

**EVALUATION OF *BEAUVERIA BASSIANA* AND HOST PLANT RESISTANCE
FOR THE MANAGEMENT OF RICE STINK BUG IN RICE AGRO-
ECOSYSTEM**

A Thesis

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ABSTRACT

Isolates of *Beauveria bassiana* (Balsamo) Vuillemin were tested for biological control of rice stink bug, *Oebalus pugnax* (Fab.), in the laboratory, in small-plot field experiments compared with conventional insecticides, and in a large-plot experiment to determine the spread and persistence of the fungus. The soil-derived isolate LRC28 was more virulent to *O. pugnax* adults than the rice stink bug-derived isolate RSB in a laboratory experiment. The fungal isolates did not differ from one another in reducing insect numbers or in infecting rice stink bugs in the small-plot experiments. A single application of *B. bassiana* reduced rice stink bug nymphs on six of nine sampling dates and adults on two of nine sampling dates from two to 10 days after application, and prevalence of the fungus was higher in the *B. bassiana* treatment than in controls for nymphs on four dates versus none for adults. Mixtures of *B. bassiana* and insecticide provided better control of rice stink bug than a single application of either material alone. Fungal epizootics lasted 17-22 days after application. High temperatures probably were the major factor limiting *B. bassiana* epizootics. Thus, *B. bassiana* has potential for integrated management programs of *O. pugnax* in rice, since it was moderately effective against nymphs and had an additive effect with insecticides.

Greenhouse experiments were conducted to evaluate the effects of panicle age and grain maturity on quantitative and qualitative damage caused by stink bug infestations on rice. The effects were measured for two infestation levels (one and two bugs per panicle). Insect feeding during anthesis and the early milk stage of grain development caused substantially higher numbers of empty kernels than feeding during later grain development and the control. Average grain weights were lower in infestations during

anthesis and milk stage than in infestations during later grain development and the control. Pecky rice was significantly higher during late milk and soft dough stages compared with remaining stages of grain development and the control. Damage was higher in the experiment in which panicles were infested with two bugs.

CHAPTER 1

INTRODUCTION

Rice is one of the three leading food crops in the world and provides 20% of the energy and 15% of the protein consumed by humans. It is a staple food for two-thirds of the world's population. It is grown on approximately 150 million ha in more than 50 countries in Asia, North and South America, Europe, Australia, and Africa (Int. Rice Res. Inst. 1997a). The United States is the second largest exporter of rice and accounts for 18% of the internationally traded rice (Int. Rice Res. Inst. 1997b).

Rice stink bug (Hemiptera: Pentatomidae), *Oebalus pugnax* (Fab.), is one of the most injurious pests of rice in the southern United States (Swanson and Newsom 1962). It is common in the United States east of the Rocky Mountains and as far north as Minnesota and New York (Sailer 1944). It is attracted to rice during reproductive phases of growth, particularly during grain development (McPherson and McPherson 2000). Both adults and nymphs feed on the developing grain (Bowling 1967, Douglas and Ingram 1942). Feeding results in yield losses and/or reduced grain quality (Smith et al. 1986, Swanson and Newsom 1962). The entire contents of the rice grain may be removed during the milk stage, resulting in false grains (Bowling 1967, Odglen and Warren 1962, Texas Agric. Ext. Serv. 1997), or a portion of the content may be sucked out, resulting in atrophied grains (Bowling 1967). Feeding during soft and hard dough stages leaves a chalky discolored area around the feeding site and rice so affected is called *pecky rice*. Fungi often enter the punctures made by rice stink bug (Lee et al. 1993, Johnson et al. 1987). Pecky rice easily breaks during milling, lowering the percentage of whole kernels and, thus, the market value of the product (Odglen and Warren 1962). If pecky rice does

not break during milling, it will appear in head rice, resulting in inferior quality of rice (Bowling 1967). For a brown rice sample to qualify as US #1 or US #2, it should contain no more than 1 or 2% pecky rice, respectively (Fryer et al. 1986). Feeding also results in losses due to empty florets and reduced viability of the grain (Odglen and Warren 1962).

Little effort has been made to develop nonchemical controls for *O. pugnax* for several reasons, including the short period of host plant vulnerability (heading to harvest, which is approximately 30 days for most varieties), the high mobility of the bug, the low economic threshold densities, and the relatively low cost of chemical controls (Way 1990). Several of the standard materials used for controlling stink bugs have been removed from the market place or are pending removal, due to label revision or cancellation because of environmental and human safety concerns or costs of the registration process (Todd et al. 1994). Chemicals can also have a negative effect on arthropod parasitoids and predators and lead to the resurgence of other arthropod pests because of the reduction in the number of the natural enemies. Drees and Plapp (1986) mentioned a possible case of insecticide resistance in *O. pugnax* in two counties in Texas. Concerns about these negative effects of chemical insecticides have led to emphasis on alternative strategies for pest control. Biological control and host plant resistance can be considered as alternatives to overcome the negative effects of insecticides.

Biological control is generally perceived as providing both long-lasting insect control and having less potential for damage to the environment or non-target organisms than chemical interventions (Grace 1997, Hokkanen and Lynch 1995, Howarth 1991, Khetan 2001). There is worldwide interest in the use of entomopathogenic fungi as biological control agents, and a significant advance in development and manufacturing of these

agents in the future is expected with recent biotechnological innovations (Khachatourians 1986). Entomopathogenic fungi are promising for control of sucking insects (Fuxa 1987). Their spreading capacity and natural epizootics are attractive features. There are over 700 species of entomopathogenic fungi (Roberts et al. 1991); of these, *Beauveria bassiana* (Balsamo) Vuillemin has been studied most extensively since it was first reported as a pathogen of the silkworm, *Bombyx mori* L., by Agostino Bassi in 1834 (Feng et al. 1994). It is a common, soil-borne entomopathogenic fungus that occurs worldwide (Fuxa and Kunimi 1997, McCoy et al. 1988). Among many entomogenous fungi, *B. bassiana* is potentially the most useful in stink bug control. The primary reasons for interest in this fungus (Fuxa 1987) include its portal of entry by contact instead of ingestion, wide host range, replication in target insects (Ferron 1978, Roberts and Humber 1981), safety to non-target organisms (Hokkanen and Lynch 1995), in vitro mass-culture (Jackson et al. 2000), numerous strains (St. Leger et al. 1992), and commercial availability (Jaronski 1997).

B. bassiana naturally infects rice stink bug in rice (Patel, Fuxa, and Stout unpublished data) and other stink bugs (Moscardi et al. 1988) but is not known to cause natural epizootics in pentatomids. One potential problem with *B. bassiana* is that this fungus generally does not grow well at temperatures up to 30-35⁰C (Fargues et al. 1997), which are common in North America rice fields. Infections of certain species of stink bugs by *B. bassiana* have been investigated under laboratory (Moscardi et al. 1985, Sosa-Gomez et al. 1997) or field conditions (Sosa-Gomez and Moscardi 1998), but the potential of this fungus for microbial control of rice stink bug has not been studied. Also, little is known about the spread and persistence of this fungus after its application in the field. It has a

wide host range, so its infection of other host insects, such as grasshoppers and hemipterans in rice, might contribute to epizootics in rice stink bug. It is not known whether *B. bassiana* can control rice stink bugs under the environmental conditions in the Louisiana agroecosystem. Capability of *B. bassiana* for season long control in the rice fields of Louisiana was examined in this research. This information might prove useful to improve the present management techniques for these bugs.

Host plant resistance is considered to be an important part of many integrated pest management programs. Resistance and tolerance of rice to stink bug damage are affected by panicle age and grain maturity. Previous studies by several authors (Bowling 1963, Douglas and Tullis 1950, Johnson et al. 1987, Odglen and Warren 1962, Robinson et al. 1980, Swanson and Newsom 1962) suggest that different stages of grain development vary in their levels of tolerance and resistance to rice stink bug damage. However, all these studies were conducted in the field where parasites (Bowling 1963) and/or pathogens, as well as weeds (Tindall 2004), might have influenced their results. Also, none of these studies examined damage specifically to each infested panicle. Obviously, tolerance and resistance of different stages of grain development to rice stink bug damage to rice panicles must to be evaluated in a controlled environment. This information might prove useful to refine the current economic threshold levels for rice stink bug in rice.

The specific purposes of this research were as follows:

Biological Control

1. To compare the virulence of *B. bassiana* isolates to *O. pugnax*;
2. To determine efficacy of *B. bassiana* against *O. pugnax* nymphs and adults in field tests;

3. To determine whether combinations of insecticides and *B. bassiana* isolates were more effective against *O. pugnax* than the separate materials;
4. To determine the spread and persistence of *B. bassiana* after its release in the field;

Host Plant Resistance

5. To evaluate the effects of panicle age and grain maturity on the quantitative and qualitative damage caused by *O. pugnax* feeding on rice panicles in a controlled environment;
6. To evaluate the effect of *O. pugnax* damage on germination of rice seeds.

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CHAPTER 2

EVALUATION OF *BEAUVERIA BASSIANA* FOR CONTROL OF *OEBALUS PUGNAX* (HEMIPTERA: PENTATOMIDAE) IN RICE

Introduction

The rice stink bug, *Oebalus pugnax* (Fab.), is a major pest of rice in the southern United States (Swanson and Newsom 1962, McPherson and McPherson 2000). This pest feeds on plant reproductive structures such as flowers and developing seeds (McPherson and McPherson 2000). Management to reduce *O. pugnax* numbers is essential since even moderate populations can inflict severe damage in yield as well as quality of rice (Bowling 1967; Patel, Stout, and Fuxa unpublished data; Swanson and Newsom 1962). Current *O. pugnax* management programs rely on broad-spectrum chemical insecticides and management is becoming increasingly difficult due to restrictions on use of some materials and environmental or human safety concerns (Todd et al. 1994). Resistance of *O. pugnax* to insecticides has been reported in Texas (Drees and Plapp 1986).

The use of fungi as biological agents against *O. pugnax* is a promising alternative to chemical control. Among many entomogenous fungi, *Beauveria bassiana* (Balsamo) Vuillemin is potentially the most useful in stink bug control. The primary reasons for interest in this fungus (Fuxa 1987) include its portal of entry by contact instead of ingestion, wide host range, replication in target insects (Ferron 1978, Roberts and Humber 1981), safety to non-target organisms (Hokkanen and Lynch 1995), in vitro mass-culture (Jackson et al. 2000), numerous strains (St. Leger et al. 1992), and commercial availability (Jaronski 1997). It is a common, soil-borne entomopathogenic fungus that occurs worldwide (Fuxa and Kunimi 1997, McCoy et al. 1988). It naturally infects *O. pugnax* (Patel, Fuxa, and Stout unpublished data) and other stink bugs

(Moscardi et al. 1988) but is not known to cause natural epizootics in pentatomids. One potential problem with *B. bassiana* is that this fungus generally does not grow well at temperatures up to 30-35⁰C (Fargues et al. 1997), which are common in North America rice fields. Infections of certain species of stink bugs by *B. bassiana* have been investigated under laboratory (Moscardi et al. 1985, Sosa-Gomez et al. 1997) or field conditions (Sosa-Gomez and Moscardi 1998), but the potential of this fungus for microbial control of *O. pugnax* has not been studied. Also, little is known about the spread and persistence of this fungus after its application in the field.

The purposes of the current study were: (1) to compare the virulence of *B. bassiana* isolates to *O. pugnax*; (2) to determine its efficacy against rice stink bug nymphs and adults in field tests; (3) to determine whether combinations of insecticides and *B. bassiana* isolates were more effective against *O. pugnax* than the separate materials; and (4) to determine the spread and persistence of *B. bassiana* after its release in the field.

Materials and Methods

Virulence Bioassay

Isolates of *B. bassiana* were selected for the experiments based on their tendency to sporulate on Sabouraud dextrose agar + yeast (SDAY) (Becton, Dickinson & Co., Sparks, MD) at high temperatures (30 to 35 °C). Isolates LRC21 and LRC28 were provided by the Lethbridge Research Center, Alberta, Canada. LRC21 was isolated from soil from Alberta, and LRC28 was isolated from soil in Bam/Burkino Faso. LRC21 and LRC28 were used in our experiments because they exhibited the greatest growth at high temperatures among *B. bassiana* isolates in a previous study (Fargues et al. 1997). Isolate

RSB originated from a rice stink bug collected from rice field of Crowley, Louisiana in 2001.

The bioassay techniques were adapted from those of Sun et al. (2002). The fungi were grown on SDAY at 27 °C. Conidia were harvested under sterile conditions by flooding the plate with 10 ml sterile distilled H₂O and then scraping the colony with sterile forceps. Conidia were stirred into suspension for 25 min in 300 ml 0.05% Triton X-100 and distilled H₂O, and the suspension was filtered through sterile cheesecloth to remove debris. Conidial concentrations were ascertained with a hemocytometer under a compound microscope. All suspensions were stored at 4 °C until used in assays.

Rice stink bugs were collected from rice fields near Crowley, Louisiana. Collected bugs were maintained on cut panicles of barnyard grass, *Echinochloa* spp., in a glass aquarium in the laboratory for at least two days before being used in assays. For the bioassay, rice stink bugs in batches of 15 or 20 in a Petri dish were anesthetized by refrigerating them at 4 °C for 5 minutes. Petri dishes with rice stink bugs were then shifted to a cold plate (Tissue Tek[®] II, Miles Inc. Diagnostics Division, Elkhart, IN), and 2 µl of conidial suspension was applied to the intersegmental region on the ventral surface of the abdomen of each bug with a micropipetter (P100, Eppendorf Inc., Hamburg, Germany). The bioassay of each fungal isolate included six fungal doses plus a control. The range of doses (4×10^2 , 4×10^3 , 4×10^4 , 4×10^5 , 4×10^6 , and 4×10^7 conidia/bug) was determined in a preliminary test. The experiment had three replications over time; two replications of 15 insects and one replication of 20 insects were treated with each dose, and 0.05% Triton X-100 in distilled water served as the control. Inoculated bugs were transferred to a cut panicle of barnyard grass, *Echinochloa* spp., in

an assay cell, one bug per cell. Each assay cell consisted of a 30-ml cup (UR1[®], Sweetheart Cup Co. Inc., Owing Mills, MI) with two pieces of wet filter paper (Whatman #1, diam 30 mm), on which three pieces of 2-3 cm sections of panicles of barnyard grass were provided as food. The assay cells were closed with transparent lids (LUR1[®], Sweetheart Cup Co. Inc., Owing Mills, MI) and maintained at room temperature and 16 h of daily illumination. The wet filter paper maintained the humidity within each cell at or near saturation. Food was changed every other day. The insects were examined daily for 12 days. Percentage mortality was calculated as the number of stink bugs that grew *B. bassiana* mycelium and conidia divided by the number of individuals treated.

Small-Plot Field Experiments

Experiments were conducted at the Louisiana State University AgCenter Rice Research Station at Crowley, Louisiana, during the summers of 2001, 2002, and 2003. The soil type was a silt loam (fine, montmorillonitic). The experimental design was a randomized complete block with four replications in 2001 and 2003 and five replications in 2002. Table 2.1 provides dates of agronomic practices and data collection. All seeds were treated with Icon[®] (Fipronil, Bayer CropScience, Monheim, Germany) to control rice water weevils. The total nitrogen fertilization rate was 120 kg/ha, with the majority of fertilizer applied before flooding. Other agronomic practices used were typical of those used in southwest Louisiana. Each plot measured 1.2 x 6.1 m in all years (7 rows at 0.17 m spacing). A buffer of at least 3.1 m was established between adjacent plots within each

Table 2.1 Dates of selected agronomic practices and sampling during the 2001, 2002, and 2003 field tests

Practice	2001	2002	2003
Planting (drill-seeding)	10-Apr.	8-May	22-Apr.
Permanent flood	22-May	31-May	21-May
Application of treatments	23-Jul.	5-Aug.	21-Jul.
Sampling*	2, 4, 8, 16, and 22	2, 7, 11, and 17	2, 4, 8, 10, 14 and 18

*days post-application.

Table 2.2 Treatments and rates in the 2001, 2002, and 2003 field tests

2001			2002			2003		
Treatment*	Group**	Rate [†]	Treatment*	Group**	Rate [†]	Treatment*	Group**	Rate [†]
Fury®	I	9.52	Fury®	I	8.16	Mustang Max®	I	11.34
Karate®	I	11.34	Karate®	I	13.61	Prolex®	I	9.07
LRC21	F	5.3 X 10 ¹²	LRC28	F	5.0 X 10 ¹²	Karate®	I	18.14
LRC28	F	5.3 X 10 ¹²	RSB	F	5.0 X 10 ¹²	Karate® (twice)	T	18.14
RSB	F	5.3 X 10 ¹²	Karate® + LRC28	M	13.61 +	LRC28	F	5.7 X 10 ¹²
Control	C	--			5.0 X 10 ¹²	LKLRC [‡]	M	9.07 +
			LKLRC [‡]	M	9.07 +			5.7 X 10 ¹²
					5.0 X 10 ¹²	Control	C	--
			Control	C	--			

* Fury® (Zeta-Cypermethrin, FMC Corp.), Karate® (lambda cyhalothrin, Syngenta), Mustang Max® (Zeta-Cypermethrin, FMC Corp.), Prolex® (Gamma cyhalothrin, Dow AgroSci.), LRC21, LRC28, RSB: isolates of *B. bassiana* (see text).

** Groups of treatments used for statistical analysis. I = insecticide; F = fungal isolate; M = insecticide plus fungal isolate; T = insecticides applied twice, the second application made a week after the application dates mentioned in Table 2.1; and C = control.

[†] Rates of treatments; AI/ha for Insecticides and conidia/ha for fungal isolates.

[‡] Reduced rate of Karate® + LRC28.

replication and 3.7 m between replications. Table 2.2 provides a list of treatments and application rates.

The plots were treated when rice headed (ca. 75% panicle emergence) and rice stink bugs were found in the plots. Treatments were applied in the evening to reduce exposure of *B. bassiana* conidia to the sun and to provide the spores with the high nighttime humidity. Applications were made with a CO₂ backpack sprayer at 2.3 kg/cm² and a flat fan Teejet 8002VS nozzle. Conidia were suspended in 1% v/v water/peanut oil; no adjuvant was used with insecticides.

Rice stink bugs were sampled with a sweep net (38 cm in diameter), 10 sweeps per plot per sampling date. Collected insects were placed individually in 30 ml cups and returned to the laboratory, where they were reared. A wet filter paper (Whatman #1, diam 30 mm) was placed in the diet cups to maintain high humidity. Cut panicles of barnyard grass were provided as food every second day. The cups were maintained at 27 °C, 14:10 L:D. Mortality was observed every alternate day. Dead individuals were moved to multiwell cell culture plates (BD Falcon, BD Biosciences, Franklin Lakes, NJ), which were wrapped in wet paper towels and placed in a closed plastic container to facilitate fungal growth by providing high humidity. The plates were maintained at 27 °C. The insects were recorded as killed by *B. bassiana* if the cadavers exhibited external growth of the fungus within 12 days.

Large-Plot Spread Experiment

The spread of *B. bassiana* released in rice fields at the Louisiana State University AgCenter Rice Research Station (Crowley, LA) was evaluated during the summer of 2003. The isolate LRC28 was chosen for this study because it performed well in the

small-plot field experiments. The experiment was replicated twice at an interval of 27 days, because rice was planted on different dates in the fields being used for these two replications, which in turn affected the time of panicle emergence and rice stink bug infestation. Each replication included a 4.6 m x 4.6 m treatment plot, which was treated with *B. bassiana* at a rate of 5.6×10^{12} conidia/ha immediately after the appearance of rice stink bugs. The fungus-treated plot was in the center of an untreated, 28 m x 28 m plot for monitoring fungal spread. The 20 m x 20 m control plot was 110 m from the fungus-treated plot and was not treated with *B. bassiana*. Sites for sampling fungus spread were established in the four cardinal directions at 4.6 m and 9.1 m from the treated plot. Sampling dates were 1, 5, 9, 13, 18, and 23 days after treatment.

Rice stink bugs, grasshoppers, and lygus bugs were sampled on every date from all of the spread-sampling sites, the treated plot, and the control plot. Each sample consisted of 10 sweeps per site with a sweep net (38 cm diameter). One random sample was collected within the treated plot; four random samples were collected from the control plot; and one sample was collected at each spread sample-site.

Throughout the experiment, precautions were taken to minimize the chances of samplers contributing to fungal spread. Foot traffic in the fields was limited to that of the samplers. The samplers always walked from sites least likely to have fungus (e.g., open spaces in the field and spread-sampling sites most distant from treated plots) to sample sites with increasing chance of having infected insects. Samplers always exited the field along the same path, in one direction away from fungal-treated plots. Sweep nets were changed frequently during each sampling date to prevent contamination to uninfected insects.

The collected insects were maintained and mycoses determined in the laboratory with the same procedures described for the small-plot field experiments.

Data Analysis

The bioassay data were subjected to probit analysis (PROC PROBIT, SAS Institute 1996) after correction for control mortality with Abbot's formula (Abbot 1925). The mortality data from the three replicates for each dosage were combined into one data point for this analysis.

Within each year of the small-plot experiments, a mixed-model, split-plot repeated measures analysis was used to test the effect of treatments on numbers of adults, nymphs, or total rice stink bugs. The data were analyzed by PROC MIXED of SAS (Littell et al. 1996), with block (replicate) as a random effect, treatment as fixed effect, and sampling date (days post application) as a repeated measure. Treatments were grouped (Table 2.2): I, insecticides applied once; F, fungal isolates applied once; M, combined insecticides and fungal isolates applied once; T, insecticides applied twice; C, untreated. Treatments nested within these groups (Table 2.2) were analyzed for differences. If they were not significantly different, then inferences were made about the groups instead of individual treatments. The slice statement of SAS was used to detect significant differences by days post application for interactions of days and groups of treatments. Means within groups of treatments were separated by the Fisher's protected LSD test (Milliken and Johnson, 1984).

Within each year, data on mortality of rice stink bug by *B. bassiana* were subjected to logistic regression analysis by PROC LOGISTIC (SAS Institute 1996) to determine the effects of treatments (isolates of *B. bassiana*), days post application, and treatment-by-

days post-application interaction. A backward elimination method was used for model building. When no adults or nymphs were present, a value of 0.0001 was used for purposes of analysis. Untransformed values for the means and standard errors of the means (SE) are presented in the tables. Mean mortality rates were separated by Fisher's protected LSD test (Milliken and Johnson, 1984).

Mortality data from the large-plot spread experiments were subjected to logistic regression analysis by PROC LOGISTIC (SAS Institute 1996) to determine the effects of species, day post application, distance, and direction from the fungus-treated plot on fungus prevalence. In a preliminary analysis, data inside the fungus-treated plot (distance = 0) were eliminated to determine whether compass direction influenced fungal spread. A backward elimination method was used for model building. Direction was not significant and was therefore removed from the final model. Further analysis was performed on the entire data set, including the treated plot.

Results

Virulence Bioassay

Table 2.3 summarizes the LD₅₀ parameters from the virulence bioassays, which indicated that both the isolate LRC28 and the isolate RSB were virulent to rice stink bug. Fiducial limits (95%) did not overlap, indicating that the LD₅₀s (median lethal doses) for these two isolates were different. Isolate LRC28 was more virulent than isolate RSB. No mortality attributable to *B. bassiana* infection occurred in the control, and total mean control mortality was 9%.

Table 2.3 Log-dose-probit parameters for isolates of *B. bassiana* against rice stink bug

Fungal Isolate*	Slope \pm SE	LD ₅₀ (95% FL) [†] (conidia x 10 ⁵ per insect)	χ^2 ‡
LRC 28	0.62 \pm 0.06	0.42 (0.21 - 0.80)	5.95
RSB	0.59 \pm 0.06	1.93 (1.01 - 3.80)	9.77

* Observed mortalities for each isolate were corrected with Abbot's (1925) formula.

[†] Fiducial limits.

[‡] Heterogeneity about regression (df = 16); table entries were not significant at $\alpha = 0.05$.

Small-Plot Field Experiments

Treatments within each group did not differ in their effects on numbers of nymphs or adults or total rice stink bugs, whereas groups of treatments and time (days post application) significantly affected the numbers (Table 2.4). There were significant interactions between treatment groups and days post application.

In 2001, applications of *B. bassiana* significantly reduced densities of rice stink bugs, but the effect was not as strong as insecticides (Table 2.5). The insecticide- and fungus-treated plots were infested with significantly lower numbers of nymphs than in control plots through day eight post application. There were more bugs of all stages in the *B. bassiana*-treated plots than in the insecticide-treated plots through day four, but these numbers were not significantly different afterward. Adults, nymphs, and total rice stink bugs were reduced by at least 50% in *B. bassiana* plots compared with control plots on day eight. The proportion of nymphs to adults in the fungus-treated plots was 0.41 on day two, 0.36 on day four, 0.38 on day eight, 0.51 on day 16, and 0.38 on day 22.

In 2002, a combined insecticide/*B. bassiana* treatment at times was more effective than individual applications of insecticides or *B. bassiana* in reducing numbers of rice stink bugs (Table 2.6). Plots treated with insecticide plus *B. bassiana* had significantly fewer bugs of all stages than in the control and *B. bassiana*-treated plots through day seven. Insecticide-treated plots were infested with fewer bugs of all stages than in *B. bassiana* treated plots on day two. These numbers were not significantly different afterwards except that the *B. bassiana* plots and insecticide plus *B. bassiana* treated plots were infested with fewer adults or total rice stink bugs than the insecticide-only plots on day seventeen. *B. bassiana* plots had fewer nymphs (day two) and adults or total rice

Table 2.4 Analysis of variance for numbers of rice stink bugs as dependent variable in small-plot field experiments, 2001-2003

Year	Tested effects*	df	Nymphs		Adults		Total RSB	
			F	<i>P</i> > F	F	<i>P</i> > F	F	<i>P</i> > F
2001	Group**	2, 6	22.64	0.0016	28.30	0.0009	74.65	< 0.0001
	Treatment (Group)†	3, 9	1.83	0.2119	1.65	0.2470	1.85	0.2084
	Time‡	4, 72	11.21	< 0.0001	7.16	< 0.0001	19.56	< 0.0001
	Group x Time	8, 72	6.06	< 0.0001	7.61	< 0.0001	17.35	< 0.0001
	Treatment (Group) x Time	12, 72	1.08	0.3897	0.76	0.6933	1.60	0.1116
	Group**	3, 12	19.45	< 0.0001	6.05	0.0095	22.18	< 0.0001
	Treatment (Group)†	3, 12	1.97	0.1717	3.24	0.0602	0.86	0.4876
	Time‡	3, 84	15.14	< 0.0001	14.20	< 0.0001	14.09	< 0.0001
2002	Group x Time	9, 84	11.78	< 0.0001	5.44	< 0.0001	8.49	< 0.0001
	Treatment (Group) x Time	9, 84	0.70	0.7090	1.99	0.1660	0.85	0.5739
	Group**	4, 6	23.50	0.0008	3.07	0.1068	35.25	0.0003
	Treatment (Group)†	2, 6	1.95	0.2225	1.24	0.3550	0.66	0.5515
	Time‡	5, 105	0.56	0.7299	1.05	0.3919	2.20	0.0601
2003	Group x Time	20, 105	1.95	0.0156	0.92	0.5633	3.95	< 0.0001
	Treatment (Group) x Time	10, 105	1.11	0.3598	2.00	0.0405	0.50	0.8840

* Effects were tested by repeated measures analysis in PROC MIXED of SAS (Littell et al. 1996) of data in Tables 2.5, 2.6, and 2.7. Analysis was performed separately for adults, nymphs, or total rice stink bugs for each year.

** Test for differences between groups; groups of treatments are shown in Table 2.2.

† Test for differences among treatments within each group.

‡ Sampling dates (days post application).

