ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 2023 – December 31, 2023

PROJECT TITLE: Rice Disease Research and Management

PROJECT LEADER: Luis Espino
Rice Farming Systems Advisor
Butte and Glenn Counties
UC Cooperative Extension
5 County Center Drive
Oroville, CA 9565
(530) 635-6234

PRINCIPAL UC INVESTIGATORS:
Whitney Brim-DeForest, UCCE Rice Farm Advisor, Sutter, Yuba, Placer and Sacramento Counties

COOPERATORS:
Ray Stogsdill, Staff Research Associate, UC Davis
Troy Clark, Junior Specialist, UCCE
Consuelo Baez, Junior Specialist, UCCE

LEVEL OF 2023 FUNDING: $31,987

OBJECTIVES AND EXPERIMENTS CONDUCTED, BY LOCATION, TO ACCOMPLISH OBJECTIVES:

OBJECIVE 1) Determine the susceptibility of California varieties to stem rot, aggregate sheath spot, and kernel smut and explore their effect on yield and quality.

For this objective, two trials were established in fields with a history of stem rot and aggregate sheath spot (AGSS). Kernel smut was observed and evaluated in two UCCE Statewide Variety trials.

Stem Rot and AGSS Trials Methods

The stem rot variety trial was established in a basin with a history of stem rot at the Rice Experiment Station (RES) in Biggs. The AGSS variety trial was established in a commercial field near Richvale. Important dates are presented in table 1. Plots were seeded at a rate of 180 lbs/acre. Trials were managed following typical recommended practices for rice in California. At the stem rot location, the N rate was increased to promote the development of stem rot, applying 180 lbs of N/a pre-plant as aqua ammonia. Varieties tested in both trials and their characteristics are presented in table 2.

In each trial, two plots were established for each variety, one was left untreated and the other was treated with Tretaban (stem rot trial) or Quadris (AGSS trial) at 15.5 oz/a (the active ingredient in both products is azoxystrobin) at the late boot to early heading stage. Because of the differences in days to heading for the varieties, treatments were made in two dates, grouping varieties that were in similar developmental stages. To rate disease incidence and severity, tiller samples were taken at drain time, when approximately 50% of kernels in panicles turned yellow. These ratings were accomplished in two dates, grouping varieties in the same way as for fungicide application. Tiller samples consisted of tillers cut below the water level randomly from the front, middle, and back of each plot. A subset of 30 tillers per sample were used to rate stem rot or AGSS incidence and severity using the scale presented in table 3. In each trial, a few samples were rated for the disease that was not the objective of the trial to determine general secondary disease level. In the stem rot trial, 10 tillers were taken from each tiller sample and tiller diameter measured.

To calculate disease incidence and severity, the following formulas were used:

- % disease incidence = (number of tillers in categories 1-4) / total tillers*100
- Disease severity = [∑(number of tillers per category*category)] / total tillers

Plots were harvested using a small plot combine and yields converted to lbs/a at 14% moisture content (MC). A 1 lb sample of rough rice was obtained from each plot and air dried to 14% MC. A sub-sample of 200 g was hulled with a McGill sheller and milled with a Yamamoto Ricepal 32. Next, whole kernels were separated using a Satake drum whole kernel separator. Whole kernels are unbroken kernels of rice and broken kernels of rice which are at least three-fourths of an unbroken kernel. With this information, the following parameters were determined:

- Milled rice yield = (milled rice weight (whole + broken)/rough rice weight)*100%
- Head rice yield = (whole kernels weight/rough rice weight)*100%

The trials were conducted as a factorial experiment, with variety and fungicide treatment as factors, with four replications for the stem rot trial and six for the AGSS trial. Analysis of variance was used to detect differences among treatment means for parameters evaluated. When significant differences were detected, the Least Significant Difference test was used to compare treatment means.

Tiller width for 2023 and level of stem rot severity per variety for each year the stem rot trial was conducted was regressed against days to 50% heading recorded in its respective year at variety trials conducted at the RES using analysis of covariance. The level of α used for all analyses was 0.05.

Results

Stem rot

Stem rot levels in the trial area were moderate, with samples from untreated plots averaging having an incidence of 81% and severity of 1.6. Aggregate sheath spot level in this trial was very low (15% incidence and 0.2 severity), indicating that this disease did not affect the results. For stem rot incidence, both the variety and treatment effects were significant (*P*=0.004 and

P=0.009; respectively), while their interaction was not. The lowest incidence was observed in varieties M-211, A-202, S-102, and M-209 (table 4). Treatment with azoxystrobin reduced stem rot incidence from 82 to 72%, a 12% reduction.

For severity, the interaction of treatment and variety was not significant, but the variety effect was (*P*=0.009). Varieties M-211, S-102, A-202, and M-209 had the lowest stem rot severity (table 4). While the treatment effect was not significant, there was a trend (*P*=0.081) to see lower severity in treated plots, with a reduction in severity from 1.6 to 1.4, an 11% reduction.

Yield were only significantly (*P*<0.001) affected by variety. Varieties L-208, M-211, and A-202 had the highest yields (table 4). Milling yield was significantly affected by treatment and variety. Treatment with azoxystrobin (*P*=0.043) resulted in a 1% increase in milling yield. Differences among varieties (*P*<0.001) were small, with L-208 having the highest milling yield and S-102 the lowest (table 4). Head rice yield was only affected by variety (*P*<0.001) (table 4).

