Project No._RU-2_

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 2004 - December 31, 2004

PROJECT TITLE: RICE UTILIZATION AND PRODUCT DEVELOPMENT

STATUS OF PROPOSAL: _____/New __X__/Continuing

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LEVEL OF 2004 FUNDING: $30,000

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

Objectives:

The goal of this research was to develop rapid, non-chemical, safe alternative methods to eliminate insect pests from paddy rice while retaining high rice quality. Alternatives are needed to replace the planned decommissioning of currently licensed pesticides. Electromagnetic radiation in the infrared and radio frequency range were evaluated for their effectiveness in eliminating adult insects, larvae and eggs and retaining milling quality. The proposed specific research objectives were:

1. Determine the effectiveness of infrared and radio frequency treatments in disinfestation of storage paddy rice.
2. Investigate the effect of infrared and radio frequency treatments on moisture loss of rice.
3. Study the milling quality of paddy rice treated with infrared and radio frequency.
4. Evaluate the feasibility of infrared and radio frequency infrared treatments.

Experimental Procedures

Paddy Rice, Moisture Determination and Milling Quality Evaluation

Two different storage California medium grain M202 samples were used for this study. A naturally infested rice sample with Angoumois grain moth (*Sitotroga cerealella*) and 12.9% moisture content from the Food Processing Lab at UC Davis was used for disinfestation tests. The moisture losses of the rice samples under different infrared treatments were determined by using oven method at 130°C for 24 h. A rice sample with 13.5% MC used for milling quality evaluation was obtained from Farmer's Rice Co-operatives in Sacramento. Under selected conditions of infrared and radio frequency treatments, the moisture losses and milling quality of treated rice samples were determined. The moisture content and milling quality were determined using standard FGIS method at the CDFA lab in Sacramento. The evaluated quality indicators included total rice yield (TRY), head rice yield (HRY), and Whiteness Index (WI). The WI was used to evaluate the whiteness of milled rice determined with the Whiteness Tester, C-300, (Kett Electronic Laboratory, Tokyo, Japan). A higher index number indicates whiter milled rice.

Evaluation of Disinfestation

After infrared and radio frequency treatments, all rice samples were transferred to plastic containers or glass jars with screen on lids to maintain sample moisture and oxygen supply to allow for surviving insects, larvae or eggs to grow. All these containers were kept inside an incubator of 80% relative humidity (RH) and 28°C for infrared treated samples and 35-43% RH and 30°C for radio frequency treated samples during an observation period of up to about 100 days (approximately 4-5 complete life cycles). No significant difference in the results was expected for the samples incubated under the slightly different conditions.

Insect populations at each observation period were determined by counting the number of emerging adults in each rice sample (both treated and control) every 2-3 days, during the entire observation period. Cumulative numbers of emerging adults as a function of time were then calculated and reported. The results showed the disinfestation effectiveness of the treatments on paddy rice infested with Angoumois grain moth. If no live adult insects were observed after 1 or two insect life cycles (about 21 days for each cycle), the treatment conditions were considered as effective. After each observation and counting, all adult insects were removed.

Infrared Treatment

The schematic diagram of the catalytic infrared heating device used in the study is illustrated in Fig. 1. It was equipped with a catalytic infrared emitter (BUREST MODEL 12-24) and vibration bed with adjustable speed for fully mixing the rice during heating. The infrared emitter was 4 inches above the rice bed. The flexible Teflon bottom or vibration bed (0.8 m x 0.4 m) was vibrated in four sections. Wave-like vibration was created by rotating rollers arranged under the flexible bottom. Vibrating frequency was set at 450 cycles/minute. Natural gas flow rate to the CFG IR dryer was measured using a flow meter (EQUIMETER MR-5). A computer based data acquisition and control (DAC) system was used to record the rice temperature and gas flow data and to control solenoid valve (UNIVERSAL MODEL36C03) of the gas supply.

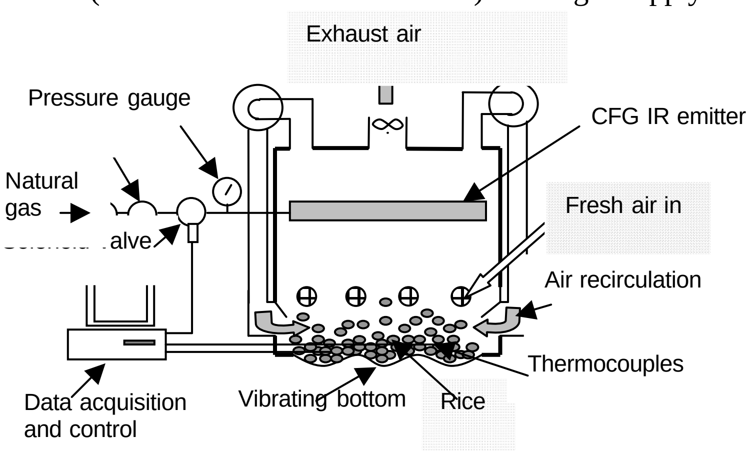


Figure 1. Schematic diagrams of catalytic infrared heating device

Since the infrared radiation directly heated the rice without heating the surrounding air, air temperature inside the heating chamber was much lower than the rice temperature. Therefore, the rice bed temperature was used as control temperature. Rice temperature was measured using two thermocouples that were inserted into the middle of the rice bed. The average of thermocouple readings was used to control the natural gas supply to the IR emitter. Gas supply to the IR emitter was controlled (switched on or off) by the DAC comparing the average bed temperature with the set point temperature. The heating times needed to reach the setting temperatures were recorded. Then the samples were kept in the heating chamber for the desired time periods.

Sample size for the disinfestation treatments was 2 kg for each batch, which was corresponded to about 2 cm thickness of rice bed. After reaching the desired treatment time, the samples were taken out from the heating chamber and saved for moisture and disinfestation evaluation. The experimental design was shown in the Table 1. Based on the results of disinfestation evaluation, only four treatment conditions, 50°C for 1 and 5 min and 60°C for 1 and 5 min, were used to obtain rice samples for milling quality evaluation.

Table 1 Experimental design of infrared treatment

Temperature (°C)	Heating time (min)		
45	1	5	10
50	1	5	10
60	1	5	10
70	1	5	10

Radio Frequency Treatment

A well-insulated paddy rice sample holder (polyethylene and styrofoam) was designed and constructed to contain 140 – 170 g paddy rice. The holder's 4-π insulation allows maintaining a homogeneous rice temperature during experimentation. The special sample holder (i.e. sample geometry) was used throughout the experimentation so as to maximize (tune) the operating RF frequency (i.e. field geometry), and optimize impedance so as to match the process parameters to obtain high energy-use efficiency, while operating with adequate heating rate (about 10^{o}C/min). Fiber optic temperature sensors were used to measure rice temperature on-line during RF treatment. The experimental design and conditions are listed in Table 2.

Table 2. Conditions for testing disinfestation efficacy and rice milling quality

Experiment Name	Features	Rice Weight (g)	Heating Phase
RF Trial-1	Constant holding time: 5 min at 70, 60, 50, 40, & 35 ºC.	465(Triplicate, 155 each)	385 kHz, 100 W, 1-5 min
RF Trial-2	Variable holding time: 5 min at 70 ºC; 10 min at 60 ºC; 20 min at 50 ºC; 30 min at 40 ºC; 40 min at 35 ºC.	155 each	385 kHz, 100 W, 1-5 min
RF Trial-3	Constant holding time: 5 min at 70, 60, 50, 40, & 35 ºC.	155 each	13.8 MHz, 100 W, 1-5 min
RF Trial-4	Variable frequency: 0.336, 1.01, 13.18, & 27.18 MHz; 5 min holding time.	160 each	0.336, 1.01, 13.18, & 27.18 MHz, 100 W, 1-9 min
RF Trial-5	Variable holding time: 28 min at 50 ºC; 35 min at 40 ºC; 40 min at 35 ºC.	480 (Triplicate, 160 each)	340 kHz, 100 W, 1-5 min
Milling quality	5 min at 70, 60 & 50 ºC; The rice weight changes < 0.5 % after RF treatments.	3792 (Triplicate, 1264 each)	378 kHz, 200 W, 12 – 19 min

SUMMARY OF 2004 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVES

Disinfestation Effectiveness of Infrared Treatment and Milling Quality

When the rice sample was heated in the heating chamber, it took about 2, 3, 4 and 5 min to reach 45, 50, 60 and 70°C, respectively. The heating was quite rapid and could be further improved if a thinner layer is used, which may reduce the moisture loss during the treatment (Table 3). The moisture losses were in range of 0.59 to 2.86% under the tested conditions. When the treatment was 50°C and 1 min, the moisture loss was about 1%.