Table 2.5 Mean number (\pm SE) of rice stink bugs in the 2001 small-plot field experiment

Days post application	Treatment* [†]	Nymphs	Adults	Total RSB
2	Insecticide	1.1 \pm 0.2 c	1.0 \pm 0.3 b	2.1 \pm 0.6 b
	<i>B. bassiana</i>	4.3 \pm 0.3 b	6.3 \pm 0.7 a	10.6 \pm 0.7 a
	Control	5.8 \pm 0.9a	6.3 \pm 1.3 a	12.0 \pm 0.7 a
	F	34.33	29.93	86.09
	<i>P</i>	< 0.0001	< 0.0001	< 0.0001
4	Insecticide	1.3 \pm 0.2 c	0.9 \pm 0.4 b	2.1 \pm 0.4 b
	<i>B. bassiana</i>	2.8 \pm 0.4 b	5.0 \pm 0.7 a	7.8 \pm 0.5 a
	Control	4.0 \pm 0.4 a	5.0 \pm 0.6 a	9.0 \pm 0.9 a
	F	10.53	18.48	39.50
	<i>P</i>	< 0.0001	< 0.0001	< 0.0001
8	Insecticide	1.4 \pm 0.4 b	1.4 \pm 0.3 b	2.8 \pm 0.5 b
	<i>B. bassiana</i>	1.5 \pm 0.2 b	2.4 \pm 0.4 b	3.9 \pm 0.3 b
	Control	3.0 \pm 0.0 a	5.5 \pm 0.9 a	8.5 \pm 0.9 a
	F	3.95	9.38	18.91
	<i>P</i>	0.0236	0.0002	< 0.0001
16	Insecticide	3.0 \pm 0.2 a	2.8 \pm 0.5 a	5.8 \pm 0.5 a
	<i>B. bassiana</i>	2.8 \pm 0.4 a	2.7 \pm 0.3 a	5.4 \pm 0.5 a
	Control	3.8 \pm 0.9 a	3.8 \pm 0.8 a	7.5 \pm 1.55 a
	F	1.44	0.76	2.72
	<i>P</i>	0.2447	0.4737	0.0723
22	Insecticide	2.8 \pm 0.3 a	5.1 \pm 0.4 a	7.9 \pm 0.2 a
	<i>B. bassiana</i>	3.0 \pm 0.2 a	4.9 \pm 0.4 a	7.9 \pm 0.3 a
	Control	4.3 \pm 0.9 a	4.5 \pm 0.5 a	8.8 \pm 0.5 a
	F	3.11	0.21	0.50
	<i>P</i>	0.0505	0.8094	0.6091

* Analysis of variance, repeated measures, in PROC MIXED with the slice statement of SAS (df = 2, 72 in every ANOVA). Means in each column within each day post application followed by the same letter did not differ at $\alpha = 0.05$ (Fisher's protected LSD test).

[†] Groups of treatments (Table 2.2) were used for inferences because treatments within each group were not significantly different ($P > 0.05$, Table 2.4).

Table 2.6 Mean number (\pm SE) of rice stink bugs in the 2002 small-plot field experiment

Days post application	Treatment* [†]	Nymphs	Adults	Total RSB
2	Insecticide (INS)	0.2 \pm 0.2 c	0.7 \pm 0.3 b	0.9 \pm 0.4 b
	INS + <i>Bb</i>	1.3 \pm 0.4 c	1.2 \pm 0.3 b	2.5 \pm 0.6 b
	<i>B. bassiana</i> (<i>Bb</i>)	7.3 \pm 1.6 b	2.6 \pm 0.3 a	9.9 \pm 1.6 a
	Control	9.4 \pm 1.2 a	2.8 \pm 0.9 a	12.2 \pm 1.4 a
	F	42.33	5.99	42.45
	P	< 0.0001	0.0010	< 0.0001
7	Insecticide (INS)	1.4 \pm 0.8 b	0.8 \pm 0.3 bc	2.2 \pm 0.7 bc
	INS + <i>Bb</i>	0.4 \pm 0.2 b	0.6 \pm 0.2 c	1.0 \pm 0.2 c
	<i>B. bassiana</i> (<i>Bb</i>)	2.5 \pm 0.4 ab	1.8 \pm 0.2 b	4.3 \pm 0.4 b
	Control	4.4 \pm 1.2 a	3.4 \pm 0.5 a	7.8 \pm 1.2 a
	F	5.40	7.27	10.72
	P	0.0019	0.0002	< 0.0001
11	Insecticide (INS)	1.1 \pm 0.2 a	1.5 \pm 0.2 a	2.6 \pm 0.2 a
	INS + <i>Bb</i>	0.9 \pm 0.2 a	1.6 \pm 0.3 a	2.5 \pm 0.4 a
	<i>B. bassiana</i> (<i>Bb</i>)	1.4 \pm 0.2 a	1.4 \pm 0.2 a	2.8 \pm 0.1 a
	Control	2.6 \pm 0.7 a	2 \pm 0.3 a	4.6 \pm 0.9 a
	F	0.95	0.29	1.07
	P	0.4189	0.8295	0.3681
17	Insecticide (INS)	2.2 \pm 0.6 a	4.6 \pm 0.8 a	6.8 \pm 1.1 a
	INS + <i>Bb</i>	2.0 \pm 0.3 a	2.0 \pm 0.5 c	4.0 \pm 0.5 c
	<i>B. bassiana</i> (<i>Bb</i>)	2.1 \pm 0.2 a	2.5 \pm 0.4 bc	4.6 \pm 0.6 bc
	Control	3.2 \pm 0.6 a	3.4 \pm 0.7 ab	6.6 \pm 1.1 ab
	F	0.49	8.57	3.05
	P	0.6899	< 0.0001	0.0329

* Analysis of variance, repeated measures, in PROC MIXED with the slice statement of SAS (df = 3, 84 in every ANOVA). Means in each column within each day post application followed by the same letter did not differ at $\alpha = 0.05$ (Fisher's protected LSD test).

[†] Groups of treatments (Table 2.2) were used for inferences because treatments within each group were not significantly different ($P > 0.05$, Table 2.4).

Table 2.7 Mean number (\pm SE) of rice stink bugs in the 2003 small-plot field experiment

Days post application	Treatment*†	Nymphs	Adults	Total RSB
2	Insecticide (INS)	0.6 \pm 0.2 b	1.2 \pm 0.3 b	1.7 \pm 0.4 b
	Insecticide (twice)	0.2 \pm 0.2 b	1.7 \pm 1.1 ab	2.0 \pm 1.4 b
	INS + <i>Bb</i>	0.0 \pm 0.0 b	2.0 \pm 0.4 ab	2.0 \pm 0.4 b
	<i>B. bassiana</i> (<i>Bb</i>)	3.0 \pm 0.6 a	2.5 \pm 0.5 ab	5.5 \pm 0.5 a
	Control	3.2 \pm 0.6 a	3.5 \pm 0.9 a	6.7 \pm 1.1 a
	F	14.50	2.43	9.86
	<i>P</i>	< 0.0001	0.0524	0.0001
4	Insecticide (INS)	0.1 \pm 0.1 b	2.3 \pm 0.5 a	2.4 \pm 0.5 c
	Insecticide (twice)	0.2 \pm 0.2 b	2.5 \pm 0.5 a	2.7 \pm 0.6 bc
	INS + <i>Bb</i>	0.0 \pm 0.0 b	2.2 \pm 0.5 a	2.2 \pm 0.5 c
	<i>B. bassiana</i> (<i>Bb</i>)	2.2 \pm 0.2 a	2.7 \pm 1.1 a	5.0 \pm 1.0 a
	Control	2.7 \pm 0.6 a	2.7 \pm 0.2 a	5.5 \pm 0.5 a
	F	11.14	0.14	4.19
	<i>P</i>	< 0.0001	0.9673	0.0035
8	Insecticide (INS)	0.2 \pm 0.1 c	1.7 \pm 0.6 a	1.9 \pm 0.6 c
	Insecticide (twice)	0.0 \pm 0.0 c	1.2 \pm 0.5 a	1.2 \pm 0.5 c
	INS + <i>Bb</i>	0.0 \pm 0.0 c	1.7 \pm 0.5 a	1.7 \pm 0.5 c
	<i>B. bassiana</i> (<i>Bb</i>)	1.7 \pm 0.2 b	2.2 \pm 0.9 a	4.0 \pm 0.8 b
	Control	3.5 \pm 0.6 a	3 \pm 0.7 a	6.5 \pm 1.3 a
	F	14.17	0.98	7.66
	<i>P</i>	< 0.0001	0.4230	< 0.0001
10	Insecticide (INS)	0.0 \pm 0.0 c	2.7 \pm 0.7 a	2.7 \pm 0.7 b
	Insecticide (twice)	0.0 \pm 0.0 c	0.2 \pm 0.2 b	0.2 \pm 0.2 c
	INS + <i>Bb</i>	2.2 \pm 0.2 ab	2.2 \pm 0.3 a	4.5 \pm 0.3 ab
	<i>B. bassiana</i> (<i>Bb</i>)	1.7 \pm 0.2 b	2.0 \pm 0.6 ab	3.7 \pm 0.8 ab
	Control	3.0 \pm 0.4 a	2.7 \pm 0.6 a	5.7 \pm 0.9 a
	F	13.47	2.69	6.51
	<i>P</i>	< 0.0001	0.0353	< 0.0001

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14	Insecticide (INS)	2.2 ± 0.6 a	1.6 ± 0.3 a	3.7 ± 0.7 a
	Insecticide (twice)	0.0 ± 0.0 b	0.5 ± 0.3 a	0.5 ± 0.3 b
	INS + <i>Bb</i>	1.0 ± 0.4 b	1.7 ± 0.2 a	2.7 ± 0.5 ab
	<i>B. bassiana</i> (<i>Bb</i>)	2.2 ± 0.5 a	2.5 ± 0.6 a	4.7 ± 1.0 a
	Control	2.5 ± 0.6 a	2.5 ± 0.5 a	5.0 ± 0.4 a
	F	6.58	1.47	4.95
	P	< 0.0001	0.2171	0.0011
18	Insecticide (INS)	1.4 ± 0.3 a	2.7 ± 0.2 a	4.2 ± 0.3 a
	Insecticide (twice)	0.8 ± 0.5 a	1.5 ± 0.6 a	2.2 ± 0.5 a
	INS + <i>Bb</i>	1.3 ± 0.2 a	2.2 ± 0.6 a	3.5 ± 0.6 a
	<i>B. bassiana</i> (<i>Bb</i>)	1.3 ± 0.2 a	2 ± 0.7 a	3.2 ± 0.9 a
	Control	2.3 ± 0.5 a	3 ± 0.4 a	5.2 ± 0.5 a
	F	1.58	0.91	1.94
	P	0.1848	0.4602	0.1098

* Analysis of variance, repeated measures, in PROC MIXED with the slice statement of SAS (df = 4, 105 in every ANOVA). Means in each column within each day post application followed by the same letter did not differ at $\alpha = 0.05$ (Fisher's protected LSD test).

† Groups of treatments (Table 2.2) were used for inferences because treatments within each group were not significantly different ($P > 0.05$, Table 2.4).

stink bugs (day seven) compared with the control plots. The proportion of nymphs to adults in the fungus-treated plots steadily decreased from 0.74 on day two to 0.46 on day 17.

A new treatment (insecticide applied twice per plot) was evaluated in 2003 in addition to the treatments of previous years (Table 2.7). Two applications of insecticides significantly reduced numbers of nymphs or total rice stink bugs for the first 14 days compared with the control and *B. bassiana* treatment. *B. bassiana*-treated plots had significantly fewer nymphs (day eight, 10) and total rice stink bugs (day eight) than control plots. Plots treated with insecticides once had significantly lower numbers of nymphs than *B. bassiana* plots through 10 days and lower numbers of total rice stink bugs through eight days. On day 14, insecticide plus *B. bassiana*-treated plots had significantly fewer nymphs than insecticide-treated (once) plots, *B. bassiana* plots, and control plots. The proportion of nymphs to adults in the fungus-treated plots was 0.55 on day two, 0.44-0.47 from day four to day 14, and 0.39 on day 18.

Significant numbers of rice stink bugs sampled from plots and reared in the laboratory exhibited signs of mycosis by *B. bassiana* (Tables 2.8-2.11). There was a significant treatment effect on disease prevalence in nymph and total bugs, but not adults, and mortality differed over time (Table 2.8). Mortality in nymphs or total rice stink bugs in the plots treated with LRC28 was significantly higher than in controls on at least one sampling date in each of the three years (Tables 2.9-2.11). Isolate LRC21 did not differ from anything. Isolate RSB differed from the control only in day-two total rice stink bugs in 2001, and the three isolates did not differ from one another (Table 2.9). Control mortality was never higher than 6.2% and was always zero after day seven (Tables 2.9-

Table 2.8 Analysis of variance for mortality of rice stink bugs by *B. bassiana* as the dependent variable in the small-plot field experiments, 2001-2003

Year	Tested effects*	df	Nymphs		Adults		Total RSB	
			χ^2	$P < \chi^2$	χ^2	$P < \chi^2$	χ^2	$P < \chi^2$
2001	Treatment	3	13.60	0.0035	3.79	0.2855	16.06	0.0011
	Time [‡]	1	14.65	0.0001	6.89	0.0087	19.96	< 0.0001
2002	Treatment	4	13.30	0.0099	3.75	0.4400	20.93	0.0003
	Time [‡]	1	6.86	0.0088	9.72	0.0018	19.49	< 0.0001
2003	Treatment	2	7.10	0.0287	3.85	0.1452	11.08	0.0039
	Time [‡]	1	4.63	0.0314	4.93	0.0264	10.10	0.0015

* Logistic regression analysis in PROC LOGISTIC (SAS Institute 1996) of data in Tables 2.9, 2.10, and 2.11. Analysis was performed separately for adults, nymphs, or total rice stink bugs for each year. Interactions of treatment by time were not significant in any year by the χ^2 -test ($P > 0.05$).

[‡] Sampling dates (days post application).

Table 2.9 Percentage infection (\pm SE) of rice stink bugs by *B. bassiana* in the 2001 small-plot field experiment

Days post application	Treatment*†	Nymphs	Adults	Total
2	LRC21	21.2 \pm 14.2 a	8.3 \pm 8.3 a	16.2 \pm 6.2 ab
	LRC28	39.6 \pm 6.2 a	21.3 \pm 4.9 a	28.2 \pm 5.0 a
	RSB Isolate	35.8 \pm 6.3 a	12.3 \pm 4.4 a	20.8 \pm 3.7 a
	Control	0 \pm 0 a	6.2 \pm 6.2 a	3.8 \pm 3.8 b
4	LRC21	31.2 \pm 23.7 ab	8.3 \pm 8.3 a	15.3 \pm 6.1 a
	LRC28	54.2 \pm 20.8 a	10.0 \pm 10.0 a	20.5 \pm 9.0 a
	RSB Isolate	24.4 \pm 10.9 ab	8.3 \pm 8.3 a	13.5 \pm 5.9 a
	Control	5.0 \pm 5.0 b	6.2 \pm 6.2 a	5.8 \pm 3.5 a
8	LRC21	25.0 \pm 25.0 a	0 \pm 0 a	12.5 \pm 12.5 a
	LRC28	37.5 \pm 23.9 a	8.3 \pm 8.3 a	19.6 \pm 7.1 a
	RSB Isolate	16.7 \pm 16.7 a	6.2 \pm 6.2 a	12.5 \pm 8.0 a
	Control	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
16	LRC21	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
	LRC28	12.5 \pm 12.5 a	12.5 \pm 12.5 a	10.0 \pm 10.0 a
	RSB Isolate	8.3 \pm 8.3 a	0 \pm 0 a	5.0 \pm 5.0 a
	Control	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
22	LRC21	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
	LRC28	12.5 \pm 12.5 a	0 \pm 0 a	3.6 \pm 3.6 a
	RSB Isolate	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
	Control	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a

* Mortality of rice stink bugs sampled on the given days post application and reared in the laboratory. Logistic regression analysis in PROC LOGISTIC was used to analyze the effect of treatments and days post application on mortality. The slice statement of SAS was used to detect significant differences by days post application for interactions of days and treatment. Means in each column within each day post application followed by the same letter did not differ at $\alpha = 0.05$ (Fisher's protected LSD test).

† Mortality data from the insecticide plots were not used because mortality in these plots was negligible; PROC LOGISTIC of SAS fails when this mortality is included.

Table 2.10 Percentage infection (\pm SE) of rice stink bugs by *B. bassiana* in the 2002 small-plot field experiment

Days post application	Treatment* [†]	Nymphs	Adults	Total
2	LRC28	34.6 \pm 4.6 a	30.0 \pm 13.33 a	31.8 \pm 4.7 a
	LRC28 + Karate 1X	50.0 \pm 50.0 a	33.3 \pm 33.3 a	40.0 \pm 24.5 a
	LRC28 + Karate 1/2X	16.7 \pm 10.5 a	10.0 \pm 10.0 a	15.0 \pm 10.0 ab
	RSB Isolate	27.4 \pm 8.1 a	24.0 \pm 11.2 a	27.2 \pm 3.1 ab
	Control	2.0 \pm 2.0 a	3.3 \pm 3.3 a	3.3 \pm 2.1 b
7	LRC28	50.0 \pm 22.3 a	6.7 \pm 6.7 a	22.7 \pm 11.3 a
	LRC28 + Karate 1X	0 \pm 0 b	0 \pm 0 a	0 \pm 0 a
	LRC28 + Karate 1/2X	25.0 \pm 25.0 ab	0 \pm 0 a	20.0 \pm 20.0 a
	RSB Isolate	30.7 \pm 9.5 ab	10.0 \pm 10.0 a	25.0 \pm 8.3 a
	Control	0 \pm 0 b	4.0 \pm 4.0 a	3.3 \pm 3.3 a
11	LRC28	30.0 \pm 20.0 a	0 \pm 0 a	13.3 \pm 81.6 a
	LRC28 + Karate 1X	25.0 \pm 25.0 a	0 \pm 0 a	10.0 \pm 10.0 a
	LRC28 + Karate 1/2X	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
	RSB Isolate	10.0 \pm 10.0 a	10.0 \pm 10.0 a	13.3 \pm 8.2 a
	Control	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
17	LRC28	6.7 \pm 6.7 a	0 \pm 0 a	3.3 \pm 3.3 a
	LRC28 + Karate 1X	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
	LRC28 + Karate 1/2X	20.0 \pm 20.0 a	0 \pm 0 a	3.3 \pm 3.3 a
	RSB Isolate	10.0 \pm 10.0 a	0 \pm 0 a	6.7 \pm 6.7 a
	Control	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a

* Mortality of rice stink bugs sampled on the given days post application and reared in the laboratory. Logistic regression analysis in PROC LOGISTIC was used to analyze the effect of treatments and days post application on mortality. The slice statement of SAS was used to detect significant differences by days post application for interactions of days and treatment. Means in each column within each day post application followed by the same letter did not differ at $\alpha = 0.05$ (Fisher's protected LSD test).

[†] Mortality data from the insecticide plots were not used because mortality in these plots was negligible; PROC LOGISTIC of SAS fails when this mortality is included.

Table 2.11 Percentage infection (\pm SE) of rice stink bugs by *B. bassiana* in the 2003 small-plot field experiment

Days post application	Treatment* [†]	Nymphs	Adults	Total
2	LRC28	31.2 \pm 12.0 a	16.7 \pm 16.7 a	24.3 \pm 12.0 a
	LRC28 + Karate 1/2X	0 \pm 0 b	20.8 \pm 12.5 a	20.8 \pm 12.5 ab
	Control	0 \pm 0 b	6.2 \pm 6.2 a	2.8 \pm 2.8 b
4	LRC28	33.3 \pm 11.8 a	16.7 \pm 16.7 a	25.0 \pm 10.2 a
	LRC28 + Karate 1/2X	0 \pm 0 b	8.3 \pm 8.3 a	8.3 \pm 8.3 a
	Control	6.2 \pm 6.2 b	0 \pm 0 a	4.2 \pm 4.2 a
8	LRC28	12.5 \pm 12.5 a	8.3 \pm 8.3 a	16.7 \pm 11.8 a
	LRC28 + Karate 1/2X	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
	Control	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
10	LRC28	12.5 \pm 12.5 a	8.3 \pm 8.3 a	10.0 \pm 5.8 a
	LRC28 + Karate 1/2X	8.3 \pm 8.3 a	0 \pm 0 a	5.0 \pm 5.0 a
	Control	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
14	LRC28	8.3 \pm 8.3 a	0 \pm 0 a	3.6 \pm 3.6 a
	LRC28 + Karate 1/2X	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
	Control	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
18	LRC28	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a
	LRC28 + Karate 1/2X	0 \pm 0 a	12.5 \pm 12.5 a	6.2 \pm 6.2 a
	Control	0 \pm 0 a	0 \pm 0 a	0 \pm 0 a

* Mortality of rice stink bugs sampled on the given days post application and reared in the laboratory. Logistic regression analysis in PROC LOGISTIC was used to analyze the effect of treatments and days post application on mortality. The slice statement of SAS was used to detect significant differences by days post application for interactions of days and treatment. Means in each column within each day post application followed by the same letter did not differ at $\alpha = 0.05$ (Fisher's protected LSD test).

[†] Mortality data from the insecticide plots were not used because mortality in these plots was negligible; PROC LOGISTIC of SAS fails when this mortality is included.

2.11). Isolate LRC28 caused mortality through 14-22 days (Tables 2.9-2.11), whereas LRC21 caused mortality for only eight days (Table 2.9). Isolate RSB sustained epizootics throughout both experiments in which it was applied except for the last sampling date in 2001 (Tables 2.9 and 2.10). Mean time to death by *B. bassiana* infection in field-collected *O. pugnax* returned to the laboratory was 4.2 days (range 3-6 days) for nymphs and 5.1 days (range 3-8 days) for adults. There was little variation in the mean and range of time to death among the three experiments.

The percentage nymphal mortality by isolates LRC28, LRC21, and RSB averaged 44, 26, and 26, respectively, during the first eight days in 2001 (Table 2.9). The average percentage mortality of total rice stink bugs through eight days in 2001 was 23% by LRC28, 16% by RSB, and 15% by LRC21. Through 11 days in 2002, nymphal mortality by isolate LRC28 averaged 39%, followed by the isolate LRC28 applied with Karate (37%), the RSB isolate (22%), and LRC28 applied with Karate at a reduced rate (13%) (Table 2.10). Mortality of total rice stink bugs through 11 days in 2002 by both LRC28 and isolate RSB averaged 17-18%, followed by LRC28 applied with Karate (12%), and Karate at ½X (9%). Through 10 days in 2003, nymphal mortality by LRC28 averaged 22% (Table 2.11), and mortality of total rice stink bugs by LRC28 averaged 13%, followed by the isolate LRC28 applied with Karate at ½X (6%).

Large-Plot Spread Experiment

B. bassiana spread rapidly after its application, but the epizootic completely died out by day 23 (Table 2.12). *Lygus* spp., *Conocephalus* spp., and *Melanopsis* spp., as well as *O. pugnax*, all became infected. Disease prevalence did not differ with direction and distance when the treated plot was not included in the analysis ($P > 0.05$). However,

Table 2.12 Mean percentage infection (n)* of hemipterans and grasshoppers by *B. bassiana* in the large-plot spread experiment in 2003

Distance (m)**	Days after application					
	1	5	9	13	18	23
	<i>Oebalus pugnax</i> †					
0	50.0 (10)	36.4 (11)	23.1 (13)	6.7 (15)	7.1 (14)	0 (9)
4.6	7.1 (28)	7.5 (53)	1.7 (58)	1.4 (72)	0 (61)	0 (29)
9.1	3.6 (28)	6.4 (47)	1.9 (54)	1.7 (60)	0 (61)	0 (26)
	<i>Lygus</i> spp.†					
0	66.7 (3)	33.3 (3)	20.0 (5)	0 (2)	0 (3)	0 (2)
4.6	11.1 (9)	6.7 (15)	0 (21)	0 (18)	0 (19)	0 (10)
9.1	14.3 (7)	0 (18)	4.5 (22)	0 (20)	0 (16)	0 (10)
	<i>Conocephalus</i> spp. and <i>Melanopsis</i> spp.†					
0	16.7 (36)	6.7 (45)	10.0 (10)	0 (10)	0 (6)	0 (6)
4.6	3.3 (184)	1.2 (164)	1.6 (126)	1.3 (75)	0 (46)	0 (28)
9.1	2.9 (174)	1.2 (166)	0.8 (126)	0 (78)	0 (36)	0 (21)

* Data are averages of two replicates. Direction ($df = 3$, $\chi^2 = 1.1723$, $P = 0.7597$) and distance ($df = 1$, $\chi^2 = 0.7867$, $P = 0.3751$) were nonsignificant independent variables in logistic regression analysis (PROC LOGISTIC, $P > 0.05$) when the treated plot (distance = 0) was excluded from the preliminary analysis. When direction was excluded and the treated plot was included in the final analysis (model 2), species, day after application, and distance were significant independent variables in logistic regression analysis (PROC LOGISTIC, $P < 0.05$). Logistic regression analysis (PROC LOGISTIC, $P < 0.05$) included percentage infection (y, Model 2), species ($df = 2$, $\chi^2 = 23.2885$, $P < 0.0001$), day (slope = -0.173 , $df = 1$, $\chi^2 = 44.8571$, $P < 0.0001$), distance (slope = -0.0876 , $df = 1$, $\chi^2 = 34.4573$, $P < 0.0001$). No infection by *B. bassiana* was observed in the control plots.

** Distance from the fungus-treated plot; 0 = within the plot.

† Wald confidence limit (95%) for species comparisons: *Conocephalus* spp. and *Melanopsis* spp. vs. *O. pugnax* (0.151, 0.479); *Lygus* spp. vs. *O. pugnax* (0.477, 2.434); *Conocephalus* spp. and *Melanopsis* spp. vs. *Lygus* spp. (0.110, 0.568).

when the treated plot (distance = 0 m) was included and direction excluded in the final analysis, disease prevalence differed with species, time, and distance ($P < 0.05$). Disease prevalence decreased over time and distance from the treated plot. Disease prevalence in *O. pugnax* and *Lygus* spp. did not differ ($P < 0.05$), but prevalence in *O. pugnax* or *Lygus* spp. was greater than in *Conocephalus* spp. and *Melanopsis* spp. ($P < 0.05$). The fungus did not spread into the control plots, a distance of 110 m, by the end of the experiment (23 days after application). Time to death for field-collected *O. pugnax* returned to the laboratory averaged 4.9 days (range 4-7 days), for *Lygus* spp. 4.1 days (range 3-6 days), and for *Conocephalus* spp. and *Melanopsis* spp. 6 days (range 4-8 days). These means and ranges of time to death were similar among all sampling dates.

Discussion

Isolates of *B. bassiana* that we tested in our bioassays, LRC28 and RSB, both infected *O. pugnax*, but their virulence differed by almost 5X (Table 2.3). The rice stink bug-derived isolate RSB was less virulent to *O. pugnax* adults than the soil-derived isolate LRC28. This suggests that the host of origin may not be a reliable indicator of the probable virulence of a specific fungal isolate to a specific host. On the other hand, *B. bassiana* isolated from an isopteran was more virulent than isolates from hosts in other phylogenetic groups to the termite *Coptotermes formosanus* Shiraki (Wells et al. 1995).

Fungal isolates did not differ from one another in reducing insect numbers (Tables 2.5 and 2.6) or percentage infection (Tables 2.9 and 2.10) of rice stink bugs in the small-plot field experiments, although isolates LRC28 and RSB, but not LRC21, occasionally differed from the control (Tables 2.9-2.11). In view of the laboratory differences between LRC28 and RSB in LD₅₀'s (Table 2.3), this suggests that virulence might not be the most

important criterion for selecting fungal pathogens to control this pest. Similarly, fungal virulence did not play a defining role in epizootics by *B. bassiana* in a laboratory population of *C. formosanus* (Sun et al. 2003). It has been hypothesized that virulence may not be the most important factor for the slow acting microbial agents to succeed in insect control (Fuxa 1987, Fuxa et al. 1998).

The overall impact of *B. bassiana* was moderate on *O. pugnax* nymphs and minimal on adults in the small-plot field experiments. A single application of *B. bassiana* reduced rice stink bug nymphs on six of nine sampling dates and adults on two of nine sampling dates from 2 to 10 days after application (Tables 2.5-2.7), and prevalence of the fungus was higher in the *B. bassiana* treatment than in controls for nymphs on four dates versus none for adults (Tables 2.9-2.11). Similarly, *B. bassiana* was more effective against nymphs than adults of *Lygus hesperus* Knight (Noma and Strickler 1999). Thus, adults may be less susceptible than nymphs to this fungus. Another possible explanation for the current results is that mobile, uninfected adults from other plots flew into, or infected adults moved out of, *B. bassiana*-treated plots. Adult movement or drift from spray treatments may explain the low prevalence of infection of adults in the control plots in all three years of our study (Tables 2.9-2.11).

A low level of fungus recycling, or replication in treated insects followed by infection of new hosts, occurred in the small-plot and spread field experiments. Insects infected by *B. bassiana* on day one or day two in these experiments died and produced conidia within 3-8 eight days in laboratory conditions, whereas epizootics in the field lasted 17-22 days after fungal application (Tables 2.5-2.7). Thus, insects almost certainly were infected by recycled conidia during at least the latter half of each of the current field experiments. In

spite of the recycling, fungal prevalence decreased even though the proportion of nymphs, the susceptible stage, was always 0.36 or greater throughout all three small-plot experiments (Tables 2.5-2.7).

Chemical insecticides gave better control of *O. pugnax* than *B. bassiana* for two to 10 days in the three experiments (Tables 2.5-2.7). A single application of insecticide reduced rice stink bug populations to lower numbers than *B. bassiana* by seven days in two experiments (Tables 2.5 and 2.6) and by 10 days in the third experiment (Table 2.7), whereas a double application was more effective than *B. bassiana* for 10 days against nymphs (Table 2.7). These results are similar to those in another study of *B. bassiana* and conventional insecticides (Bifenthrin or Oxydemetonmethyl) in *L. hesperus* (Noma and Strickler 1999).

