# Insect Numbers in Traps and Product Samples Before and After Heat Treatment

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# I. Methods to Assess Heat Treatment Effectiveness


A. Test Cages
    1. Known numbers of an economically-damaging stored-product insect
    2. Placed in commonly infested areas, or locations where heat may have difficulty reaching

*Advantages:*

    a. Data is useful and easily interpreted
    b. Bug Chek cages (LSB Product, Manhattan, Kansas) are compact to allow insertion into equipment or small structural spaces.

# Continue test cages

*Disadvantages:*

a. **How many test cages are needed for a thorough assessment of the treatment?**

   Rule of thumb is useful, but each facility is different and requires varying numbers of test cages.

b. **Where should cages be placed?**

   A manager with more experience about his/her facility's "problem areas" would better be able to answer this question. For a manager to acquire this experience, sufficient temperature monitoring of a previous heat treatment would need to be conducted.

# B. Trap Sampling

1. Indirect sampling method
2. Food and pheromone baited traps
3. Assessing food facility fumigations and heat treatments
4. Rennie et. al. (Trap catches of stored-product insects before and after heat treatment in a pilot feed mill) used two-way analysis of variance for trap analysis
5. Hot spots (Surfer, Golden Software)

# Continue trap sampling

*Advantages:*

1. Presence of viable insects
2. Proportion of insects found
3. Assessment of facility treatments
4. Insect hot spots

*Disadvantages:*

1. Surrounding food sources
2. Initial investment in traps, lures, and time
3. Regular costs; lure replacement and monitoring
4. Interpretation

## C. Commodity Sampling

1. Direct sampling method
2. Finished products, ingredients, product streams, and residual patches residing on equipment, floors, and structural surfaces

*Advantages:*

1. More accurate assessment of insect proportions
2. Validates insect hot spots

*Disadvantages:*

1. Time consuming
2. Representative sampling
3. Costly due to damaged packages, and the time required for sampling and processing

# D. Heat Treatment Assessments Using Trap and Product Samples



## Materials and Methods

Trap Sampling

a. June 02' to January 03' at KSU pilot mill
b. 85-dome traps (Trécé), CFB/RFB aggregated pheromone lures, and food oil
c. 85-Pherocon II (Trécé) traps and IMM sex pheromone lures
d. Traps were paired and placed in a grid fashion on each floor
e. Ten trap pairs/floor were used except the flour mill sub-basement, which used five trap pairs
f. Checked weekly and reported as mean number of insects/trap/floor/week

# Continue materials and methods

Commodity Samples

a. Spouts, equipment, floor, and structural surfaces
b. Mean sample sizes of 20.49 grams
c. Samples were weighed, sieved for live adults, and placed in the incubation chamber for six weeks at 32$^{o}$C
d. After incubation, samples were re-sieved
e. Collected as often as traps
f. Reported as the mean number of insects/gram/floor/week

Slope Comparison-*Traps*

1. Weekly red flour beetle (RFB) capture data was partitioned into four segments
2. Segmented: 19-Aug-02, 17-Oct- 02, and 26-Nov-02
   e.g. Segment 1 data is between the start of the experiment (2-Jun-02) and the first heat treatment (19-Aug-02) and segment 2 is between the first and the second heat treatment etc…
3. Mean insects captured for each segment were cumulated
4. A linear model was fit for each segment
5. The x-axis=week and y-axis=mean cumulative insects/trap/floor/week

## Continue Slope Comparison

6. A slope comparison model was used to compare the slopes between the three heat treatments

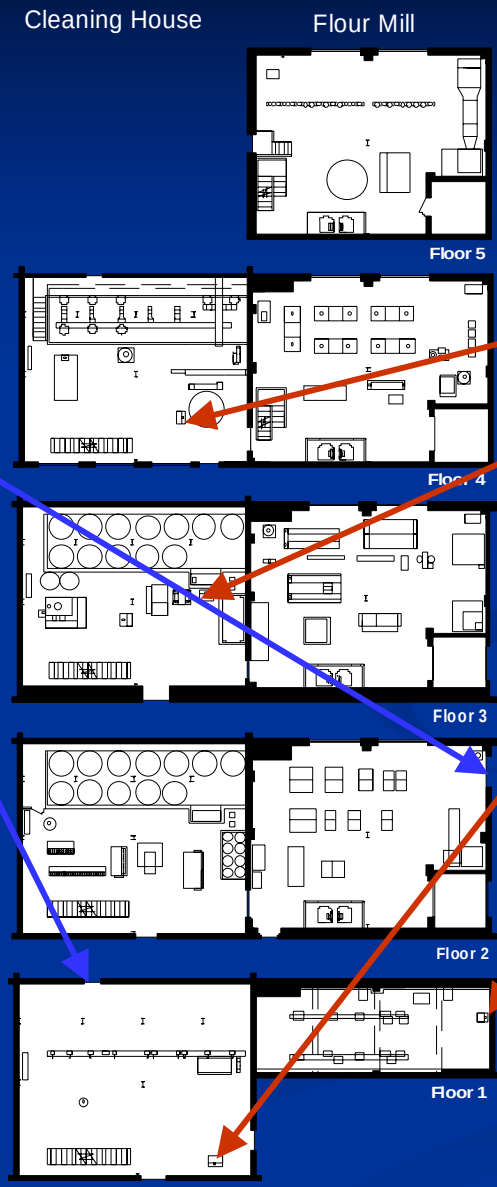
## Analysis of Variance-*Commodity Samples*

1. Transformed data to log scale
2. Two-way analysis of variance (ANOVA)
3. Determined the significant difference in the mean number of insects/gram/floor/week before and after each heat treatment (alpha<0.05)