Table 3. Moisture content of rice sample treated with infrared at different conditions (% wb)

Temperature (°C)	Treatment time (min)			
	0	1	5	10
Control	12.92			
45		12.33	11.87	11.78
50		11.87	11.75	11.45
60		11.71	11.24	10.79
70		10.91	10.87	10.06

The disinfestation results showed that only control and treated samples at 45°C had emerging adult insects (Fig. 2). No insects were found in the rest of samples after two insect life cycles. The results clearly indicated that using 50°C or above temperature treatment could

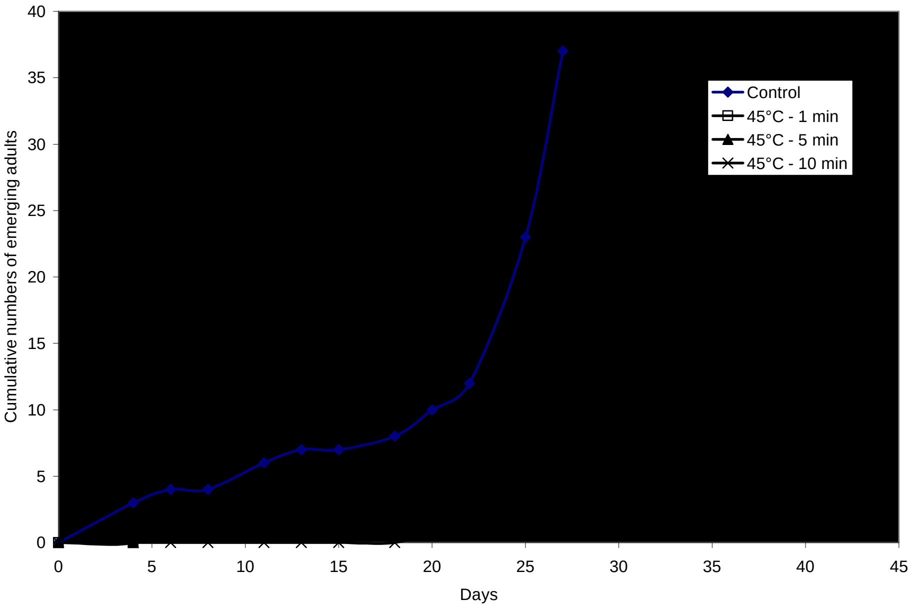


Fig. 2. Emerging adult insects in infrared treated samples (no insects found for the samples treated at 50°C or above)

effectively kill all forms of Angoumois grain moth (*Sitotroga cerealella*). The minimum treatment under the test conditions was 50°C and 1 min. The total time including heating was about 4 min with about 1% moisture loss. Reducing the thickness of the rice bed and heating time could minimize the moisture loss.

The milling quality of rice samples treated with infrared at 50°C for 1 and 5 min was not affected compared with the control sample (Table 4). Also, no difference in whiteness was observed between milled rice samples treated at 50°C and the control. As it was expected based on previous test results, the treatment at 50°C and 1 min caused about 1% MC loss. However, significant quality loss occurred for the rice samples treated at 60°C. Therefore, it can be concluded that the infrared could be an effective method for storage rice disinfestation without quality loss. Through optimization of the treatment conditions, the moisture loss could be minimized.

Table 4. Moisture change and milling quality of infrared treated rice samples

	MC (%)	TRY (%)	HRY (%)	WI
Control	13.5±0.1	68.5±0.4	54.1±0.7	44.4±0.3
50°C - 1 min	12.3±0.0	69.2±0.4	53.8±0.6	45.1±0.3
50°C - 5 min	12.0±0.0	69.5±0.2	54.6±0.1	44.7±0.3
60°C - 1 min	11.9±0.1	69.8±0.4	52.4±0.0	45.1±0.4
60°C - 5 min	11.4±0.1	70.3±0.4	44.9±0.4	44.5±0.2

Disinfestation Effectiveness of Radio Frequency Treatment and Milling Quality

The Trial 1 used 385kHz, 100W with 5 min holding time showed that radio frequency (RF) power could be used to treat paddy rice with a 100 % insect mortality for Angoumois grain moth with a minimum of 60 ºC and 5 minutes of processing time (i.e. thermal load of 300 ^{o}C min). The first two figures of Trial 1 showed the cumulative numbers of emerging adult insects in two different scales. The third figure of Trial 1 showed the relationship between cumulative number of insects and temperature after 100 days of observation.

The Trial 5 used variable times (28 to 40 min) at different treatment temperatures (35 to 50°C) at 340 kHz, 100W. The treatment at 50 ºC holding for 28 minutes (thermal load = 1,400 ^{o}C min) also produced a disinfestation level as an insect mortality of 99.4 % in the observation period up to 82 days.

The Trial 2, 3, and 4 used different frequencies and holding times. No significant difference was found among the samples treated with different frequencies.

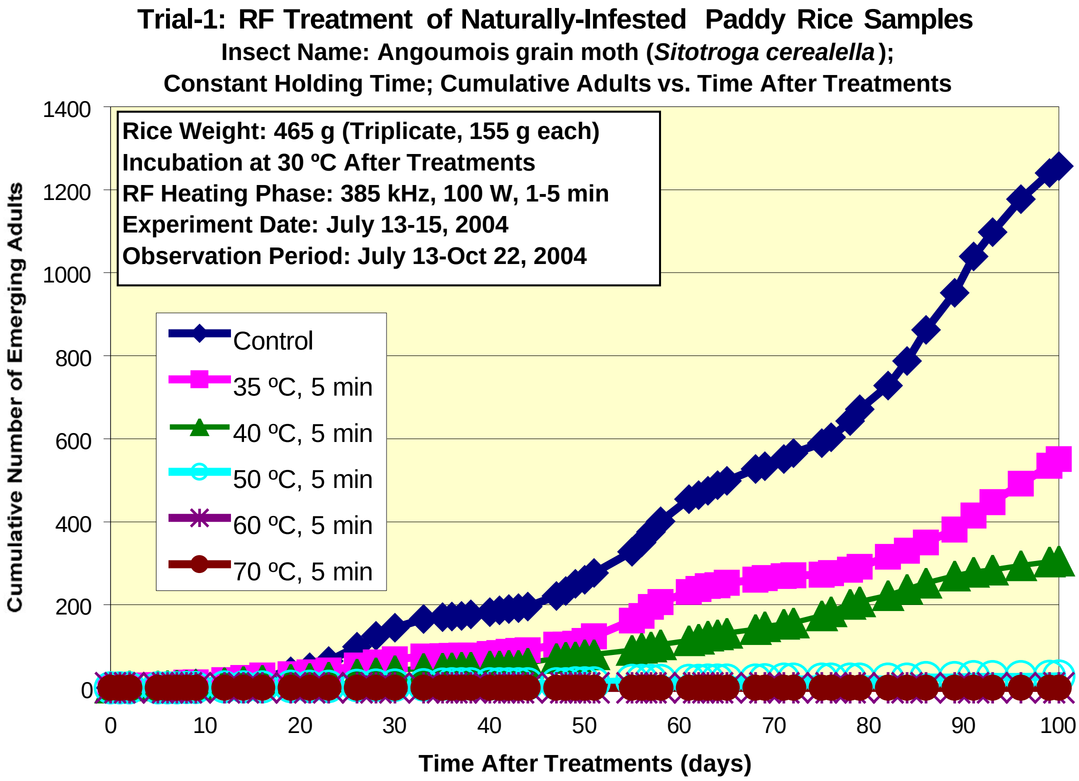
Paddy rice milling quality treated with RF at 50, 60 and 70ºC for 5 min (holding time) was not significantly affected, statistically, and remained similar to the control samples (Table 5). The RF treatment also did not cause any significant moisture loss.