In this trial, all varieties responded similarly to the application of a fungicide, resulting in a reduction in stem rot incidence and severity. However, when looking at the data closely, the stem rot severity in variety M-105 was not reduced by the fungicide, in fact, severity was higher in the treated plots (1.8) than in the untreated plots (1.3). This result is unusual and does not fit with the pattern observed this year or in previous years. If the effect of the fungicide on severity in this variety is not used in the analysis, the fungicide application would have resulted in a reduction in stem rot severity of 17%. This level of reduction is similar to what was observed in 2022 (18%) but lower than in 2021 (32%).

Grain yield was not affected by fungicide application. During the three years this study was conducted, a significant increase in yield was only obtained only in 2021 (4% increase). Head rice yield was significantly improved by the fungicide treatment in 2022 (3.3% increase) but not in 2023 (grain quality was not measured in 2021).

Levels of disease severity varied between varieties. Like in previous years, varieties with longer periods of development tended to have lower levels of stem rot severity. However, this year the results were not as clear as in previous years. Nevertheless, when relating days to 50% heading (at RES trials) for each of the years the stem rot variety trial was conducted, a strong relationship is found (fig. 1).

Regression between tiller width and days to 50% heading indicates that varieties that have longer periods of development have tillers with larger diameters (fig. 2A) (*P*=0.004). Plants of these varieties tend to be larger and therefore having bigger tillers is not unexpected. When regressing days to 50% heading against average stem rot severity, the relationship is not significant, however, there is a trend (*P*=0.199) that indicates that varieties with larger tiller width had lower stem rot severity (fig. 2B).

Aggregate sheath spot

Aggregate sheath spot level in the trial was moderate to low. Average incidence and severity in untreated plots were 61% and 1.07, respectively. Stem rot level was low, with average incidence and severity of 58% and 1.03, respectively, in untreated plots.

In all the analyses, the interaction between variety and treatment was always not significant. Treatment with azoxystrobin significantly reduced AGSS incidence and severity (P<0.001 for both) by 58 and 66%. Treatment also resulted in a significant (P=0.004) increase in yield from 8,133 lbs/a in untreated plots to 8,429 lbs/a in treated plots. Treatment had a slight effect on milling yield (P=0.033) and no effect on head rice yield. Milling yield was slightly higher (0.5%) in untreated plots.

There were no significant differences among varieties in AGSS incidence or severity (table 5). As expected, there were significant differences among the varieties in yield, milling yield, and head rice yield (P<0.001 for all three, table 5).

All varieties responded similarly to the application of the fungicide. As in previous years, AGSS incidence and severity were reduced greatly with azoxystrobin. In 2022 and 2023, fungicide application resulted in a yield increase (between 3 and 4%). Head rice yield was only improved in 2022.

All varieties showed similar levels of AGSS incidence and severity. Some difference had been observed in 2021 and 2022, with varieties A-202, L-208 having the lowest levels of AGSS in 2021 and variety L-208 having the lowest level in 2022. While in 2023 we did not see significant differences, A-202 had the lowest AGSS numerical level. These results seem to suggest that varieties A-202 and L-208 may be allow less development of AGSS than other tested varieties. This conclusion should be taken with care because disease levels in the trials were generally low.

Yield increases because of the fungicide application in these trials may be the result of the great reduction in AGSS severity. However, disease levels were low, and they were very low in 2022. It is important to notice that in the Sacramento Valley, AGSS is not a major disease and the levels obtained this year are typical of fields where this disease is prominent. This year we also sampled for stem rot in this trial and found low levels. It is possible that the yield increase obtained by the fungicide application may be the result of reducing the severity of both diseases. Another possibility is that azoxystrobin provides a yield and quality bump even in the absence of disease. This was investigated in other trials this year which are described later.

As in the stem rot trial, differences in head rice yield among varieties should be taken carefully. The trial was in a M-206 field and was harvested when the grain moisture content was adequate for this variety. This might be too late for early heading varieties and even for M-211, which has more stringent grain moisture requirements than other varieties.

Kernel Smut Trial Methods

Kernel smut was observed in two of the UCCE Statewide Variety Trials conducted in 2023, Glenn and Butte County trials. Kernel smut was evaluated in commercial varieties only, which were replicated three times in each trial. At harvest, a 400 g grain sample was taken from each plot and later processed using KOH. The KOH method consists in soaking three 25 g grain samples in a 0.27 M KOH solution (15 gr/lt) for 24 hours to clear the hulls and then count the number of smutted kernels by placing the grains in a shallow film of water. The number of smutted kernels per sample was analyzed using a one way analysis of variance with variety as factor.

Results

Smut levels were higher in Glenn than Butte. In both trials, there were significant differences among varieties in the level of smut ($P<0.001$ for both). In Butte (fig. 3A), higher number of smutted kernels were observed in CJ201 and CT202. These two varieties are aromatic long grains. Among the medium grains, M-209 and M-211 showed the highest levels of smut. Among the short grains, S-102 had the highest level, which was comparable to the medium grains.

In Glenn (fig. 3B), CJ201 and CT 202 had the highest number of smutted kernels. All other varieties had similar levels, with the short grains trending lower than the medium grains.

OBJECTIVE 2) Investigate the relationship between disease ratings at drain time and ratings before heading for stem rot and aggregate sheath spot.

Methods

Five locations were sampled at late boot and at drain, when approximately 50% of grains in the panicles had turn yellow (table 6). At the Biggs and Maxwell fields, 32, 10x20 ft plots were arranged in a 8x4 grid. Four treatments were applied approximately 35 days after seeding on equal number of plots: topdress with 20 lbs N/a as ammonium sulfate, Quadris at 8 oz/a, Quadris at 15 oz/a, or no treatment. These treatments were applied so a range of disese levels were found in the plots area. In the Willows fields, eight 10x20 ft plots were established in four rows 20 to 60 ft apart into the field.