B. bassiana was nearly as effective as a single application of insecticide in suppressing rice stink bug populations 7-8 days after application in the small-plot field experiments (Tables 2.5-2.7); in one case (Table 2.6, day 17), the fungus was superior to the chemical in suppressing the bugs by the end of the experiment. This supports the concept that *B. bassiana* is a slowly acting agent that must be used to advantage where immediate control is not required (Fuxa 1987).

If the economics are favorable, mixtures of *B. bassiana* and insecticide may provide better control of rice stink bug than a single application of either material alone. This was most evident in nymphs on day 14 (Table 2.7). This may be an additive effect with the insecticide suppressing the population for two to 10 days and *B. bassiana* taking over 7-8 days after application. Chemicals also may act as stressors to enhance the efficacy of mycopathogens (Anderson et al. 1989, Hassan et al. 1989, Quintela and McCoy 1998a).

Another possibility is synergism, such as that between imidacloprid and *B. bassiana* in termites (Boucias et al. 1996) and in larvae of the root weevil *Diaprepes abbreviatus* L. (Quintela and McCoy 1998b).

The large-plot spread experiment generally had similar patterns of epizootics (Table 2.12) as the small-plot experiments (Tables 2.9-2.11), with prevalence of *B. bassiana* infections decreasing steadily to zero by day 23 in spite of the recycling. Spread of *B. bassiana* up to 9.6 m within 24 h after application may have been caused by high mobility of the treated insects and perhaps, to a lesser degree, by spray drift. Further spread may have been impeded by a limited source of inoculum in the relatively small treated area as well as the low level of pathogen recycling.

Prevalence of *B. bassiana* was significantly greater in the hemipterans than in the orthopterans in the spread study (Table 2.12). This is probably due to differential physiological susceptibility, but differences in host mobility, behavior, life cycles, and population density may also have affected prevalence. Behavioral thermoregulation can inhibit *B. bassiana* mycosis in grasshoppers (Inglis et al. 1996b), but it is unknown whether this occurs in rice stink bug and *Lygus* spp. Infection and production of conidia by *B. bassiana* in several species of insects in rice in the current research seemingly is promising for enhanced control of *O. pugnax*.

High temperatures probably were a major factor limiting *B. bassiana* epizootics in the current research. Temperatures above 35 °C are known to inhibit growth and development of *B. bassiana* (McCoy et al. 1988), delay germination of its conidia, and decrease mycosis (Inglis et al. 1996b). Isolates LRC21 and LRC28, which were selected for our experiments based on their relatively good growth at high temperatures, grew best

at 28-30 °C on a semi-synthetic medium in the laboratory conditions, but their growth rates were reduced by 27-48% at 32 °C, by 61-92% at 35 °C, and by 100% above 35 °C (Fargues et al. 1997). During three years of the current study, daytime high temperatures were greater than 32 °C on at least 20 of the 30 days after application of *B. bassiana* in each of the four experiments, with temperatures as high as 36-37 °C on some dates (Anonymous 2005).

There are several other explanations for the limited efficacy of *B. bassiana* against rice stink bug in the current field experiments. Ultraviolet-B (UV-B) radiation in the field environment rapidly deactivates conidia and slows their germination on insect cuticle (Inglis et al. 1996a, Rangel et al. 2004). UV-B radiation should not have affected sprayed conidia, because the treatments were applied in the evening in our experiments. However, radiation might have affected recycled conidia later during the experiments. Additionally, the small plots in the current research may have been disadvantageous if infected bugs emigrated, thereby depriving that plot of further inoculum through fungal recycling.

Our results indicate that *B. bassiana* has potential for integrated management programs of rice stink bug in rice, considering its high infection rates and moderate efficacy against nymphs, its additive effect with insecticides, and its wide host range in rice insects. In future trials, the fungus should be sprayed in very large plots or even entire fields to eliminate negative effects of bug movement on evaluation and recycling. Similarly, inoculation earlier in the season may provide better control of rice stink bug than in the current research. An interesting continuation of current research would be to study sublethal effects of *B. bassiana* on rice stink bug. *B. bassiana* is known to affect feeding and oviposition of *L. hesperus* in alfalfa (Noma and Strickler 2000). If such

research demonstrated that *B. bassiana* significantly reduces feeding and/or oviposition of infected bugs, it would add to the potential of *B. bassiana* as a microbial agent for control of rice stink bug.

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CHAPTER 3

EFFECTS OF RICE PANICLE AGE ON QUANTITATIVE AND QUALITATIVE DAMAGE BY THE RICE STINK BUG (HEMIPTERA: PENTATOMIDAE)

Introduction

Rice stink bug (Hemiptera: Pentatomidae), *Oebalus pugnax* (Fab.), is one of the most injurious pests of rice in the southern United States (Swanson and Newsom 1962). It is common in the United States east of the Rocky Mountains and as far north as Minnesota and New York (Sailer 1944). It is attracted to rice during reproductive phases of growth, in particular during grain development (McPherson and McPherson 2000). Both adults and nymphs feed on developing grains (Bowling 1967, Douglas and Ingram 1942). Feeding results in yield losses and/or reduced grain quality (Smith et al. 1986, Swanson and Newsom 1962). The entire contents of the rice grain may be removed during the milk stage, resulting in false grains (Bowling 1967, Odglen and Warren 1962, Texas Agric. Ext. Serv. 1997), or a portion of the content may be sucked out, resulting in atrophied grains (Bowling 1967). Feeding during soft and hard dough stages leaves a chalky discolored area around the feeding site and rice so affected is called *pecky rice*. Fungi often enter the punctures made by rice stink bug (Lee et al. 1993, Johnson et al. 1987). Pecky rice easily breaks during milling, lowering the percentage of whole kernels and, thus, the market value of the product (Odglen and Warren 1962). If pecky rice does not break during milling, it will appear in head rice, resulting in inferior quality of rice (Bowling 1967). For a brown rice sample to qualify as US #1 or US #2, it should contain no more than 1 or 2% pecky rice, respectively (Fryer et al. 1986). Feeding also results in losses due to empty florets and reduced viability of the grain (Odglen and Warren 1962).

There has been little effort made to develop nonchemical controls for rice stink bug for several reasons, including the short period of rice plant vulnerability (heading to harvest, which is approximately 30 days for most varieties), the high mobility of the bug, the low economic thresholds, and the relatively low cost of chemical controls (Way 1990). Several of the standard chemical pesticides used for controlling stink bugs have been removed from the market place or may be removed in the future by label revision or cancellation because of environmental and human safety concerns or costs of the registration process (Todd et al. 1994, McPherson and McPherson 2000). Host plant resistance is an important part of many integrated pest management programs. Resistance and tolerance of rice to stink bug damage are affected by panicle age and grain maturity. Previous studies by several authors (Bowling 1963, Douglas and Tullis 1950, Johnson et al. 1987, Odglen and Warren 1962, Robinson et al. 1980, Swanson and Newsom 1962) suggest that different stages of grain development vary in their levels of tolerance and resistance to rice stink bug damage. However, all these studies were conducted in the field where parasites (Bowling 1963) and/or pathogens, as well as weeds (Tindall 2004), might have influenced their results. Also, none of these studies examined damage specifically to each infested panicle. The objective of this study was to evaluate the effects of panicle age and grain maturity on the quantitative and qualitative damage caused by rice stink bug feeding on rice panicles in a controlled environment. These effects were measured for two infestation levels of rice stink bug. Effects on germination of infested kernels were also evaluated.

Materials and Methods

Qualitative and Quantitative Damage

Plants and Insects

Experiments were conducted during the summer of 2003 in a greenhouse on the campus of Louisiana State University, Baton Rouge, LA. Rice (cv 'Cocodrie') was planted in pots and grown in the greenhouse from March to July. Rice for the first experiment was planted on March 19 and for the second experiment on March 25. Rice stink bugs were collected from heading or headed rice as well as barnyard grass at the LSU AgCenter Rice Research Station, Crowley, LA. They were maintained on panicles of barnyard grass in the laboratory for approximately 2 days to remove damaged or diseased bugs. Healthy bugs were then used in these experiments. Pots were 7" inches in height and 7" diameter. Growth medium was a mixture composed of 4 parts soil: 2 parts peat moss: 1 part sand: 1 part vermiculite. Each pot was supplied with approximately 3.5 g of 23:12:12 NPK fertilizer at planting. Plants were watered as needed during these experiments. Natural lighting was the only source of light. Temperature ranged from 25 to 35 °C in the greenhouse throughout these experiments.

Experiments were initiated by tagging a large number of panicles at anthesis stage (approximately 1 day after initial emergence of panicle) on June 09 (experiment one) and June 13 (experiment two). Panicles were randomly assigned to the following treatments: infestation at 1, 5, 9, 13, 17, and 21 days after anthesis. In the first experiment, each panicle was infested with one sexed female rice stink bug at the appropriate day for 4 days. In second experiment, panicles were infested with two rice stink bugs instead of one bug per panicle for 4 days. In both experiments, bugs were placed inside muslin cloth

sleeves enclosing a rice panicle and tied at the bottom. Panicles serving as controls were enclosed by muslin cloth without stink bugs. Bugs were removed from the muslin cloths after 4 days and the muslin cloth was again put back on the panicle until harvest. Treatments were arranged in a completely randomized design with 18 replications in the first experiment (one bug per panicle) and 10 replications in the second experiment (two bugs per panicle).

Rice panicles were in the anthesis stage approximately during the first 4 days after tagging (personal observation). Panicles then advanced into the milk stage (approximately 5 to 12 days after tagging). The soft dough stage ran approximately from 13 to 17 days after tagging and then gradually progressed into the hard dough stage.

Panicles were gently harvested by hand at maturity and individually placed in plastic Ziploc bags. All panicles were taken out of the Ziploc bags and air-dried on the lab bench at room temperature for one week. Panicles were then individually threshed by hand. The numbers of empty and filled kernels per panicle were counted and the data were used to calculate the percentages of empty and filled kernels in each treatment. Total weight of the filled kernels was also measured. The weight and number of the filled kernels per sample were then used to determine the average weight of a filled kernel per treatment. Hulls were then removed mechanically from the rough rice samples by a McGill Sheller (H.T. McGill Inc., Houston, TX). The resultant samples were visually separated into pecky vs. nonpecky rice and then weighed separately. All chalky discolored kernels were classified as “pecky.” Weights of pecky and pecky plus nonpecky rice were then used to calculate the percentage of pecky rice for each treatment (time of infestation).

Effects on Germination

Pecky and nonpecky kernels from the one rice stink bug per panicle experiment were used in the germination experiment. Kernels were included from panicles infested 1, 9, and 17 days after anthesis as well as those from the control. The effects of rice quality (pecky vs. nonpecky), time of infestation (1, 9, or 17 days after anthesis), and their interaction were tested in this experiment. For each of the eight treatment x time combinations, five replicates of 20 kernels were placed in a 5 x 4 matrix in 100 mm x 15 mm sterile Petri dish (BD Falcon™, BD Biosciences, Franklin Lakes, NJ), lined with three layers of germination paper (Anchor Paper Co., St. Paul, MN) saturated with 8 ml distilled water. Kernels were treated with Quadris 2.08 SC (Syngenta Crop Protection, Greensboro, NC), a fungicide, and covered with two layers of Kimwipe tissue paper to ensure uniform hydration. Closed dishes were incubated at 100% relative humidity for 14 days at 30° C in darkness. Radical emergence was the criterion for germination. The number of kernels germinated during the 14 days was recorded for each Petri dish.

Data Analysis

Data on quantitative (percentage of empty kernels and average weight of filled kernels) as well as qualitative damage (percentage of pecky rice) were subjected to multivariate analysis of variance using the MANOVA statement in PROC GLM of SAS (SAS Institute 1996). Data from the two experiments with different infestation levels were analyzed separately. This MANOVA determined if there was an overall significant treatment (time of infestation) effect on all three response variables. Correlations among response variables were assessed with Pearson correlation coefficients produced by PROC CORR of SAS (SAS Institute 1996). Then, each of these response variables was

individually subjected to analysis of variance by PROC GLM with the Tukey HSD test among means (SAS Institute 1996). Germination data were subjected to two-way analysis of variance and were analyzed with PROC GLM of SAS (SAS Institute 1996).

Results

MANOVA Procedure and Pearson Correlation Coefficients

The multivariate analysis suggested that treatment (time of infestation) had an overall significant effect on the response variables (percentage of empty kernels, average weight of filled kernels, and percentage of pecky rice) in both experiments: (one rice stink bug per panicle: $F_{18, 332} = 331.41$, $P < 0.0001$; two rice stink bugs per panicle: $F_{18, 174} = 61.71$, $P < 0.0001$). Pearson correlation coefficients revealed that only the percentage of empty kernels and average weight of filled kernels were significantly correlated with each other. This correlation was stronger at higher infestation level ($r = -0.5245$, $P < 0.0001$ [one bug/panicle], $r = -0.7548$, $P < 0.0001$ [two bugs/panicle]).

Percentage of Empty Kernels

The percentage of empty kernels in panicles decreased as time of infestation after anthesis increased in both experiments (one rice stink bug per panicle: $F_{6, 119} = 31.25$, $P < 0.0001$, Fig. 3.1; two rice stink bugs per panicle: $F_{6, 63} = 81.11$, $P < 0.001$, Fig. 3.1). In both experiments, the percentage of empty kernels was statistically greater in panicles infested 1 day after anthesis compared with that in panicles infested during later grain development and panicles in the control. Regardless of infestation level, the percentage of empty kernels in panicles infested 1 day after anthesis was approximately 2 times greater than the percentage in panicles infested 9 days after anthesis. In both experiments, infestation of panicles for 4 days beginning 1 and 5 days after anthesis produced greater

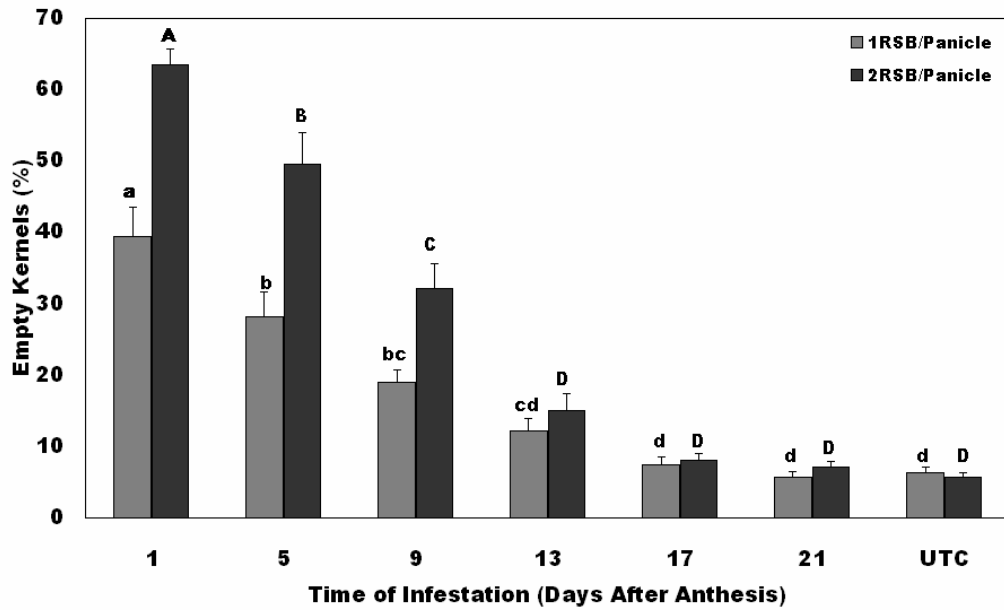


Fig. 3.1 Mean percentage (\pm SE) of empty kernels in rice panicles infested for a period of 4 days beginning 1, 5, 9, 13, 17, or 21 days after anthesis and in panicles from the untreated control (UTC). Two bars at each infestation time represent data from two experiments with infestation levels of one or two rice stink bugs (RSB) per panicle. Means within each infestation level followed by same lower or upper case letter did not differ significantly at $\alpha = 0.05$ (Tukey, HSD)

percentages of empty kernels compared with panicles infested 13, 17, and 21 days after anthesis and panicles in the control. In two bugs per panicle experiment, panicles infested 9 days after anthesis also produced greater percentage of empty kernels than panicles infested during later grain development and panicles in the control. Infestation of panicles 13, 17, and 21 days after anthesis did not produce any significant reductions in the percentage of empty kernels compared with the control in either experiment. Panicles in the control averaged 6 - 7% empty kernels in the two experiments. Feeding by two rice stink bugs produced at least 1 ½ times as many empty kernels as feeding by one bug in panicles infested 1, 5, and 9 days after anthesis.

Average Weight of Filled Kernels

Treatments significantly affected the average weights of filled kernels in rice panicles infested with one rice stink bug per panicle ($F_{6, 119} = 6.45, P < 0.0001$, Fig. 3.2) as well as two rice stink bugs per panicle ($F_{6, 63} = 33.86, P < 0.0001$, Fig. 3.2). Average weights generally increased with the time of infestation after anthesis in both experiments. In the one rice stink bug per panicle experiment, panicles infested 1 and 5 days after anthesis had lower average weights compared with panicles infested 21 days after anthesis and panicles in the control. In the two rice stink bugs per panicle experiment, panicles infested 1 day after anthesis had lower average weights compared with panicles infested 13, 17, and 21 days after anthesis and panicles in the control. In the same experiment, panicles infested 5 days after anthesis had lower average weights compared with panicles infested during later grain development and panicles in the control. When infested with one rice stink bug per panicle, there was a reduction of 8% and 10% in average weights in panicles infested 1 and 5 days after anthesis, respectively, compared with the control;

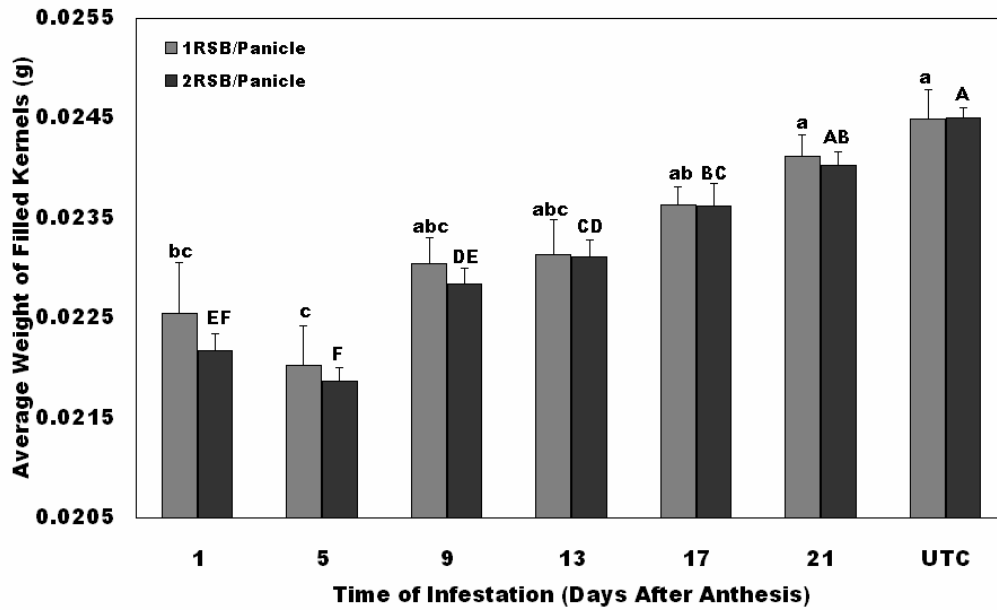


Fig. 3.2 Average weight (g) of filled kernels (\pm SE) in rice panicles infested for a period of 4 days beginning 1, 5, 9, 13, 17, or 21 days after anthesis and in panicles from the untreated control (UTC). Two bars at each infestation time represent data from two experiments with infestation levels of one or two rice stink bugs (RSB) per panicle. Means within each infestation level followed by same lower or upper case letter did not differ significantly at $\alpha = 0.05$ (Tukey, HSD)

however, these reductions were 10% and 11% with two rice stink bugs. This result suggests that feeding during the anthesis, milk and soft dough stages of grain development reduced the average weights of filled kernels, with more damage during early milk stage. Bug reductions in average weights were high in infestation of panicles for 4 days beginning 1, 5, and 9 days after anthesis and low thereafter, demonstrating that the first 12 days after anthesis were the most critical for damage in terms of reduced grain weight due to an increased infestation level.

Percentage of Pecky Rice

Pecky rice as a percentage of the total weight of the de-hulled kernels in each sample (rice panicle) is shown in Fig. 3.3. In both experiments, controls had approximately 3% pecky rice. This result indicates that pecky rice was caused by factors in addition to rice stink bug. The percentage pecky rice in panicles differed significantly with the time of infestation after anthesis in both experiments: (one rice stink bug per panicle: $F_{6, 119} = 138.92$, $P < 0.0001$, Fig. 3.3; two rice stink bugs per panicle: $F_{6, 63} = 200.23$, $P < 0.001$, Fig. 3.3). In both experiments, the percentage pecky rice was statistically greater in panicles infested 9 and 13 days after anthesis compared with that in panicles in all other treatments and the control. Similarly, the percentage pecky rice was statistically greater in panicles infested 5 and 17 days after anthesis compared with that in panicles infested 21 and 1 day(s) after anthesis as well as those in the control. The percentage of pecky rice in panicles infested 1 and 21 days after anthesis did not differ, and infestation at day 1 did not differ from the control. In both experiments, the percentage pecky rice in panicles infested 9 or 13 days after anthesis was at least 2 times greater than that in panicles infested 5 or 17 days after anthesis and approximately 4 times greater than in panicles

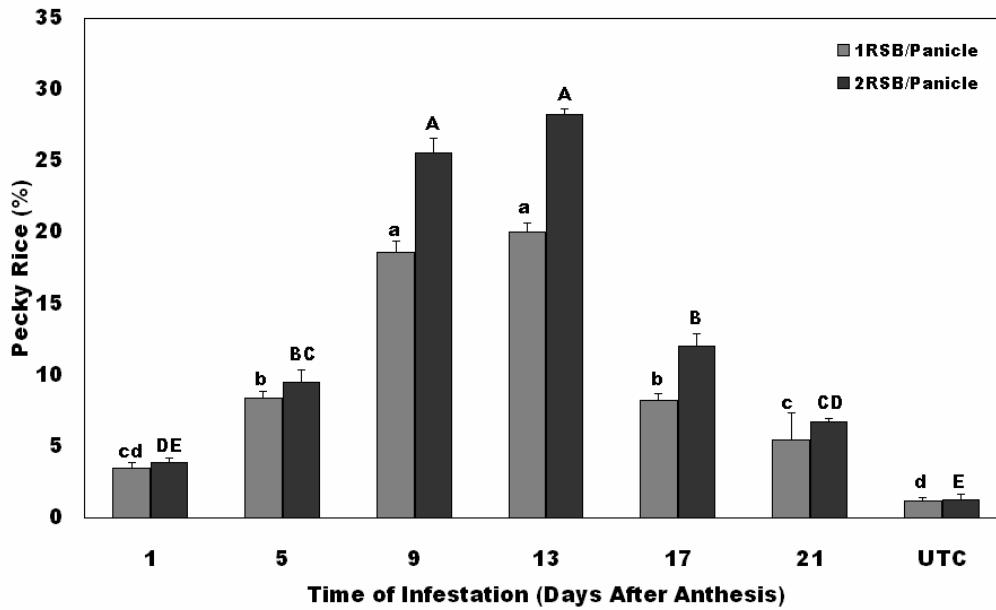


Fig. 3.3 Mean percentage (\pm SE) of pecky rice in rice panicles infested for a period of 4 days beginning 1, 5, 9, 13, 17, or 21 days after anthesis and in panicles from the untreated control (UTC). Two bars at each infestation time represent data from two experiments with infestation levels of one or two rice stink bugs (RSB) per panicle. Means within each infestation level followed by same lower or upper case letter did not differ significantly at $\alpha = 0.05$ (Tukey, HSD)

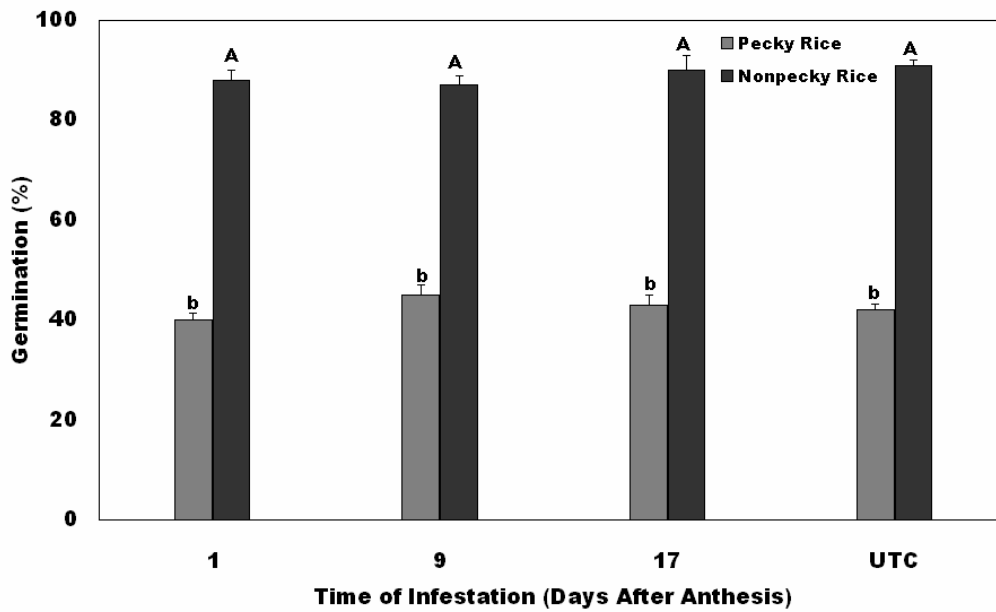


Fig. 3.4 Mean percent germination (\pm SE) of kernels from rice panicles infested for a period of 4 days beginning 1, 9, or 17 days after anthesis and in panicles from the untreated control (UTC). Two bars at each infestation time represent data for pecky and nonpecky kernels from the one rice stink bugs (RSB) per panicle experiment. Means within each infestation level followed by same lower or upper case letter did not differ significantly at $\alpha = 0.05$ (Tukey, HSD)

infested 1 or 21 days after anthesis or those in the control. Thus, rice stink bug caused pecky rice damage when rice panicles were infested for 4 days at 5 to 21 days after anthesis, with the most severe damage inflicted in panicles infested on day nine and 13. Incidence of pecky rice was higher in the two bugs per panicle experiment than one bug.

Percent Germination of Infested Kernels

Percentages of germination of the pecky as well as nonpecky kernels from the first experiment are shown in Fig. 3.4. Peckiness was associated with highly significant reductions in the germination of rice kernels ($F_{1, 32} = 935.03$, $P < 0.0001$, Fig. 3.4), but the level of reduction did not differ with time of infestation ($F_{3, 32} = 0.61$, $P < 0.6118$, Fig. 3.4). There was no significant quality of rice x time of infestation interaction ($F_{3, 32} = 1.05$, $P < 0.3860$, Fig. 3.4). This result indicates that qualitative injury by rice stink bug feeding reduced germination by nearly the same amount at all times of infestation after anthesis as well as in the control. Germination of nonpecky kernels averaged 89% while that in pecky kernels was 43%.

Discussion

The data in these experiments clearly showed that rice grains became less susceptible to quantitative damage by the rice stink bug as the grains developed. Feeding during anthesis and the milk stage produced significantly higher percentages of empty kernels than did feeding during later grain development. This finding supports previous field work by Pantoja et al. (2000) with a related stink bug species, *Oebalus ornatus* (Sailer), that showed severe losses in rice yields resulting from rice stink bug feeding during the flowering and the milk stage compared with feeding during the soft dough stage. This result is partly explained by the feeding method of this bug, which sucks out the contents

of kernels in the milk stage (Odglen and Warren 1962). The exact feeding mechanism of this bug for rice kernels at anthesis is not reported in the literature. However, previous work by Ferrell and Stufkens (1990) indicated that the wheat bug, *Nysius huttoni* White, could suck sap rich in amino acids and sugars from the ovary of the wheat seed at late anthesis. Rice stink bug feeding during anthesis restricted further grain development in rice kernels (Lee et al., 1993). Kernels injured prior to the early dough stage often did not develop (Swanson and Newsom 1962).

Stink bug feeding also reduced the average weights of filled kernels during anthesis and the milk stage (first 12 days after anthesis). There are two possible explanations for this result. Feeding during the milk stage has been shown to produce atrophied kernels (Bowling 1967), which probably was a major contributing factor to the reduced average weights during the milk stage. Additionally, Fryer et al. (1986) showed that many pecky kernels weighed substantially less because they were not fully developed. Therefore, it is likely that the higher percentages of pecky rice during the milk and soft dough stages in our experiments significantly contributed to the reduced average weights during those stages. Previous work by Fuchs et al. (1988) indicated that rice stink bug infestation during grain development in sorghum reduced the weight and size of the seeds.