# Heat Treatments

- 19-Aug-02

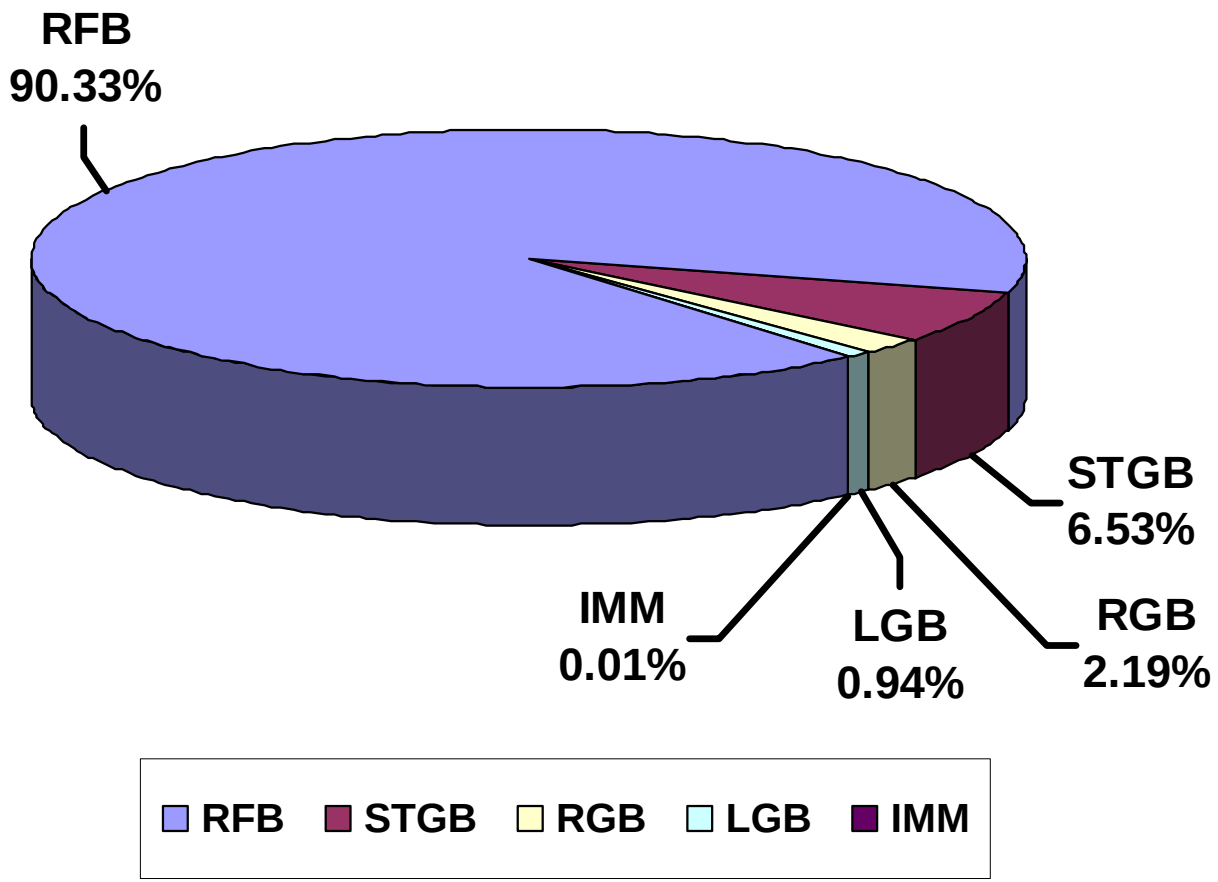
- 19-Aug-02




- 17-Oct-02
- 26-Nov-02

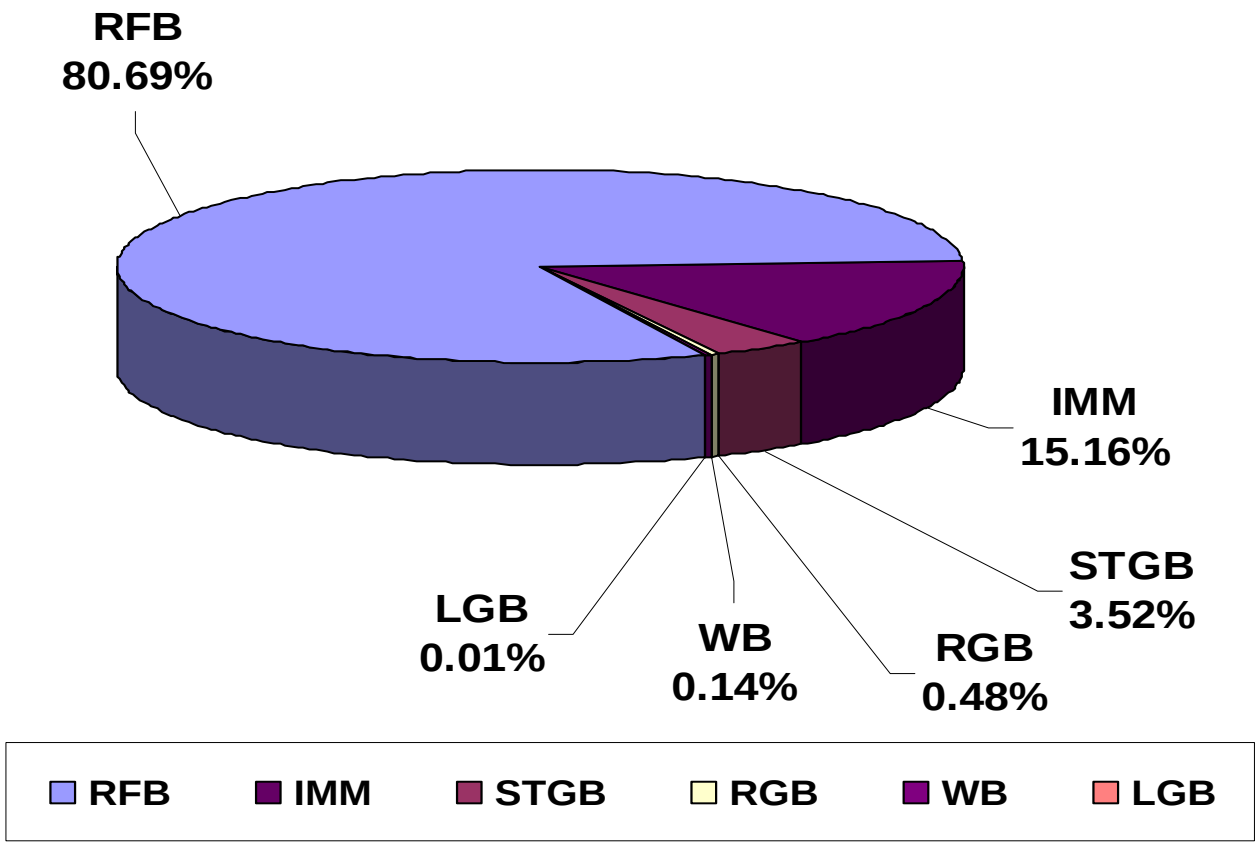
- All floors

## Figure 1: Proportion of Total Insects Captured from Absolute Samples: June 15, 2002 to January 2, 2003




RFB= red flour beetle, STGB= sawtoothed grain beetle, RGB=rusty grain beetle, LGB=lesser grain borer, & IMM= Indianmeal moth

## Figure 2: Proportion of Total Insects Captured from Traps: June 15, 2002 to January 2, 2003.




RFB= red flour beetle, STGB= sawtoothed grain beetle,
RGB=rusty grain beetle, LGB=lesser grain borer,
IMM= Indianmeal moth, & WB= warehouse beetle

# Figure 3: Slope Comparisons Between the Mean Cumulative Trap Captures of Red Flour Beetles (RFB) Before and After the Heat Treatments