Tiller samples consisted of tillers cut below the water level randomly from the front, middle, and back of each plot. A subset of 30 tillers per sample were used to rate stem rot or aggregate sheath spot incidence and severity using the scale presented in table 3. To calculate disease incidence and severity, the following formulas were used:

- % disease incidence = (number of tillers in categories 1-4) / total tillers*100
- Disease severity = [∑(number of tillers per category*category)] / total tillers

Linear regression of incidence or severity at the first sampling time versus severity at the second sampling time were used to explore the data and determine if disease levels before heading could predict disease levels near maturity.

Results

The main tiller disease observed in all locations was stem rot. Aggregate sheath spot was present and evaluated at Biggs, Willows T, and Willows S; however, severity was low, ranging from 0.03 to 0.10 at late boot and 0.5 to 0.57 at drain time. Analysis of these data are not shown.

Average stem rot levels are presented in figure 4. Except for the Maxwell location, stem rot severity more than doubled at drain time with respect to levels at late boot. The variety grown in Maxwell was M-209; this variety tends to develop less stem rot than shorter season varieties. The varieties used in other locations, M-206 or M-210, are very similar in growth and yield, with the only difference being that M-210 is resistant to blast.

The treatments applied at Biggs and Maxwell had little effect on the level of the disease. However, a good range of stem rot severity was found when data from all trials were pooled (fig. 5). Because of the difference on how stem rot progressed in M-209, the Maxwell location was removed from the analysis.

There was a significant relationship between stem rot incidence or severity at late boot and stem rot severity at drain time (P<0.001 for both, fig. 5). The data indicate that stem rot incidence around 20% or severity about 0.2 would develop into a severity level of 1 at drain time.

OBJECTIVE 3) Test biological fungicides and plant health stimulants for control of stem rot and AGSS.

The main fungicide used in rice in California is azoxystrobin, which has been in use since the early 2000s. Currently, there are no conventional fungicides in development for the California rice market. However, there are some products that claim to increase plant health that are or may become available in the future. Additionally, there is a push from regulatory agencies to adopt these types of products and rely less on synthetic pesticides.

One type of products that have shown efficacy in other crops are inducers of plant resistance to pathogens. Application of these products stimulate plants to produce their own defenses and become less susceptible to diseases. Rather than replacing synthetic fungicides, these products could be used in combination with fungicides to reduce the likelihood of resistance evolution or reduce fungicide rates without losing efficacy. For this objective, products that promote induced resistance were tested in combination with a reduced rate of azoxystrobin.

Methods

Two trials were conducted, one in a basing with a history of stem rot at the RES in Biggs and another one at a commercial field in Maxwell, CA. Important dates and information for the trials are presented in table 7. High N rates were used to promote disease development. In Biggs, 180 lbs N/a was applied pre-plant as aqua ammonia. In Maxwell, 130 lbs of N/a were provided pre-plant as aqua ammonia and 40 lbs/a were provided as ammonium sulfate at panicle initiation (45 days after seeding). Management followed typical practices for rice in California. Treatments were applied to 10x20 ft plots using a CO_2-powered sprayer**.** Products tested are presented in table 8. The standard treatment (Quadris) was applied at the early heading stage. Treatments that included LifeGard, Vacciplant, Timorex, Romeo and Regalia consisted of one or two applications. For a single application, the product was mixed with a reduced rate of Quadris and applied at early heading. When two applications were made, the product was applied alone at the mid tillering stage followed by an application of a mix of the product with a reduced rate of Quadris at early heading. ReyZox, a premix of azoxystrobin and Regalia, was applied at the early heading stage. The surfactant Clarion (Biggs) or DynAmic (Maxwell) at 0.25% was used in all applications.

To assess disease incidence and severity, tiller samples were taken from each plot at drain time. Samples consisted of tillers cut below the water level randomly from the front, middle, and back of each plot. A subset of 30 tillers per sample were used to rate stem rot and AGSS incidence and severity as well as aggregate sheath spot incidence and severity using the scale presented in table 3. To calculate disease incidence and severity, the following formulas were used:

- % disease incidence = (number of tillers in categories 1-4) / total tillers*100
- Disease severity = [∑(number of tillers per category*category)] / total tillers

Percent reduction in disease severity was calculated by subtracting the treatment severity in a block from severity in the untreated plot in the same block, dividing by the treatment severity and multiplying by 100. If the reduction was negative, it was set to zero.

Plots were harvested using a small plot combine and yields converted to lbs/a at 14% moisture content (MC). A 1 lb sample of rough rice was obtained from each plot and air dried to 14% MC. A sub-sample of 200 g was hulled with a McGill sheller and milled with a Yamamoto Ricepal 32. Next, whole kernels were separated using a Satake drum whole kernel separator. Whole kernels are unbroken kernels of rice and broken kernels of rice which are at least three-fourths of an unbroken kernel. With this information, the following parameters were determined:

- Milled rice yield = (milled rice weight (whole + broken)/rough rice weight)*100%
- Head rice yield = (whole kernels weight/rough rice weight)*100%

The trial was conducted as randomized complete block with four replications. Analysis of variance was used to detect differences among treatment means for parameters evaluated. When significant differences were detected, Tukey’s HSD test was used to compare treatment means. The level of α used was 0.05.