The incidence of empty kernels and reductions in weights of filled kernels were greater under the higher infestation level, particularly during anthesis and the milk stage. A previous study by Robinson et al. (1980) also found significant reductions in the total weight per kernel at higher infestation levels compared to that in the control.

The data for percentage of pecky rice revealed two valuable pieces of information. First, in contrast to the results for quantitative damage, the highest levels of pecky rice

occurred in grains infested during the soft dough stage. Severe qualitative damage, at both infestation levels, occurred in panicles infested during the soft dough stage (13 days after anthesis). Panicles infested during the late milk stage (9 days after anthesis), which had a significant number of kernels in the soft dough stage, also suffered heavily. Panicles infested during the hard dough stage (17 and 21 days after anthesis) also had considerable pecky rice. The vulnerability of the soft and hard dough stages is probably explained by the fact that this bug removes a portion of the contents of grain, leaving a discolored area around the site. Similarly, previous studies have shown that kernels attacked during the soft and hard dough stages resulted in pecky rice (Douglas and Ingram 1942, Johnson et al. 1987); although not as common, pecky rice was also reported in kernels attacked during the milk stage in the field (Harper et al. 1993).

Second, the presence of pecky rice in the control in current experiments suggested that it was caused by a combination of rice stink bug and other factors, perhaps fungi, as previously reported by McPherson and McPherson (2000). It is clear, however, that rice stink bug feeding was a major factor contributing to pecky rice in infested panicles in the current experiments, either directly or indirectly by facilitating the entry of microbes. The rice stink bug is known to vector several pathogens through its stylets in a transient manner (Lee et al. 1993, Hollay et al. 1987). However, it was unlikely that pathogens were vectored through the bug stylets in these experiments because at least 24 hours transpired between collection of bugs in the field and infestation of the panicles, during which bugs were kept in a controlled environment in the laboratory. Previous studies by Marchetti and Peterson (1984) have shown that rice stink bug feeding was a major factor in kernel discoloration, although *Bipolaris oryzae* (Breda de Haan), a fungus that causes

brown spot, was a primary cause of some kernel discoloration and was one of several microbes that colonize kernels through feeding punctures. *Nematospora coryli* Peglion, a fungus capable of causing discolored areas, was also noted (Way 1990). Previous work by Lee et al. (1993) demonstrated that discoloration in pecky rice resulted from fungi that were introduced when rice stink bug was feeding.

Pecky rice germinated significantly less than nonpecky rice, indicating that injury due to rice stink bug feeding and/or microbes associated with pecky kernels may have damaged the embryo of the attacked kernels. It is also possible that microbes present within the pecky kernels interrupted the germination process, although no visible sign of differences in the microbial growth between pecky and nonpecky kernels were observed during the germination test. A previous study has documented reductions in viability of kernels because of rice stink bug feeding (see Swanson and Newsom 1962). Also in this study, kernels that were atrophied or damaged at the proximal (germ) end had reduced viability. Apparently, the embryo is extremely sensitive to injury by the rice stink bug. Also, rice stink bug attack during grain development in sorghum reduced seed germination (Fuchs et al. 1988). Although the seed cleaning process would eliminate much of the seed severely atrophied by rice stink bug damage, observed reductions in germination were substantial enough to prevent certification of seed for commercial sale, which has an acceptable limit of 85% (Douglas and Tullis 1950).

There are at least two explanations for the decrease in damage to rice grains as they matured. First, resistance of the grains to the feeding may increase as they mature, that is, rice stink bug may feed less as grains develop and harden. Second, stink bug feeding may

be equal on grains of different ages, but grains may become more tolerant to rice stink bug feeding as they mature.

Rice producers have long relied on synthetic insecticides to control rice stink bugs (McPherson and McPherson 2000). Concerns about the toxicity of insecticides to non-target organisms, continued availability of currently registered insecticides, and adverse effects of insecticides on the environment have prompted investigations of alternative strategies for management of the rice stink bug. The short window of vulnerability of the rice plant to rice stink bug (approximately 30 days for most varieties) has been an important factor in restricting research in the development of nonchemical control measures (Way 1990). The current available action thresholds for rice stink bug in rice (30 bugs per 100 sweeps for the first two weeks of heading and 100 bugs per 100 sweeps from the dough stage until two weeks before harvest (Louisiana AgCtr. Res. Ext. 2004)) accounts to some degree for changes in grain resistance. However, more precise information from the research reported here on the resistance and/or tolerance of rice panicles may be important for the refinement of the current thresholds and for the development of a more diverse integrated pest management program for the rice stink bug. Additional studies involving various infestation levels, different varieties, and nymphs as well as adults should be considered for the future trials in controlled environments. Interactions among population size, panicle age, pathogens, and weeds would be useful.

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CHAPTER 4

SUMMARY AND CONCLUSION

As part of developing sustainable management programs for the control of rice stink bug, the current studies were initiated to test two hypotheses: 1) *Beauveria bassiana* can be released to suppress damaging populations of *O. pugnax* (Chapter 2) and 2) resistance and tolerance of rice to *O. pugnax* damage are affected by panicle age and grain maturity (Chapter 3). The major research of this thesis was focused on 1) determining the efficacy of *B. bassiana* against *O. pugnax* and determining whether combinations of insecticides and *B. bassiana* isolates were more effective against *O. pugnax* than the separate materials in small-plot field tests; 2) determining the spread and persistence of *B. bassiana* after its release in a large-plot experiment; 3) evaluating the effects of panicle age and grain maturity on the quantitative and qualitative damage caused by *O. pugnax* feeding on rice panicles in a controlled environment.

Median lethal doses (LD₅₀s) of two isolates of *B. bassiana* to *O. pugnax* were quantified; isolation from a particular host species was not positively correlated with virulence to that host. Isolates LRC28 and RSB both infected *O. pugnax* but their virulence differed by almost 5X. The rice stink bug-derived isolate RSB was less virulent to *O. pugnax* adults than the soil-derived isolate LRC28.

Fungal isolates did not differ from one another in reducing densities or percentage infection of *O. pugnax* in three years of small-plot field experiments, although isolates LRC28 and RSB, but not LRC21, occasionally differed from the control. Considering laboratory differences between LRC28 and RSB in LD₅₀'s, this suggests that virulence did not play a defining role in efficacy of fungal isolates against this pest.

B. bassiana was moderately effective against nymphs and had an additive effect with insecticides. In small-plot experiments, a single application of *B. bassiana* reduced rice stink bug nymphs on six of nine sampling dates and adults on two of nine sampling dates from two to 10 days after application, and prevalence of the fungus was higher in the *B. bassiana* treatment than in controls for nymphs on four dates versus none for adults. A single application of insecticide reduced total rice stink bug numbers more than *B. bassiana* for at least seven days, whereas a double application was more effective than *B. bassiana* for 10 days against nymphs. *B. bassiana* was nearly as effective as a single application of insecticide in suppressing rice stink bug numbers 7-8 days after application. Mixtures of *B. bassiana* and insecticide provided better control of rice stink bug than a single application of either material alone.

In selecting fungal isolates for use against *O. pugnax*, it is important to take into account tolerance to high temperatures. High temperatures probably were the major factor limiting *B. bassiana* epizootics in the current research. Fungal epizootics lasted 17-22 days after application, and a low level of fungus recycling occurred in the field experiments. In the spread experiment, *B. bassiana* spread rapidly after its application, probably because of adult movement. However, disease prevalence did not differ with distance from the treated plot.

Disease prevalence was significantly greater in *O. pugnax* and *Lygus* spp. than in orthopterans. Infection and production of conidia by *B. bassiana* in several species of insects in rice is promising for enhanced control of *O. pugnax*.

Effects of panicle age and grain maturity on quantitative and qualitative damage caused by rice stink bug infestations on rice was evaluated in greenhouse experiments.

Insect feeding during anthesis and the early milk stage of grain development (first 8 days after anthesis) caused substantially higher numbers of empty kernels than feeding during later grain development and the control. Average grain weights were lower in infestations during anthesis and milk stage and higher in infestations during later grain development and the control. Pecky rice was significantly higher during late milk and soft dough stages, 9-16 days after anthesis, compared with remaining stages of grain development and the control. Percentages of empty kernels and pecky rice, and decreases in average weights of filled kernels were higher in the experiment in which panicle were infested with 2 bugs. Pecky rice was associated with highly significant reductions in germination of the kernels. This information is important for the refinement of the current thresholds and for the development of a more diverse integrated pest management program for the rice stink bug.

In conclusion, this research showed that the use of *B. bassiana* is compatible with the use of insecticides and has potential for integrated management programs of *O. pugnax* in rice. Information that rice is most vulnerable to rice stink bug damage during the first two weeks after anthesis should also be utilized to strengthen the existing management programs for this pest.

APPENDIX 1
RAW DATA FOR CHAPTER 2 -- *B. BASSIANA* VIRULENCE AGAINST *O. PUGNAX* IN BIOASSAY

Isolate	Inoculated dose (conidia/insect)	Replicates	Total tested insects	Number of dead insects
LRC28	4.0x10 ²	1	15	3
LRC28	4.0x10 ²	2	15	2
LRC28	4.0x10 ²	3	20	5
LRC28	4.0x10 ³	1	15	4
LRC28	4.0x10 ³	2	15	4
LRC28	4.0x10 ³	3	20	6
LRC28	4.0x10 ⁴	1	15	8
LRC28	4.0x10 ⁴	2	15	9
LRC28	4.0x10 ⁴	3	20	11
LRC28	4.0x10 ⁵	1	15	12
LRC28	4.0x10 ⁵	2	15	13
LRC28	4.0x10 ⁵	3	20	17
LRC28	4.0x10 ⁶	1	15	15
LRC28	4.0x10 ⁶	2	15	15
LRC28	4.0x10 ⁶	3	20	20
LRC28	4.0x10 ⁷	1	15	15
LRC28	4.0x10 ⁷	2	15	15
LRC28	4.0x10 ⁷	3	20	20
RSB	4.0x10 ²	1	15	2
RSB	4.0x10 ²	2	15	4
RSB	4.0x10 ²	3	20	4
RSB	4.0x10 ³	1	15	3
RSB	4.0x10 ³	2	15	4
RSB	4.0x10 ³	3	20	5
RSB	4.0x10 ⁴	1	15	6
RSB	4.0x10 ⁴	2	15	6
RSB	4.0x10 ⁴	3	20	7
RSB	4.0x10 ⁵	1	15	9
RSB	4.0x10 ⁵	2	15	10
RSB	4.0x10 ⁵	3	20	10
RSB	4.0x10 ⁶	1	15	13
RSB	4.0x10 ⁶	2	15	15
RSB	4.0x10 ⁶	3	20	20
RSB	4.0x10 ⁷	1	15	15
RSB	4.0x10 ⁷	2	15	15
RSB	4.0x10 ⁷	3	20	20

APPENDIX 2
RAW DATA FOR CHAPTER 2 -- POPULATION DENSITY OF *O. PUGNAX* IN
SMALL-PLOT FIELD EXPERIMENTS IN 2001, 2002, AND 2003

Year	Days after application	Group*	Treatment	Block	Adults (bugs/10 sweeps)	Nymphs (bugs/10 sweeps)
2001	2	I	Fury	1	0	0
2001	2	I	Fury	2	2	1
2001	2	I	Fury	3	1	2
2001	2	I	Fury	4	0	1
2001	2	I	Karate	1	2	1
2001	2	I	Karate	2	1	2
2001	2	I	Karate	3	0	1
2001	2	I	Karate	4	2	1
2001	2	F	RSB	1	8	5
2001	2	F	RSB	2	5	6
2001	2	F	RSB	3	6	5
2001	2	F	RSB	4	11	4
2001	2	F	LRC21	1	6	3
2001	2	F	LRC21	2	5	5
2001	2	F	LRC21	3	6	5
2001	2	F	LRC21	4	2	4
2001	2	F	LRC28	1	3	4
2001	2	F	LRC28	2	7	3
2001	2	F	LRC28	3	8	4
2001	2	F	LRC28	4	8	4
2001	2	C	Control	1	4	8
2001	2	C	Control	2	9	4
2001	2	C	Control	3	8	5
2001	2	C	Control	4	4	6
2001	4	I	Fury	1	0	1
2001	4	I	Fury	2	1	1
2001	4	I	Fury	3	0	0
2001	4	I	Fury	4	1	2
2001	4	I	Karate	1	1	2

2001	4	I	Karate	2	1	1
2001	4	I	Karate	3	0	2
2001	4	I	Karate	4	3	1
2001	4	F	RSB	1	7	2
2001	4	F	RSB	2	4	3
2001	4	F	RSB	3	9	3
2001	4	F	RSB	4	0	7
2001	4	F	LRC21	1	5	2
2001	4	F	LRC21	2	4	2
2001	4	F	LRC21	3	3	2
2001	4	F	LRC21	4	4	4
2001	4	F	LRC28	1	5	3
2001	4	F	LRC28	2	8	2
2001	4	F	LRC28	3	5	2
2001	4	F	LRC28	4	6	1
2001	4	C	Control	1	6	5
2001	4	C	Control	2	4	3
2001	4	C	Control	3	4	4
2001	4	C	Control	4	6	4
2001	8	I	Fury	1	1	1
2001	8	I	Fury	2	0	1
2001	8	I	Fury	3	2	2
2001	8	I	Fury	4	1	0
2001	8	I	Karate	1	1	2
2001	8	I	Karate	2	2	0
2001	8	I	Karate	3	2	2
2001	8	I	Karate	4	2	3
2001	8	F	RSB	1	1	2
2001	8	F	RSB	2	2	2
2001	8	F	RSB	3	4	2
2001	8	F	RSB	4	3	0
2001	8	F	LRC21	1	1	1
2001	8	F	LRC21	2	2	2
2001	8	F	LRC21	3	1	3

2001	8	F	LRC21	4	3	1
2001	8	F	LRC28	1	1	2
2001	8	F	LRC28	2	3	1
2001	8	F	LRC28	3	4	1
2001	8	F	LRC28	4	4	1
2001	8	C	Control	1	4	3
2001	8	C	Control	2	7	3
2001	8	C	Control	3	4	3
2001	8	C	Control	4	7	3
2001	16	I	Fury	1	2	3
2001	16	I	Fury	2	2	3
2001	16	I	Fury	3	5	3
2001	16	I	Fury	4	4	3
2001	16	I	Karate	1	4	2
2001	16	I	Karate	2	3	3
2001	16	I	Karate	3	1	3
2001	16	I	Karate	4	1	4
2001	16	F	RSB	1	2	1
2001	16	F	RSB	2	2	3
2001	16	F	RSB	3	4	2
2001	16	F	RSB	4	2	2
2001	16	F	LRC21	1	3	2
2001	16	F	LRC21	2	2	3
2001	16	F	LRC21	3	3	3
2001	16	F	LRC21	4	2	5
2001	16	F	LRC28	1	3	2
2001	16	F	LRC28	2	2	3
2001	16	F	LRC28	3	2	2
2001	16	F	LRC28	4	5	5
2001	16	C	Control	1	6	6
2001	16	C	Control	2	3	4
2001	16	C	Control	3	3	2
2001	16	C	Control	4	3	3
2001	22	I	Fury	1	3	4

2001	22	I	Fury	2	5	3
2001	22	I	Fury	3	5	2
2001	22	I	Fury	4	6	2
2001	22	I	Karate	1	5	3
2001	22	I	Karate	2	5	3
2001	22	I	Karate	3	6	2
2001	22	I	Karate	4	6	3
2001	22	F	RSB	1	7	2
2001	22	F	RSB	2	4	4
2001	22	F	RSB	3	3	4
2001	22	F	RSB	4	6	3
2001	22	F	LRC21	1	5	3
2001	22	F	LRC21	2	4	3
2001	22	F	LRC21	3	5	4
2001	22	F	LRC21	4	7	3
2001	22	F	LRC28	1	5	2
2001	22	F	LRC28	2	5	3
2001	22	F	LRC28	3	5	2
2001	22	F	LRC28	4	3	3
2001	22	C	Control	1	5	5
2001	22	C	Control	2	5	3
2001	22	C	Control	3	5	4
2001	22	C	Control	4	3	5
2002	2	C	Control	1	3	14
2002	2	C	Control	2	3	8
2002	2	C	Control	3	1	8
2002	2	C	Control	4	1	10
2002	2	C	Control	5	6	7
2002	2	I	Karate	1	0	0
2002	2	I	Karate	2	0	0
2002	2	I	Karate	3	1	0
2002	2	I	Karate	4	1	0
2002	2	I	Karate	5	0	0
2002	2	I	Fury	1	3	0

2002	2	I	Fury	2	0	0
2002	2	I	Fury	3	0	0
2002	2	I	Fury	4	1	2
2002	2	I	Fury	5	1	0
2002	2	M	Karate + LRC28	1	1	0
2002	2	M	Karate + LRC28	2	0	1
2002	2	M	Karate + LRC28	3	1	0
2002	2	M	Karate + LRC28	4	0	1
2002	2	M	Karate + LRC28	5	1	0
2002	2	M	LKLRC	1	3	1
2002	2	M	LKLRC	2	2	4
2002	2	M	LKLRC	3	2	1
2002	2	M	LKLRC	4	1	3
2002	2	M	LKLRC	5	1	2
2002	2	F	LRC28	1	2	12
2002	2	F	LRC28	2	3	14
2002	2	F	LRC28	3	2	8
2002	2	F	LRC28	4	3	4
2002	2	F	LRC28	5	2	4
2002	2	F	RSB	1	3	3
2002	2	F	RSB	2	2	16
2002	2	F	RSB	3	5	7
2002	2	F	RSB	4	2	4
2002	2	F	RSB	5	2	1
2002	7	C	Control	1	5	1
2002	7	C	Control	2	3	7
2002	7	C	Control	3	3	2
2002	7	C	Control	4	2	5
2002	7	C	Control	5	4	7
2002	7	I	Karate	1	2	0
2002	7	I	Karate	2	1	0
2002	7	I	Karate	3	2	0
2002	7	I	Karate	4	2	2
2002	7	I	Karate	5	0	0

2002	7	I	Fury	1	0	1
2002	7	I	Fury	2	0	2
2002	7	I	Fury	3	0	0
2002	7	I	Fury	4	0	8
2002	7	I	Fury	5	1	1
2002	7	M	Karate + LRC28	1	1	0
2002	7	M	Karate + LRC28	2	0	0
2002	7	M	Karate + LRC28	3	1	0
2002	7	M	Karate + LRC28	4	1	0
2002	7	M	Karate + LRC28	5	0	0
2002	7	M	LKLRC	1	0	1
2002	7	M	LKLRC	2	1	1
2002	7	M	LKLRC	3	1	0
2002	7	M	LKLRC	4	0	1
2002	7	M	LKLRC	5	1	1
2002	7	F	LRC28	1	3	2
2002	7	F	LRC28	2	3	2
2002	7	F	LRC28	3	2	3
2002	7	F	LRC28	4	2	2
2002	7	F	LRC28	5	2	1
2002	7	F	RSB	1	1	3
2002	7	F	RSB	2	2	4
2002	7	F	RSB	3	1	1
2002	7	F	RSB	4	1	5
2002	7	F	RSB	5	1	2
2002	11	C	Control	1	3	4
2002	11	C	Control	2	2	4
2002	11	C	Control	3	2	3
2002	11	C	Control	4	2	1
2002	11	C	Control	5	1	1
2002	11	I	Karate	1	1	2
2002	11	I	Karate	2	2	0
2002	11	I	Karate	3	1	2
2002	11	I	Karate	4	2	0

2002	11	I	Karate	5	1	1
2002	11	I	Fury	1	2	1
2002	11	I	Fury	2	2	1
2002	11	I	Fury	3	1	2
2002	11	I	Fury	4	2	1
2002	11	I	Fury	5	1	1
2002	11	M	Karate + LRC28	1	1	1
2002	11	M	Karate + LRC28	2	2	1
2002	11	M	Karate + LRC28	3	1	1
2002	11	M	Karate + LRC28	4	1	1
2002	11	M	Karate + LRC28	5	1	0
2002	11	M	LKLRC	1	1	1
2002	11	M	LKLRC	2	1	0
2002	11	M	LKLRC	3	2	1
2002	11	M	LKLRC	4	2	2
2002	11	M	LKLRC	5	4	1
2002	11	F	LRC28	1	2	1
2002	11	F	LRC28	2	1	2
2002	11	F	LRC28	3	2	1
2002	11	F	LRC28	4	2	1
2002	11	F	LRC28	5	1	1
2002	11	F	RSB	1	1	1
2002	11	F	RSB	2	2	1
2002	11	F	RSB	3	1	2
2002	11	F	RSB	4	1	2
2002	11	F	RSB	5	1	2
2002	17	C	Control	1	5	3
2002	17	C	Control	2	3	5
2002	17	C	Control	3	1	2
2002	17	C	Control	4	5	4
2002	17	C	Control	5	3	2
2002	17	I	Karate	1	7	6
2002	17	I	Karate	2	3	0
2002	17	I	Karate	3	2	1

2002	17	I	Karate	4	8	1
2002	17	I	Karate	5	8	3
2002	17	I	Fury	1	4	1
2002	17	I	Fury	2	3	2
2002	17	I	Fury	3	2	4
2002	17	I	Fury	4	7	2
2002	17	I	Fury	5	2	2
2002	17	M	Karate + LRC28	1	1	2
2002	17	M	Karate + LRC28	2	1	3
2002	17	M	Karate + LRC28	3	2	1
2002	17	M	Karate + LRC28	4	1	2
2002	17	M	Karate + LRC28	5	1	2
2002	17	M	LKLRC	1	5	1
2002	17	M	LKLRC	2	5	3
2002	17	M	LKLRC	3	1	2
2002	17	M	LKLRC	4	2	1
2002	17	M	LKLRC	5	1	3
2002	17	F	LRC28	1	1	1
2002	17	F	LRC28	2	2	1
2002	17	F	LRC28	3	5	2
2002	17	F	LRC28	4	2	2
2002	17	F	LRC28	5	3	3
2002	17	F	RSB	1	1	2
2002	17	F	RSB	2	3	3
2002	17	F	RSB	3	1	2
2002	17	F	RSB	4	3	2
2002	17	F	RSB	5	4	3
2003	2	C	Control	1	4	5
2003	2	C	Control	2	1	3
2003	2	C	Control	3	5	3
2003	2	C	Control	4	4	2
2003	2	I	Prolex	1	0	2
2003	2	I	Prolex	2	1	1
2003	2	I	Prolex	3	0	0

2003	2	I	Prolex	4	2	1
2003	2	I	Mustang Max	1	3	0
2003	2	I	Mustang Max	2	1	0
2003	2	I	Mustang Max	3	2	0
2003	2	I	Mustang Max	4	1	0
2003	2	I	Karate	1	2	1
2003	2	I	Karate	2	0	0
2003	2	I	Karate	3	2	2
2003	2	I	Karate	4	0	0
2003	2	T	TKarate	1	5	1
2003	2	T	TKarate	2	1	0
2003	2	T	TKarate	3	1	0
2003	2	T	TKarate	4	0	0
2003	2	M	LKLRC	1	2	0
2003	2	M	LKLRC	2	2	0
2003	2	M	LKLRC	3	3	0
2003	2	M	LKLRC	4	1	0
2003	2	F	LRC28	1	3	4
2003	2	F	LRC28	2	3	2
2003	2	F	LRC28	3	3	2
2003	2	F	LRC28	4	1	4
2003	4	C	Control	1	3	3
2003	4	C	Control	2	2	4
2003	4	C	Control	3	3	3
2003	4	C	Control	4	3	1
2003	4	I	Prolex	1	1	0
2003	4	I	Prolex	2	4	0
2003	4	I	Prolex	3	0	0
2003	4	I	Prolex	4	5	0
2003	4	I	Mustang Max	1	2	1
2003	4	I	Mustang Max	2	4	0
2003	4	I	Mustang Max	3	5	0
2003	4	I	Mustang Max	4	3	0
2003	4	I	Karate	1	1	0

2003	4	I	Karate	2	1	0
2003	4	I	Karate	3	1	0
2003	4	I	Karate	4	1	0
2003	4	T	TKarate	1	3	1
2003	4	T	TKarate	2	1	0
2003	4	T	TKarate	3	3	0
2003	4	T	TKarate	4	3	0
2003	4	M	LKLRC	1	2	0
2003	4	M	LKLRC	2	3	0
2003	4	M	LKLRC	3	1	0
2003	4	M	LKLRC	4	3	0
2003	4	F	LRC28	1	2	2
2003	4	F	LRC28	2	2	2
2003	4	F	LRC28	3	1	3
2003	4	F	LRC28	4	6	2
2003	8	C	Control	1	3	3
2003	8	C	Control	2	5	5
2003	8	C	Control	3	2	4
2003	8	C	Control	4	2	2
2003	8	I	Prolex	1	0	0
2003	8	I	Prolex	2	4	1
2003	8	I	Prolex	3	0	0
2003	8	I	Prolex	4	3	0
2003	8	I	Mustang Max	1	3	0
2003	8	I	Mustang Max	2	1	1
2003	8	I	Mustang Max	3	0	0
2003	8	I	Mustang Max	4	2	0
2003	8	I	Karate	1	6	0
2003	8	I	Karate	2	1	0
2003	8	I	Karate	3	0	0
2003	8	I	Karate	4	1	0
2003	8	T	TKarate	1	2	0
2003	8	T	TKarate	2	2	0
2003	8	T	TKarate	3	1	0

2003	8	T	TKarate	4	0	0
2003	8	M	LKLRC	1	1	0
2003	8	M	LKLRC	2	2	0
2003	8	M	LKLRC	3	3	0
2003	8	M	LKLRC	4	1	0
2003	8	F	LRC28	1	0	2
2003	8	F	LRC28	2	3	1
2003	8	F	LRC28	3	2	2
2003	8	F	LRC28	4	4	2
2003	10	C	Control	1	3	4
2003	10	C	Control	2	4	3
2003	10	C	Control	3	3	3
2003	10	C	Control	4	1	2
2003	10	I	Prolex	1	2	0
2003	10	I	Prolex	2	6	0
2003	10	I	Prolex	3	3	0
2003	10	I	Prolex	4	8	0
2003	10	I	Mustang Max	1	5	0
2003	10	I	Mustang Max	2	2	0
2003	10	I	Mustang Max	3	1	0
2003	10	I	Mustang Max	4	0	0
2003	10	I	Karate	1	3	0
2003	10	I	Karate	2	2	0
2003	10	I	Karate	3	1	0
2003	10	I	Karate	4	0	0
2003	10	T	TKarate	1	0	0
2003	10	T	TKarate	2	1	0
2003	10	T	TKarate	3	0	0
2003	10	T	TKarate	4	0	0
2003	10	M	LKLRC	1	2	2
2003	10	M	LKLRC	2	2	3
2003	10	M	LKLRC	3	3	2
2003	10	M	LKLRC	4	2	2
2003	10	F	LRC28	1	3	2

2003	10	F	LRC28	2	3	2
2003	10	F	LRC28	3	1	2
2003	10	F	LRC28	4	1	1
2003	14	C	Control	1	1	4
2003	14	C	Control	2	3	2
2003	14	C	Control	3	3	1
2003	14	C	Control	4	3	3
2003	14	I	Prolex	1	1	8
2003	14	I	Prolex	2	2	1
2003	14	I	Prolex	3	1	2
2003	14	I	Prolex	4	1	0
2003	14	I	Mustang Max	1	1	2
2003	14	I	Mustang Max	2	4	3
2003	14	I	Mustang Max	3	1	2
2003	14	I	Mustang Max	4	2	1
2003	14	I	Karate	1	1	2
2003	14	I	Karate	2	2	2
2003	14	I	Karate	3	2	3
2003	14	I	Karate	4	1	0
2003	14	T	TKarate	1	0	0
2003	14	T	TKarate	2	1	0
2003	14	T	TKarate	3	0	0
2003	14	T	TKarate	4	1	0
2003	14	M	LKLRC	1	1	1
2003	14	M	LKLRC	2	2	2
2003	14	M	LKLRC	3	2	0
2003	14	M	LKLRC	4	2	1
2003	14	F	LRC28	1	2	3
2003	14	F	LRC28	2	3	2
2003	14	F	LRC28	3	4	3
2003	14	F	LRC28	4	1	1
2003	18	C	Control	1	2	2
2003	18	C	Control	2	3	3
2003	18	C	Control	3	4	1

2003	18	C	Control	4	3	3
2003	18	I	Prolex	1	2	3
2003	18	I	Prolex	2	3	0
2003	18	I	Prolex	3	3	1
2003	18	I	Prolex	4	3	2
2003	18	I	Mustang Max	1	3	3
2003	18	I	Mustang Max	2	1	2
2003	18	I	Mustang Max	3	4	0
2003	18	I	Mustang Max	4	3	1
2003	18	I	Karate	1	3	1
2003	18	I	Karate	2	2	2
2003	18	I	Karate	3	2	1
2003	18	I	Karate	4	4	1
2003	18	T	TKarate	1	1	2
2003	18	T	TKarate	2	0	1
2003	18	T	TKarate	3	3	0
2003	18	T	TKarate	4	2	0
2003	18	M	LKLRC	1	1	1
2003	18	M	LKLRC	2	2	1
2003	18	M	LKLRC	3	2	2
2003	18	M	LKLRC	4	4	1
2003	18	F	LRC28	1	1	1
2003	18	F	LRC28	2	2	1
2003	18	F	LRC28	3	4	2
2003	18	F	LRC28	4	1	1

LKLRC = Reduced rate of Karate® + LRC28; TKarate = Karate applied twice.