| | | | Comparison Results | | | Slopes | | |
|---|---|---|---|---|---|---|---|---|
| Building[a] | Floor | Treatment[b] | T[c] | DF[d] | P[e] | Before | After | % Reduction[f] |
| CH | 1 | 1 | 2.714 | 15 | 0.008 | 12.522 | 8.458 | 32.45 |
| | | 2 | 13.988 | 10 | <0.001 | 8.458 | 3.417 | 59.60 |
| | | 3 | 9.027 | 6 | <0.001 | 3.417 | 0.436 | 87.24 |
| CH | 2 | 1 | 4.970 | 15 | <0.001 | 4.936 | 2.690 | 45.50 |
| | | 2 | 11.504 | 10 | <0.001 | 2.690 | 0.481 | 82.12 |
| | | 3 | 6.783 | 6 | <0.001 | 0.481 | 0.152 | 68.40 |
| CH | 3 | 1 | 6.200 | 15 | <0.001 | 4.057 | 2.651 | 34.66 |
| | | 2 | 5.795 | 10 | <0.001 | 2.651 | 1.289 | 51.38 |
| | | 3 | 3.514 | 6 | <0.006 | 1.289 | 0.229 | 82.23 |
| CH | 4 | 1 | 5.966 | 15 | <0.001 | 4.130 | 2.100 | 49.15 |
| | | 2 | 4.714 | 10 | <0.001 | 2.100 | 1.179 | 43.86 |
| | | 3 | 3.805 | 6 | <0.004 | 1.179 | 0.217 | 81.59 |
| FM | 1 | 1 | 8.006 | 15 | <0.001 | 2.402 | 7.765 | _[h] |
| | | 2 | 12.520 | 10 | <0.001 | 7.765 | 0.734 | 90.55 |
| | | 3[g] | | | | | | |
| FM | 2 | 1 | 14.311 | 15 | <0.001 | 1.650 | 7.453 | _[h] |
| | | 2 | 11.808 | 10 | <0.001 | 7.453 | 0.354 | 95.25 |
| | | 3 | 6.871 | 6 | <0.001 | 0.354 | 0.115 | 67.51 |
| FM | 3 | 1 | 1.657 | 15 | 0.059 | 1.525 | 1.956 | _[h] |
| | | 2 | 16.941 | 10 | <0.001 | 1.956 | 0.536 | 72.60 |
| | | 3[g] | | | | | | |
| FM | 4 | 1 | 0.980 | 15 | 0.171 | 2.886 | 2.534 | 12.20 |
| | | 2 | 5.663 | 10 | <0.001 | 2.534 | 0.220 | 91.32 |
| | | 3 | 2.434 | 6 | <0.025 | 0.220 | 0.031 | 85.91 |
| FM | 5 | 1 | 2.717 | 15 | 0.008 | 2.495 | 1.831 | 26.61 |
| | | 2 | 5.212 | 10 | <0.001 | 1.831 | 0.288 | 84.27 |
| | | 3 | 2.622 | 6 | 0.020 | 0.288 | 0.031 | 89.24 |

[a] CH=cleaning house and FM=flour mill.

[b] The numbers 1, 2, and 3 are related to three heat treatments occurring on 19-Aug-02, 17-Oct-02, 26-Nov-02, respectively.

[c] T=test statistic using the t-distribution.

[d] DF=degrees of freedom.

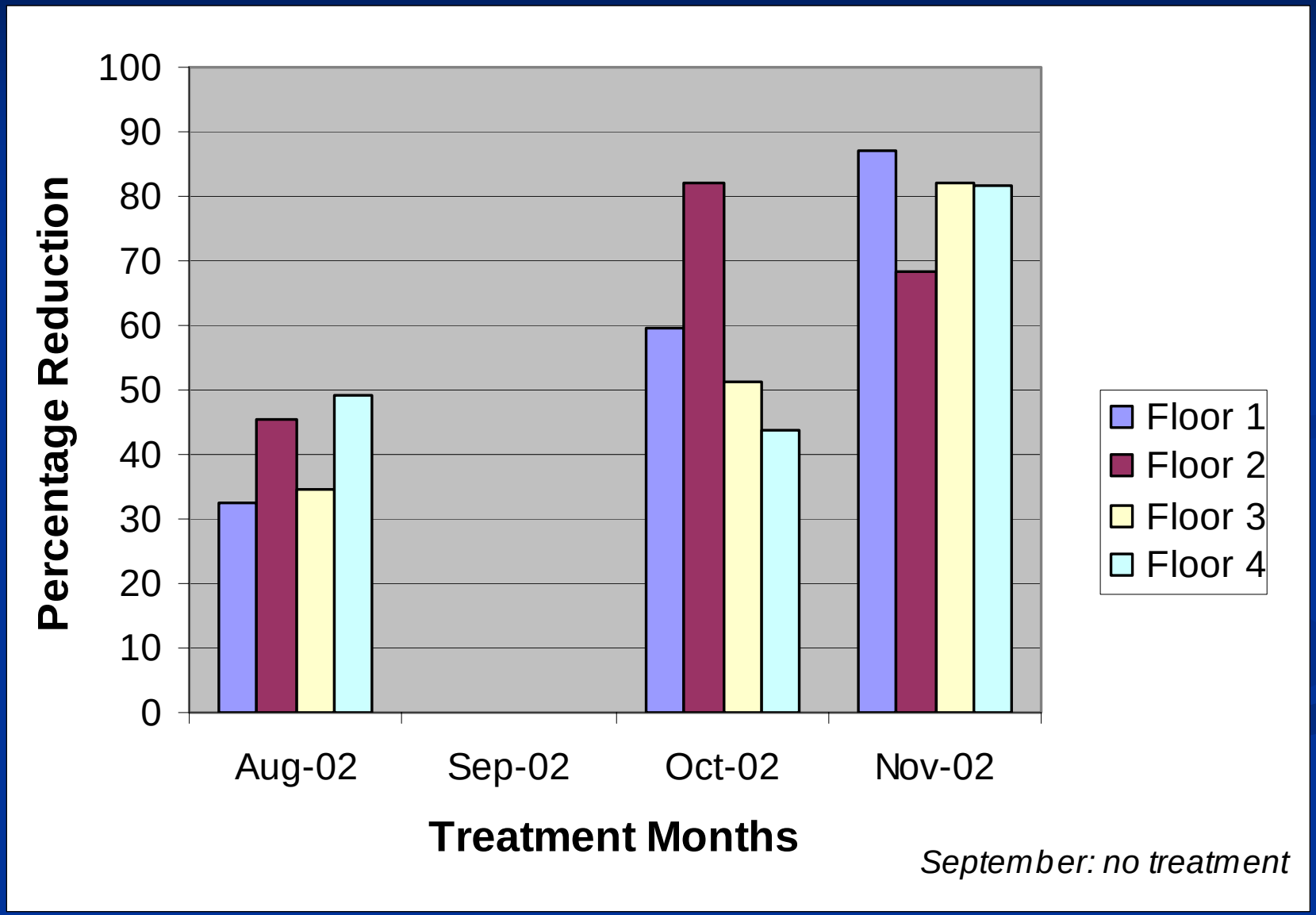
[e] P=p-value.

[f] % reduction=(1-after treatment slope/before treatment slope)*100.