Results

At the Biggs trial, stem rot incidence and severity were moderate, ranging 43 to 100% and 0.77 to 2.16, respectively, in untreated plots. Aggregate sheath spot incidence and severity were low, ranging from 3.33 to 63% and 0.03 to 0.8, respectively in untreated plots.

Treatments significantly affected stem rot incidence and severity (P<0.001 for both) but did not significantly affect AGSS. The effect on stem rot incidence and severity was similar, therefore the discussion of results will focus on severity (table 9). The application of Quadris at either rate significantly reduced stem rot severity. One or two applications of Vacciplant, Romeo, Regalia or RayZox, or two applications of Timorex significantly reduced severity. However, severity in these treatments was not significantly different from either of the Quadris treatments.

On average, all treatments reduced stem rot severity by 58%. Statistically, there were no differences in the percentage of severity reduction among the products. However, there were some interesting trends. Over 60% reduction was obtained with Quadris at 12.5 oz/a, Vacciplant or Regalia applied at tillering followed by an application at heading, and ReyZox. While none of these products produced significantly better results than the application of the low rate of Quadris, they produced more consistent results, as shown by the smaller variability around the mean (fig. 6A).

Although the treatments did not significantly reduce the levels of AGSS, treated plots had lower incidence and severity than untreated plots (table 9). On average, treatments reduced AGSS severity by 72%. The lack of significance of these results may be due to the high levels of variability in the data (fig. 6B).

Yield, grain moisture content, milling yield or head rice yield were not significantly affected by the treatments (table 10). However, there was a trend (P=0.080) for plots with higher stem rot severity to have lower yields (fig. 7A). Similarly, there was a significant (P=0.046) relationship between stem rot severity reduction and head rice yield (fig. 7B). This indicates the potential benefits of reducing stem rot disease levels.

At the Maxwell location, disease levels were lower than at Biggs. Stem rot incidence and severity in untreated plots ranged from 43 to 58% and from 0.53 to 0.71, respectively. Aggregate sheath spot incidence and severity in untreated plots ranged from 13 to 60% and from 0.13 and 0.67, respectively.

Treatments did not significantly affect any of the parameters measured (tables 11 and 12). However, there was a trend to lower stem rot levels after application of the treatments. On average, stem rot severity was reduced by 60%. The levels of AGSS were too low to draw any meaningful conclusions.

OBJECTIVE 4) Investigate the effect of azoxystrobin on disease control and yield in different growing regions of California.

Methods

Six of the UCCE statewide variety trial locations were selected for the trials. Important dates are presented in table 13. Except for the San Joaquin location, all locations were water seeded. At these locations, 10, 10x20 ft plots were seeded with variety M-206 at a rate of 180 lbs/a. At San Joaquin, 10, 5.5x28 ft plots were drill seeded at a rate of 150 lbs/a. Trials were managed following typical recommended practices for rice in California. At the late boot to early heading stage, azoxystrobin was applied as Quadris or Tetraban at 12.5 or 15.5 oz/a. Three plots were randomly assigned to each of the treatments, and four plots remained untreated. The surfactant Clarion at 0.25% was included in all applications. Treatments were applied using a CO_2-powered sprayer**.**

To assess stem rot and AGSS incidence and severity, tiller samples were taken from each plot at drain time. Samples consisted of tillers cut below the water level randomly from the front, middle, and back of each plot. A subset of 30 tillers per sample were used to rate stem rot and aggregate sheath spot incidence and severity using the scale presented in table 3. To calculate disease incidence and severity, the following formulas were used:

- % disease incidence = (number of tillers in categories 1-4) / total tillers*100
- Disease severity = [∑(number of tillers per category*category)] / total tillers

Plots were harvested using a small plot combine except at the San Joaquin location, where a 3x5 ft section per plot was harvested by hand. Yields were converted to lbs/a at 14% moisture content (MC). A 1 lb sample of rough rice was obtained from each plot and air dried to 14% MC. A sub-sample of 200 g was hulled with a McGill sheller and milled with a Yamamoto Ricepal 32. Next, whole kernels were separated using a Satake drum whole kernel separator. Whole kernels are unbroken kernels of rice and broken kernels of rice which are at least three-fourths of an unbroken kernel. With this information, the following parameters were determined:

- Milled rice yield = (milled rice weight (whole + broken)/rough rice weight)*100%
- Head rice yield = (whole kernels weight/rough rice weight)*100%

The trials were conducted as completely randomized designs. Analysis of variance with fixed factor treatment and random factor location was used to detect differences among treatment means for parameters evaluated. When significant differences were detected, the Least Significant Difference test was used to compare treatment means. The level of α used was 0.05.

Results

Severity of stem rot and AGSS differed significantly (P<0.001 for both) across locations (fig. 8). Stem rot levels were very low at North Yolo and Sutter, moderate at Glenn and San Joaquin, and high at Yuba and South Yolo. Aggregate sheath spot level was moderate to high at San Joaquin.

The response to the disease differed across locations, as indicated by the significant treatment by location interaction (P=0.043 for stem rot and P=0.026 for AGSS). Treatments resulted in significant differences in stem rot severity in Glenn (P=0.002) and South Yolo (P=0.020). In Glenn, both rates of the fungicide reduced stem rot severity on average 61%. Similarly, in South Yolo, both rates of the fungicide reduced stem rot severity on average 45%. For AGSS, only in San Joaquin the fungicide produced a significant reduction in severity (P<0.001). There, the average reduction in AGSS severity was 42%.