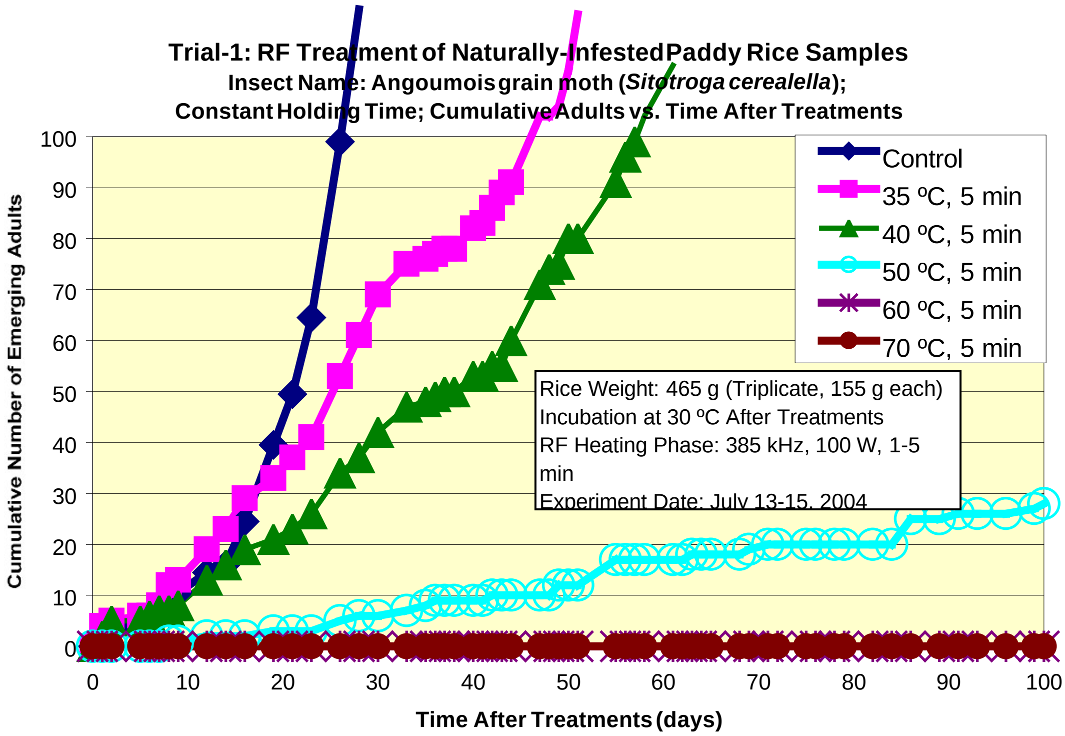
Since the thermal load (temperature × time) is an important factor for insect mortality. At an identical temperature, a longer holding time (higher thermal load) increases the insect mortality even at a temperature below 50 ºC. RF treatment at a temperature less than 50ºC is expected to have 100 % insect mortality as long as the holding time is long enough (when thermal load reaches certain level). More experiments may be conducted to evaluate this lower temperature alternative.

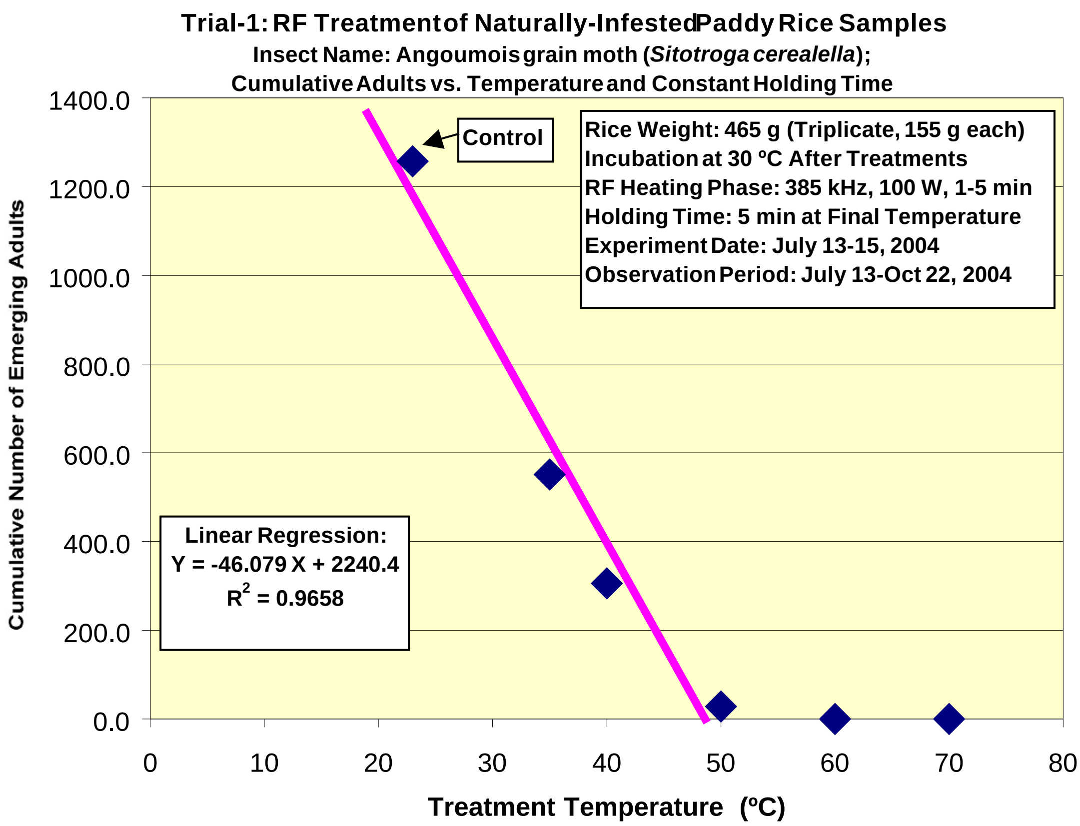
Table 5. Moisture change and milling quality of radio frequency treated rice samples

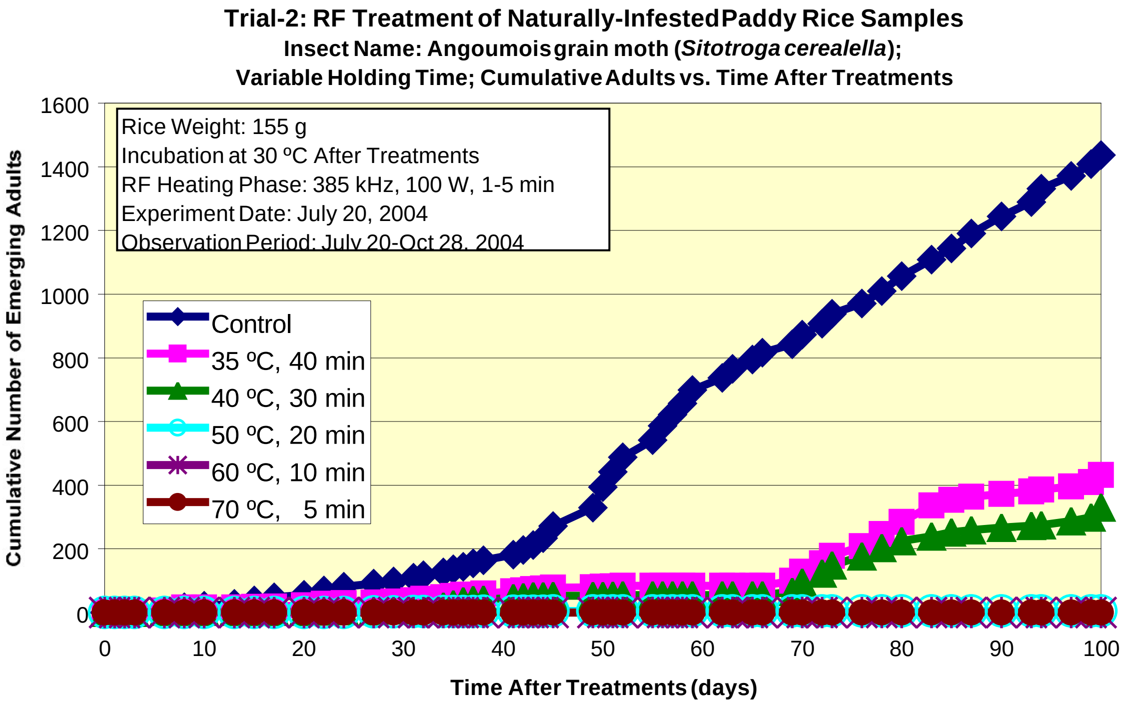
	MC (%)	TRY (%)	HRY (%)	WI
Control	13.5±0.1	68.1±0.3	54.0±0.8	44.2±0.4
50°C – 5 min	13.5±0.1	68.3±0.1	53.3±2.7	45.1±0.2
60°C – 5 min	13.5±0.3	68.2±0.0	53.4±0.3	44.2±0.2
70°C – 5 min	13.5±0.1	68.0±0.1	53.0±0.6	45.3±0.1