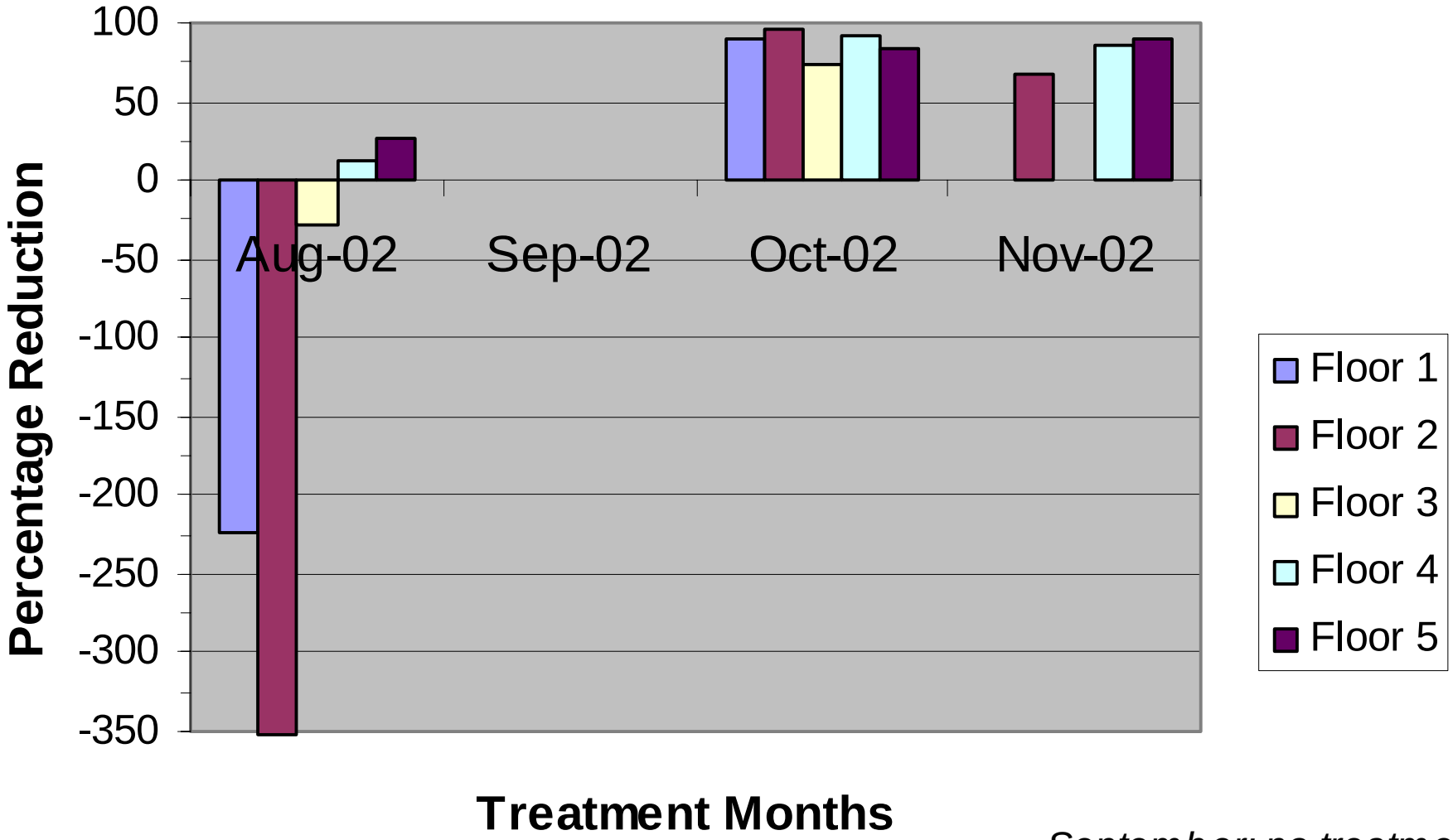
[g] Linear model had a $r^2 < 0.79$

h Increase in insect numbers

# Figure 4: Percentage Reduction in Mean RFB Trap Captures in the Cleaning House for the Three Heat Treatments



# Figure 5: Percentage Reduction in Mean RFB Trap Captures in the Flour Mill for the Three Heat Treatments




*September: no treatment*

# Figure 6: Mean Temperature Profiles Between Floors of the KSU Pilot Mill During Aug. 19-20, Oct. 17-20, and Nov. 26-30, 2002 Heat Treatments

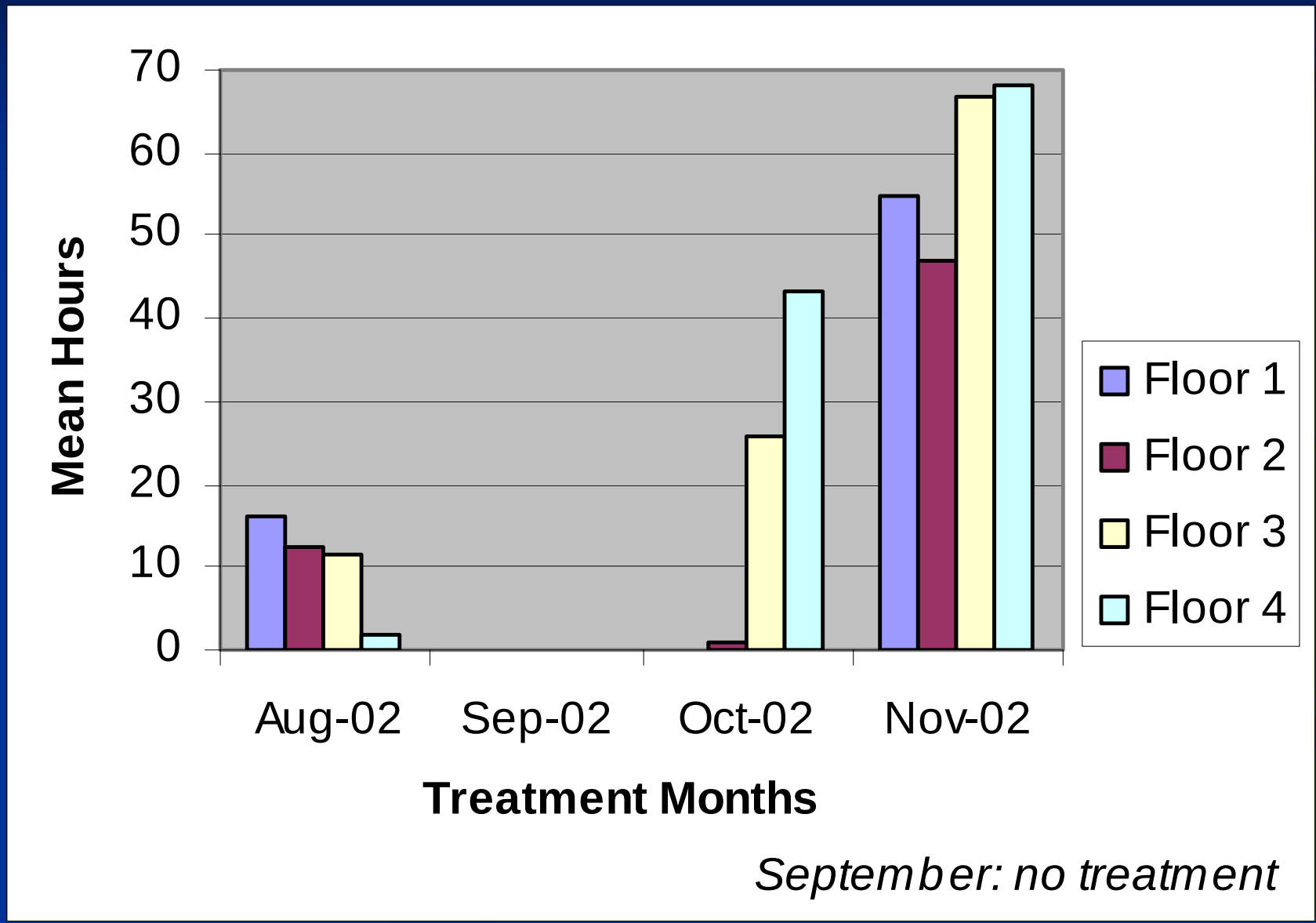
| Building[a] | Date | Floor | Hobos per floor | Hobos not reaching 50ºC | Mean Temperature (ºC) | | Mean hours to reach 50ºC | Rate of increase (ºC/h)[b] | Mean hours above 50ºC |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Start | Max | | | |
| CH | 19-Aug-02 | 1 | 9 | 3 | 30.19 | 56.50 | 5.64 | 3.51 | 16.14 |
| | | 2 | 7 | 0 | 31.82 | 57.73 | 12.52 | 1.45 | 12.40 |
| | | 3 | 7 | 1 | 32.00 | 54.37 | 13.14 | 1.37 | 11.59 |
| | | 4 | 8 | 5 | 31.23 | 47.92 | 26.00 | 0.72 | 1.67 |
| FM | 19-Aug-02 | 1 | 5 | 0 | 27.99 | 58.25 | 11.43 | 1.93 | 15.83 |
| | | 2 | 7 | 1 | 27.86 | 57.21 | 9.25 | 2.39 | 18.91 |
| | | 3 | 5 | 0 | 29.74 | 57.70 | 13.97 | 1.45 | 16.36 |
| | | 4 | 7 | 1 | 30.45 | 55.27 | 20.28 | 0.96 | 7.55 |
| | | 5 | 6 | 1 | 30.04 | 51.86 | 17.40 | 1.15 | 5.70 |
| CH | 17-Oct-02 | 1 | 4 | 3 | 23.89 | 47.22 | —[c] | —[c] | —[c] |
| | | 2 | 4 | 3 | 23.45 | 50.11 | 72.29 | 0.37 | 0.71 |
| | | 3 | 4 | 0 | 24.44 | 54.00 | 47.40 | 0.54 | 25.60 |
| | | 4 | 4 | 0 | 22.67 | 59.11 | 29.58 | 0.92 | 43.42 |
| FM | 17-Oct-02 | 1 | 5 | 2 | 26.11 | 50.83 | 70.63 | 0.34 | 2.37 |
| | | 2 | 5 | 2 | 23.19 | 46.95 | —[c] | —[c] | —[c] |
| | | 3 | 5 | 0 | 22.09 | 56.81 | 48.72 | 0.57 | 24.28 |
| | | 4 | 5 | 0 | 19.58 | 55.70 | 52.50 | 0.58 | 20.50 |
| | | 5 | 5 | 0 | 18.19 | 54.59 | 53.23 | 0.60 | 19.77 |
| CH | 26-Nov-02 | 1 | 1 | 0 | 21.33 | 58.58 | 36.00 | 0.80 | 55.00 |
| | | 2 | 1 | 0 | 22.48 | 57.89 | 44.00 | 0.63 | 47.00 |
| | | 3 | 1 | 0 | 22.09 | 67.42 | 24.00 | 1.16 | 67.00 |
| | | 4 | 1 | 0 | 18.28 | 65.01 | 23.00 | 1.38 | 68.00 |
| FM | 26-Nov-02 | 1 | 1 | 0 | 20.57 | 55.35 | 44.00 | 0.67 | 47.00 |
| | | 2 | 1 | 0 | 21.33 | 56.60 | 51.00 | 0.56 | 40.00 |
| | | 3 | 1 | 0 | 19.42 | 61.29 | 43.00 | 0.71 | 48.00 |
| | | 4 | 1 | 0 | 16.76 | 61.29 | 40.00 | 0.83 | 51.00 |
| | | 5 | 1 | 0 | 16.38 | 61.29 | 42.00 | 0.80 | 49.00 |