Yields were significantly different among locations (P<0.001) but treatments did not have a significant effect in any of the locations. However, yields from treated plots tended to be higher in Glenn (P=0.130) and South Yolo (P=0.066) (fig. 9). Head rice yield was significantly different across locations (P<0.001) and the effect of treatment was different across locations (P=0.022 for the treatment by location interaction). Only in San Joaquin the application of azoxystrobin resulted in a significant increase in milling yield (P<0.001) (fig. 9).

Considering these results, the locations can be classified as locations where the fungicide reduced disease severity significantly: Glenn, San Joaquin, and South Yolo. In these locations, disease levels were moderate to high and application of azoxystrobin resulted in a trend to improved yields or quality. In locations where disease levels low (North Yolo and Sutter), azoxystrobin had no effect on yield or quality. In Yuba, where disease levels were moderate to high, the fungicide did not produce a positive effect on yield or quality.

OBJECTIVE 5) Monitor blast in recently released varieties and document occurrence of emerging diseases.

Blast is a disease that can cause significant damage in some years. Recently, during 2019 and 2020, blast reached high levels in the northwestern part of the Valley, resulting in yield losses. M-210 is a medium grain variety resistant to blast released in 2018. After its release, there were some reports that blast affected M-210. In 2021 and 2022 blast was present in the Valley at very low levels. During 2023, blast was again a significant issue in several areas. Blast was observed in M-105, M-206, and M-211. Blast was not observed or reported in M-210. This confirms the expectation that M-210 is resistant to the race of blast present in California.

Currently, azoxystrobin is the only registered fungicide in California that can effectively reduce the severity of blast. Azoxystrobin has been in use since the early 2000s and is used against blast, stem rot, and AGSS. This fungicide belongs to the QoI (Quinone outside Inhibitors) group of fungicides, which are considered high risk for resistance development in pathogens. Due to the repeated use of azoxystrobin in rice in California, there is a concern that resistance may develop in the target pathogens.

During 2023, blast was observed in one of the azoxystrobin trials in Glenn County (objective 4). Quadris applied at 12.5 or 15.5 oz/a was effective in reducing blast infections (fig. 10). While we cannot generalize about the status of the blast pathogen resistance to azoxystrobin across the California rice growing area, this result indicates that, at this location, Quadris still provides protection. The grower in this location typically uses Quadris to manage blast and other diseases.

In previous years we have reported on identification of pathogens causing uncommon symptoms (table 14). In general, these samples have come from fields with low incidence of these symptoms. In 2023, *Nigrospora oryzae* was identified in samples from three fields. Symptoms in one of these fields, leaf sheath discoloration (fig. 11A), can be commonly found and are sometimes confused with aggregate sheath spot symptoms. Although common, these symptoms do not seem to have a negative effects on yield. Symptoms in the other sample identified as *Nigrospora oryzae* consisted of a panicle rot (fig. 11B) that was starkly different from panicle blanking caused by blast in that there was no neck lesion and the panicle was discolored. These are two more symptoms of several that have been found in the past few years that are associated with this pathogen.

The Compendium of Rice Diseases and Pests (2018, APS Press) indicates that *Nigrospora* species are common and occur in senescing plant tissue, and may cause lesions in plants weakened by diseases, insects, or poor nutrition. Addtionally, *Nigrospora oryzae* has recently been identified as the causal agent of panicle branch rot disease in China (Liu et al., 2021, Plant

Disease 105 (9): 2724), with reported yield and quality losses. Given the information in the literature, at this point the identification of *Nigrospora oryzae* from California rice samples warrants vigilance from the industry.

Another pathogen that was found in one of the samples submitted in 2023 was *Gaeumannomyces graminis*. The Compendium of Rice Diseases and Pests reports this pathogen as causing crown sheath rot. Crown sheath rot symptoms are similar to symptoms of stem rot, causing dark lesions on lower leaf sheaths that can infect the crown and culm. This disease is considered a minor disease that may occasionally cause serious damage. It is reported to be enhanced by excess nitrogen.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS

OBJECIVE 1) Determine the susceptibility of California varieties to stem rot, aggregate sheath spot, and kernel smut and explore their effect on yield and quality.

Three years of variety trials indicate that varieties with longer periods of development such as M-209 and M-211, tend to develop less severe stem rot than varieties with shorts periods of development, such as CM-101 or M-105. With respect to AGSS, the study showed that all varieties tested had similar susceptibility to AGSS, with a tendency of the long grains A-202 and L-208 to have lower AGSS severity.

All varieties tested responded similarly to the fungicide azoxystrobin. Over the three years of the study, stem rot was reduced 11 to 32%, which resulted in a yield increase of 4% in 2021 and a 3% head rice yield increase in 2022. Similarly, treatment with azoxystrobin resulted in an average AGSS severity reduction of 65%, which produced a 3 and 4% yield increase in 2022 and 2023, respectively, and a 5% head rice yield increase in 2022.

OBJECTIVE 2) Investigate the relationship between disease ratings at drain time and ratings before heading for stem rot and aggregate sheath spot.

For varieties M-206 or M-210, stem rot incidence or severity at late boot was found to be linearly related to stem rot severity at drain time. For example, a 20% stem rot incidence at late boot predicts a stem rot severity of 1 at drain time; a 70% incidence at late boot predicts a severity of 2 a drain time. Data on aggregate sheath spot was collected but because disease levels were low no conclusions could be drawn.

OBJECTIVE 3) Test biological fungicides and plant health stimulants for control of stem rot and aggregate sheath spot.