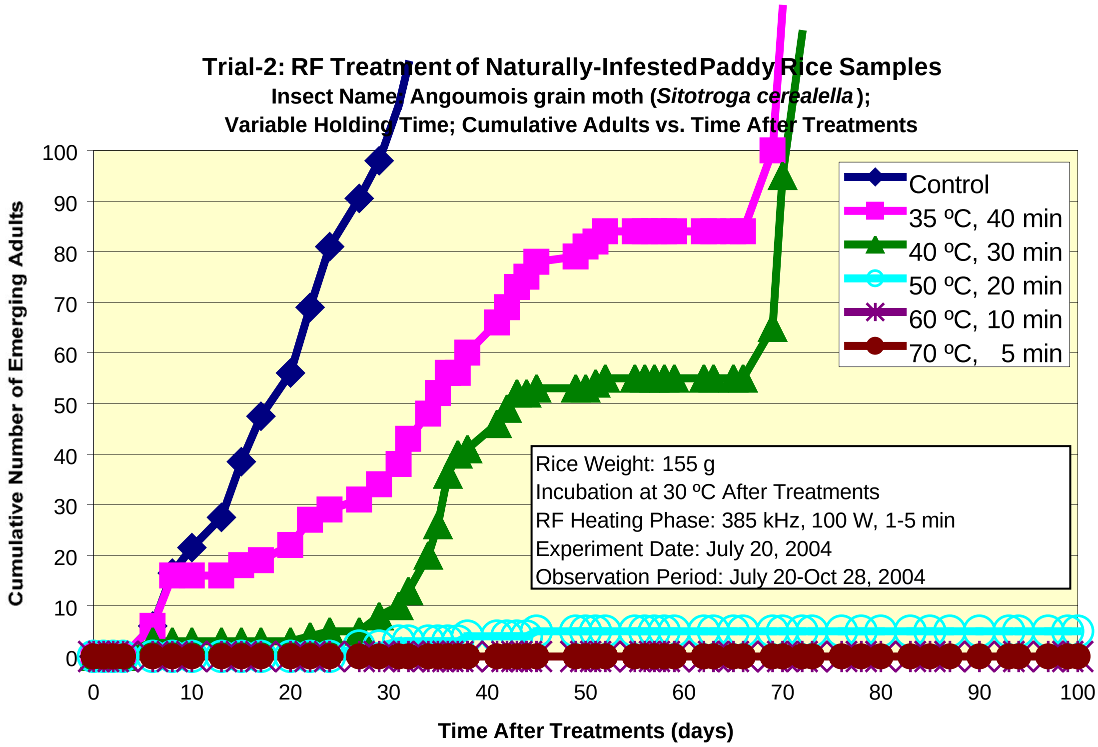
No difference among the samples treated and control at a confidence level of 95 % based on t-test.

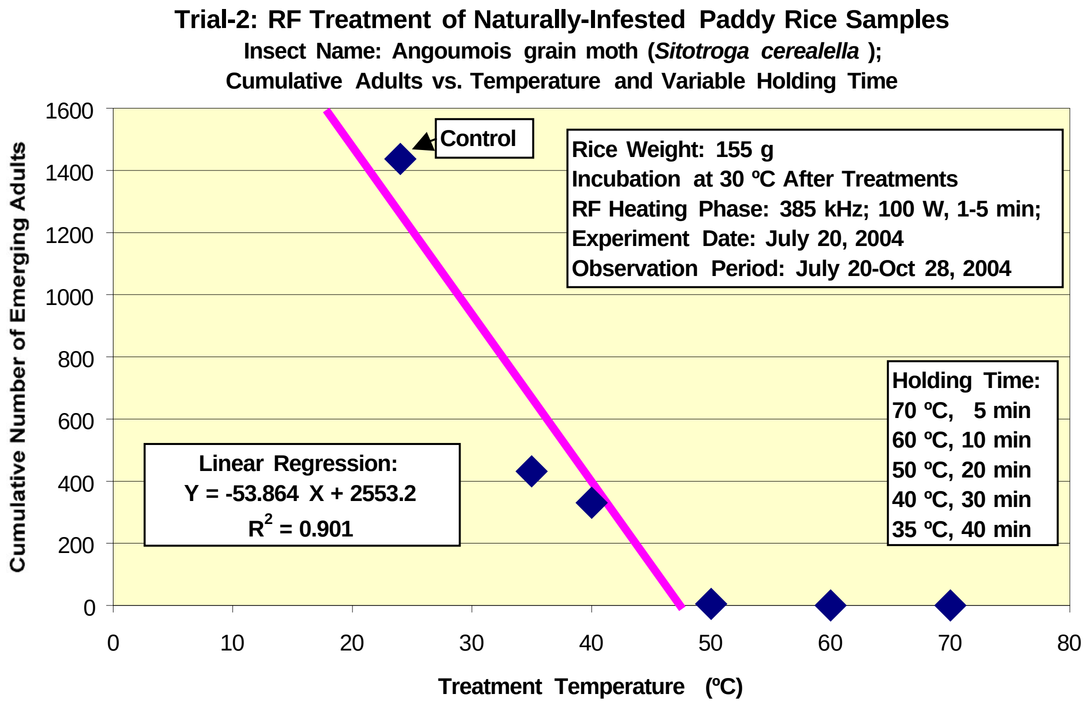


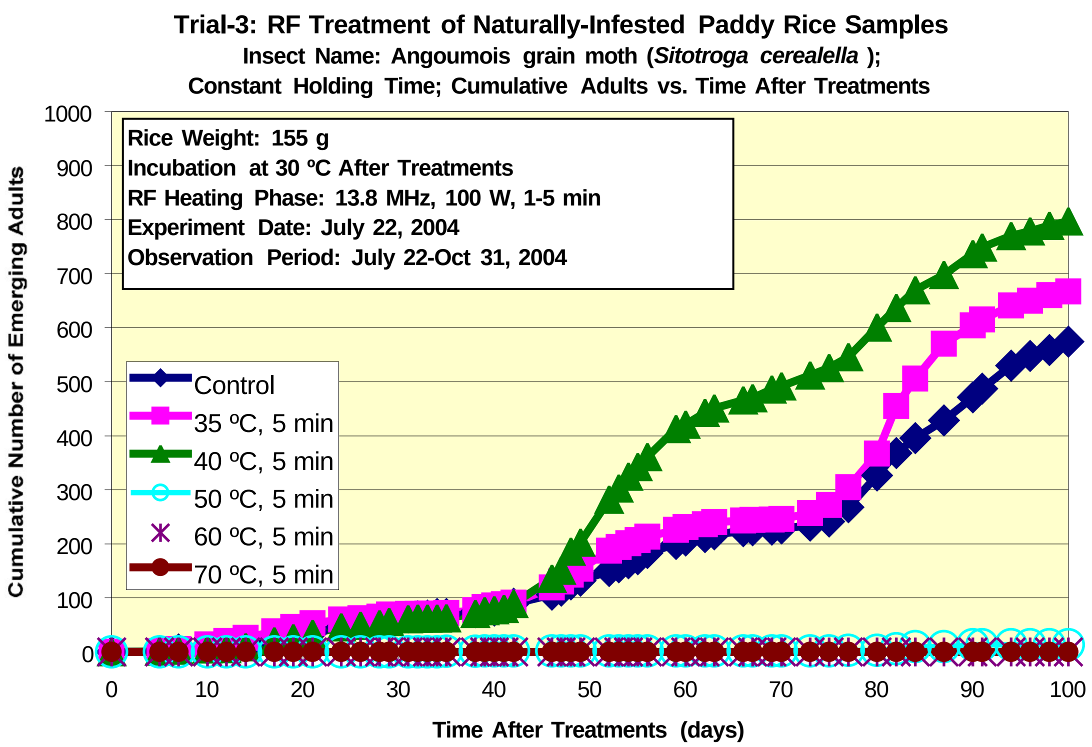

Trial-1: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (*Sitotroga cerealella*);
Constant Holding Time; Cumulative Adults vs. Time After Treatments
Cumulative Number of Emerging Adults
Time After Treatments (days)
Control
35 ºC, 5 min
40 ºC, 5 min
50 ºC, 5 min
60 ºC, 5 min
70 ºC, 5 min
Rice Weight: 465 g (Triplicate, 155 g each)
Incubation at 30 ºC After Treatments
RF Heating Phase: 385 kHz, 100 W, 1-5 min
Experiment Date: July 13-15, 2004