Group = Groups of treatments used for statistical analysis. I = insecticide; F = fungal isolate; M = insecticide plus fungal isolate; T = insecticides applied twice, the second application made a week after the application dates mentioned in Table 1.1; and C = control.

APPENDIX 3
RAW DATA FOR CHAPTER 2 -- MYCOSIS OF *O. PUGNAX* BY *B. BASSIANA* IN
SMALL-PLOT FIELD EXPERIMENTS IN 2001, 2002, AND 2003

Year	Days after application	Treatment (Isolate)	Block	Adult (bugs/10 sweeps)	Nymph (bugs/10 sweeps)	No. of dead adult	No. of dead nymph
2001	2	RSB	1	8	5	1	1
2001	2	RSB	2	5	6	1	2
2001	2	RSB	3	6	5	1	2
2001	2	RSB	4	11	4	0	2
2001	2	LRC21	1	6	3	0	0
2001	2	LRC21	2	5	5	0	3
2001	2	LRC21	3	6	5	2	0
2001	2	LRC21	4	2	4	0	1
2001	2	LRC28	1	3	4	1	2
2001	2	LRC28	2	7	3	1	1
2001	2	LRC28	3	8	4	1	2
2001	2	LRC28	4	8	4	2	1
2001	2	Control	1	4	8	0	0
2001	2	Control	2	9	4	0	0
2001	2	Control	3	8	5	2	0
2001	2	Control	4	4	6	0	0
2001	4	RSB	1	7	2	0	1
2001	4	RSB	2	4	3	1	1
2001	4	RSB	3	9	3	0	0
2001	4	RSB	4	0	7	0	1
2001	4	LRC21	1	5	2	0	2
2001	4	LRC21	2	4	2	0	0
2001	4	LRC21	3	3	2	1	0
2001	4	LRC21	4	4	4	0	1
2001	4	LRC28	1	5	3	0	2
2001	4	LRC28	2	8	2	0	0
2001	4	LRC28	3	5	2	2	1
2001	4	LRC28	4	6	1	0	1

2001	4	Control	1	6	5	0	1
2001	4	Control	2	4	3	1	0
2001	4	Control	3	4	4	0	0
2001	4	Control	4	6	4	0	0
2001	8	RSB	1	1	2	0	1
2001	8	RSB	2	2	2	0	0
2001	8	RSB	3	4	2	1	0
2001	8	RSB	4	3	0	0	0
2001	8	LRC21	1	1	1	0	1
2001	8	LRC21	2	2	2	0	0
2001	8	LRC21	3	1	3	0	0
2001	8	LRC21	4	3	1	0	0
2001	8	LRC28	1	1	2	0	1
2001	8	LRC28	2	3	1	1	0
2001	8	LRC28	3	4	1	0	0
2001	8	LRC28	4	4	1	0	1
2001	8	Control	1	4	3	0	0
2001	8	Control	2	7	3	0	0
2001	8	Control	3	4	3	0	0
2001	8	Control	4	7	3	0	0
2001	16	RSB	1	2	1	0	0
2001	16	RSB	2	2	3	0	1
2001	16	RSB	3	4	2	0	0
2001	16	RSB	4	2	2	0	0
2001	16	LRC21	1	3	2	0	0
2001	16	LRC21	2	2	3	0	0
2001	16	LRC21	3	3	3	0	0
2001	16	LRC21	4	2	5	0	0
2001	16	LRC28	1	3	2	0	1
2001	16	LRC28	2	2	3	1	0
2001	16	LRC28	3	2	2	0	0
2001	16	LRC28	4	5	5	0	0
2001	16	Control	1	6	6	0	0
2001	16	Control	2	3	4	0	0

2001	16	Control	3	3	2	0	0
2001	16	Control	4	3	3	0	0
2001	22	RSB	1	7	2	0	0
2001	22	RSB	2	4	4	0	0
2001	22	RSB	3	3	4	0	0
2001	22	RSB	4	6	3	0	0
2001	22	LRC21	1	5	3	0	0
2001	22	LRC21	2	4	3	0	0
2001	22	LRC21	3	5	4	0	0
2001	22	LRC21	4	7	3	0	0
2001	22	LRC28	1	5	2	0	1
2001	22	LRC28	2	5	3	0	0
2001	22	LRC28	3	5	2	0	0
2001	22	LRC28	4	3	3	0	0
2001	22	Control	1	5	5	0	0
2001	22	Control	2	5	3	0	0
2001	22	Control	3	5	4	0	0
2001	22	Control	4	3	5	0	0
2002	2	LRC28	1	2	12	1	3
2002	2	LRC28	2	3	14	2	5
2002	2	LRC28	3	2	8	0	3
2002	2	LRC28	4	3	4	1	2
2002	2	LRC28	5	2	4	0	1
2002	2	RSB	1	3	3	0	1
2002	2	RSB	2	2	16	1	4
2002	2	RSB	3	5	7	1	2
2002	2	RSB	4	2	4	0	2
2002	2	RSB	5	2	1	1	0
2002	2	Karate + LRC28	1	1	0	0	0
2002	2	Karate + LRC28	2	0	1	0	1
2002	2	Karate + LRC28	3	1	0	1	0
2002	2	Karate + LRC28	4	0	1	0	0
2002	2	Karate + LRC28	5	1	0	0	0
2002	2	LKLRC	1	3	1	0	0

2002	2	LKLRC	2	2	4	1	2
2002	2	LKLRC	3	2	1	0	0
2002	2	LKLRC	4	1	3	0	1
2002	2	LKLRC	5	1	2	0	0
2002	2	Control	1	3	14	0	0
2002	2	Control	2	3	8	0	0
2002	2	Control	3	1	8	0	0
2002	2	Control	4	1	10	0	1
2002	2	Control	5	6	7	1	0
2002	7	LRC28	1	3	2	0	1
2002	7	LRC28	2	3	2	1	2
2002	7	LRC28	3	2	3	0	0
2002	7	LRC28	4	2	2	0	0
2002	7	LRC28	5	2	1	0	1
2002	7	RSB	1	1	3	0	1
2002	7	RSB	2	2	4	1	2
2002	7	RSB	3	1	1	0	0
2002	7	RSB	4	1	5	0	1
2002	7	RSB	5	1	2	0	1
2002	7	Karate + LRC28	1	1	0	0	0
2002	7	Karate + LRC28	2	0	0	0	0
2002	7	Karate + LRC28	3	1	0	0	0
2002	7	Karate + LRC28	4	1	0	0	0
2002	7	Karate + LRC28	5	0	0	0	0
2002	7	LKLRC	1	0	1	0	1
2002	7	LKLRC	2	1	1	0	0
2002	7	LKLRC	3	1	0	0	0
2002	7	LKLRC	4	0	1	0	0
2002	7	LKLRC	5	1	1	0	0
2002	7	Control	1	5	1	1	0
2002	7	Control	2	3	7	0	0
2002	7	Control	3	3	2	0	0
2002	7	Control	4	2	5	0	0
2002	7	Control	5	4	7	0	0

2002	11	LRC28	1	2	1	0	0
2002	11	LRC28	2	1	2	0	1
2002	11	LRC28	3	2	1	0	0
2002	11	LRC28	4	2	1	0	1
2002	11	LRC28	5	1	1	0	0
2002	11	RSB	1	1	1	0	0
2002	11	RSB	2	2	1	1	0
2002	11	RSB	3	1	2	0	0
2002	11	RSB	4	1	2	0	1
2002	11	RSB	5	1	2	0	0
2002	11	Karate + LRC28	1	1	1	0	0
2002	11	Karate + LRC28	2	2	1	0	0
2002	11	Karate + LRC28	3	1	1	0	0
2002	11	Karate + LRC28	4	1	1	0	1
2002	11	Karate + LRC28	5	1	0	0	0
2002	11	LKLRC	1	1	1	0	0
2002	11	LKLRC	2	1	0	0	0
2002	11	LKLRC	3	2	1	0	0
2002	11	LKLRC	4	2	2	0	0
2002	11	LKLRC	5	4	1	0	0
2002	11	Control	1	3	4	0	0
2002	11	Control	2	2	4	0	0
2002	11	Control	3	2	3	0	0
2002	11	Control	4	4	3	0	0
2002	11	Control	5	1	1	0	0
2002	17	LRC28	1	1	1	0	0
2002	17	LRC28	2	2	1	0	0
2002	17	LRC28	3	5	2	0	0
2002	17	LRC28	4	2	2	0	0
2002	17	LRC28	5	3	3	0	1
2002	17	RSB	1	1	2	0	0
2002	17	RSB	2	3	3	0	0
2002	17	RSB	3	1	2	0	1
2002	17	RSB	4	3	2	0	0

2002	17	RSB	5	4	3	0	0
2002	17	Karate + LRC28	1	1	2	0	0
2002	17	Karate + LRC28	2	1	3	0	0
2002	17	Karate + LRC28	3	2	1	0	0
2002	17	Karate + LRC28	4	1	2	0	0
2002	17	Karate + LRC28	5	1	2	0	0
2002	17	LKLRC	1	5	1	0	1
2002	17	LKLRC	2	5	3	0	0
2002	17	LKLRC	3	1	2	0	0
2002	17	LKLRC	4	2	1	0	0
2002	17	LKLRC	5	1	3	0	0
2002	17	Control	1	5	3	0	0
2002	17	Control	2	3	5	0	0
2002	17	Control	3	1	2	0	0
2002	17	Control	4	5	4	0	0
2002	17	Control	5	3	2	0	0
2003	2	LKLRC	1	2	0	0	0
2003	2	LKLRC	2	2	0	1	0
2003	2	LKLRC	3	3	0	1	0
2003	2	LKLRC	4	1	0	0	0
2003	2	LRC28	1	3	4	2	2
2003	2	LRC28	2	3	2	0	0
2003	2	LRC28	3	3	2	0	1
2003	2	LRC28	4	1	4	0	1
2003	2	Control	1	4	5	1	0
2003	2	Control	2	1	3	0	0
2003	2	Control	3	5	3	0	0
2003	2	Control	4	4	2	0	0
2003	4	LKLRC	1	2	0	0	0
2003	4	LKLRC	2	3	0	1	0
2003	4	LKLRC	3	1	0	0	0
2003	4	LKLRC	4	3	0	0	0
2003	4	LRC28	1	2	2	1	1
2003	4	LRC28	2	2	2	0	0

2003	4	LRC28	3	1	3	0	1
2003	4	LRC28	4	6	2	1	1
2003	4	Control	1	3	3	0	0
2003	4	Control	2	2	4	0	1
2003	4	Control	3	3	3	0	0
2003	4	Control	4	3	1	0	0
2003	8	LKLRC	1	1	0	0	0
2003	8	LKLRC	2	2	0	0	0
2003	8	LKLRC	3	3	0	0	0
2003	8	LKLRC	4	1	0	0	0
2003	8	LRC28	1	0	2	0	1
2003	8	LRC28	2	3	1	0	0
2003	8	LRC28	3	2	2	0	0
2003	8	LRC28	4	4	2	1	0
2003	8	Control	1	3	3	0	0
2003	8	Control	2	5	5	0	0
2003	8	Control	3	2	4	0	0
2003	8	Control	4	2	2	0	0
2003	10	LKLRC	1	2	2	0	0
2003	10	LKLRC	2	2	3	0	1
2003	10	LKLRC	3	3	2	0	0
2003	10	LKLRC	4	2	2	0	0
2003	10	LRC28	1	3	2	0	1
2003	10	LRC28	2	3	2	1	0
2003	10	LRC28	3	1	2	0	0
2003	10	LRC28	4	1	1	0	0
2003	10	Control	1	3	4	0	0
2003	10	Control	2	4	3	0	0
2003	10	Control	3	3	3	0	0
2003	10	Control	4	1	2	0	0
2003	14	LKLRC	1	1	1	0	0
2003	14	LKLRC	2	2	2	0	0
2003	14	LKLRC	3	2	0	0	0
2003	14	LKLRC	4	2	1	0	0

2003	14	LRC28	1	2	3	0	0
2003	14	LRC28	2	3	2	0	0
2003	14	LRC28	3	4	3	0	1
2003	14	LRC28	4	1	1	0	0
2003	14	Control	1	1	4	0	0
2003	14	Control	2	3	2	0	0
2003	14	Control	3	3	1	0	0
2003	14	Control	4	3	3	0	0
2003	18	LKLRC	1	1	1	0	0
2003	18	LKLRC	2	2	1	0	0
2003	18	LKLRC	3	2	2	1	0
2003	18	LKLRC	4	4	1	0	0
2003	18	LRC28	1	1	1	0	0
2003	18	LRC28	2	2	1	0	0
2003	18	LRC28	3	4	2	0	0
2003	18	LRC28	4	1	1	0	0
2003	18	Control	1	2	2	0	0
2003	18	Control	2	3	3	0	0
2003	18	Control	3	4	1	0	0
2003	18	Control	4	3	3	0	0

LKLRC = Reduced rate of Karate® + LRC28.

APPENDIX 4
RAW DATA FOR CHAPTER 2 -- SPREAD AND PERSISTANCE OF *B. BASSIANA* IN
LARGE-PLOT SPREAD EXPERIMENTS

Species	Distance from treated plot (ft)	Day after application	Direction from treated plot	Replicates	No. of bugs per 10 sweeps	No. of dead bugs
RSB	0	1	NA	1	4	2
RSB	0	1	NA	2	6	3
RSB	0	5	NA	1	6	2
RSB	0	5	NA	2	5	2
RSB	0	9	NA	1	5	1
RSB	0	9	NA	2	8	2
RSB	0	13	NA	1	5	0
RSB	0	13	NA	2	10	1
RSB	0	18	NA	1	10	1
RSB	0	18	NA	2	4	0
RSB	0	23	NA	1	5	0
RSB	0	23	NA	2	4	0
RSB	15	1	E	1	2	0
RSB	15	1	E	2	4	0
RSB	15	1	W	1	3	1
RSB	15	1	W	2	5	0
RSB	15	1	N	1	2	0
RSB	15	1	N	2	3	0
RSB	15	1	S	1	1	0
RSB	15	1	S	2	8	1
RSB	15	5	E	1	4	0
RSB	15	5	E	2	9	1
RSB	15	5	W	1	5	1
RSB	15	5	W	2	8	0
RSB	15	5	N	1	4	1
RSB	15	5	N	2	10	1
RSB	15	5	S	1	5	0
RSB	15	5	S	2	8	0
RSB	15	9	E	1	6	0

RSB	15	9	E	2	9	0
RSB	15	9	W	1	4	0
RSB	15	9	W	2	13	1
RSB	15	9	N	1	4	0
RSB	15	9	N	2	9	0
RSB	15	9	S	1	3	0
RSB	15	9	S	2	10	0
RSB	15	13	E	1	9	0
RSB	15	13	E	2	10	0
RSB	15	13	W	1	6	0
RSB	15	13	W	2	10	0
RSB	15	13	N	1	8	1
RSB	15	13	N	2	9	0
RSB	15	13	S	1	10	0
RSB	15	13	S	2	10	0
RSB	15	18	E	1	11	0
RSB	15	18	E	2	6	0
RSB	15	18	W	1	8	0
RSB	15	18	W	2	7	0
RSB	15	18	N	1	9	0
RSB	15	18	N	2	8	0
RSB	15	18	S	1	7	0
RSB	15	18	S	2	5	0
RSB	15	23	E	1	3	0
RSB	15	23	E	2	3	0
RSB	15	23	W	1	4	0
RSB	15	23	W	2	2	0
RSB	15	23	N	1	6	0
RSB	15	23	N	2	5	0
RSB	15	23	S	1	4	0
RSB	15	23	S	2	4	0
RSB	30	1	E	1	3	0
RSB	30	1	E	2	5	0
RSB	30	1	W	1	2	0

RSB	30	1	W	2	4	0
RSB	30	1	N	1	3	1
RSB	30	1	N	2	3	0
RSB	30	1	S	1	3	0
RSB	30	1	S	2	5	0
RSB	30	5	E	1	2	0
RSB	30	5	E	2	8	1
RSB	30	5	W	1	3	0
RSB	30	5	W	2	7	0
RSB	30	5	N	1	4	0
RSB	30	5	N	2	10	1
RSB	30	5	S	1	4	1
RSB	30	5	S	2	9	0
RSB	30	9	E	1	6	1
RSB	30	9	E	2	9	0
RSB	30	9	W	1	3	0
RSB	30	9	W	2	9	0
RSB	30	9	N	1	5	0
RSB	30	9	N	2	11	0
RSB	30	9	S	1	5	0
RSB	30	9	S	2	6	0
RSB	30	13	E	1	6	0
RSB	30	13	E	2	8	0
RSB	30	13	W	1	4	0
RSB	30	13	W	2	11	1
RSB	30	13	N	1	8	0
RSB	30	13	N	2	9	0
RSB	30	13	S	1	7	0
RSB	30	13	S	2	7	0
RSB	30	18	E	1	10	0
RSB	30	18	E	2	7	0
RSB	30	18	W	1	7	0
RSB	30	18	W	2	8	0
RSB	30	18	N	1	6	0

RSB	30	18	N	2	9	0
RSB	30	18	S	1	6	0
RSB	30	18	S	2	8	0
RSB	30	23	E	1	2	0
RSB	30	23	E	2	5	0
RSB	30	23	W	1	3	0
RSB	30	23	W	2	3	0
RSB	30	23	N	1	3	0
RSB	30	23	N	2	5	0
RSB	30	23	S	1	3	0
RSB	30	23	S	2	2	0
GH	0	1	NA	1	23	3
GH	0	1	NA	2	13	3
GH	0	5	NA	1	25	1
GH	0	5	NA	2	20	2
GH	0	9	NA	1	6	0
GH	0	9	NA	2	4	0
GH	0	13	NA	1	5	0
GH	0	13	NA	2	5	1
GH	0	18	NA	1	3	0
GH	0	18	NA	2	3	0
GH	0	23	NA	1	3	0
GH	0	23	NA	2	3	0
GH	15	1	E	1	21	1
GH	15	1	E	2	21	1
GH	15	1	W	1	24	0
GH	15	1	W	2	18	1
GH	15	1	N	1	27	1
GH	15	1	N	2	23	0
GH	15	1	S	1	30	2
GH	15	1	S	2	20	0
GH	15	5	E	1	24	0
GH	15	5	E	2	15	0
GH	15	5	W	1	19	1

GH	15	5	W	2	20	0
GH	15	5	N	1	24	0
GH	15	5	N	2	21	0
GH	15	5	S	1	22	0
GH	15	5	S	2	19	1
GH	15	9	E	1	19	1
GH	15	9	E	2	13	0
GH	15	9	W	1	15	0
GH	15	9	W	2	11	0
GH	15	9	N	1	21	1
GH	15	9	N	2	13	0
GH	15	9	S	1	20	0
GH	15	9	S	2	14	0
GH	15	13	E	1	12	0
GH	15	13	E	2	7	1
GH	15	13	W	1	13	0
GH	15	13	W	2	6	0
GH	15	13	N	1	10	0
GH	15	13	N	2	6	0
GH	15	13	S	1	12	0
GH	15	13	S	2	9	0
GH	15	18	E	1	5	0
GH	15	18	E	2	5	0
GH	15	18	W	1	9	0
GH	15	18	W	2	6	0
GH	15	18	N	1	6	0
GH	15	18	N	2	7	0
GH	15	18	S	1	3	0
GH	15	18	S	2	5	0
GH	15	23	E	1	3	0
GH	15	23	E	2	3	0
GH	15	23	W	1	5	0
GH	15	23	W	2	2	0
GH	15	23	N	1	4	0

GH	15	23	N	2	4	0
GH	15	23	S	1	5	0
GH	15	23	S	2	2	0
GH	30	1	E	1	26	1
GH	30	1	E	2	19	1
GH	30	1	W	1	21	0
GH	30	1	W	2	18	1
GH	30	1	N	1	25	1
GH	30	1	N	2	21	1
GH	30	1	S	1	25	0
GH	30	1	S	2	19	0
GH	30	5	E	1	27	0
GH	30	5	E	2	17	0
GH	30	5	W	1	24	1
GH	30	5	W	2	18	0
GH	30	5	N	1	21	0
GH	30	5	N	2	17	0
GH	30	5	S	1	25	1
GH	30	5	S	2	17	0
GH	30	9	E	1	19	0
GH	30	9	E	2	11	0
GH	30	9	W	1	22	0
GH	30	9	W	2	14	0
GH	30	9	N	1	21	0
GH	30	9	N	2	8	0
GH	30	9	S	1	16	0
GH	30	9	S	2	11	1
GH	30	13	E	1	9	0
GH	30	13	E	2	5	0
GH	30	13	W	1	8	0
GH	30	13	W	2	11	0
GH	30	13	N	1	12	0
GH	30	13	N	2	8	0
GH	30	13	S	1	12	0

GH	30	13	S	2	13	0
GH	30	18	E	1	3	0
GH	30	18	E	2	4	0
GH	30	18	W	1	5	0
GH	30	18	W	2	5	0
GH	30	18	N	1	5	0
GH	30	18	N	2	6	0
GH	30	18	S	1	3	0
GH	30	18	S	2	5	0
GH	30	23	E	1	4	0
GH	30	23	E	2	2	0
GH	30	23	W	1	1	0
GH	30	23	W	2	1	0
GH	30	23	N	1	3	0
GH	30	23	N	2	3	0
GH	30	23	S	1	3	0
GH	30	23	S	2	4	0
LYG	0	1	NA	1	0	0
LYG	0	1	NA	2	3	2
LYG	0	5	NA	1	2	1
LYG	0	5	NA	2	1	0
LYG	0	9	NA	1	3	2
LYG	0	9	NA	2	2	1
LYG	0	13	NA	1	1	0
LYG	0	13	NA	2	1	0
LYG	0	18	NA	1	2	0
LYG	0	18	NA	2	1	0
LYG	0	23	NA	1	1	0
LYG	0	23	NA	2	1	0
LYG	15	1	E	1	1	0
LYG	15	1	E	2	2	0
LYG	15	1	W	1	0	0
LYG	15	1	W	2	1	0
LYG	15	1	N	1	1	0

LYG	15	1	N	2	2	1
LYG	15	1	S	1	1	0
LYG	15	1	S	2	1	0
LYG	15	5	E	1	2	0
LYG	15	5	E	2	2	1
LYG	15	5	W	1	2	0
LYG	15	5	W	2	2	0
LYG	15	5	N	1	1	0
LYG	15	5	N	2	3	0
LYG	15	5	S	1	2	0
LYG	15	5	S	2	1	0
LYG	15	9	E	1	2	0
LYG	15	9	E	2	3	0
LYG	15	9	W	1	3	0
LYG	15	9	W	2	4	0
LYG	15	9	N	1	2	0
LYG	15	9	N	2	2	0
LYG	15	9	S	1	3	0
LYG	15	9	S	2	2	0
LYG	15	13	E	1	3	0
LYG	15	13	E	2	1	0
LYG	15	13	W	1	2	0
LYG	15	13	W	2	2	0
LYG	15	13	N	1	3	0
LYG	15	13	N	2	2	0
LYG	15	13	S	1	3	0
LYG	15	13	S	2	2	0
LYG	15	18	E	1	2	0
LYG	15	18	E	2	3	0
LYG	15	18	W	1	4	0
LYG	15	18	W	2	1	0
LYG	15	18	N	1	3	0
LYG	15	18	N	2	2	0
LYG	15	18	S	1	2	0

LYG	15	18	S	2	2	0
LYG	15	23	E	1	2	0
LYG	15	23	E	2	1	0
LYG	15	23	W	1	1	0
LYG	15	23	W	2	0	0
LYG	15	23	N	1	1	0
LYG	15	23	N	2	2	0
LYG	15	23	S	1	2	0
LYG	15	23	S	2	1	0
LYG	30	1	E	1	1	0
LYG	30	1	E	2	2	0
LYG	30	1	W	1	0	0
LYG	30	1	W	2	1	0
LYG	30	1	N	1	0	0
LYG	30	1	N	2	1	0
LYG	30	1	S	1	1	0
LYG	30	1	S	2	1	0
LYG	30	5	E	1	2	0
LYG	30	5	E	2	3	0
LYG	30	5	W	1	1	0
LYG	30	5	W	2	3	0
LYG	30	5	N	1	2	0
LYG	30	5	N	2	2	0
LYG	30	5	S	1	2	0
LYG	30	5	S	2	3	0
LYG	30	9	E	1	3	0
LYG	30	9	E	2	2	0
LYG	30	9	W	1	2	0
LYG	30	9	W	2	4	0
LYG	30	9	N	1	4	1
LYG	30	9	N	2	2	0
LYG	30	9	S	1	3	0
LYG	30	9	S	2	2	0
LYG	30	13	E	1	3	0

LYG	30	13	E	2	1	0
LYG	30	13	W	1	3	0
LYG	30	13	W	2	3	0
LYG	30	13	N	1	2	0
LYG	30	13	N	2	2	0
LYG	30	13	S	1	4	0
LYG	30	13	S	2	2	0
LYG	30	18	E	1	2	0
LYG	30	18	E	2	2	0
LYG	30	18	W	1	2	0
LYG	30	18	W	2	1	0
LYG	30	18	N	1	3	0
LYG	30	18	N	2	1	0
LYG	30	18	S	1	4	0
LYG	30	18	S	2	1	0
LYG	30	23	E	1	2	0
LYG	30	23	E	2	0	0
LYG	30	23	W	1	1	0
LYG	30	23	W	2	2	0
LYG	30	23	N	1	2	0
LYG	30	23	N	2	0	0
LYG	30	23	S	1	2	0
LYG	30	23	S	2	1	0

RSB = Rice stink bug; GH = Grasshoppers; LYG = Lygus bugs; NA = Direction was unavailable as only one sample was taken from fungus-treated plot; Zero distance = treated plot. Control (110 m distance) had zero infection.