One or two applications of several induced resistance products were tested in combination with azoxystrobin for management of tiller diseases. Use of the products in combination with Quadris did not significantly reduce severity of stem rot or AGSS when compared to the application of Quadris at 6 or 12.5 oz. Use of Vacciplant and Regalia produced the least variable results.

OBJECTIVE 4) Investigate the effect of azoxystrobin on disease control and yield in different growing regions of California.

Trials with azoxystrobin at six locations with varied disease reduced stem rot severity 45 to 61% and AGSS severity 42%. When disease levels were reduced, yields or head rice yield tended to be higher. When disease levels were very low, yield or quality was not affected by application of the fungicide.

OBJECTIVE 5) Monitor blast in recently released varieties and document occurrence of emerging diseases.

The 2023 season saw high levels of blast in several regions. Blast affected varieties M-105, M-206, and M-211. Blast was not observed or reported in variety M-210, a recently released blast-resistant variety.

Three samples of unidentified symptoms were sent for identification to the UC Davis plant pathology lab. *Nigrospora oryzae* was identified causing leaf sheath discoloration and panicle branch rot.

PUBLICATIONS OR REPORTS

1. **Espino, L. 2022.** 2022 pest review. Rice Leaf Newsletter. November.
2. **Espino, L. 2022.** Disease management in California. Rice Farming 56 (6): 17.
3. **Espino, L., and A. W. Brim-DeForest. 2022.** Response of California rice varieties to stem rot and aggregate sheath spot, two common tiller diseases. CAPCA Adviser 25 (4): 52-54.
4. **Espino, L. 2022.** Pest management update, Rice Field Day Booklet, Rice Experiment Station, Biggs, CA.
5. **Espino, L., and A. W. Brim-DeForest. 2022.** Response of California rice varieties to stem rot and aggregate sheath spot, Rice Field Day Booklet, Rice Experiment Station, Biggs, CA.
6. **Espino, L., and A. W. Brim-DeForest. 2022.** Response of California rice varieties to stem rot and aggregate sheath spot (Abstract). Phytopathology 112: S3.36.
7. **Espino, L., and M. Leinfelder-Miles. 2023.** 2022 Disease observations. Rice Leaf Newsletter. January.
8. **Espino, L. 2023.** Stem rot management update. Rice Leaf Newsletter. April.
9. **Espino, L. 2023.** California disease update. Rice Farming 57 (6): 21.
10. **Espino, L. 2023.** Guidelines for Bakanae seed treatment, Rice Field Day Booklet, Rice Experiment Station, Biggs, CA.
11. **Espino, L., and A. W. Brim-DeForest. 2023.** Management of rice stem rot, Rice Field Day Booklet, Rice Experiment Station, Biggs, CA.
12. **Espino, L. 2023.** Rice disease and arthropod update, Rice Field Day Booklet, Rice Experiment Station, Biggs, CA.

Table 1. Location and important dates for stem rot and aggregate sheath spot (AGSS) variety trials, 2023.

Location	Target	Seeding date	Quadris application date	Tiller samples	Harvest date
Biggs, Butte County (RES)	Stem rot	5/27	8/9* and 8/15**	9/25* and 10/2**	11/2
Richvale, Butte County	AGSS	5/11	7/22* and 7/25**	9/8* and 9/15**	10/17

* S-102, CM-101, M-105, L-208
** M-206, M-209, M-211, A-202
RES – Rice Experiment Station

Table 2. Varieties used in stem rot and aggregate sheath spot variety trials, 2022. Days to 50% heading is the average from trials conducted at the Rice Experiment Station during 2018-2023.

Variety	Grain type	Maturity	Days to 50% heading at RES
CM-101	Specialty (Glutinous)	Very early	75
S-102	Short	Very early	74
M-105	Medium	Very early	78
M-206	Medium	Early	79
M-209	Medium	Early	84
M-211	Medium	Early	84
L-208	Long	Early	79
A-202	Long	Early	82

Table 3. Stem rot and aggregate sheath spot disease severity scale.

Category	Stem rot	Aggregate sheath spot
0	No disease	No disease
1	Disease lesions on outer leaf sheath	Disease affecting second leaf below flag leaf or lower
2	Disease lesions have penetrated into inner leaf sheaths	Disease affecting leaf below flag leaf
3	Disease lesions on culm	Disease affecting flag leaf
4	Culm is rotted though	Disease affecting panicle

Table 4. Average incidence, severity, yield and milling quality parameters for stem rot variety trial, Biggs, Butte County, 2023.

Variety	Incidence (%)	Severity	Yield (lbs/a)	MY (%)	HRY (%)
M-105	78.84 bcd	1.59 bcde	7,273 c	72.09 bc	59.49 de
M-206	88.14 d	1.89 e	7,392 cd	72.35 c	61.83 e
M-209	77.23 abcd	1.41 abcd	7,928 de	72.16 bc	61.54 de
M-211	63.07 a	1.14 a	8,228 e	71.47 b	58.38 d
CM-101	89.13 d	1.79 de	6,273 b	71.74 bc	49.05 c
S-102	70.48 abc	1.31 ab	5,518 a	67.72 a	38.07 a
L-208	83.23 cd	1.61 cde	9,145 f	73.70 d	49.60 c
A-202	64.46 ab	1.34 abc	7,993 e	71.57 b	42.80 b

MY= milling yield

HRY= head rice yield

Means within a column followed by different letters are statistically different (LSD, $P<0.05$).

Table 5. Incidence, severity, yield and milling quality parameters for aggregate sheath spot variety trial, Richvale, Butte County, 2023.