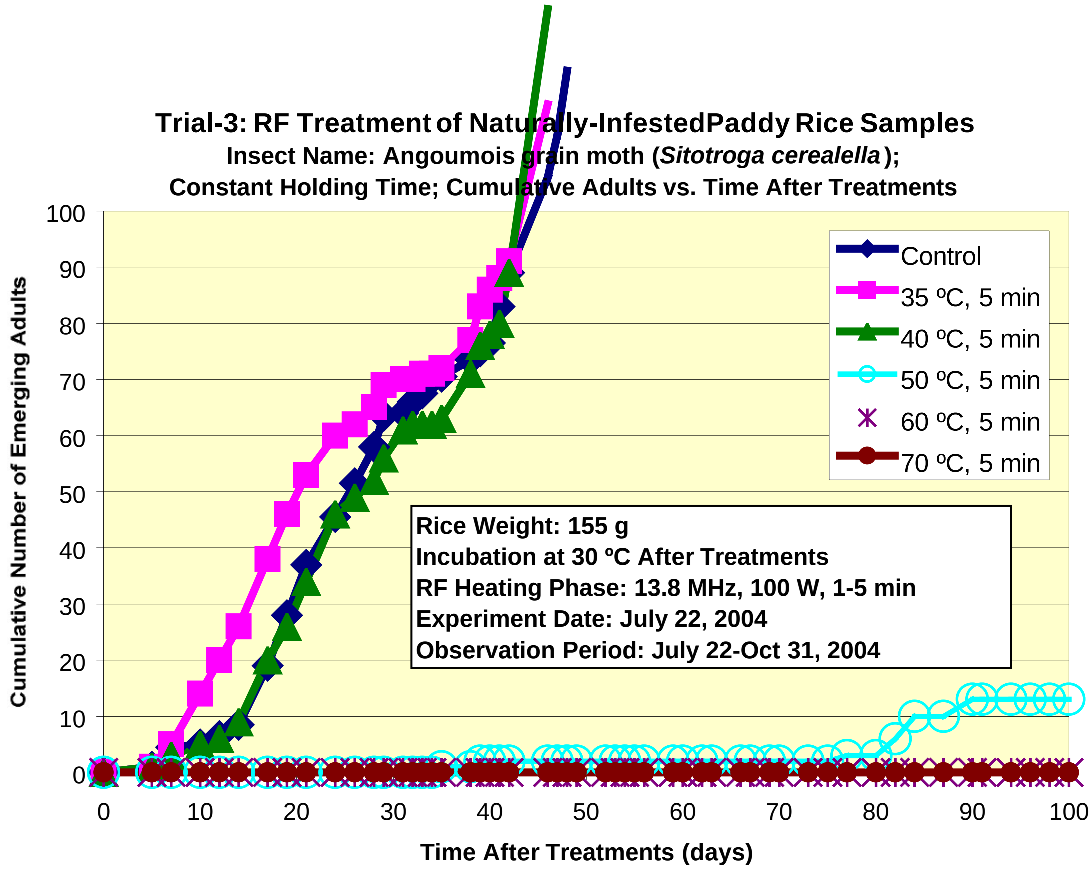

Trial-1: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (*Sitotroga cerealella*);
Cumulative Adults vs. Temperature and Constant Holding Time
Cumulative Number of Emerging Adults
Treatment Temperature (ºC)
Control
Rice Weight: 465 g (Triplicate, 155 g each)
Incubation at 30 ºC After Treatments
RF Heating Phase: 385 kHz, 100 W, 1-5 min
Holding Time: 5 min at Final Temperature
Experiment Date: July 13-15, 2004
Observation Period: July 13-Oct 22, 2004
Linear Regression:
Y = -46.079 X + 2240.4
R^2 = 0.9658

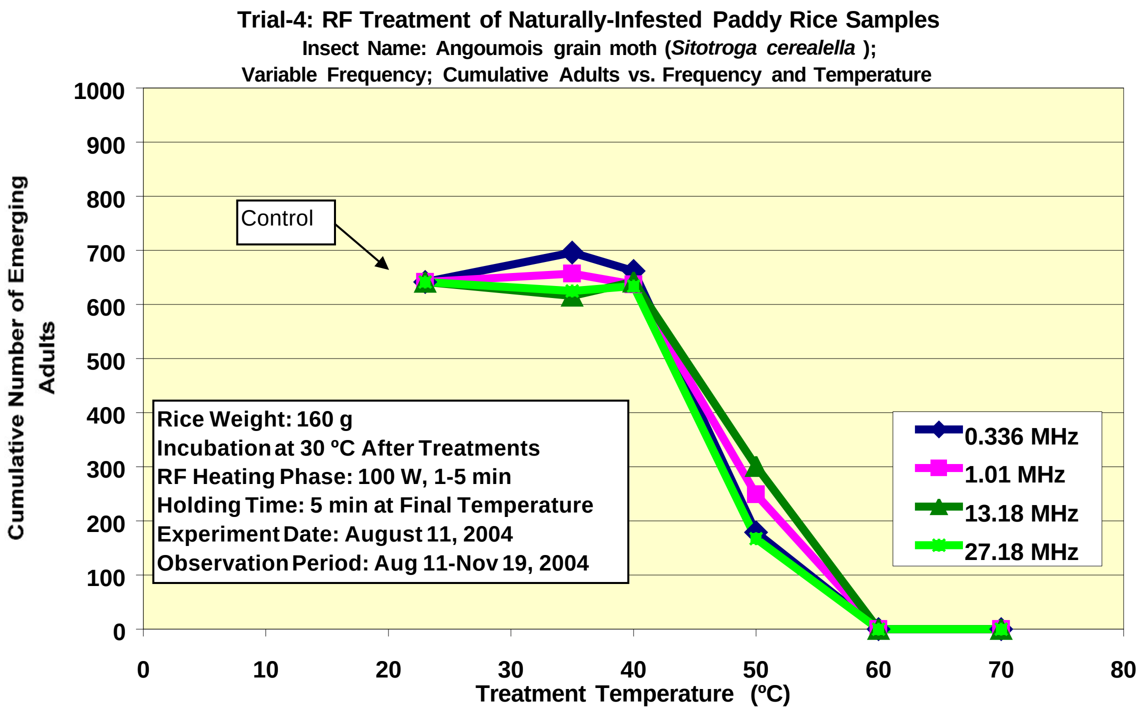

Trial-2: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (*Sitotroga cerealella*);
Variable Holding Time; Cumulative Adults vs. Time After Treatments
Rice Weight: 155 g
Incubation at 30 ºC After Treatments
RF Heating Phase: 385 kHz, 100 W, 1-5 min
Experiment Date: July 20, 2004
Observation Period: July 20-Oct 28, 2004
Control
35 ºC, 40 min
40 ºC, 30 min
50 ºC, 20 min
60 ºC, 10 min
70 ºC, 5 min
Cumulative Number of Emerging Adults
Time After Treatments (days)
0
200
400
600
800
1000
1200
1400
1600
0
10
20
30
40
50
60
70
80
90
100

