes)
N_o
N_t
T_t
Temperature profile
Predicted population
Observed population
0
20
40
60
80
100
120
0
200
400
600
800
1000
1200
1400
1600

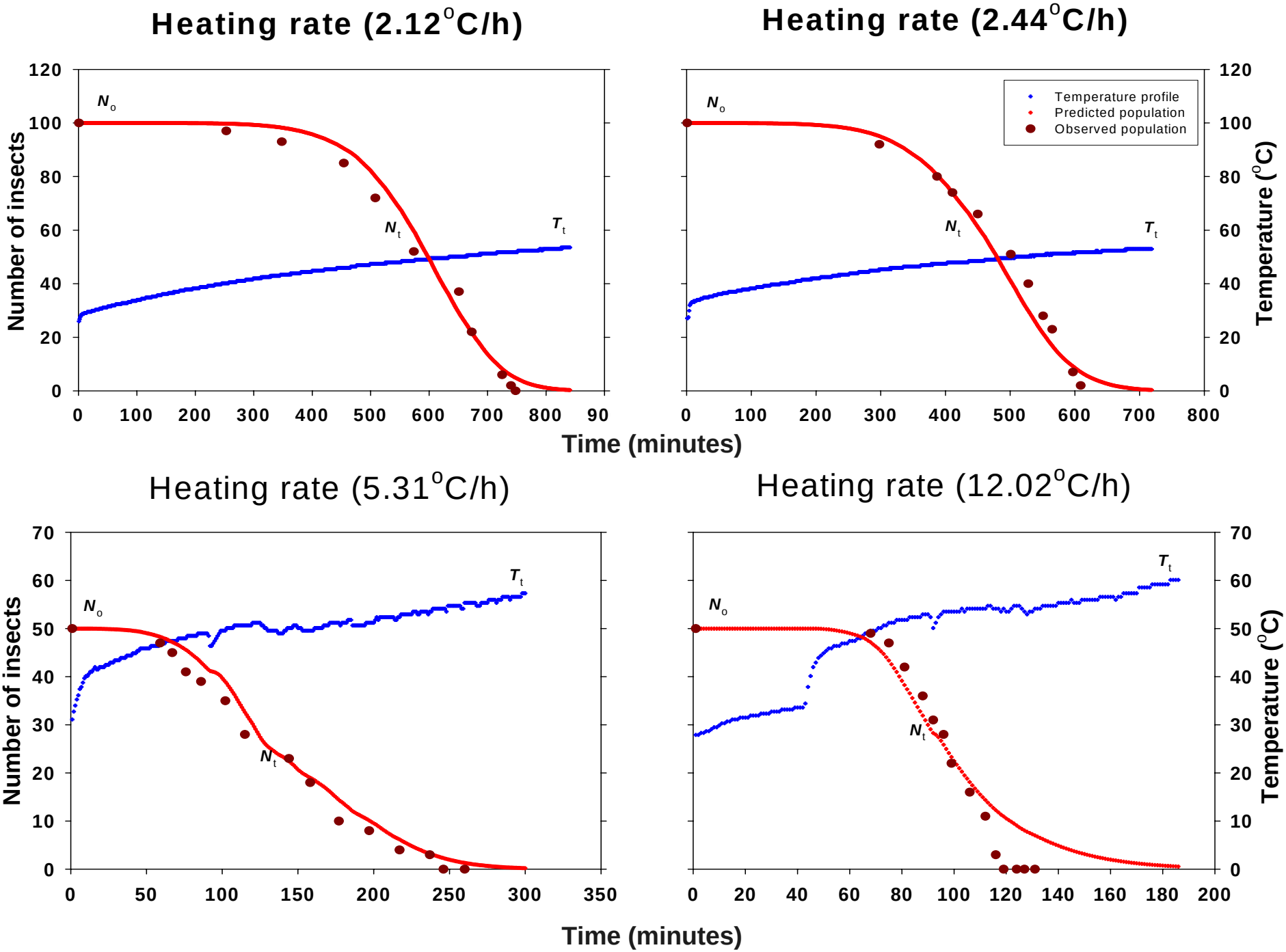

Heating rate (2.12°C/h)
Heating rate (2.44°C/h)
Heating rate (5.31°C/h)
Heating rate (12.02°C/h)
Number of insects
Temperature (°C)
Time (minutes)
Temperature profile
Predicted population
Observed population
N_o
N_t
T_t

Table 3. Model Performance

Heating rate (°C/hr)	Absolute deviation (%) in terms of	
	Larval survival (No. larvae/100 larvae)	Time to equal larval survival (No. min/100 min)
1.09	6.5	4.16
1.16	5.5	3.49
1.19	6.6	3.85
1.22	4.5	2.91
1.76	6.0	3.67
2.12	4.8	4.77
2.44	4.9	2.98
5.31	4.8	5.11
12.02	9.2	16.03

Utility of the model: Predict mortality at different locations during a heat treatment and alter heat treatment for effective insect kill

Conclusions

- Heat treatments are part art, part science
- Use heat tolerant insects of a species to measure effectiveness
- Monitor insects before and after heat treatment
- Use predictive models
- A lot of additional research data are needed!