APPENDIX 5
RAW DATA FOR CHAPTER 3 -- QUANTITATIVE AND QUALITATIVE DAMAGES
BY *O. PUGNAX* FEEDING TO RICE KERNELS IN AN EXPERIMENT WITH ONE
RICE STINK BUG PER PANICLE

Treatment (Day of release after anthesis)	Replicates (panicles)	Total weight (mg)	No. of empty kernels	No. of filled kernels	Weight of filled kernels (mg)	Proportion of pecky rice
1	1	1.814	31	82	1.696	0.0626
1	2	1.417	29	57	1.309	0.0310
1	3	1.695	26	67	1.603	0.0331
1	4	1.516	26	63	1.432	0.0233
1	5	1.082	29	42	0.974	0.0108
1	6	1.973	21	81	1.904	0.0123
1	7	1.925	44	80	1.775	0.0504
1	8	1.501	36	61	1.486	0.0209
1	9	0.952	35	36	0.829	0.0265
1	10	0.963	22	36	0.887	0.0309
1	11	1.185	49	43	1.023	0.0464
1	12	1.269	68	46	1.051	0.0392
1	13	1.431	28	59	1.336	0.0582
1	14	0.223	55	2	0.03	0.0607
1	15	1.027	20	42	0.956	0.0374
1	16	2.35	27	92	2.255	0.0227
1	17	1.515	25	61	1.378	0.0102
1	18	0.765	26	33	0.677	0.0470
5	1	1.896	36	70	1.726	0.0927
5	2	1.797	25	72	1.679	0.0687
5	3	1.245	17	49	1.1514	0.1086
5	4	1.49	32	56	1.33	0.0870
5	5	1.457	30	62	1.3121	0.0824
5	6	2.251	41	91	2.047	0.0572
5	7	1.682	24	82	1.582	0.0465
5	8	1.332	17	64	1.257	0.0507
5	9	2.02	20	80	1.896	0.1077
5	10	1.156	56	43	0.926	0.0974

5	11	2.107	20	84	1.988	0.0656
5	12	1.88	21	76	1.779	0.0832
5	13	0.849	58	29	0.557	0.0761
5	14	2.079	17	92	2.014	0.1203
5	15	1.598	23	72	1.514	0.1206
5	16	1.663	9	73	1.634	0.0852
5	17	2.402	12	109	2.359	0.0828
5	18	1.603	38	72	1.463	0.0938
9	1	2.057	12	86	2.016	0.2248
9	2	2.534	24	105	2.356	0.1786
9	3	2.179	23	83	1.985	0.1475
9	4	2.283	14	102	2.241	0.1672
9	5	1.405	13	63	1.306	0.2482
9	6	3.167	19	133	3.042	0.2179
9	7	2.311	11	94	2.252	0.1829
9	8	1.496	31	51	1.225	0.2131
9	9	2.291	13	97	2.255	0.1750
9	10	2.247	27	88	2.076	0.1945
9	11	1.285	15	55	1.1804	0.1278
9	12	2.062	11	85	2.021	0.1777
9	13	1.835	23	72	1.676	0.2251
9	14	1.283	11	52	1.216	0.1744
9	15	1.906	16	77	1.833	0.1777
9	16	1.644	23	76	1.555	0.1609
9	17	1.209	14	46	1.121	0.1836
9	18	1.057	15	40	0.96	0.1741
13	1	1.619	6	71	1.599	0.2037
13	2	1.864	4	73	1.684	0.2143
13	3	2.39	10	102	2.364	0.2617
13	4	2.387	15	101	2.318	0.2005
13	5	2.157	4	94	2.143	0.1668
13	6	1.976	15	77	1.915	0.1792
13	7	0.856	12	39	0.784	0.1789
13	8	1.603	21	61	1.495	0.1857

13	9	1.993	5	76	1.982	0.1722
13	10	2.087	5	88	2.075	0.2058
13	11	1.596	15	69	1.502	0.1680
13	12	1.723	27	71	1.557	0.1796
13	13	2.598	16	108	2.514	0.1966
13	14	2.504	7	115	2.482	0.1798
13	15	1.668	10	72	1.632	0.1892
13	16	1.905	8	74	1.882	0.2866
13	17	1.908	11	86	1.871	0.1833
13	18	1.192	3	48	1.179	0.2794
17	1	2.098	13	95	2.065	0.0773
17	2	2.454	5	99	2.444	0.0866
17	3	2.639	11	114	2.604	0.0880
17	4	2.657	4	112	2.646	0.1021
17	5	1.883	5	80	1.87	0.0925
17	6	2.749	7	115	2.729	0.1028
17	7	1.412	1	63	1.408	0.0824
17	8	2.316	10	97	2.256	0.1207
17	9	1.776	6	73	1.749	0.0867
17	10	1.772	12	71	1.727	0.0491
17	11	1.732	6	73	1.704	0.0782
17	12	2.612	7	107	2.591	0.0637
17	13	2.678	5	108	2.623	0.0737
17	14	1.021	10	41	0.974	0.0861
17	15	1.641	2	70	1.634	0.1029
17	16	1.035	5	41	1.017	0.1130
17	17	1.873	2	79	1.865	0.0271
17	18	2.317	8	95	2.291	0.0480
21	1	2.297	4	96	2.284	0.0526
21	2	1.861	2	81	1.859	0.0409
21	3	2.619	6	104	2.6	0.0201
21	4	2.113	3	87	2.109	0.0324
21	5	1.635	6	69	1.616	0.0451
21	6	2.493	15	98	2.45	0.0444

21	7	1.45	1	61	1.449	0.0431
21	8	1.792	5	69	1.773	0.0703
21	9	2.667	6	108	2.646	0.0861
21	10	2.068	3	81	2.032	0.0599
21	11	1.713	5	70	1.7	0.0515
21	12	1.923	5	75	1.894	0.0738
21	13	2.494	2	101	2.487	0.0592
21	14	1.979	4	80	1.966	0.0609
21	15	1.73	3	77	1.724	0.0763
21	16	1.637	1	68	1.635	0.0353
21	17	1.142	9	47	1.062	0.0934
21	18	0.858	3	37	0.848	0.0500
Control	1	2.945	6	119	2.926	0.0390
Control	2	1.535	6	64	1.517	0.0293
Control	3	2.09	4	76	2.079	0.0184
Control	4	2.342	7	96	2.317	0.0783
Control	5	2.05	2	81	2.035	0.0245
Control	6	1.454	6	52	1.434	0.0212
Control	7	2.103	3	88	2.094	0.0309
Control	8	2.167	10	86	2.139	0.0329
Control	9	1.981	12	83	1.966	0.0204
Control	10	2.619	4	106	2.604	0.0208
Control	11	1.925	2	83	1.92	0.0681
Control	12	1.787	5	70	1.777	0.0221
Control	13	1.294	2	53	1.286	0.0240
Control	14	2.089	10	86	2.044	0.0126
Control	15	1.101	2	46	1.095	0.0344
Control	16	1.338	1	59	1.332	0.0430
Control	17	2.288	3	91	2.278	0.0403
Control	18	0.993	4	42	0.983	0.0784

APPENDIX 6
RAW DATA FOR CHAPTER 3 -- QUANTITATIVE AND QUALITATIVE DAMAGES BY
***O. PUGNAX* FEEDING TO RICE KERNELS IN AN EXPERIMENT WITH TWO RICE**
STINK BUG PER PANICLE

Treatment (Day of release after anthesis)	Replicates (panicles)	Total weight (mg)	No. of empty kernels	No. of filled kernels	Weight of filled kernels (mg)	Proportion of pecky rice
1	1	0.6485	51	21	0.4679	0.0160
1	2	1.0817	59	39	0.8693	0.0526
1	3	1.1597	65	42	0.9267	0.0313
1	4	0.8936	56	31	0.6860	0.0415
1	5	1.1138	51	44	0.9652	0.0382
1	6	0.7414	71	23	0.4858	0.0407
1	7	0.8131	55	27	0.6251	0.0274
1	8	1.0992	55	41	0.9212	0.0469
1	9	1.2164	55	46	1.0194	0.0502
1	10	0.7975	62	26	0.5743	0.0470
5	1	1.4987	47	60	1.2242	0.1027
5	2	0.9173	43	33	0.7303	0.0937
5	3	0.9860	55	33	0.7468	0.0456
5	4	1.5668	32	66	1.4276	0.0585
5	5	0.7016	69	19	0.4015	0.0761
5	6	0.8524	28	33	0.7306	0.1028
5	7	1.5510	34	62	1.4031	0.0906
5	8	1.5875	43	63	1.4005	0.1395
5	9	0.9332	43	33	0.7461	0.1028
5	10	1.1077	35	45	0.9555	0.1382
9	1	2.2738	22	94	2.1723	0.3179
9	2	2.1133	36	85	1.9474	0.2829
9	3	1.2697	24	52	1.1591	0.2131
9	4	1.9872	20	82	1.8950	0.2350
9	5	1.7269	32	69	1.5794	0.2145
9	6	1.1746	20	49	1.0824	0.2248
9	7	1.8165	25	74	1.7013	0.2786

9	8	1.4492	45	53	1.2417	0.2875
9	9	1.0722	23	43	0.9662	0.2672
9	10	1.0636	45	37	0.8562	0.2482
13	1	1.6341	9	69	1.5953	0.2822
13	2	1.6781	7	71	1.6479	0.2894
13	3	2.4011	13	100	2.2850	0.2680
13	4	2.3538	18	99	2.1761	0.2950
13	5	2.1334	7	92	2.1032	0.2966
13	6	1.8170	18	75	1.7393	0.2598
13	7	0.9209	15	37	0.8562	0.2892
13	8	1.4913	24	59	1.3877	0.2664
13	9	1.8194	8	74	1.7849	0.3092
13	10	2.0228	8	86	1.9883	0.2794
17	1	2.2571	14	94	2.1940	0.1473
17	2	2.3781	6	98	2.3510	0.1464
17	3	2.0445	6	85	2.0174	0.1180
17	4	2.6348	5	111	2.6123	0.1421
17	5	2.0110	6	85	1.9839	0.0984
17	6	2.1915	11	88	2.1419	0.1761
17	7	1.6468	3	69	1.6332	0.0829
17	8	0.9383	6	40	0.9112	0.0944
17	9	1.8674	6	78	1.8404	0.0971
17	10	2.2904	9	94	2.2498	0.0980
21	1	2.7231	8	109	2.7169	0.0816
21	2	2.2640	5	91	2.2113	0.0753
21	3	1.9300	7	82	1.8983	0.0587
21	4	1.8671	7	76	1.8154	0.0700
21	5	1.8519	4	75	1.8338	0.0661
21	6	1.9882	6	81	1.9610	0.0599
21	7	1.4403	5	61	1.4176	0.0615
21	8	2.1841	3	91	2.2105	0.0629
21	9	1.6832	11	69	1.6333	0.0792
21	10	1.8098	5	74	1.7871	0.0509
Control	1	2.1633	6	89	2.2369	0.0303

Control	2	1.8588	6	76	1.8494	0.0256
Control	3	1.7879	3	74	1.7747	0.0309
Control	4	2.2187	7	92	2.2480	0.0399
Control	5	2.0645	3	86	2.1513	0.0381
Control	6	1.5811	2	65	1.5994	0.0521
Control	7	2.3892	4	97	2.3817	0.0233
Control	8	1.4569	5	59	1.4399	0.0217
Control	9	1.8434	8	75	1.8183	0.0344
Control	10	2.1297	4	91	2.2121	0.0256

APPENDIX 7
RAW DATA FOR CHAPTER 3 -- GERMINATION OF PECKY AND
NONPECKY (GOOD) RICE FROM ONE RICE STINK BUG PER PANICLE
EXPERIMENT

Treatment (days of infestation after anthesis)	Rice quality	Replication	No. of rice kernels/petridish	No. of kernels germinated
1	pecky	1	20	8
1	pecky	2	20	9
1	pecky	3	20	7
1	pecky	4	20	8
1	pecky	5	20	8
9	pecky	1	20	11
9	pecky	2	20	9
9	pecky	3	20	9
9	pecky	4	20	8
9	pecky	5	20	8
17	pecky	1	20	8
17	pecky	2	20	8
17	pecky	3	20	9
17	pecky	4	20	8
17	pecky	5	20	10
0	pecky	1	20	9
0	pecky	2	20	8
0	pecky	3	20	9
0	pecky	4	20	8
0	pecky	5	20	8
1	good	1	20	18
1	good	2	20	16
1	good	3	20	19
1	good	4	20	17
1	good	5	20	18
9	good	1	20	18
9	good	2	20	18
9	good	3	20	17

9	good	4	20	16
9	good	5	20	18
17	good	1	20	18
17	good	2	20	16
17	good	3	20	20
17	good	4	20	18
17	good	5	20	18
0	good	1	20	18
0	good	2	20	18
0	good	3	20	18
0	good	4	20	19
0	good	5	20	18

APPENDIX 8
SAS OUTPUT FOR CHAPTER 2 – VIRULENCE OF FUNGAL ISOLATES
AGAINST RICE STINK BUG IN BIOASSAY

Probit analysis for LRC28 isolate (adjusted by abbot formula)

Probit Procedure

Goodness-of-Fit Tests

Statistic	Value	DF	Pr > ChiSq
Pearson Chi-Square	5.9426	16	0.9887
L.R. Chi-Square	5.5075	16	0.9926

Type III Analysis of Effects

Effect	Wald		Pr > ChiSq
	DF	Chi-Square	
Log10(dose)	1	106.8486	<.0001

Analysis of Parameter Estimates

Parameter	DF	Standard Estimate	95% Confidence		Chi-Square	Pr > ChiSq
			Error	Limits		
Intercept	1	-2.9007	0.3045	-3.4976 -2.3039	90.73	<.0001
Log10(dose)	1	0.6265	0.0606	0.5077 0.7452	106.85	<.0001

Probit Analysis on dose

Probability	dose	95% Fiducial Limits	
0.01	8.25815	0.90390	38.64985
0.02	22.49188	3.07113	90.93110
0.03	42.47273	6.66177	156.74052
0.04	68.51689	11.91527	236.33742
0.05	101.09634	19.10536	330.33710
0.06	140.77580	28.53647	439.56423
0.07	188.19408	40.54470	564.99956
0.08	244.05839	55.49993	707.75864
0.09	309.14388	73.80861	869.08438
0.10	384.29588	95.91691	1050
0.15	946.11067	282.31857	2313
0.20	1936	660.61042	4367
0.25	3579	1359	7590
0.30	6213	2578	12571
0.35	10359	4624	20240
0.40	16825	7972	32111
0.45	26902	13363	50721
0.50	42695	21959	80467
0.55	67759	35639	129256
0.60	108340	57537	211967
0.65	175976	93147	358171
0.70	293402	152713	630904

0.75	509386	256971	1177590
0.80	941532	452820	2390155
0.85	1926678	864972	5527034
0.90	4743351	1924856	16100238
0.91	5896446	2330859	20882068
0.92	7468910	2867667	27717378
0.93	9686012	3599110	37868767
0.94	12948605	4634996	53701511
0.95	18030823	6179454	80056366
0.96	26604391	8654267	128112543
0.97	42918135	13076075	228670518
0.98	81044810	22590461	494906683
0.99	220733548	53292772	1676957529

Probit analysis for RSB isolate (adjusted by abbot formula)

Goodness-of-Fit Tests

Statistic	Value	DF	Pr > ChiSq
Pearson Chi-Square	9.7789	16	0.8779
L.R. Chi-Square	9.7339	16	0.8802

Type III Analysis of Effects

Effect	Wald		
	DF	Chi-Square	Pr > ChiSq
Log10(dose)	1	105.6055	<.0001

Analysis of Parameter Estimates

Parameter	DF	Standard Estimate	95% Confidence		Chi-Square	Pr > ChiSq
			Error	Limits		
Intercept	1	-3.1533	0.3123	-3.7654 -2.5412	101.95	<.0001
Log10(dose)	1	0.5964	0.0580	0.4826 0.7101	105.61	<.0001

Probit Analysis on dose

Probability	dose	95% Fiducial Limits	
0.01	24.35650	2.75900	111.31474
0.02	69.77814	9.97341	273.64030
0.03	136.06222	22.49168	485.21471
0.04	224.85726	41.41016	747.58196
0.05	338.35365	67.96387	1064
0.06	479.09380	103.52542	1437
0.07	649.92251	149.61470	1873
0.08	853.97808	207.91167	2375
0.09	1095	280.27082	2950
0.10	1376	368.73709	3604
0.15	3545	1140	8312
0.20	7521	2764	16328
0.25	14339	5847	29464
0.30	25597	11327	50637

0.35	43793	20649	84667
0.40	72896	36035	139698
0.45	119347	60925	229882
0.50	193877	100745	380550
0.55	314948	164321	638672
0.60	515641	266595	1095214
0.65	858313	434190	1936309
0.70	1468454	717641	3570956
0.75	2621415	1221084	6987115
0.80	4997909	2184572	14905289
0.85	10603687	4260167	36414963
0.90	27319991	9763431	113287659
0.91	34336437	11912168	149223971
0.92	44015300	14778195	201394299
0.93	57834743	18721264	280192523
0.94	78456665	24366064	405403360
0.95	111091168	32886113	618248998
0.96	167164279	46735736	1015904400
0.97	276256714	71917055	1872750712
0.98	538680184	127348716	4229112361
0.99	1543247246	312544202	1.53127E10

APPENDIX 9
SAS OUTPUT FOR CHAPTER 2 -- EFFECTS OF *B. BASSIANA* AND
INSECTICIDES ON THE DENSITY OF RICE STINK BUGS IN 2001 SMALL
PLOT FIELD EXPERIMENT

Total number of rice stink bugs in 2001

Obs	TIME	GROUP	_TYPE_	_FREQ_	MEAN	N	STDERR
1	2	C	0	4	12.0000	4	0.70711
2	2	F	0	12	10.5833	12	0.71200
3	2	I	0	8	2.1250	8	0.44068
4	4	C	0	4	9.0000	4	0.91287
5	4	F	0	12	7.7500	12	0.53831
6	4	I	0	8	2.1250	8	0.44068
7	8	C	0	4	8.5000	4	0.86603
8	8	F	0	12	3.9167	12	0.31282
9	8	I	0	8	2.7500	8	0.52610
10	16	C	0	4	7.5000	4	1.55456
11	16	F	0	12	5.4167	12	0.51432
12	16	I	0	8	5.7500	8	0.45316
13	22	C	0	4	8.7500	4	0.47871
14	22	F	0	12	7.9167	12	0.33616
15	22	I	0	8	7.8750	8	0.22658

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
GROUP	2	6	74.65	<.0001
TREAT(GROUP)	3	9	1.85	0.2084
TIME	4	72	19.56	<.0001
GROUP*TIME	8	72	17.35	<.0001
TREAT*TIME(GROUP)	12	72	1.60	0.1116

Tests of Effect Slices

Effect	TIME	Num DF	Den DF	F Value	Pr > F
GROUP*TIME	2	2	72	86.09	<.0001
GROUP*TIME	4	2	72	39.50	<.0001
GROUP*TIME	8	2	72	18.91	<.0001
GROUP*TIME	16	2	72	2.72	0.0723
GROUP*TIME	22	2	72	0.50	0.6091

Effect=GROUP*TIME Method=LSD(P<.05) Set=3

Standard	Letter				
Obs	GROUP	TIME	Estimate	Error	Group
9	C	2	12.0000	0.7768	A
10	F	2	10.5833	0.4532	AB
11	C	4	9.0000	0.7768	BC
12	C	22	8.7500	0.7768	C
13	C	8	8.5000	0.7768	C
14	F	22	7.9167	0.4532	C
15	I	22	7.8750	0.5522	C
16	F	4	7.7500	0.4532	C
17	C	16	7.5000	0.7768	CD
18	I	16	5.7500	0.5522	DE
19	F	16	5.4167	0.4532	E
20	F	8	3.9167	0.4532	F
21	I	8	2.7500	0.5522	FG
22	I	2	2.1250	0.5522	G
23	I	4	2.1250	0.5522	G

Number of adults in 2001

Obs	TIME	GROUP	_TYPE_	_FREQ_	MEAN	N	STDERR
1	2	C	0	4	6.25000	4	1.31498
2	2	F	0	12	6.25000	12	0.69767
3	2	I	0	8	1.00000	8	0.32733
4	4	C	0	4	5.00000	4	0.57735
5	4	F	0	12	5.00000	12	0.68534
6	4	I	0	8	0.87500	8	0.35038
7	8	C	0	4	5.50000	4	0.86603
8	8	F	0	12	2.41667	12	0.35799
9	8	I	0	8	1.37500	8	0.26305
10	16	C	0	4	3.75000	4	0.75000
11	16	F	0	12	2.66667	12	0.28427
12	16	I	0	8	2.75000	8	0.52610
13	22	C	0	4	4.50000	4	0.50000
14	22	F	0	12	4.91667	12	0.37856
15	22	I	0	8	5.12500	8	0.35038

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
GROUP	2	6	28.30	0.0009
TREAT(GROUP)	3	9	1.65	0.2470
TIME	4	72	7.16	<.0001
GROUP*TIME	8	72	7.61	<.0001
TREAT*TIME(GROUP)	12	72	0.76	0.6933

Tests of Effect Slices

Effect	TIME	Num DF	Den DF	F Value	Pr > F
GROUP*TIME	2	2	72	29.93	<.0001
GROUP*TIME	4	2	72	18.48	<.0001
GROUP*TIME	8	2	72	9.37	0.0002
GROUP*TIME	16	2	72	0.76	0.4737
GROUP*TIME	22	2	72	0.21	0.8094

Effect=GROUP*TIME Method=LSD(P<.05) Set=3

Standard Obs	Letter GROUP	TIME	Estimate	Error	Group
9	C	2	6.2500	0.7835	AB
10	F	2	6.2500	0.4524	A
11	C	8	5.5000	0.7835	ABC
12	I	22	5.1250	0.5540	ABC
13	C	4	5.0000	0.7835	ABC
14	F	4	5.0000	0.4524	ABC
15	F	22	4.9167	0.4524	BC
16	C	22	4.5000	0.7835	ABCD
17	C	16	3.7500	0.7835	CDE
18	I	16	2.7500	0.5540	DEF
19	F	16	2.6667	0.4524	EF
20	F	8	2.4167	0.4524	EFG
21	I	8	1.3750	0.5540	FGH
22	I	2	1.0000	0.5540	GH
23	I	4	0.8750	0.5540	H

Number of nymphs in 2001

Obs	TIME	GROUP	_TYPE_	_FREQ_	MEAN	N	STDERR
1	2	C	0	4	5.75000	4	0.85391
2	2	F	0	12	4.33333	12	0.25624
3	2	I	0	8	1.12500	8	0.22658
4	4	C	0	4	4.00000	4	0.40825
5	4	F	0	12	2.75000	12	0.44594
6	4	I	0	8	1.25000	8	0.25000
7	8	C	0	4	3.00000	4	0.00000
8	8	F	0	12	1.50000	12	0.23028
9	8	I	0	8	1.37500	8	0.37500
10	16	C	0	4	3.75000	4	0.85391
11	16	F	0	12	2.75000	12	0.35086
12	16	I	0	8	3.00000	8	0.18898
13	22	C	0	4	4.25000	4	0.47871
14	22	F	0	12	3.00000	12	0.21320
15	22	I	0	8	2.75000	8	0.25000

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
GROUP	2	6	22.64	0.0016
TREAT(GROUP)	3	9	1.83	0.2119
TIME	4	72	11.21	<.0001
GROUP*TIME	8	72	6.06	<.0001
TREAT*TIME(GROUP)	12	72	1.08	0.3897

Tests of Effect Slices

Effect	TIME	Num DF	Den DF	F Value	Pr > F
GROUP*TIME	2	2	72	34.33	<.0001
GROUP*TIME	4	2	72	10.53	<.0001
GROUP*TIME	8	2	72	3.95	0.0236
GROUP*TIME	16	2	72	1.44	0.2447
GROUP*TIME	22	2	72	3.11	0.0505

Effect=GROUP*TIME Method=LSD(P<.05) Set=3

Obs	GROUP	TIME	Standard Estimate	Letter Error	Group
9	C	2	5.7500	0.5009	A
10	F	2	4.3333	0.3131	B
11	C	22	4.2500	0.5009	BC
12	C	4	4.0000	0.5009	BCD
13	C	16	3.7500	0.5009	BCDE
14	F	22	3.0000	0.3131	DE
15	I	16	3.0000	0.3691	DE
16	C	8	3.0000	0.5009	CDE
17	F	16	2.7500	0.3131	E
18	F	4	2.7500	0.3131	E
19	I	22	2.7500	0.3691	E
20	F	8	1.5000	0.3131	F
21	I	8	1.3750	0.3691	F
22	I	4	1.2500	0.3691	F
23	I	2	1.1250	0.3691	F

APPENDIX 10
SAS OUTPUT FOR CHAPTER 2 -- EFFECTS OF *B. BASSIANA* AND
INSECTICIDES ON THE DENSITY OF RICE STINK BUGS IN 2002 SMALL
PLOT FIELD EXPERIMENT

Total number of rice stink bugs in 2002

Obs	TIME	GROUP	_TYPE_	_FREQ_	MEAN	N	STDERR
1	2	C	0	5	12.2	5	1.35647
2	2	F	0	10	9.9	10	1.62925
3	2	I	0	10	0.9	10	0.37859
4	2	M	0	10	2.5	10	0.56273
5	7	C	0	5	7.8	5	1.15758
6	7	F	0	10	4.3	10	0.42295
7	7	I	0	10	2.2	10	0.74237
8	7	M	0	10	1.0	10	0.21082
9	11	C	0	5	4.6	5	0.92736
10	11	F	0	10	2.8	10	0.13333
11	11	I	0	10	2.6	10	0.16330
12	11	M	0	10	2.5	10	0.40139
13	17	C	0	5	6.6	5	1.12250
14	17	F	0	10	4.6	10	0.58119
15	17	I	0	10	6.8	10	1.10353
16	17	M	0	10	4.0	10	0.53748

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
GROUP	3	12	19.45	<.0001
TREAT(GROUP)	3	12	1.97	0.1717
TIME	3	84	15.14	<.0001
GROUP*TIME	9	84	11.78	<.0001
TREAT*TIME(GROUP)	9	84	0.70	0.7090

Tests of Effect Slices

Effect	TIME	Num DF	Den DF	F Value	Pr > F
GROUP*TIME	2	3	84	42.45	<.0001
GROUP*TIME	7	3	84	10.72	<.0001
GROUP*TIME	11	3	84	1.07	0.3681
GROUP*TIME	17	3	84	3.05	0.0329

Effect=GROUP*TIME Method=LSD(P<.05) Set=3

Standard	Letter				
Obs	GROUP	TIME	Estimate	Error	Group
9	C	2	12.2000	1.0224	A
10	F	2	9.9000	0.7653	AB
11	C	7	7.8000	1.0224	BC
12	I	17	6.8000	0.7653	CD
13	C	17	6.6000	1.0224	CDE
14	C	11	4.6000	1.0224	DEFG
15	F	17	4.6000	0.7653	EF
16	F	7	4.3000	0.7653	EFG
17	M	17	4.0000	0.7653	FG
18	F	11	2.8000	0.7653	FGH
19	I	11	2.6000	0.7653	FGH
20	M	11	2.5000	0.7653	FGH
21	M	2	2.5000	0.7653	FGH
22	I	7	2.2000	0.7653	GH
23	M	7	1.0000	0.7653	H
24	I	2	0.9000	0.7653	H

Number of adults in 2002

Obs	TIME	GROUP	_TYPE_	_FREQ_	MEAN	N	STDERR
1	2	C	0	5	2.8	5	0.91652
2	2	F	0	10	2.6	10	0.30551
3	2	I	0	10	0.7	10	0.30000
4	2	M	0	10	1.2	10	0.29059
5	7	C	0	5	3.4	5	0.50990
6	7	F	0	10	1.8	10	0.24944
7	7	I	0	10	0.8	10	0.29059
8	7	M	0	10	0.6	10	0.16330
9	11	C	0	5	2.0	5	0.31623
10	11	F	0	10	1.4	10	0.16330
11	11	I	0	10	1.5	10	0.16667
12	11	M	0	10	1.6	10	0.30551
13	17	C	0	5	3.4	5	0.74833
14	17	F	0	10	2.5	10	0.42817
15	17	I	0	10	4.6	10	0.81921
16	17	M	0	10	2.0	10	0.51640

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
GROUP	3	12	6.05	0.0095
TREAT (GROUP)	3	12	3.24	0.0602
TIME	3	84	14.20	<.0001
GROUP*TIME	9	84	5.44	<.0001
TREAT*TIME (GROUP)	9	84	1.49	0.1660

Tests of Effect Slices

Effect	TIME	Num DF	Den DF	F Value	Pr > F
GROUP*TIME	2	3	84	5.99	0.0010
GROUP*TIME	7	3	84	7.27	0.0002
GROUP*TIME	11	3	84	0.29	0.8295
GROUP*TIME	17	3	84	8.57	<.0001

Effect=GROUP*TIME Method=LSD(P<.05) Set=3

Standard Obs	Letter GROUP	TIME	Estimate	Error	Group
9	I	17	4.6000	0.3879	A
10	C	17	3.4000	0.5323	AB
11	C	7	3.4000	0.5323	AB
12	C	2	2.8000	0.5323	BCD
13	F	2	2.6000	0.3879	BC
14	F	17	2.5000	0.3879	BCD
15	M	17	2.0000	0.3879	CDE
16	C	11	2.0000	0.5323	BCDEFG
17	F	7	1.8000	0.3879	CDEF
18	M	11	1.6000	0.3879	CDEFGH
19	I	11	1.5000	0.3879	DEFGH
20	F	11	1.4000	0.3879	EFGH
21	M	2	1.2000	0.3879	EFGH
22	I	7	0.8000	0.3879	FGH
23	I	2	0.7000	0.3879	GH
24	M	7	0.6000	0.3879	H

Number of nymphs in 2002

Obs	TIME	GROUP	_TYPE_	_FREQ_	MEAN	N	STDERR
1	2	C	0	5	9.4	5	1.24900
2	2	F	0	10	7.3	10	1.61280
3	2	I	0	10	0.2	10	0.20000
4	2	M	0	10	1.3	10	0.42295
5	7	C	0	5	4.4	5	1.24900
6	7	F	0	10	2.5	10	0.40139
7	7	I	0	10	1.4	10	0.77746
8	7	M	0	10	0.4	10	0.16330
9	11	C	0	5	2.6	5	0.67823
10	11	F	0	10	1.4	10	0.16330
11	11	I	0	10	1.1	10	0.23333
12	11	M	0	10	0.9	10	0.17951
13	17	C	0	5	3.2	5	0.58310
14	17	F	0	10	2.1	10	0.23333
15	17	I	0	10	2.2	10	0.55377
16	17	M	0	10	2.0	10	0.25820

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num	Den	F Value	Pr > F
	DF	DF		
GROUP	3	12	22.18	<.0001
TREAT(GROUP)	3	12	0.86	0.4876
TIME	3	84	14.09	<.0001
GROUP*TIME	9	84	8.49	<.0001
TREAT*TIME(GROUP)	9	84	0.85	0.5739

Tests of Effect Slices

Effect	TIME	Num	Den	F Value	Pr > F
		DF	DF		
GROUP*TIME	2	3	84	42.33	<.0001
GROUP*TIME	7	3	84	5.40	0.0019
GROUP*TIME	11	3	84	0.95	0.4189
GROUP*TIME	17	3	84	0.49	0.6899