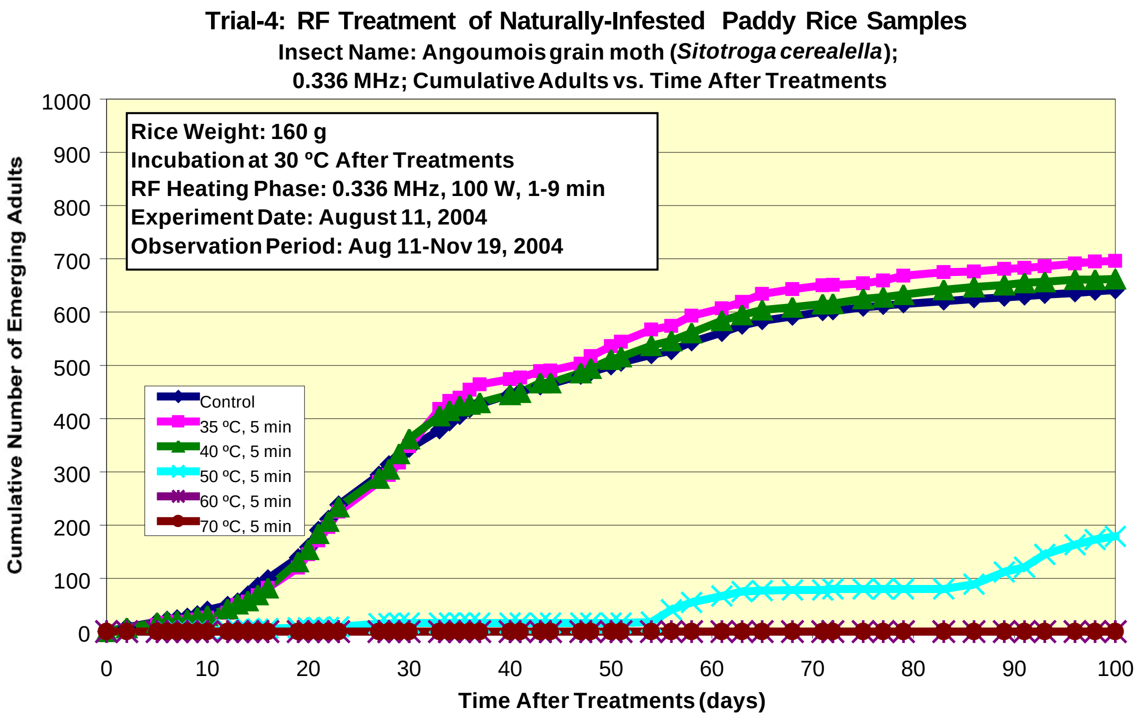

Trial-2: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (*Sitotroga cerealella*);
Variable Holding Time; Cumulative Adults vs. Time After Treatments
Control
35 ºC, 40 min
40 ºC, 30 min
50 ºC, 20 min
60 ºC, 10 min
70 ºC, 5 min
Rice Weight: 155 g
Incubation at 30 ºC After Treatments
RF Heating Phase: 385 kHz, 100 W, 1-5 min
Experiment Date: July 20, 2004
Observation Period: July 20-Oct 28, 2004
Cumulative Number of Emerging Adults
Time After Treatments (days)
0
10
20
30
40
50
60
70
80
90
100
0
10
20
30
40
50
60
70
80
90
100

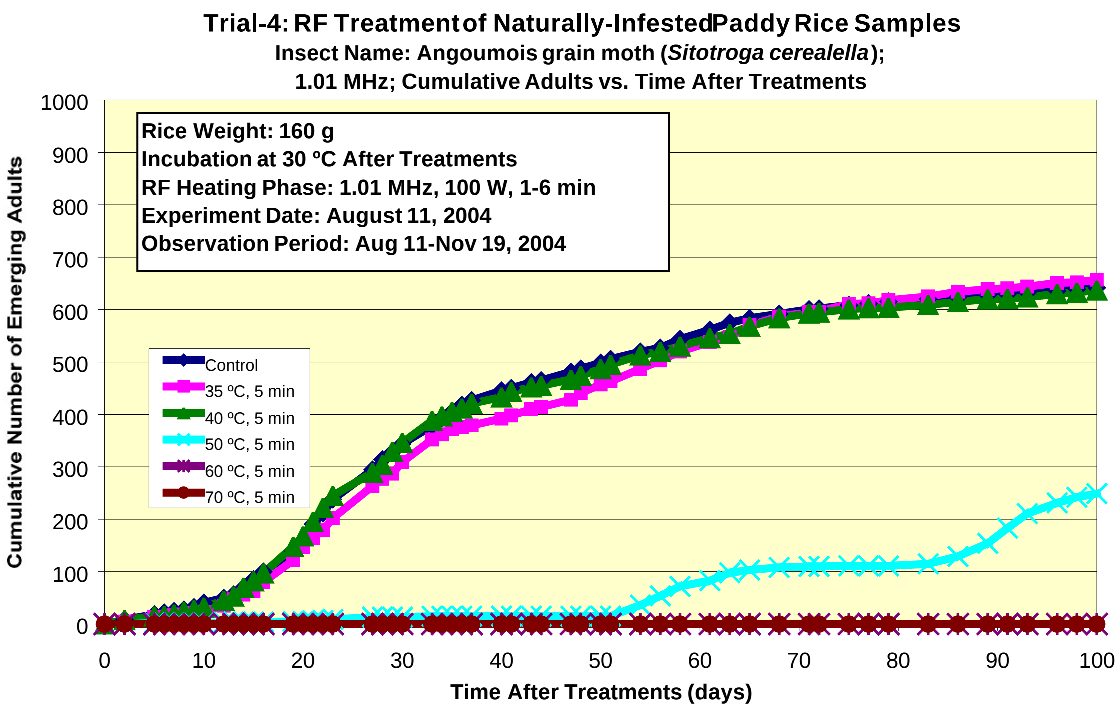

Trial-2: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (Sitotroga cerealella);
Cumulative Adults vs. Temperature and Variable Holding Time
Control
Rice Weight: 155 g
Incubation at 30 ºC After Treatments
RF Heating Phase: 385 kHz; 100 W, 1-5 min;
Experiment Date: July 20, 2004
Observation Period: July 20-Oct 28, 2004
Holding Time:
70 ºC, 5 min
60 ºC, 10 min
50 ºC, 20 min
40 ºC, 30 min
35 ºC, 40 min
Linear Regression:
Y = -53.864 X + 2553.2
R2 = 0.901
Cumulative Number of Emerging Adults
Treatment Temperature (ºC)
0
200
400
600
800
1000
1200
1400
1600
0
10
20
30
40
50
60
70
80

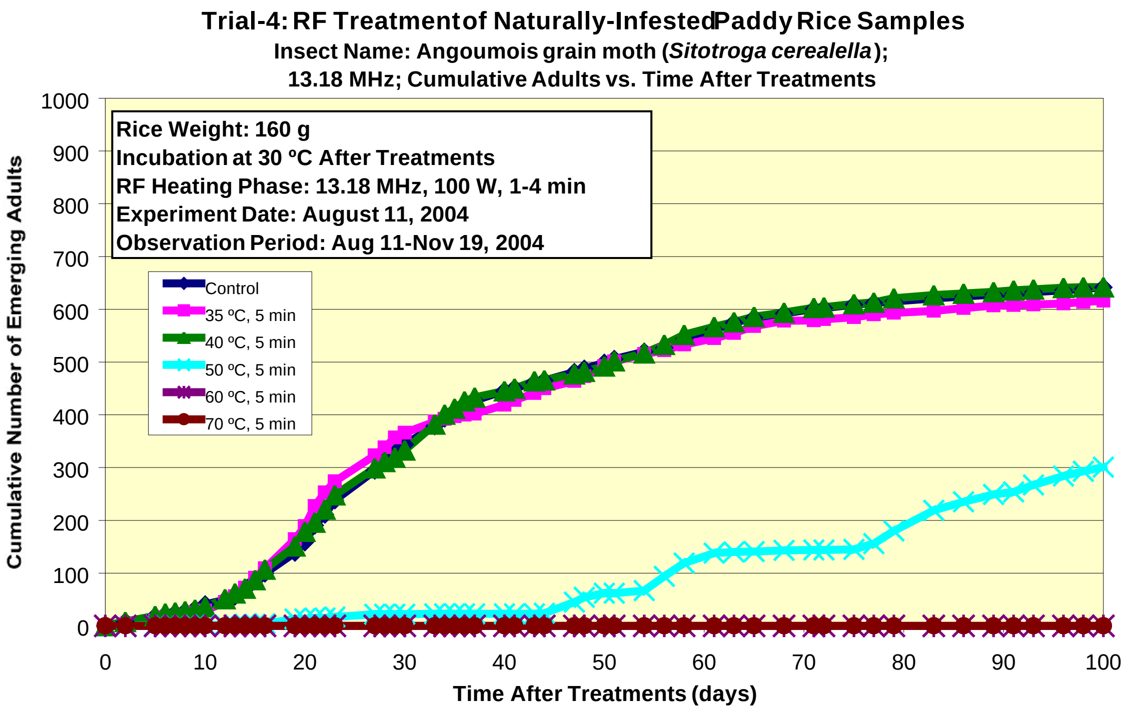

Trial-3: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (Sitotroga cerealella);
Constant Holding Time; Cumulative Adults vs. Time After Treatments
Rice Weight: 155 g
Incubation at 30 ºC After Treatments
RF Heating Phase: 13.8 MHz, 100 W, 1-5 min
Experiment Date: July 22, 2004
Observation Period: July 22-Oct 31, 2004
Control
35 ºC, 5 min
40 ºC, 5 min
50 ºC, 5 min
60 ºC, 5 min
70 ºC, 5 min
Cumulative Number of Emerging Adults
Time After Treatments (days)
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90
100