[a] FM=Flour Mill CH=Cleaning House

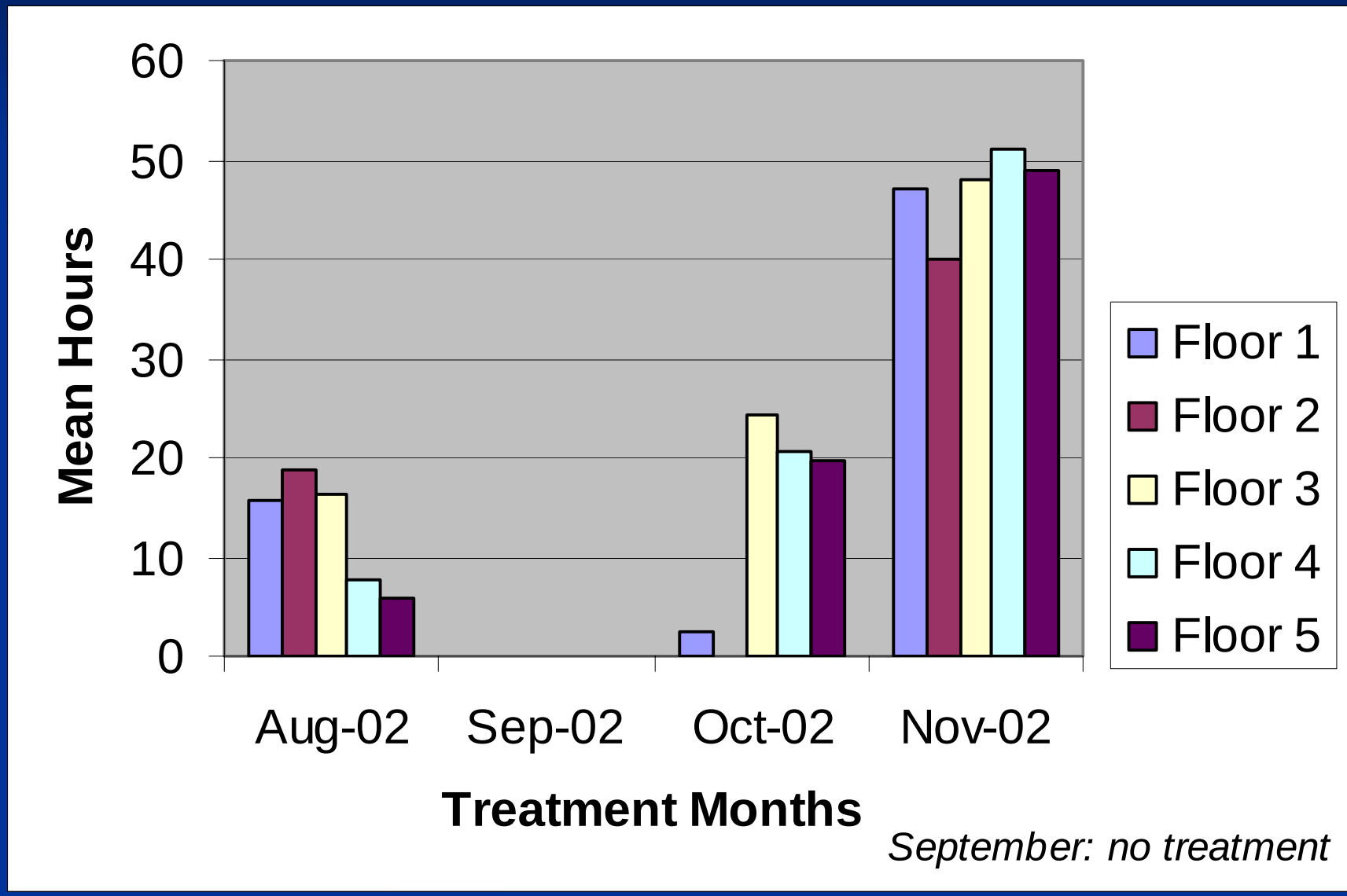
[b] Rate of increase from the ambient air to the target air temperature of 50ºC was calculated as: (50-mean starting temperature)/mean hours to reach 50ºC.