Effect=GROUP*TIME Method=LSD(P<.05) Set=3

Standard Obs	GROUP	Letter	Estimate	Error	Group
		TIME			
9	C	2	9.4000	0.8620	A
10	F	2	7.3000	0.6236	B
11	C	7	4.4000	0.8620	C
12	C	17	3.2000	0.8620	CD
13	C	11	2.6000	0.8620	CDE
14	F	7	2.5000	0.6236	CDE
15	I	17	2.2000	0.6236	DE
16	F	17	2.1000	0.6236	DEF
17	M	17	2.0000	0.6236	DEF
18	I	7	1.4000	0.6236	DEFG
19	F	11	1.4000	0.6236	DEFG
20	M	2	1.3000	0.6236	DEFG
21	I	11	1.1000	0.6236	EFG
22	M	11	0.9000	0.6236	EFG
23	M	7	0.4000	0.6236	FG
24	I	2	0.2000	0.6236	G

APPENDIX 11
SAS OUTPUT FOR CHAPTER 2 -- EFFECTS OF *B. BASSIANA* AND
INSECTICIDES ON THE DENSITY OF RICE STINK BUGS IN 2003 SMALL
PLOT FIELD EXPERIMENT

Total number of rice stink bugs in 2003

Obs	TIME	GROUP	_TYPE_	_FREQ_	MEAN	N	STDERR
1	2	C	0	4	6.75000	4	1.10868
2	2	F	0	4	5.50000	4	0.50000
3	2	I	0	12	1.75000	12	0.39167
4	2	M	0	4	2.00000	4	0.40825
5	2	T	0	4	2.00000	4	1.35401
6	4	C	0	4	5.50000	4	0.50000
7	4	F	0	4	5.00000	4	1.00000
8	4	I	0	12	2.41667	12	0.51432
9	4	M	0	4	2.25000	4	0.47871
10	4	T	0	4	2.75000	4	0.62915
11	8	C	0	4	6.50000	4	1.25831
12	8	F	0	4	4.00000	4	0.81650
13	8	I	0	12	1.91667	12	0.58333
14	8	M	0	4	1.75000	4	0.47871
15	8	T	0	4	1.25000	4	0.47871
16	10	C	0	4	5.75000	4	0.94648
17	10	F	0	4	3.75000	4	0.75000
18	10	I	0	12	2.75000	12	0.70844
19	10	M	0	4	4.50000	4	0.28868
20	10	T	0	4	0.25000	4	0.25000
21	14	C	0	4	5.00000	4	0.40825
22	14	F	0	4	4.75000	4	1.03078
23	14	I	0	12	3.75000	12	0.66430
24	14	M	0	4	2.75000	4	0.47871
25	14	T	0	4	0.50000	4	0.28868
26	18	C	0	4	5.25000	4	0.47871
27	18	F	0	4	3.25000	4	0.94648
28	18	I	0	12	4.16667	12	0.27061
29	18	M	0	4	3.50000	4	0.64550
30	18	T	0	4	2.25000	4	0.47871

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
GROUP	4	6	23.50	0.0008
TREAT(GROUP)	2	6	1.95	0.2225
TIME	5	105	0.56	0.7299
GROUP*TIME	20	105	1.95	0.0156
TREAT*TIME(GROUP)	10	105	1.11	0.3598

Tests of Effect Slices

Effect	TIME	Num DF	Den DF	F Value	Pr > F
GROUP*TIME	2	4	105	9.86	<.0001
GROUP*TIME	4	4	105	4.19	0.0035
GROUP*TIME	8	4	105	7.66	<.0001
GROUP*TIME	10	4	105	6.51	0.0001
GROUP*TIME	14	4	105	4.95	0.0011
GROUP*TIME	18	4	105	1.94	0.1098

Effect=GROUP*TIME Method=LSD(P<.05) Set=3

Standard Obs	Letter GROUP	TIME	Estimate	Error	Group
12	C	2	6.7500	0.8315	A
13	C	8	6.5000	0.8315	A
14	C	10	5.7500	0.8315	AB
15	F	2	5.5000	0.8315	ABC
16	C	4	5.5000	0.8315	ABC
17	C	18	5.2500	0.8315	ABC
18	F	4	5.0000	0.8315	ABCD
19	C	14	5.0000	0.8315	ABCD
20	F	14	4.7500	0.8315	ABCD
21	M	10	4.5000	0.8315	ABCDE
22	I	18	4.1667	0.4853	BCD
23	F	8	4.0000	0.8315	BCDEF
24	F	10	3.7500	0.8315	BCDEFH
25	I	14	3.7500	0.4853	CDEG
26	M	18	3.5000	0.8315	BCDEFHI
27	F	18	3.2500	0.8315	CDEFHI
28	T	4	2.7500	0.8315	DEFHIJ
29	M	14	2.7500	0.8315	DEFHIJ
30	I	10	2.7500	0.4853	EFHI
31	I	4	2.4167	0.4853	FHI
32	T	18	2.2500	0.8315	EFHIJK
33	M	4	2.2500	0.8315	EFHIJK
34	T	2	2.0000	0.8315	FGHIJK
35	M	2	2.0000	0.8315	FGHIJK
36	I	8	1.9167	0.4853	HIJK
37	M	8	1.7500	0.8315	FHIJK
38	I	2	1.7500	0.4853	IJK
39	T	8	1.2500	0.8315	IJK
40	T	14	0.5000	0.8315	JK
41	T	10	0.2500	0.8315	K

Number of adults in 2003

Obs	TIME	GROUP	_TYPE_	_FREQ_	MEAN	N	STDERR
1	2	C	0	4	3.50000	4	0.86603
2	2	F	0	4	2.50000	4	0.50000
3	2	I	0	12	1.16667	12	0.29729
4	2	M	0	4	2.00000	4	0.40825

5	2	T	0	4	1.75000	4	1.10868
6	4	C	0	4	2.75000	4	0.25000
7	4	F	0	4	2.75000	4	1.10868
8	4	I	0	12	2.33333	12	0.51247
9	4	M	0	4	2.25000	4	0.47871
10	4	T	0	4	2.50000	4	0.50000
11	8	C	0	4	3.00000	4	0.70711
12	8	F	0	4	2.25000	4	0.85391
13	8	I	0	12	1.75000	12	0.55220
14	8	M	0	4	1.75000	4	0.47871
15	8	T	0	4	1.25000	4	0.47871
16	10	C	0	4	2.75000	4	0.62915
17	10	F	0	4	2.00000	4	0.57735
18	10	I	0	12	2.75000	12	0.70844
19	10	M	0	4	2.25000	4	0.25000
20	10	T	0	4	0.25000	4	0.25000
21	14	C	0	4	2.50000	4	0.50000
22	14	F	0	4	2.50000	4	0.64550
23	14	I	0	12	1.58333	12	0.25990
24	14	M	0	4	1.75000	4	0.25000
25	14	T	0	4	0.50000	4	0.28868
26	18	C	0	4	3.00000	4	0.40825
27	18	F	0	4	2.00000	4	0.70711
28	18	I	0	12	2.75000	12	0.25000
29	18	M	0	4	2.25000	4	0.62915
30	18	T	0	4	1.50000	4	0.64550

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
GROUP	4	6	3.07	0.1068
TREAT(GROUP)	2	6	1.24	0.3550
TIME	5	105	1.05	0.3919
GROUP*TIME	20	105	0.92	0.5633
TREAT*TIME(GROUP)	10	105	2.00	0.0405

Tests of Effect Slices

Effect	TIME	Num DF	Den DF	F Value	Pr > F
GROUP*TIME	2	4	105	2.43	0.0524
GROUP*TIME	4	4	105	0.14	0.9673
GROUP*TIME	8	4	105	0.98	0.4230
GROUP*TIME	10	4	105	2.69	0.0353
GROUP*TIME	14	4	105	1.47	0.2171
GROUP*TIME	18	4	105	0.91	0.4602

Effect=GROUP*TIME Method=LSD(P<.05) Set=3

Standard Obs	Letter GROUP	TIME	Estimate	Error	Group
12	C	2	3.5000	0.6857	A
13	C	8	3.0000	0.6857	ABC
14	C	18	3.0000	0.6857	ABC
15	F	4	2.7500	0.6857	ABC
16	C	4	2.7500	0.6857	ABC
17	C	10	2.7500	0.6857	ABC
18	I	10	2.7500	0.3959	AB
19	I	18	2.7500	0.3959	AB
20	T	4	2.5000	0.6857	ABCD
21	F	2	2.5000	0.6857	ABCD
22	F	14	2.5000	0.6857	ABCD
23	C	14	2.5000	0.6857	ABCD
24	I	4	2.3333	0.3959	ABC
25	F	8	2.2500	0.6857	ABCDE
26	M	4	2.2500	0.6857	ABCDE
27	M	18	2.2500	0.6857	ABCDE
28	M	10	2.2500	0.6857	ABCDE
29	F	18	2.0000	0.6857	ABCDEF
30	M	2	2.0000	0.6857	ABCDEF
31	F	10	2.0000	0.6857	ABCDEF
32	T	2	1.7500	0.6857	ABCDEF
33	I	8	1.7500	0.3959	BCDEF
34	M	8	1.7500	0.6857	ABCDEF
35	M	14	1.7500	0.6857	ABCDEF
36	I	14	1.5833	0.3959	CDEF
37	T	18	1.5000	0.6857	BCDEF
38	T	8	1.2500	0.6857	BCDEF
39	I	2	1.1667	0.3959	DEF
40	T	14	0.5000	0.6857	EF
41	T	10	0.2500	0.6857	F

Number of nymphs in 2003

Obs	TIME	GROUP	_TYPE_	_FREQ_	MEAN	N	STDERR
1	2	C	0	4	3.25000	4	0.62915
2	2	F	0	4	3.00000	4	0.57735
3	2	I	0	12	0.58333	12	0.22891
4	2	M	0	4	0.00000	4	0.00000
5	2	T	0	4	0.25000	4	0.25000
6	4	C	0	4	2.75000	4	0.62915
7	4	F	0	4	2.25000	4	0.25000
8	4	I	0	12	0.08333	12	0.08333
9	4	M	0	4	0.00000	4	0.00000
10	4	T	0	4	0.25000	4	0.25000
11	8	C	0	4	3.50000	4	0.64550
12	8	F	0	4	1.75000	4	0.25000
13	8	I	0	12	0.16667	12	0.11237
14	8	M	0	4	0.00000	4	0.00000
15	8	T	0	4	0.00000	4	0.00000
16	10	C	0	4	3.00000	4	0.40825
17	10	F	0	4	1.75000	4	0.25000

18	10	I	0	12	0.00000	12	0.00000
19	10	M	0	4	2.25000	4	0.25000
20	10	T	0	4	0.00000	4	0.00000
21	14	C	0	4	2.50000	4	0.64550
22	14	F	0	4	2.25000	4	0.47871
23	14	I	0	12	2.16667	12	0.60093
24	14	M	0	4	1.00000	4	0.40825
25	14	T	0	4	0.00000	4	0.00000
26	18	C	0	4	2.25000	4	0.47871
27	18	F	0	4	1.25000	4	0.25000
28	18	I	0	12	1.41667	12	0.28758
29	18	M	0	4	1.25000	4	0.25000
30	18	T	0	4	0.75000	4	0.47871

The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num	Den	F Value	Pr > F
	DF	DF		
GROUP	4	6	35.25	0.0003
TREAT(GROUP)	2	6	0.66	0.5515
TIME	5	105	2.20	0.0601
GROUP*TIME	20	105	3.95	<.0001
TREAT*TIME(GROUP)	10	105	0.50	0.8840

Tests of Effect Slices

Effect	TIME	Num	Den	F Value	Pr > F
		DF	DF		
GROUP*TIME	2	4	105	14.50	<.0001
GROUP*TIME	4	4	105	11.14	<.0001
GROUP*TIME	8	4	105	14.17	<.0001
GROUP*TIME	10	4	105	13.44	<.0001
GROUP*TIME	14	4	105	6.58	<.0001
GROUP*TIME	18	4	105	1.58	0.1848

Effect=GROUP*TIME Method=LSD(P<.05) Set=3

Standard Obs	Letter GROUP	TIME	Estimate	Error	Group
13	C	2	3.2500	0.4564	AB
14	F	2	3.0000	0.4564	ABC
15	C	10	3.0000	0.4564	ABC
16	C	4	2.7500	0.4564	ABCD
17	C	14	2.5000	0.4564	ABCD
18	C	18	2.2500	0.4564	BCDE
19	F	4	2.2500	0.4564	BCDE
20	M	10	2.2500	0.4564	BCDE
21	F	14	2.2500	0.4564	BCDE
22	I	14	2.1667	0.2878	CDF
23	F	8	1.7500	0.4564	DEG

24	F	10	1.7500	0.4564	DEG
25	I	18	1.4167	0.2878	EG
26	M	18	1.2500	0.4564	EFGH
27	F	18	1.2500	0.4564	EFGH
28	M	14	1.0000	0.4564	GHI
29	T	18	0.7500	0.4564	GHIJ
30	I	2	0.5833	0.2878	HIJ
31	T	4	0.2500	0.4564	HIJ
32	T	2	0.2500	0.4564	HIJ
33	I	8	0.1667	0.2878	IJ
34	I	4	0.08333	0.2878	IJ
35	T	8	1.11E-16	0.4564	IJ
36	T	14	-222E-18	0.4564	IJ
37	T	10	-333E-18	0.4564	IJ
38	M	2	-555E-18	0.4564	IJ
39	M	8	-555E-18	0.4564	IJ
40	I	10	-706E-18	0.2878	J
41	M	4	-722E-18	0.4564	IJ

APPENDIX 12
SAS OUTPUT FOR CHAPTER 2 – MYCOSIS OF RICE STINK BUGS BY *B.*
***BASSIANA* IN 2001 SMALL PLOT FIELD EXPERIMENT**

MEAN MORTALITY OF TOTAL RICE STINK BUGS, SUMMER-2001

Obs	TREAT	TIME	_TYPE_	_FREQ_	n	mean	stderr
1	LRC21	2	0	4	4	16.2121	6.1713
2	LRC21	4	0	4	4	15.2679	6.0563
3	LRC21	8	0	4	4	12.5000	12.5000
4	LRC21	16	0	4	4	0.0000	0.0000
5	LRC21	22	0	4	4	0.0000	0.0000
6	LRC28	2	0	4	4	28.2143	5.0212
7	LRC28	4	0	4	4	20.5357	9.0321
8	RC28	8	0	4	4	19.5833	7.0833
9	LRC28	16	0	4	4	10.0000	5.7735
10	LRC28	22	0	4	4	3.5714	3.5714
11	RSB	2	0	4	4	20.8159	3.7513
12	RSB	4	0	4	4	13.4921	5.8859
13	RSB	8	0	4	4	12.5000	7.9786
14	RSB	16	0	4	4	5.0000	5.0000
15	RSB	22	0	4	4	0.0000	0.0000
16	UTC	2	0	4	4	3.8462	3.8462
17	UTC	4	0	4	4	5.8442	3.5368
18	UTC	8	0	4	4	0.0000	0.0000
19	UTC	16	0	4	4	0.0000	0.0000
20	UTC	22	0	4	4	0.0000	0.0000

MEAN MORTALITY OF ADULTS, SUMMER-2001

Obs	TREAT	TIME	_TYPE_	_FREQ_	n	mean	stderr
1	LRC21	2	0	4	4	8.3333	8.3333
2	LRC21	4	0	4	4	8.3333	8.3333
3	LRC21	8	0	4	4	0.0000	0.0000
4	LRC21	16	0	4	4	0.0000	0.0000
5	LRC21	22	0	4	4	0.0000	0.0000
6	LRC28	2	0	4	4	21.2798	4.8745
7	LRC28	4	0	4	4	10.0000	10.0000
8	LRC28	8	0	4	4	8.3333	8.3333
9	LRC28	16	0	4	4	12.5000	12.5000
10	LRC28	22	0	4	4	0.0000	0.0000
11	RSB	2	0	4	4	12.2917	4.3750
12	RSB	4	0	4	3	8.3333	8.3333
13	RSB	8	0	4	4	6.2500	6.2500
14	RSB	16	0	4	4	0.0000	0.0000
15	RSB	22	0	4	4	0.0000	0.0000
16	UTC	2	0	4	4	6.2500	6.2500
17	UTC	4	0	4	4	6.2500	6.2500
18	UTC	8	0	4	4	0.0000	0.0000
19	UTC	16	0	4	4	0.0000	0.0000
20	UTC	22	0	4	4	0.0000	0.0000

MEAN MORTALITY OF NYMPHS, SUMMER-2001

Obs	TREAT	TIME	_TYPE_	_FREQ_	n	mean	stderr
1	LRC21	2	0	4	4	21.2500	14.1973
2	LRC21	4	0	4	4	31.2500	23.6621
3	LRC21	8	0	4	4	25.0000	25.0000
4	LRC21	16	0	4	4	0.0000	0.0000
5	LRC21	22	0	4	4	0.0000	0.0000
6	LRC28	2	0	4	4	39.5833	6.2500
7	LRC28	4	0	4	4	54.1667	20.8333
8	LRC28	8	0	4	4	37.5000	23.9357
9	LRC28	16	0	4	4	12.5000	12.5000
10	LRC28	22	0	4	4	12.5000	12.5000
11	RSB	2	0	4	4	35.8333	6.2915
12	RSB	4	0	4	4	24.4048	10.9271
13	RSB	8	0	4	3	16.6667	16.6667
14	RSB	16	0	4	4	8.3333	8.3333
15	RSB	22	0	4	4	0.0000	0.0000
16	UTC	2	0	4	4	0.0000	0.0000
17	UTC	4	0	4	4	5.0000	5.0000
18	UTC	8	0	4	4	0.0000	0.0000
19	UTC	16	0	4	4	0.0000	0.0000
20	UTC	22	0	4	4	0.0000	0.0000

Logistic regression and means comparison by protected LSD: for total rice stink bugs

The LOGISTIC Procedure

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	56.6241	4	<.0001
Score	46.7030	4	<.0001
Wald	35.3160	4	<.0001

Type 3 Analysis of Effects

Effect	Wald		
	DF	Chi-Square	Pr > ChiSq
TREAT	3	16.0553	0.0011
TIME	1	19.9593	<.0001

The Mixed Procedure

Tests of Effect Slices

Effect	TIME	Num		Den	
		DF	DF	F Value	Pr > F
TREAT*TIME	2	3	48	3.70	0.0179
TREAT*TIME	4	3	48	1.31	0.2830
TREAT*TIME	8	3	48	2.35	0.0845
TREAT*TIME	16	3	48	0.81	0.4945
TREAT*TIME	22	3	48	0.11	0.9522

Effect=TREAT*TIME Method=LSD(P<.05) Set=3

Obs	TREAT	Standard TIME	Letter Estimate	Error	Group
10	LRC28	2	28.2143	5.4715	A
11	RSB	2	20.8159	5.4715	AB
12	LRC28	4	20.5357	5.4715	AB
13	LRC28	8	19.5833	5.4715	ABC
14	LRC21	2	16.2121	5.4715	ABCD
15	LRC21	4	15.2679	5.4715	ABCD
16	RSB	4	13.4916	5.4715	ABCDE
17	LRC21	8	12.5000	5.4715	BCDE
18	RSB	8	12.5000	5.4715	BCDE
19	LRC28	16	10.0000	5.4715	BCDE
20	UTC	4	5.8442	5.4715	BCDE
21	RSB	16	5.0000	5.4715	CDE
22	UTC	2	3.8462	5.4715	DE
23	LRC28	22	3.5714	5.4715	DE
24	LRC21	16	1.99E-15	5.4715	E
25	UTC	8	-384E-17	5.4715	E
26	UTC	16	-501E-17	5.4715	E
27	LRC21	22	-934E-17	5.4715	E
28	UTC	22	-109E-16	5.4715	E
29	RSB	22	-117E-16	5.4715	E

Logistic regression and means comparison by protected LSD: for adults

The LOGISTIC Procedure

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	18.9776	4	0.0008
Score	15.1679	4	0.0044
Wald	10.7134	4	0.0300

Type 3 Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
TREAT	3	3.7866	0.2855
TIME	1	6.8895	0.0087

The Mixed Procedure

Tests of Effect Slices

Effect	TIME	Num	Den	F Value	Pr > F
		DF	DF		
TREAT*TIME	2	3	48	1.45	0.2395
TREAT*TIME	4	3	48	0.11	0.9549
TREAT*TIME	8	3	48	0.61	0.6147
TREAT*TIME	16	3	48	1.28	0.2912
TREAT*TIME	22	3	48	0.00	1.0000

Effect=TREAT*TIME Method=LSD(P<.05) Set=3

Standard	Letter				
Obs	TREAT	TIME	Estimate	Error	Group
10	LRC28	2	21.2798	5.7607	A
11	LRC28	16	12.5000	5.7607	AB
12	RSB	2	12.2917	5.7607	AB
13	LRC28	4	10.0000	5.7607	AB
14	LRC21	2	8.3333	5.7607	AB
15	LRC21	4	8.3333	5.7607	AB
16	LRC28	8	8.3333	5.7607	AB
17	UTC	4	6.2500	5.7607	AB
18	RSB	4	6.2500	5.7607	AB
19	RSB	8	6.2500	5.7607	AB
20	UTC	2	6.2500	5.7607	AB
21	UTC	22	7.12E-15	5.7607	B
22	LRC21	16	1.58E-15	5.7607	B
23	LRC21	8	7.32E-16	5.7607	B
24	RSB	22	3.58E-17	5.7607	B
25	UTC	16	-488E-18	5.7607	B
26	RSB	16	-585E-18	5.7607	B
27	UTC	8	-707E-18	5.7607	B
28	LRC28	22	-112E-17	5.7607	B
29	LRC21	22	-129E-17	5.7607	B

Logistic regression and means comparison by protected LSD: for nymphs

The LOGISTIC Procedure

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	48.3865	4	<.0001
Score	38.7253	4	<.0001
Wald	25.9654	4	<.0001

Type 3 Analysis of Effects

Effect	Wald		
	DF	Chi-Square	Pr > ChiSq
TREAT	3	13.6011	0.0035
TIME	1	14.6480	0.0001

The Mixed Procedure

Tests of Effect Slices

Effect	TIME	Num	Den	F Value	Pr > F
		DF	DF		
TREAT*TIME	2	3	48	2.33	0.0864
TREAT*TIME	4	3	48	2.97	0.0408
TREAT*TIME	8	3	48	1.88	0.1453
TREAT*TIME	16	3	48	0.28	0.8380
TREAT*TIME	22	3	48	0.28	0.8380

Effect=TREAT*TIME Method=LSD(P<.05) Set=3

Obs	TREAT	TIME	Standard Estimate	Letter Error	Group
10	LRC28	4	54.1667	12.5592	A
11	LRC28	2	39.5833	12.5592	AB
12	LRC28	8	37.5000	12.5592	ABC
13	RSB	2	35.8333	12.5592	ABC
14	LRC21	4	31.2500	12.5592	ABCD
15	LRC21	8	25.0000	12.5592	ABCD
16	RSB	4	24.4048	12.5592	ABCD
17	LRC21	2	21.2500	12.5592	ABCD
18	RSB	8	12.5000	12.5592	BCD
19	LRC28	16	12.5000	12.5592	BCD
20	LRC28	22	12.5000	12.5592	BCD
21	RSB	16	8.3333	12.5592	BCD
22	UTC	4	5.0000	12.5592	CD
23	UTC	22	2.35E-14	12.5592	D
24	LRC21	16	-346E-17	12.5592	D
25	UTC	16	-166E-16	12.5592	D
26	UTC	8	-18E-15	12.5592	D
27	LRC21	22	-222E-16	12.5592	D
28	RSB	22	-222E-16	12.5592	D
29	UTC	2	-234E-16	12.5592	D

APPENDIX 13
SAS OUTPUT FOR CHAPTER 2 – MYCOSIS OF RICE STINK BUGS BY *B.*
***BASSIANA* IN 2002 SMALL PLOT FIELD EXPERIMENT**

MEAN MORTALITY OF TOTAL RICE STINK BUGS, SUMMER-2002

Obs	TREAT	TIME	_TYPE_	_FREQ_	n	mean	stderr
1	LRC28	2	0	5	5	31.8543	4.7584
2	LRC28	7	0	5	5	22.6667	11.2744
3	LRC28	11	0	5	5	13.3333	8.1650
4	LRC28	17	0	5	5	3.3333	3.3333
5	RSBIsola	2	0	5	5	27.2222	3.0932
6	RSBIsola	7	0	5	5	25.0000	8.3333
7	RSBIsola	11	0	5	5	13.3333	8.1650
8	RSBIsola	17	0	5	5	6.6667	6.6667
9	UTC	2	0	5	5	3.3566	2.0674
10	UTC	7	0	5	5	3.3333	3.3333
11	UTC	11	0	5	5	0.0000	0.0000
12	UTC	17	0	5	5	0.0000	0.0000
13	hklrc	2	0	5	5	39.9600	24.4704
14	hklrc	7	0	5	5	0.0000	0.0000
15	hklrc	11	0	5	5	10.0000	10.0000
16	hklrc	17	0	5	5	0.0000	0.0000
17	lklrc	2	0	5	5	15.0000	10.0000
18	lklrc	7	0	5	5	19.9800	19.9800
19	lklrc	11	0	5	5	0.0000	0.0000
20	lklrc	17	0	5	5	3.3333	3.3333

MEAN MORTALITY OF ADULTS, SUMMER-2002

Obs	TREAT	TIME	_TYPE_	_FREQ_	n	mean	stderr
1	LRC28	2	0	5	5	30.0000	13.3333
2	LRC28	7	0	5	5	6.6667	6.6667
3	LRC28	11	0	5	5	0.0000	0.0000
4	LRC28	17	0	5	5	0.0000	0.0000
5	RSBIsola	2	0	5	5	24.0000	11.2250
6	RSBIsola	7	0	5	5	10.0000	10.0000
7	RSBIsola	11	0	5	5	10.0000	10.0000
8	RSBIsola	17	0	5	5	0.0000	0.0000
9	UTC	2	0	5	5	3.3333	3.3333
10	UTC	7	0	5	5	4.0000	4.0000
11	UTC	11	0	5	5	0.0000	0.0000
12	UTC	17	0	5	5	0.0000	0.0000
13	hklrc	2	0	5	5	20.0000	20.0000
14	hklrc	7	0	5	5	0.0000	0.0000
15	hklrc	11	0	5	5	0.0000	0.0000
16	hklrc	17	0	5	5	0.0000	0.0000
17	lklrc	2	0	5	5	10.0000	10.0000
18	lklrc	7	0	5	5	0.0000	0.0000
19	lklrc	11	0	5	5	0.0000	0.0000
20	lklrc	17	0	5	5	0.0000	0.0000

MEAN MORTALITY OF NYMPHS, SUMMER-2002

Obs	TREAT	TIME	_TYPE_	_FREQ_	n	mean	stderr
1	LRC28	2	0	5	5	34.6429	4.6429
2	LRC28	7	0	5	5	50.0000	22.3607
3	LRC28	11	0	5	5	30.0000	20.0000
4	LRC28	17	0	5	5	6.6667	6.6667
5	RSBisola	2	0	5	5	27.3810	8.0742
6	RSBisola	7	0	5	5	30.6667	9.5102
7	RSBisola	11	0	5	5	10.0000	10.0000
8	RSBisola	17	0	5	5	10.0000	10.0000
9	UTC	2	0	5	5	2.0000	2.0000
10	UTC	7	0	5	5	0.0000	0.0000
11	UTC	11	0	5	5	0.0000	0.0000
12	UTC	17	0	5	5	0.0000	0.0000
13	hklrc	2	0	5	5	20.0000	20.0000
14	hklrc	7	0	5	5	0.0000	0.0000
15	hklrc	11	0	5	5	20.0000	20.0000
16	hklrc	17	0	5	5	0.0000	0.0000
17	lklrc	2	0	5	5	16.6667	10.5409
18	lklrc	7	0	5	5	20.0000	20.0000
19	lklrc	11	0	5	5	0.0000	0.0000
20	lklrc	17	0	5	5	20.0000	20.0000

Logistic regression and means comparison by protected LSD: for total rice stink bugs

The LOGISTIC Procedure
 Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	65.4811	5	<.0001
Score	56.2688	5	<.0001
Wald	41.7637	5	<.0001

Type 3 Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
TREAT	4	20.9326	0.0003
TIME	1	19.4933	<.0001

The Mixed Procedure

Tests of Effect Slices

Effect	TIME	Num	Den	F Value	Pr > F
		DF	DF		
TREAT*TIME	2	4	60	2.55	0.0481
TREAT*TIME	7	4	60	1.66	0.1713
TREAT*TIME	11	4	60	0.57	0.6839
TREAT*TIME	17	4	60	0.10	0.9836