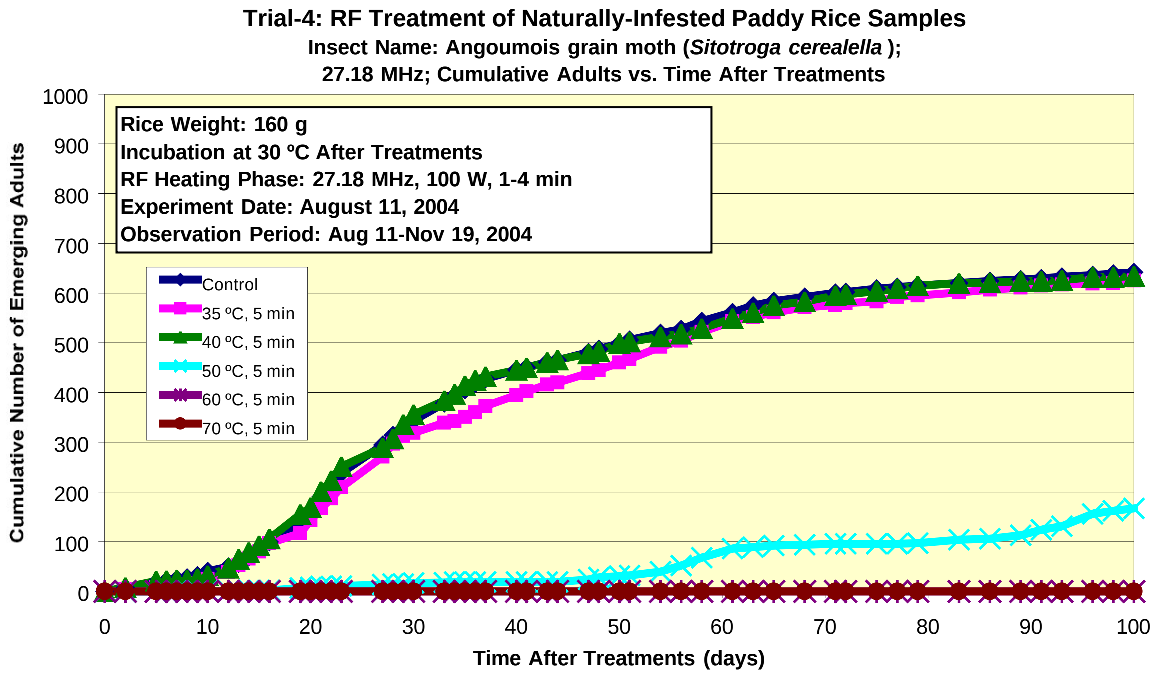

Trial-3: RF Treatment of Naturally-InfestedPaddy Rice Samples
Insect Name: Angoumois grain moth (*Sitotroga cerealella*);
Constant Holding Time; Cumulative Adults vs. Time After Treatments
Cumulative Number of Emerging Adults
Time After Treatments (days)
Control
35 ºC, 5 min
40 ºC, 5 min
50 ºC, 5 min
60 ºC, 5 min
70 ºC, 5 min
Rice Weight: 155 g
Incubation at 30 ºC After Treatments
RF Heating Phase: 13.8 MHz, 100 W, 1-5 min
Experiment Date: July 22, 2004
Observation Period: July 22-Oct 31, 2004

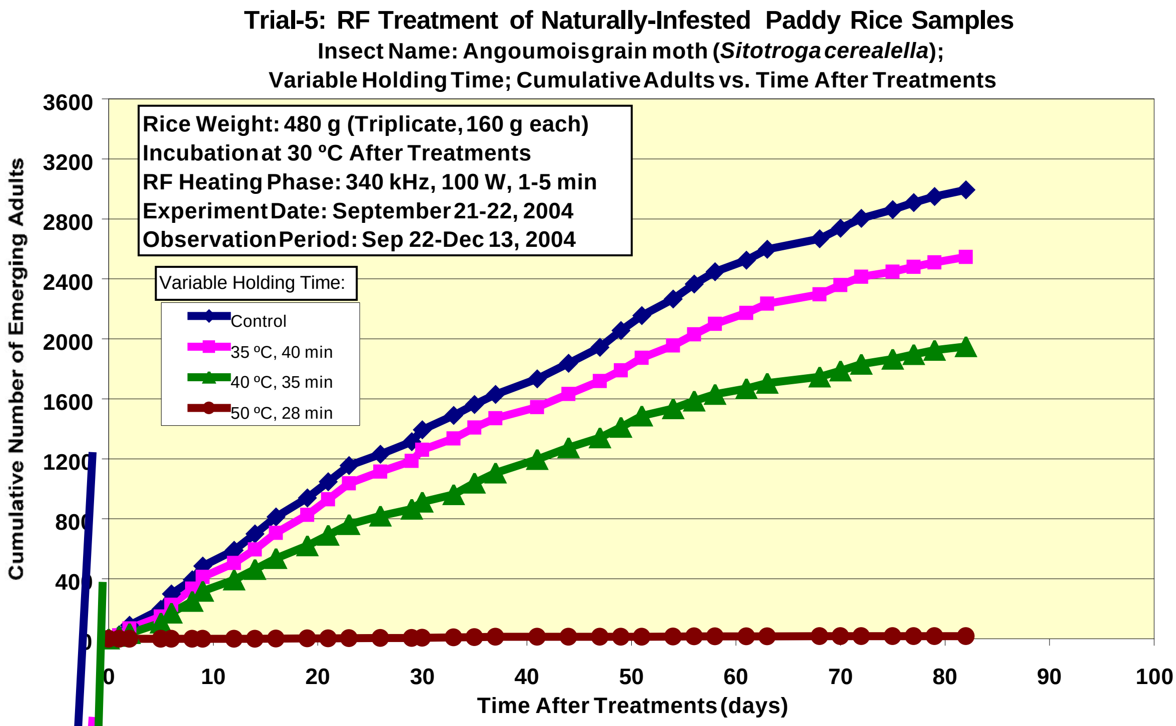

Trial-4: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (*Sitotroga cerealella*);
Variable Frequency; Cumulative Adults vs. Frequency and Temperature
Cumulative Number of Emerging Adults
Treatment Temperature (ºC)
Control
Rice Weight: 160 g
Incubation at 30 ºC After Treatments
RF Heating Phase: 100 W, 1-5 min
Holding Time: 5 min at Final Temperature
Experiment Date: August 11, 2004
Observation Period: Aug 11-Nov 19, 2004
0.336 MHz
1.01 MHz
13.18 MHz
27.18 MHz