Variety	Incidence (%)	Severity	Yield (lbs/a)	MY (%)	HRY (%)
M-105	41.38	0.69	8,802 c	71.27 e	61.18 f
M-206	45.85	0.68	8,270 b	70.40 de	59.66 ef
M-209	55.78	0.91	9,118 c	70.42 dc	58.03 e
M-211	42.50	0.68	8,911 c	69.15 c	55.58 d
CM-101	40.99	0.70	6,916 a	66.35 b	41.02 b
S-102	36.58	0.73	6,563 a	64.48 a	35.51 a
L-208	38.41	0.76	9,666 d	73.40 f	48.39 c
A-202	48.46	0.63	8,000 b	70.30 d	42.02 b

MY= milling yield
HRY= head rice yield
Means within a column followed by different letters are statistically different (LSD, $P<0.05$).

Table 6. Trials sampled to collect data to relate disease ratings before heading to disease ratings at drain time, Biggs, Butte County, 2022.

Field	Variety	Sampling at late boot	Sampling at drain
Biggs	M-206	8/8	9/18
Maxwell	M-209	7/27	9/6
Willows T	M-210	8/1	9/13
Willows P	M-206	7/27	9/12
Willows S	M-210	8/1	9/12

Table 7. Trial locations, treatment, evaluation, and harvest dates for the 2023 fungicide trials.

Location	Target	Variety	Seeding date	Application dates (DAS*, stage)	Tiller samples	Harvest date
Biggs, Butte County (RES)	Stem rot/ AGSS	M-206	5/31	7/11 (42 DAS, mid tillering) 8/18 (80 DAS, 10% heading)	9/20	10/31
Maxwell, Colusa County	Stem rot/ AGSS	M-209	4/29	6/8 (41 DAS, mid tillering) 7/31 (94 DAS, 5-10% heading)	9/6	9/21

*=Days after seeding
RES=Rice Experiment Station
AGSS=Aggregate sheath spot

Table 8. Products used in 2023 fungicide trials and estimated cost per acre of treatments applied.

Product	**Rate/a**	**Inducer/Active ingredient**	**FRAC Code**
Quadris	6 or 12 oz	Azoxystrobin	11
LifeGard	1 oz	*Bacillus mycoides* isolate J	P 06
Vacciplant	14 oz	Laminarin	P 04
Timorex	20 oz	Extract from *Melaleuca alternifolia* (tee tree oil)	BM 01
Romeo	0.5 lb	Cell walls of *Saccharomyces cerevisiae* strain LAS117	P 06
Regalia	16 oz	Extract from *Reynoutria sachalinensis* (giant knotweed)	P 05
ReyZox	11 or 14.7 oz	Azoxystrobin + extract from *Reynoutria sachalinensis*	11 + P 05

Treatment	**Rate/a**	**Estimated cost ($/a)**
Quadris	12.5 oz	25
Quadris	6 oz	12.5
LifeGard + Quadris	1 oz + 6 oz	22
LifeGard fb LifeGard + Quadris	1 oz fb 1oz + 6 oz	31
Vacciplant + Quadris	14 oz + 6 oz	31
Vacciplant fb Vacciplant + Quadris	14 oz fb 14 oz + 6 oz	49
Timorex + Quadris	20 oz + 6 oz	38
Timorex fb Timorex +Quadris	20 oz fb 20 oz + 6 oz	63
Romeo + Quadris	0.5 lb +6 oz	34
Romeo fb Romeo + Quadris	0.5 lb fb 0.5 lb + 6 oz	55
Regalia + Quadris	16 oz + 6 oz	22
Regalia fb Regalia + Quadris	16 oz fb 16 oz + 6 oz	31
ReyZox	11 oz	11
ReyZox	14.7 oz	15

Table 9. Disease incidence and severity for fungicide trial, Biggs, Butte County, 2023.

Treatment	**Timing**	**Rate/a**	**Stem Rot Incidence (%)**	**Stem Rot Severity**	**AGSS Incidence (%)**	**AGSS Severity**
Untreated	--	--	70.90 a	1.45 a	23.15	0.29
Quadris	Heading	12.5 oz	30.00 b	0.40 b	9.17	0.09
Quadris	Heading	6 oz	30.31 b	0.44 b	4.17	0.04
LifeGard + Quadris	Heading	1 oz + 6 oz	45.81 ab	0.76 ab	14.17	0.16
LifeGard fb LifeGard + Quadris	Tillering fb Heading	1 oz fb 1oz + 6 oz	50.00 ab	0.79 ab	6.67	0.08
Vacciplant + Quadris	Heading	14 oz + 6 oz	42.50 ab	0.61 b	8.33	0.10
Vacciplant fb Vacciplant + Quadris	Tillering fb Heading	14 oz fb 14 oz + 6 oz	25.83 b	0.37 b	9.17	0.09
Timorex + Quadris	Heading	20 oz + 6 oz	42.69 ab	0.75 ab	9.17	0.09
Timorex fb Timorex +Quadris	Tillering fb Heading	20 oz fb 20 oz + 6 oz	42.74 ab	0.66 b	5.0	0.05
Romeo + Quadris	Heading	0.5 lb +6 oz	45.05 ab	0.65 b	5.83	0.06
Romeo fb Romeo + Quadris	Tillering fb Heading	0.5 lb fb 0.5 lb + 6 oz	38.74 ab	0.71 b	1.67	0.02
Regalia + Quadris	Heading	16 oz + 6 oz	40.00 ab	0.62 b	7.50	0.09
Regalia fb Regalia + Quadris	Tillering fb Heading	16 oz fb 16 oz + 6 oz	27.23 b	0.47 b	1.67	0.02
ReyZox	Heading	11 oz	25.00 b	0.36 b	20.83	0.21
ReyZox	Heading	14.7 oz	29.17 b	0.40 b	10.0	0.10

Table 10. Grain yield and quality for induced resistance products trial, Biggs, Butte County, 2023.