Effect=TREAT*TIME Method=LSD(P<.05) Set=3

Obs	TREAT	TIME	Estimate	Standard Error	Letter Group
10	hklrc	2	39.9600	9.0613	A
11	LRC28	2	31.8543	9.0613	AB
12	RSBisola	2	27.2222	9.0613	ABC
13	RSBisola	7	25.0000	9.0613	ABCD
14	LRC28	7	22.6667	9.0613	ABCD
15	lklrc	7	19.9800	9.0613	ABCD
16	lklrc	2	15.0000	9.0613	ABCD
17	LRC28	11	13.3333	9.0613	BCD
18	RSBisola	11	13.3333	9.0613	BCD
19	hklrc	11	10.0000	9.0613	BCD
20	RSBisola	17	6.6667	9.0613	BCD
21	UTC	2	3.3566	9.0613	CD
22	lklrc	17	3.3333	9.0613	CD
23	UTC	7	3.3333	9.0613	CD
24	LRC28	17	3.3333	9.0613	CD
25	UTC	17	-444E-18	9.0613	D
26	UTC	11	-888E-18	9.0613	D
27	hklrc	7	-222E-17	9.0613	D
28	hklrc	17	-577E-17	9.0613	D
29	lklrc	11	-711E-17	9.0613	D

Logistic regression and means comparison by protected LSD: for adults

The LOGISTIC Procedure

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	22.8750	5	0.0004
Score	19.9869	5	0.0013
Wald	13.6230	5	0.0182

Type 3 Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
TREAT	4	3.7561	0.4400
TIME	1	9.7229	0.0018

The Mixed Procedure

Tests of Effect Slices

Effect	TIME	Num	Den	F Value	Pr > F
		DF	DF		
TREAT*TIME	2	4	60	2.23	0.0768
TREAT*TIME	7	4	60	0.36	0.8349
TREAT*TIME	11	4	60	0.39	0.8181
TREAT*TIME	17	4	60	0.00	1.0000

Effect=TREAT*TIME Method=LSD(P<.05) Set=3

Obs	TREAT	TIME	Estimate	Standard Error	Letter Group
10	LRC28	2	30.0000	7.3326	A
11	RSBIsola	2	24.0000	7.3326	AB
12	hklrc	2	20.0000	7.3326	ABC
13	lklrc	2	10.0000	7.3326	ABCD
14	RSBIsola	7	10.0000	7.3326	ABCD
15	RSBIsola	11	10.0000	7.3326	ABCD
16	LRC28	7	6.6667	7.3326	BCD
17	UTC	7	4.0000	7.3326	BCD
18	UTC	2	3.3333	7.3326	CD
19	LRC28	17	4.1E-15	7.3326	CD
20	hklrc	7	2.95E-15	7.3326	D
21	lklrc	17	2.9E-15	7.3326	CD
22	hklrc	11	2.33E-15	7.3326	D
23	RSBIsola	17	2.33E-15	7.3326	CD
24	LRC28	11	1.49E-15	7.3326	CD
25	UTC	11	1.4E-15	7.3326	CD
26	lklrc	7	-214E-19	7.3326	CD
27	UTC	17	-171E-18	7.3326	CD
28	hklrc	17	-239E-17	7.3326	D
29	lklrc	11	-357E-17	7.3326	CD

Logistic regression and means comparison by protected LSD: for nymphs

The LOGISTIC Procedure
Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	47.6884	5	<.0001
Score	38.2444	5	<.0001
Wald	21.7415	5	0.0006

Type 3 Analysis of Effects

Effect	DF	Chi-Square	Pr > ChiSq
TREAT	4	13.3095	0.0099
TIME	1	6.8693	0.0088

The Mixed Procedure

Tests of Effect Slices

Effect	TIME	Num DF	Den DF	F Value	Pr > F
TREAT*TIME	2	4	60	1.00	0.4139
TREAT*TIME	7	4	60	3.01	0.0250
TREAT*TIME	11	4	60	1.13	0.3520
TREAT*TIME	17	4	60	0.46	0.7669

Effect=TREAT*TIME Method=LSD(P<.05) Set=3

Obs	TREAT	TIME	Estimate	Standard Error	Letter Group
10	LRC28	7	50.0000	12.3222	A
11	LRC28	2	34.6429	12.3222	AB
12	RSBIsola	7	30.6667	12.3222	AB
13	LRC28	11	30.0000	12.3222	AB
14	RSBIsola	2	27.3810	12.3222	AB
15	lklrc	17	20.0000	12.3222	AB
16	hklrc	11	20.0000	12.3222	AB
17	hklrc	2	20.0000	12.3222	AB
18	lklrc	7	20.0000	12.3222	AB
19	lklrc	2	16.6667	12.3222	AB
20	RSBIsola	17	10.0000	12.3222	B
21	RSBIsola	11	10.0000	12.3222	B
22	LRC28	17	6.6667	12.3222	B
23	UTC	2	2.0000	12.3222	B
24	UTC	11	0	12.3222	B
25	UTC	7	-533E-17	12.3222	B
26	hklrc	7	-755E-17	12.3222	B
27	hklrc	17	-107E-16	12.3222	B
28	UTC	17	-142E-16	12.3222	B
29	lklrc	11	-178E-16	12.3222	B

APPENDIX 14
SAS OUTPUT FOR CHAPTER 2 – MYCOSIS OF RICE STINK BUGS BY *B.*
***BASSIANA* IN 2003 SMALL PLOT FIELD EXPERIMENT**

MEAN MORTALITY OF TOTAL RICE STINK BUGS, SUMMER-2003

Obs	TREAT	TIME	_TYPE_	_FREQ_	n	mean	stderr
1	LKLRC	2	0	4	4	20.8243	12.4942
2	LKLRC	4	0	4	4	8.3306	8.3306
3	LKLRC	8	0	4	4	0.0000	0.0000
4	LKLRC	10	0	4	4	5.0000	5.0000
5	LKLRC	14	0	4	4	0.0000	0.0000
6	LKLRC	18	0	4	4	6.2500	6.2500
7	LRC28	2	0	4	4	24.2857	11.9238
8	LRC28	4	0	4	4	25.0000	10.2062
9	LRC28	8	0	4	4	16.6604	11.7792
10	LRC28	10	0	4	4	10.0000	5.7735
11	LRC28	14	0	4	4	3.5714	3.5714
12	LRC28	18	0	4	4	0.0000	0.0000
13	UTC	2	0	4	4	2.7778	2.7778
14	UTC	4	0	4	4	4.1667	4.1667
15	UTC	8	0	4	4	0.0000	0.0000
16	UTC	10	0	4	4	0.0000	0.0000
17	UTC	14	0	4	4	0.0000	0.0000
18	UTC	18	0	4	4	0.0000	0.0000

MEAN MORTALITY OF ADULTS, SUMMER-2003

Obs	TREAT	TIME	_TYPE_	_FREQ_	n	mean	stderr
1	LKLRC	2	0	4	4	20.8333	12.5000
2	LKLRC	4	0	4	4	8.3333	8.3333
3	LKLRC	8	0	4	4	0.0000	0.0000
4	LKLRC	10	0	4	4	0.0000	0.0000
5	LKLRC	14	0	4	4	0.0000	0.0000
6	LKLRC	18	0	4	4	12.5000	12.5000
7	LRC28	2	0	4	4	16.6667	16.6667
8	LRC28	4	0	4	4	16.6667	11.7851
9	LRC28	8	0	4	4	6.2500	6.2500
10	LRC28	10	0	4	4	8.3333	8.3333
11	LRC28	14	0	4	4	0.0000	0.0000
12	LRC28	18	0	4	4	0.0000	0.0000
13	UTC	2	0	4	4	6.2500	6.2500
14	UTC	4	0	4	4	0.0000	0.0000
15	UTC	8	0	4	4	0.0000	0.0000
16	UTC	10	0	4	4	0.0000	0.0000
17	UTC	14	0	4	4	0.0000	0.0000
18	UTC	18	0	4	4	0.0000	0.0000

MEAN MORTALITY OF NYMPHS, SUMMER-2003

Obs	TREAT	TIME	_TYPE_	_FREQ_	n	mean	stderr
1	LKLRC	2	0	4	4	0.0000	0.0000
2	LKLRC	4	0	4	4	0.0000	0.0000
3	LKLRC	8	0	4	4	0.0000	0.0000

4	LKLRC	10	0	4	4	8.3333	8.3333
5	LKLRC	14	0	4	4	0.0000	0.0000
6	LKLRC	18	0	4	4	0.0000	0.0000
7	LRC28	2	0	4	4	31.2500	11.9678
8	LRC28	4	0	4	4	33.3333	11.7851
9	LRC28	8	0	4	4	12.5000	12.5000
10	LRC28	10	0	4	4	12.5000	12.5000
11	LRC28	14	0	4	4	8.3333	8.3333
12	LRC28	18	0	4	4	0.0000	0.0000
13	UTC	2	0	4	4	0.0000	0.0000
14	UTC	4	0	4	4	6.2500	6.2500
15	UTC	8	0	4	4	0.0000	0.0000
16	UTC	10	0	4	4	0.0000	0.0000
17	UTC	14	0	4	4	0.0000	0.0000
18	UTC	18	0	4	4	0.0000	0.0000

Logistic regression and means comparison by protected LSD: for total rice stink bugs

The LOGISTIC Procedure

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	30.9019	3	<.0001
Score	27.6157	3	<.0001
Wald	20.8773	3	0.0001

Type 3 Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
TREAT	2	11.0859	0.0039
TIME	1	10.1089	0.0015

The Mixed Procedure

Tests of Effect Slices

Effect	TIME	Num		Den	F Value	Pr > F
		DF	DF			
TREAT*TIME	2	2	45	3.22	0.0494	
TREAT*TIME	4	2	45	2.93	0.0635	
TREAT*TIME	8	2	45	2.23	0.1190	
TREAT*TIME	10	2	45	0.60	0.5513	
TREAT*TIME	14	2	45	0.10	0.9027	
TREAT*TIME	18	2	45	0.31	0.7319	

Effect=TREAT*TIME Method=LSD(P<.05) Set=3

Obs	TREAT	TIME	Estimate	Standard Error	Letter Group
10	LRC28	4	25.0000	6.4369	A
11	LRC28	2	24.2857	6.4369	AB
12	LKLRC	2	20.8243	6.4369	ABC
13	LRC28	8	16.6604	6.4369	ABCD
14	LRC28	10	10.0000	6.4369	ABCDE
15	LKLRC	4	8.3306	6.4369	ABCDE
16	LKLRC	18	6.2500	6.4369	BCDE
17	LKLRC	10	5.0000	6.4369	DE
18	UTC	4	4.1667	6.4369	CDE
19	LRC28	14	3.5714	6.4369	CDE
20	UTC	2	2.7778	6.4369	CDE
21	UTC	18	2.19E-14	6.4369	DE
22	LKLRC	8	5.81E-15	6.4369	DE
23	UTC	14	4.61E-15	6.4369	DE
24	UTC	8	4.03E-15	6.4369	DE
25	UTC	10	3.12E-15	6.4369	DE
26	LKLRC	14	1.94E-15	6.4369	DE
27	LRC28	18	-239E-16	6.4369	E

Logistic regression and means comparison by protected LSD: for adults

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	12.3973	3	0.0061
Score	10.4940	3	0.0148
Wald	8.4420	3	0.0377

Type 3 Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
TREAT	2	3.8587	0.1452
TIME	1	4.9325	0.0264

The Mixed Procedure

Tests of Effect Slices

Effect	TIME	Num	Den	F Value	Pr > F
		DF	DF		
TREAT*TIME	2	2	45	1.07	0.3504
TREAT*TIME	4	2	45	1.32	0.2770
TREAT*TIME	8	2	45	0.25	0.7816
TREAT*TIME	10	2	45	0.44	0.6465
TREAT*TIME	14	2	45	0.00	1.0000
TREAT*TIME	18	2	45	0.99	0.3792

Effect=TREAT*TIME Method=LSD(P<.05) Set=3

Obs	TREAT	TIME	Estimate	Standard Error	Letter Group
10	LKLRC	2	20.8333	7.2501	A
11	LRC28	4	16.6667	7.2501	AB
12	LRC28	2	16.6667	7.2501	AB
13	LKLRC	18	12.5000	7.2501	AB
14	LKLRC	4	8.3333	7.2501	AB
15	LRC28	10	8.3333	7.2501	AB
16	LRC28	8	6.2500	7.2501	AB
17	UTC	2	6.2500	7.2501	AB
18	UTC	4	6.13E-15	7.2501	B
19	UTC	18	2.51E-15	7.2501	B
20	UTC	8	1.46E-15	7.2501	B
21	LKLRC	14	1.16E-15	7.2501	B
22	LKLRC	8	-312E-18	7.2501	B
23	UTC	14	-613E-18	7.2501	B
24	LRC28	14	-112E-17	7.2501	B
25	LKLRC	10	-188E-17	7.2501	B
26	UTC	10	-188E-17	7.2501	B
27	LRC28	18	-491E-17	7.2501	B

Logistic regression and means comparison by protected LSD: for nymphs

The LOGISTIC Procedure

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	19.4542	3	0.0002
Score	18.1095	3	0.0004
Wald	12.6029	3	0.0056

Type 3 Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
TREAT	2	7.1006	0.0287
TIME	1	4.6325	0.0314

The Mixed Procedure

Tests of Effect Slices

Effect	TIME	Num	Den	F Value	Pr > F
		DF	DF		
TREAT*TIME	2	2	45	7.58	0.0015
TREAT*TIME	4	2	45	7.31	0.0018
TREAT*TIME	8	2	45	1.21	0.3067
TREAT*TIME	10	2	45	0.94	0.3967
TREAT*TIME	14	2	45	0.54	0.5869
TREAT*TIME	18	2	45	0.00	1.0000

Effect=TREAT*TIME Method=LSD(P<.05) Set=3

Obs	TREAT	TIME	Estimate	Standard Error	Letter Group
10	LRC28	4	33.3333	6.5514	A
11	LRC28	2	31.2500	6.5514	A
12	LRC28	8	12.5000	6.5514	B
13	LRC28	10	12.5000	6.5514	B
14	LKLRC	10	8.3333	6.5514	B
15	LRC28	14	8.3333	6.5514	B
16	UTC	4	6.2500	6.5514	B
17	UTC	18	1.58E-14	6.5514	B
18	UTC	10	4.87E-15	6.5514	B
19	LKLRC	2	4.27E-15	6.5514	B
20	LKLRC	4	4.09E-15	6.5514	B
21	LKLRC	8	3.85E-15	6.5514	B
22	LKLRC	14	2.53E-15	6.5514	B
23	UTC	8	1.74E-15	6.5514	B
24	LKLRC	18	1.42E-15	6.5514	B
25	UTC	14	6.52E-16	6.5514	B
26	UTC	2	-584E-17	6.5514	B
27	LRC28	18	-115E-16	6.5514	B

APPENDIX 15
SAS OUTPUT FOR CHAPTER 2 – SPREAD AND PERSISTANCE OF *B. BASSIANA* AFTER ITS APPLICATION IN LARGE PLOT EXPERIMENT

Logistic regression analysis when center plot was excluded from analysis
The LOGISTIC Procedure

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	28.9226	7	0.0001
Score	24.8706	7	0.0008
Wald	23.3814	7	0.0015

Type 3 Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
species	2	8.2789	0.0159
distance	1	0.7867	0.3751
day	1	18.8746	<.0001
direction	3	1.1723	0.7597

Logistic regression analysis when center plot was included and direction excluded

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	105.3315	4	<.0001
Score	103.3508	4	<.0001
Wald	86.7181	4	<.0001

Type 3 Analysis of Effects

Effect	DF	Wald	
		Chi-Square	Pr > ChiSq
species	2	23.2885	<.0001
distance	1	44.8571	<.0001
day	1	34.4573	<.0001

Odds Ratio Estimates

Effect	Point Estimate	95% Wald Confidence Limits	
		Estimate	Confidence Limits
species gh vs rsb	0.269	0.151	0.479
species lyg vs rsb	1.077	0.477	2.434
species gh vs lyg	0.250	0.110	0.568
distance	0.916	0.893	0.940
day	0.841	0.793	0.891

APPENDIX 16
SAS OUTPUT FOR CHAPTER 3 – EFFECTS OF PANICLE AGE ON THE
DAMAGE OF RICE BY RICE STINK BUG IN ONE BUG PER PANICLE
EXPERIMENT

Obs	treat	Mean proportion of empty kernels				N
		TYPE	_FREQ_	MEAN	STDERR	
1	13DAA	0	18	0.12175	0.017246	18
2	17DAA	0	18	0.07518	0.010781	18
3	1DAA	0	18	0.39403	0.041457	18
4	21DAA	0	18	0.05670	0.009102	18
5	5DAA	0	18	0.28251	0.034027	18
6	9DAA	0	18	0.19078	0.016621	18
7	UTC	0	18	0.06039	0.007961	18

Obs	treat	Mean average weights of filled kernels				N
		TYPE	_FREQ_	MEAN	STDERR	
1	13DAA	0	18	0.023146	.000355508	18
2	17DAA	0	18	0.023631	.000183800	18
3	1DAA	0	18	0.022549	.000516334	18
4	21DAA	0	18	0.024118	.000226957	18
5	5DAA	0	18	0.022033	.000394627	18
6	9DAA	0	18	0.023040	.000274651	18
7	UTC	0	18	0.024487	.000307834	18

Obs	treat	Mean proportion of pecky rice				N
		TYPE	_FREQ_	MEAN	STDERR	
1	13DAA	0	18	0.20174	.008673670	18
2	17DAA	0	18	0.08227	.005609870	18
3	1DAA	0	18	0.03464	.003962390	18
4	21DAA	0	18	0.05529	.004526086	18
5	5DAA	0	18	0.08481	.005128171	18
6	9DAA	0	18	0.18617	.007044416	18
7	UTC	0	18	0.03548	.004711386	18

The GLM Procedure
Multivariate Analysis of Variance

Characteristic Roots and Vectors of: E Inverse * H, where
H = Type III SSCP Matrix for treat
E = Error SSCP Matrix

Characteristic Root	Percent	Characteristic Vector			V'EV=1
		Pempty	FavWt	Ppecky	
7.11161390	81.53	-0.1277559	-5.4156765	3.6639539	
1.54952333	17.76	0.9138187	-3.5209988	0.2524072	
0.06188119	0.71	0.4041738	68.1041771	0.2939316	

MANOVA Test Criteria and F Approximations for
the Hypothesis of No Overall treat Effect
H = Type III SSCP Matrix for treat
E = Error SSCP Matrix

S=3 M=1 N=57.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.04553631	36.47	18	331.41	<.0001
Pillai's Trace	1.54276485	21.00	18	357	<.0001
Hotelling-Lawley Trace	8.72301842	56.22	18	228.07	<.0001
Roy's Greatest Root	7.11161390	141.05	6	119	<.0001

NOTE: F Statistic for Roy's Greatest Root is an upper bound.

The CORR Procedure

Pearson Correlation Coefficients, N = 126
Prob > |r| under H0: Rho=0

	Pempty	FAvWt	Ppecky
Pempty	1.00000 <.0001	-0.52456 0.4333	-0.07042
FAvWt	-0.52456 <.0001	1.00000 0.1868	-0.11838
Ppecky	-0.07042 0.4333	-0.11838 0.1868	1.00000

The GLM Procedure
Dependent Variable: Pempty

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	1.78988309	0.29831385	31.25	<.0001
Error	119	1.13608101	0.00954690		
Corrected Total	125	2.92596410			

R-Square	Coeff Var	Root MSE	Pempty Mean
0.611724	57.89715	0.097708	0.168762

Tukey's Studentized Range (HSD) Test for Pempty

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	119
Error Mean Square	0.009547
Critical Value of Studentized Range	4.24179
Minimum Significant Difference	0.0977

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	treat
A	0.39403	18	1DAA
B	0.28251	18	5DAA
B			
C B	0.19078	18	9DAA
C			
C D	0.12175	18	13DAA
D			
D	0.07518	18	17DAA
D			
D	0.06039	18	UTC
D			
D	0.05670	18	21DAA

The GLM Procedure

Dependent Variable: FAVWt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	0.00008006	0.00001334	6.45	<.0001
Error	119	0.00024609	0.00000207		
Corrected Total	125	0.00032615			

R-Square	Coeff Var	Root MSE	FAVWt Mean
0.245484	6.175463	0.001438	0.023286

Tukey's Studentized Range (HSD) Test for FAVWt

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	119
Error Mean Square	2.068E-6
Critical Value of Studentized Range	4.24179
Minimum Significant Difference	0.0014

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	treat
A	0.0244873	18	UTC
A			
B A	0.0241181	18	21DAA
B			
B A C	0.0236310	18	17DAA

B		A	C			
B	D	A	C	0.0231461	18	13DAA
B	D		C			
B	D		C	0.0230400	18	9DAA
D		C				
D		C		0.0225486	18	1DAA
D						
D				0.0220331	18	5DAA

The GLM Procedure

Dependent Variable: Ppecky

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	0.51657865	0.08609644	138.92	<.0001
Error	119	0.07374853	0.00061974		
Corrected Total	125	0.59032718			

R-Square	Coeff Var	Root MSE	Ppecky Mean
0.875072	25.61161	0.024894	0.097200

Tukey's Studentized Range (HSD) Test for Ppecky

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	119
Error Mean Square	0.00062
Critical Value of Studentized Range	4.24179
Minimum Significant Difference	0.0249

Means with the same letter are not significantly different.

Tukey grouping	Mean	N	treat
A	0.201739	18	13DAA
A			
A	0.186167	18	9DAA
B	0.084806	18	5DAA
B			
B	0.082272	18	17DAA
C	0.055294	18	21DAA
C			
C	0.035478	18	UTC
C			
C	0.034644	18	1DAA

APPENDIX 17
SAS OUTPUT FOR CHAPTER 3 – EFFECTS OF PANICLE AGE ON THE
DAMAGE OF RICE BY RICE STINK BUG IN TWO BUGS PER PANICLE
EXPERIMENT

Obs	treat	Mean proportion of empty kernels				N
		TYPE	_FREQ_	MEAN	STDERR	
1	13DAA	0	10	0.14986	0.025765	10
2	17DAA	0	10	0.08043	0.010448	10
3	1DAA	0	10	0.63464	0.023465	10
4	21DAA	0	10	0.07115	0.008852	10
5	5DAA	0	10	0.49628	0.044018	10
6	9DAA	0	10	0.32147	0.035094	10
7	UTC	0	10	0.05658	0.007159	10

Obs	treat	Mean average weights of filled kernels				N
		TYPE	_FREQ_	MEAN	STDERR	
1	13DAA	0	10	0.023111	.000170338	10
2	17DAA	0	10	0.023626	.000134938	10
3	1DAA	0	10	0.022169	.000158208	10
4	21DAA	0	10	0.024027	.000173716	10
5	5DAA	0	10	0.021877	.000238785	10
6	9DAA	0	10	0.022843	.000133910	10
7	UTC	0	10	0.024502	.000110139	10

Obs	treat	Mean proportion of pecky rice				N
		TYPE	_FREQ_	MEAN	STDERR	
1	13DAA	0	10	0.28352	0.004881	10
2	17DAA	0	10	0.12007	0.009769	10
3	1DAA	0	10	0.03918	0.003604	10
4	21DAA	0	10	0.06661	0.003100	10
5	5DAA	0	10	0.09505	0.009533	10
6	9DAA	0	10	0.25697	0.011162	10
7	UTC	0	10	0.03219	0.002938	10

The GLM Procedure
Multivariate Analysis of Variance

Characteristic Roots and Vectors of: E Inverse * H, where
H = Type III SSCP Matrix for treat
E = Error SSCP Matrix

Characteristic Root	Percent	Characteristic Vector			V'EV=1
		Pempty	FAvWt	Ppecky	
21.0393933	67.61	0.379510	-76.142800	5.562203	
9.8689835	31.72	1.281147	-106.530722	-0.863229	
0.2092171	0.67	0.832400	207.316386	0.586523	

MANOVA Test Criteria and F Approximations for
the Hypothesis of No Overall treat Effect
H = Type III SSCP Matrix for treat
E = Error SSCP Matrix

S=3 M=1 N=29.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.00345229	61.71	18	173.02	<.0001
Pillai's Trace	2.03564043	22.16	18	189	<.0001
Hotelling-Lawley Trace	31.11759392	103.78	18	116.13	<.0001
Roy's Greatest Root	21.03939327	220.91	6	63	<.0001

NOTE: F Statistic for Roy's Greatest Root is an upper bound.

The CORR Procedure
 Pearson Correlation Coefficients, N = 70
 Prob > |r| under H0: Rho=0

	Pempty	FAvWt	Ppecky
Pempty	1.00000	-0.75489 <.0001	-0.12768 0.2922
FAvWt	-0.75489 <.0001	1.00000	-0.13319 0.2717
Ppecky	-0.12768 0.2922	-0.13319 0.2717	1.00000

The GLM Procedure
 Dependent Variable: Pempty

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	3.21372808	0.53562135	81.11	<.0001
Error	63	0.41602038	0.00660350		
Corrected Total	69	3.62974846			

R-Square	Coeff Var	Root MSE	Pempty Mean
0.885386	31.42014	0.081262	0.258630

Tukey's Studentized Range (HSD) Test for Pempty

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	63
Error Mean Square	0.006603
Critical Value of Studentized Range	4.30714
Minimum Significant Difference	0.1107

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	treat
A	0.63464	10	1DAA
B	0.49628	10	5DAA
C	0.32147	10	9DAA
D	0.14986	10	13DAA
D	0.08043	10	17DAA
D	0.07115	10	21DAA
D	0.05658	10	UTC

The GLM Procedure
Dependent Variable: FAvWt

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	0.00005501	0.00000917	33.86	<.0001
Error	63	0.00001706	0.00000027		
Corrected Total	69	0.00007206			

R-Square	Coeff Var	Root MSE	FAvWt Mean
0.763320	2.246133	0.000520	0.023165

Tukey's Studentized Range (HSD) Test for FAvWt

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	63
Error Mean Square	2.707E-7
Critical Value of Studentized Range	4.30714
Minimum Significant Difference	0.0007

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	treat
A	0.0245018	10	UTC
A			
B	0.0240275	10	21DAA
B			
B	0.0236257	10	17DAA
C			
D	0.0231113	10	13DAA
D			

D	E	0.0228429	10	9DAA
	E			
F	E	0.0221692	10	1DAA
F				
F		0.0218768	10	5DAA

The GLM Procedure
Dependent Variable: Ppecky

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	0.62804770	0.10467462	200.23	<.0001
Error	63	0.03293426	0.00052277		
Corrected Total	69	0.66098195			

R-Square	Coeff Var	Root MSE	Ppecky Mean
0.950174	17.91073	0.022864	0.127656

Tukey's Studentized Range (HSD) Test for Ppecky

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	63
Error Mean Square	0.000523
Critical Value of Studentized Range	4.30714
Minimum Significant Difference	0.0311

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	treat
A	0.28352	10	13DAA
A			
A	0.25697	10	9DAA
B	0.12007	10	17DAA
B			
C	0.09505	10	5DAA
C			
C	0.06661	10	21DAA
D			
E	0.03918	10	1DAA
E			
E	0.03219	10	UTC

APPENDIX 18
SAS OUTPUT FOR CHAPTER 3 – EFFECTS OF QUALITATIVE DAMAGE BY
RICE STINK BUG ON THE GERMINATION OF RICE

The GLM Procedure
 Dependent Variable: P_GERM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	869.5000000	124.2142857	134.29	<.0001
Error	32	29.6000000	0.9250000		
Corrected Total	39	899.1000000			

R-Square	Coeff Var	Root MSE	P_GERM Mean
0.967078	7.313834	0.961769	13.15000

Source	DF	Type III SS	Mean Square	F Value	Pr > F
QUALITY	1	864.9000000	864.9000000	935.03	<.0001
TIME	3	1.7000000	0.5666667	0.61	0.6118
QUALITY*TIME	3	2.9000000	0.9666667	1.05	0.3860

Tukey's Studentized Range (HSD) Test for P_GERM

NOTE: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	32
Error Mean Square	0.925
Critical Value of Studentized Range	2.88068
Minimum Significant Difference	0.6195

Means with the same letter are not significantly different.

Tukey Grouping	Mean	N	QUALITY
A	17.8000	20	good
B	8.5000	20	pecky

The GLM Procedure

Level of QUALITY	Level of TIME	N	-----P_GERM----- Mean	Std Dev
good	0	5	18.2000000	0.44721360
good	1	5	17.6000000	1.14017543
good	17	5	18.0000000	1.41421356
good	9	5	17.4000000	0.89442719
pecky	0	5	8.4000000	0.54772256
pecky	1	5	8.0000000	0.70710678
pecky	17	5	8.6000000	0.89442719
pecky	9	5	9.0000000	1.22474487

VITA

Dilipkumar Patel, the first son in the family, was born on October 14, 1975, in diver village, Gujarat, India. He obtained his Bachelor of Science degree in agricultural sciences from Gujarat Agricultural University, Navsari Campus, Gujarat, India, in 1997. He completed his Master of Science degree in agricultural entomology from the Gujarat Agricultural University, Anand Campus, Gujarat, India, in 2000. He began his graduate studies in entomology in 2001 at Louisiana State University, Agricultural Center, under the direction of Dr. Michael J. Stout and Dr. James R. Fuxa. Mr. Patel is expected to receive the degree of Master of Science in May 2005.