[c] Did not reach 50°C

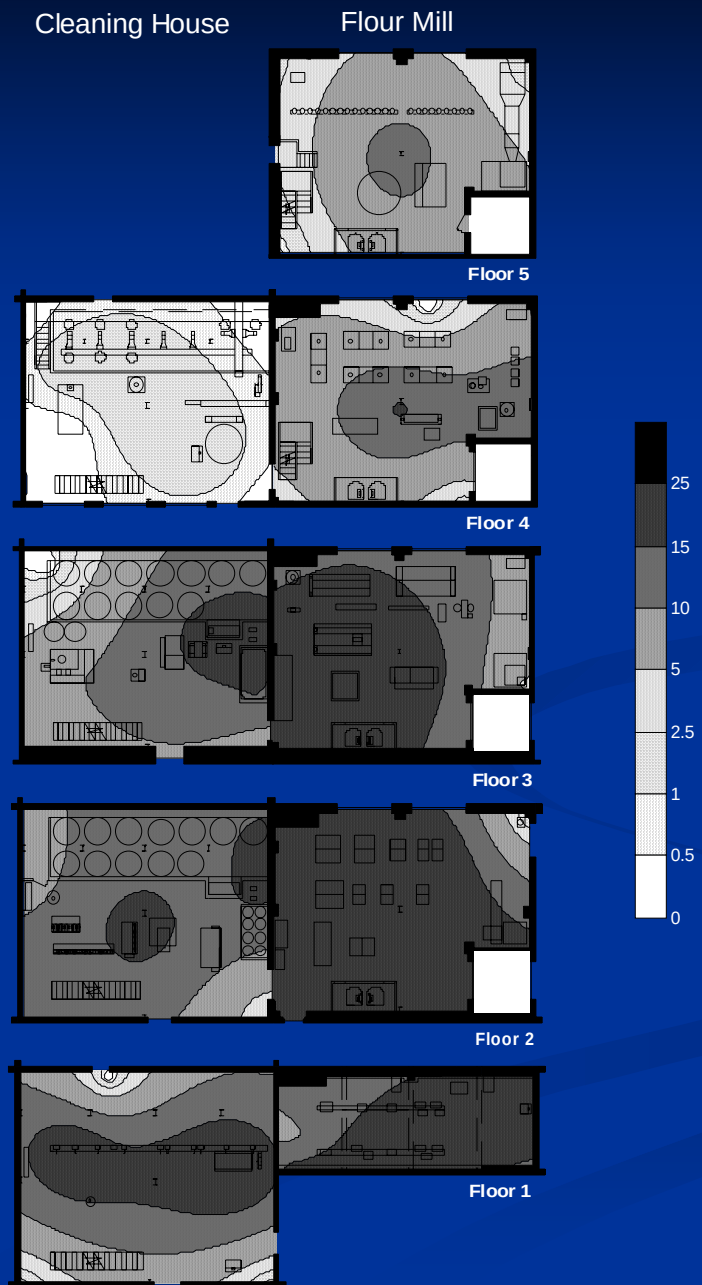
# Figure 7: Mean Hours Above 50°C in the Cleaning House



# Figure 8: Mean Hours Above 50°C in the Flour Mill



# Figure 9: Time (hrs.) Above 50°C in Pilot Flour Mill During the 19-Aug-02 Heat Treatment



# Figure 10: Product Sample Results using Analysis of Variance

| Building[a] | Date | Date[b] | | Floor | | Date x Floor | | Mean ± SE[c] | | % Reduction |
|---|---|---|---|---|---|---|---|---|---|---|
| | | F | P | F | P | F | P | Before | After | |
| CH | 19-Aug-02 | 0.22 | 0.643 | 3.41 | 0.035 | 0.66 | 0.584 | 0.18 ± 0.13 | 0.09 ± 0.05 | 50.00 |
| FM | 19-Aug-02 | 0.52 | 0.476 | 1.99 | 0.125 | 1.33 | 0.285 | 0.11 ± 0.03 | 0.13 ± 0.05 | __[d] |
| CH | 17-Oct-02 | 2.23 | 0.152 | 2.65 | 0.079 | 1.48 | 0.251 | 0.29 ± 0.13 | 0.02 ± 0.02 | 93.10 |
| FM | 17-Oct-02 | 0.29 | 0.597 | 1.93 | 0.145 | 0.20 | 0.937 | 0.09 ± 0.03 | 0.09 ± 0.09 | 0.00 |
| CH | 26-Nov-02 | 0.23 | 0.636 | 1.23 | 0.317 | 0.26 | 0.852 | 0.04 ± 0.04 | 0.01 ± 0.01 | 75.00 |
| FM | 26-Nov-02 | 3.17 | 0.084 | 1.16 | 0.346 | 1.16 | 0.346 | 0.01 ± 0.00 | 0.00 ± 0.00 | 100.00 |