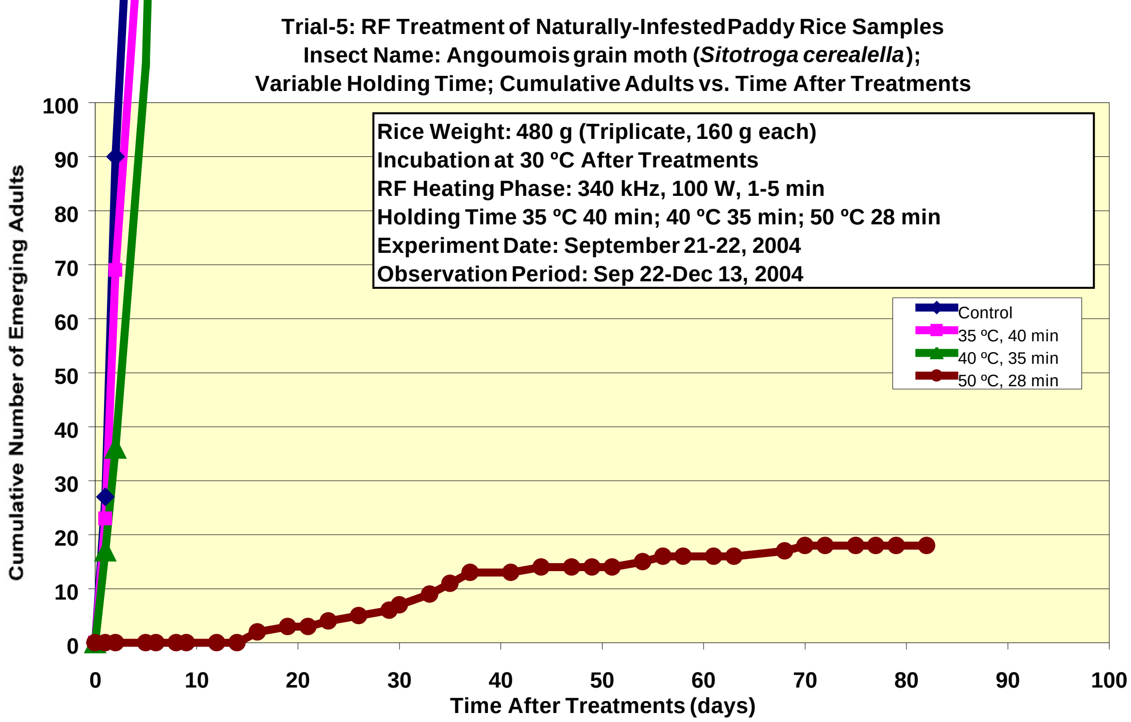

Trial-4: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (*Sitotroga cerealella*);
0.336 MHz; Cumulative Adults vs. Time After Treatments
Rice Weight: 160 g
Incubation at 30 °C After Treatments
RF Heating Phase: 0.336 MHz, 100 W, 1-9 min
Experiment Date: August 11, 2004
Observation Period: Aug 11-Nov 19, 2004
Control
35 ºC, 5 min
40 ºC, 5 min
50 ºC, 5 min
60 ºC, 5 min
70 ºC, 5 min
Cumulative Number of Emerging Adults
Time After Treatments (days)
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90
100


Trial-4: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (*Sitotroga cerealella*);
1.01 MHz; Cumulative Adults vs. Time After Treatments
Rice Weight: 160 g
Incubation at 30 °C After Treatments
RF Heating Phase: 1.01 MHz, 100 W, 1-6 min
Experiment Date: August 11, 2004
Observation Period: Aug 11-Nov 19, 2004
Control
35 ºC, 5 min
40 ºC, 5 min
50 ºC, 5 min
60 ºC, 5 min
70 ºC, 5 min
Cumulative Number of Emerging Adults
Time After Treatments (days)
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90
100


Trial-4: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (*Sitotroga cerealella*);
13.18 MHz; Cumulative Adults vs. Time After Treatments
Rice Weight: 160 g
Incubation at 30 °C After Treatments
RF Heating Phase: 13.18 MHz, 100 W, 1-4 min
Experiment Date: August 11, 2004
Observation Period: Aug 11-Nov 19, 2004
Control
35 °C, 5 min
40 °C, 5 min
50 °C, 5 min
60 °C, 5 min
70 °C, 5 min
Cumulative Number of Emerging Adults
Time After Treatments (days)


Trial-4: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (*Sitotroga cerealella*);
27.18 MHz; Cumulative Adults vs. Time After Treatments
Rice Weight: 160 g
Incubation at 30 °C After Treatments
RF Heating Phase: 27.18 MHz, 100 W, 1-4 min
Experiment Date: August 11, 2004
Observation Period: Aug 11-Nov 19, 2004
Control
35 °C, 5 min
40 °C, 5 min
50 °C, 5 min
60 °C, 5 min
70 °C, 5 min
Cumulative Number of Emerging Adults
Time After Treatments (days)


Trial-5: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (Sitotroga cerealella);
Variable Holding Time; Cumulative Adults vs. Time After Treatments
Rice Weight: 480 g (Triplicate, 160 g each)
Incubation at 30 °C After Treatments
RF Heating Phase: 340 kHz, 100 W, 1-5 min
Experiment Date: September 21-22, 2004
Observation Period: Sep 22-Dec 13, 2004
Variable Holding Time:
Control
35 °C, 40 min
40 °C, 35 min
50 °C, 28 min
Cumulative Number of Emerging Adults
Time After Treatments (days)


Trial-5: RF Treatment of Naturally-Infested Paddy Rice Samples
Insect Name: Angoumois grain moth (Sitotroga cerealella);
Variable Holding Time; Cumulative Adults vs. Time After Treatments
Rice Weight: 480 g (Triplicate, 160 g each)
Incubation at 30 °C After Treatments
RF Heating Phase: 340 kHz, 100 W, 1-5 min
Holding Time 35 °C 40 min; 40 °C 35 min; 50 °C 28 min
Experiment Date: September 21-22, 2004
Observation Period: Sep 22-Dec 13, 2004
Control
35 °C, 40 min
40 °C, 35 min
50 °C, 28 min
Cumulative Number of Emerging Adults
Time After Treatments (days)

Preliminary Feasibility Analysis of Infrared and Radio Frequency Treatments

Based on the test results, technically speaking, both infrared and radio frequency can be used for storage paddy rice disinfestation. The cost of infrared treatment is not available at present. However, since the infrared device manufacturer has produced a large-scale infrared heating device for paddy rice disinfestation for a rice processing company, it is expected that the disinfestation technology is also economically feasible. The detailed economical feasibility will be studied in the proposed research next year.

The radio frequency (RF) operation costs were estimated and the results for paddy rice appeared very promising. Preliminary experiment results indicated that the energy use efficiency of 80-90% from RF to thermal energy was practical, and the efficiency of 85-90% from AC supply to RF was reachable, so that an overall energy-use efficiency of greater than 70% could be achievable. Based on the obtained data, RF treatment of paddy rice at 60 ºC holding for 5 minutes with a throughput of 1 ton/h needed approximately 22 kW RF power, and the electricity cost was estimated to be less than $2.00/ton.

Conclusions

The research results indicated that both infrared and radio frequency could be used to disinfest storage paddy rice. The required temperature and time were 50°C for 1 min and 60°C for 5 min for infrared and radio frequency treatments, respectively. Under such treatments, no rice milling quality was affected, but infrared caused about 1% moisture loss. No significant moisture loss for the rice samples treated with radio frequency was observed under the tested conditions. Further research is needed to optimize the treatment methods and conduct detailed feasibility analysis for the development and application of the infrared and radio frequency technologies in California.

PUBLICATIONS OR REPORTS

N/A

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS

The objective of this research was to develop rapid, non-chemical, safe alternative methods to eliminate insect pests from paddy rice with retaining high rice quality. The alternative disinfestation methods are needed to replace the planned decommissioning of currently licensed pesticides. Two different thermal treatment methods, infrared and radio frequency, were evaluated for their effectiveness in eliminating insect, Angoumois grain moth (*Sitotroga cerealella*), that existed in naturally infested medium grain M202 paddy rice at moisture content about 13%. The rice samples were heated with infrared to different temperatures from 45 to 70°C and held for various times, from 1 to 10 min. The rice samples were also heated with radio frequency to various temperatures from 35 to 70°C and held for 5 to 40 min. The disinfestation effectiveness of the treatment was evaluated by observing the numbers of emerging adult insects of samples incubated under the conditions that the insects can emerge. If no live adult insects were observed after two insect life cycles (about 42 days), the treatment method and conditions were considered as effective. The moisture losses of treated rice samples were determined. The milling quality of rice samples treated with selected conditions was determined following the standard the FGIS method at the CDFA lab. The total rice yield, head rice yield, and whiteness were reported.

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Acknowledgement

The investigators would like to express their appreciation for the great support received from the following personnel at UC Davis, CDFA and FGIS for the project.

Sanath Amaratunga
Chuck Britton
Homer Formentera
Michael Johnson
Sandra Newell
Dale Rice
Xianzhe Zheng