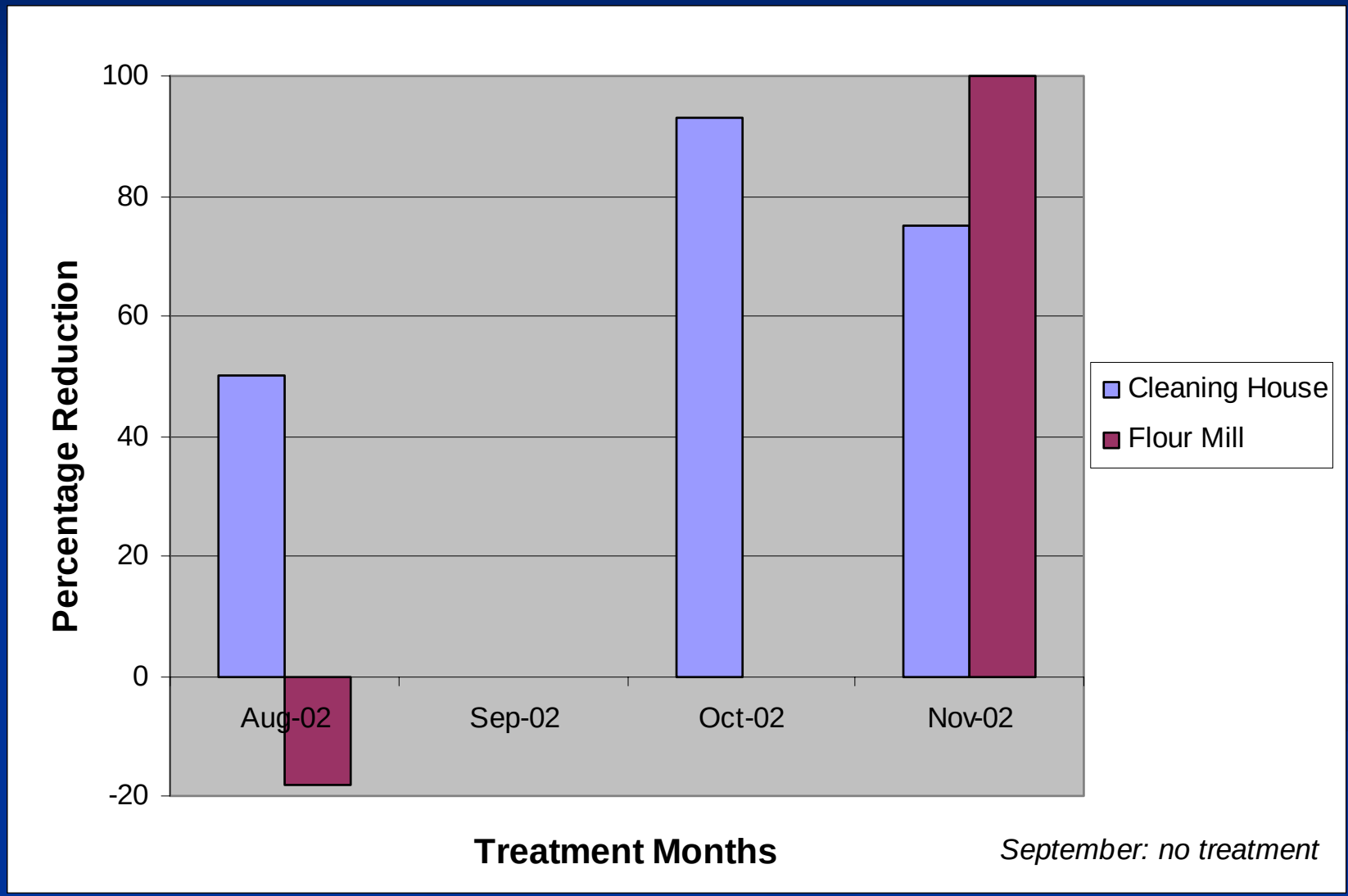
[a] FM=Flour Mill, CH=Cleanining House

[c] Comparison of product samples collected before and after each heat treatment; Aug. 16, (before) with samples on Aug. 28, 2002 (after); Oct. 12, (before) with samples on Oct. 24, 2002 (after); Nov. 26 (before) with samples on Dec. 7, 20

[d] Mean number of insects/floor/week/gram.

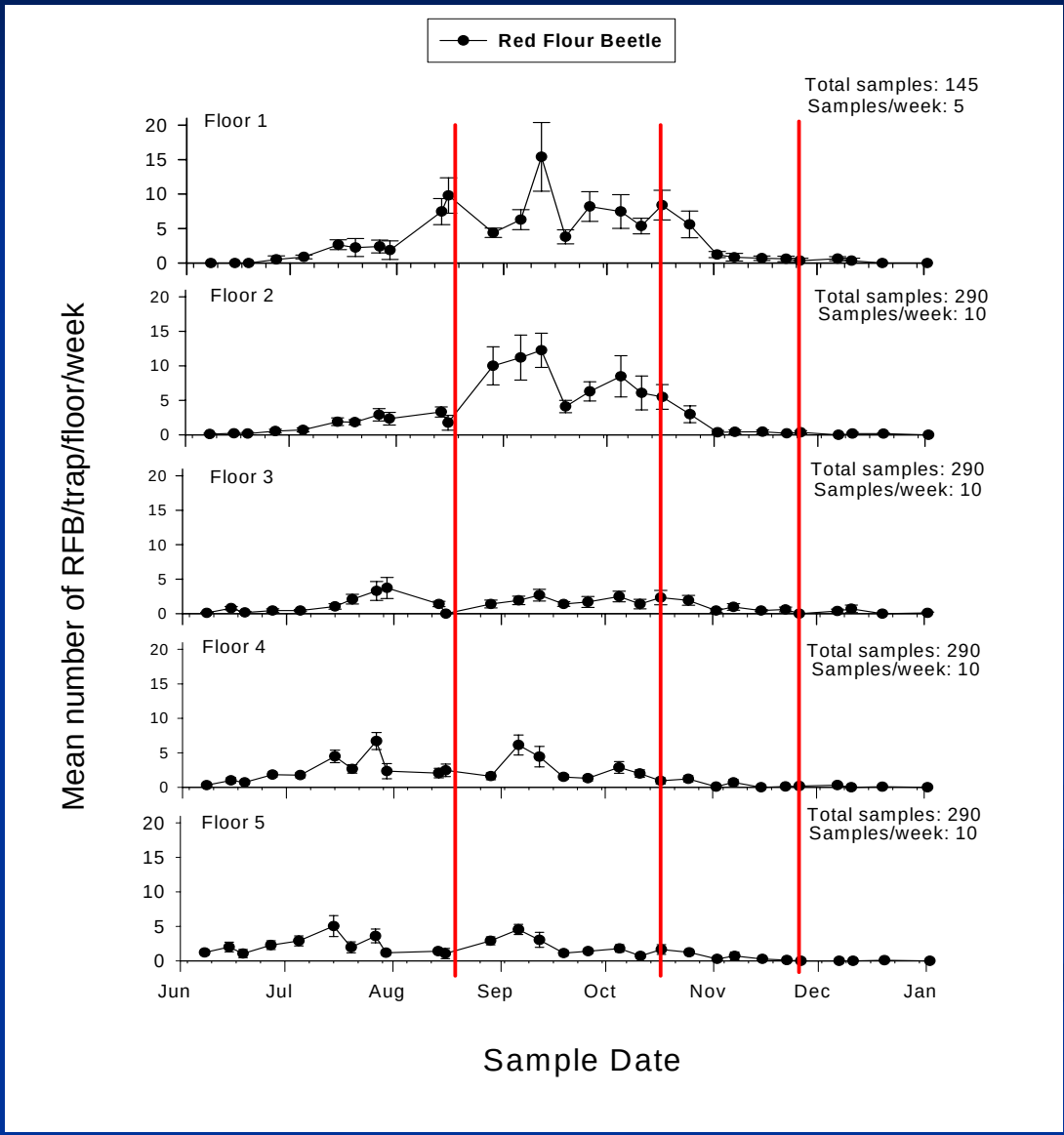
[d] There is an increase in insects found in product samples after treatment.

# Figure 11: Percentage Reduction in Insect numbers for Product Samples



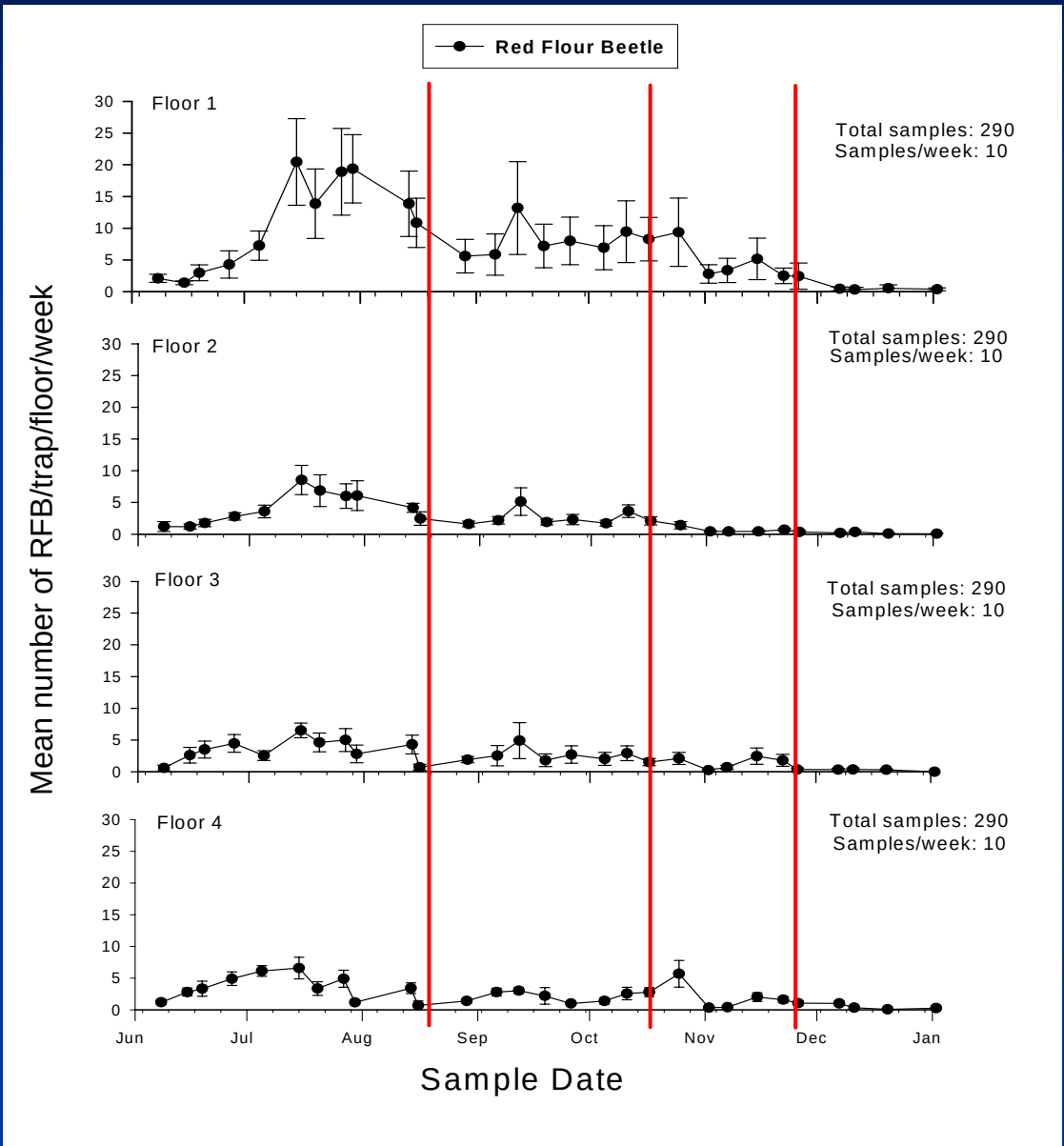
# Figure 12: Mean RFB Trap Captures on all Flour Mill Floors

*Heat treatments; 19-Aug-02, 17-Oct-02, and 26-Nov-02*



# Figure 13: Mean RFB Trap Captures on all Cleaning House Floors

*Heat treatments; 19-Aug-02, 17-Oct-02, and 26-Nov-02*



# Figure 14: Heat Treatment Results

| | 19-Aug-02 | | 17-Oct-02 | | 26-Nov-02 | |
|---|---|---|---|---|---|---|
| | C-House | Flour Mill | C-House | Flour Mill | C-House | Flour Mill |
| **Slope Comparisons** | | | | | | |
| Significant difference | All floors | Floors 1,2, & 5 | All floors | All floors | All floors | Floors 2,4,&5 |
| Reduction in insect numbers | All floors | Floors 4 & 5 | All floors | All floors | All floors | Floors 2,4,&5 |
| % reduction range | 32.45 - 49.15% | 0.00 - 26.61% | 43.86 - 82.12% | 72.60 - 95.25% | 68.40 - 87.24% | 67.51-89.24% |
| Floors with $r^2<0.79$ | None | None | None | None | None | Floors 1 & 3 |
| **Analysis of Variance** | | | | | | |
| Significant differences | Between floors | None | None | None | None | None |
| % reduction | 50% | Increase | 93.10% | 0% | 75% | 100% |
| **Temperature Profiles** | | | | | | |
| Range of mean hrs. above 50°C | 1.67 - 16.14 hr | 5.70 - 18.91 hr | 0.71 - 43.42 hr | 2.37 - 24.28 hr | 47.00-68.00 hr | 40.00-51.00 hr |
| Range of mean hrs. to 50°C | 5.64 - 26.00 hr | 9.25 - 20.28 hr | 29.58 - 72.29 hr | 52.50 - 70.63 hr | 23.00 - 44.00 hr | 40.00-51.00 hr |
| Floors not reaching 50°C | None | None | Floor 1 | Floor 2 | None | None |
| **Insect Rebound (Avg. wks)** | | | | | | |
| Traps | 1 | 0.6 | increase-fl.1,3,&4 | No rebound | No rebound | No rebound |
| | | | no rebound -fl. 2 | | | |

# Discussion

A. 19-Aug-02 Treatment

1. Whole mill, 1.67 - 18.91 hours above 50°C
2. C-house treatment appeared more affective than the mill, due to significant differences and higher % reduction values
3. Flour mill: floors 1, 2, & 3 had increased trap captures
4. Insect numbers rebounded after 1 wk. in C-house and 0.6 wk. in flour mill
5. Heat treatment was unsuccessful due to length of treatment

# Continue Discussion

B. 17-Oct-02 Heat Treatment

1. Whole mill, 0.71 - 43.42 hrs. above 50°C
2. The first two floors of both facilities had difficulty reaching 50°C
3. Based on slope analysis, % reductions were slightly higher for the mill
4. ANOVA analysis showed the C-house had the highest % reduction with the mill showing no change – low insect numbers/representative
5. C- house floors 1, 3, & 4 had slight increases in trap captures after treatment
6. Based primarily on trapping results, this treatment provided a sufficient knock down

## Continue Discussion

C. 26-Nov-02 Heat Treatment

1. Whole mill, 40.00 - 68.00 hrs. above 50°C
2. Low trap captures before treatment made analysis more difficult for mill floors 1 & 3
3. Slope comparisons: floors 4 & 5 had high % reductions and floor 2 had the lowest
3. Product samples also had large % reductions, which were between 75 and 100%
4. Insect numbers did not rebound
5. Treatment was not necessary, but it was still successful

# Conclusion

Steps for Heat Treatment Assessment

1. Determine insect monitoring method
2. Conduct sampling immediately before treatment
3. Thoroughly monitor temperature throughout the facility
4. Sample immediately after treatment
5. Collect data
6. Analysis
    a. Slope comparison-traps
    b. Analysis of variance-traps or product
    c. Temperature profiles
    d. Insect Rebound
7. Interpret Results

# Future Research

- Insect behavior
- Trap interpretation
- Improve trap efficiency-design
- Relate insect density to rebolt tailings