Treatment	Timing	Rate/a	MC (%)	Grain Yield (lbs/a)	MY (%)	HRY (%)
Untreated	--	--	13.90	9,001	72.57	61.95
Quadris	Heading	12.5 oz	15.03	9,239	71.35	60.89
Quadris	Heading	6 oz	14.88	9,320	72.61	62.81
LifeGard + Quadris	Heading	1 oz + 6 oz	15.45	8,987	70.66	60.17
LifeGard fb LifeGard + Quadris	Tillering fb Heading	1 oz fb 1oz + 6 oz	14.88	9,035	71.94	61.33
Vacciplant + Quadris	Heading	14 oz + 6 oz	14.55	9,252	71.84	61.73
Vacciplant fb Vacciplant + Quadris	Tillering fb Heading	14 oz fb 14 oz + 6 oz	14.98	9,060	72.45	62.41
Timorex + Quadris	Heading	20 oz + 6 oz	14.0	9,162	71.29	61.34
Timorex fb Timorex +Quadris	Tillering fb Heading	20 oz fb 20 oz + 6 oz	14.98	9,284	70.71	60.05
Romeo + Quadris	Heading	0.5 lb +6 oz	14.78	9,044	71.42	61.55
Romeo fb Romeo + Quadris	Tillering fb Heading	0.5 lb fb 0.5 lb + 6 oz	14.83	9,112	71.36	60.78
Regalia + Quadris	Heading	16 oz + 6 oz	14.68	8,996	72.16	61.96
Regalia fb Regalia + Quadris	Tillering fb Heading	16 oz fb 16 oz + 6 oz	14.95	9,166	72.70	63.01
ReyZox	Heading	11 oz	14.63	9,375	72.86	63.26
ReyZox	Heading	14.7 oz	14.28	9,431	72.26	61.81

Table 11. Disease incidence and severity for induced resistance products trial, Maxwell, Colusa County, 2023.

Treatment	**Timing**	**Rate/a**	**Stem Rot Incidence (%)**	**Stem Rot Severity**	**AGSS Incidence (%)**	**AGSS Severity**
Untreated	--	--	50.70	0.62	33.87	0.38
Quadris	Heading	12.5 oz	20.84	0.22	35.36	0.41
Quadris	Heading	6 oz	17.50	0.19	25.62	0.27
LifeGard + Quadris	Heading	1 oz + 6 oz	28.33	0.36	29.17	0.33
LifeGard fb LifeGard + Quadris	Tillering fb Heading	1 oz fb 1oz + 6 oz	18.34	0.22	26.37	0.26
Vacciplant + Quadris	Heading	14 oz + 6 oz	17.50	0.18	20.00	0.20
Vacciplant fb Vacciplant + Quadris	Tillering fb Heading	14 oz fb 14 oz + 6 oz	29.64	0.37	36.09	0.38
Timorex + Quadris	Heading	20 oz + 6 oz	17.15	0.22	27.50	0.28
Timorex fb Timorex +Quadris	Tillering fb Heading	20 oz fb 20 oz + 6 oz	14.69	0.16	23.33	0.23
Romeo + Quadris	Heading	0.5 lb +6 oz	24.17	0.32	29.17	0.35
Romeo fb Romeo + Quadris	Tillering fb Heading	0.5 lb fb 0.5 lb + 6 oz	30.00	0.36	31.43	0.32
Regalia + Quadris	Heading	16 oz + 6 oz	18.20	0.20	42.29	0.45
Regalia fb Regalia + Quadris	Tillering fb Heading	16 oz fb 16 oz + 6 oz	26.45	0.31	28.69	0.30
Reyzox	Heading	11 oz	26.67	0.30	22.76	0.23
Reyzox	Heading	14.7 oz	16.97	0.22	19.17	0.19

Table 12. Grain yield and quality for induced resistance products trial, Maxwell, Colusa County, 2023.

Treatment	Timing	Rate/a	MC (%)	Grain Yield (lbs/a)	MY (%)	HRY (%)
Untreated	--	--	20.33	9,094	71.84	63.15
Quadris	Heading	12.5 oz	20.03	9,325	70.54	61.60
Quadris	Heading	6 oz	20.53	8,704	69.60	58.27
LifeGard + Quadris	Heading	1 oz + 6 oz	19.95	9,412	70.88	61.42
LifeGard fb LifeGard + Quadris	Tillering fb Heading	1 oz fb 1oz + 6 oz	19.95	9,062	72.49	64.50
Vacciplant + Quadris	Heading	14 oz + 6 oz	20.38	9,512	71.63	63.12
Vacciplant fb Vacciplant + Quadris	Tillering fb Heading	14 oz fb 14 oz + 6 oz	19.98	8,733	71.51	62.78
Timorex + Quadris	Heading	20 oz + 6 oz	19.93	9,592	71.71	62.23
Timorex fb Timorex +Quadris	Tillering fb Heading	20 oz fb 20 oz + 6 oz	20.53	8,985	71.27	62.08
Romeo + Quadris	Heading	0.5 lb +6 oz	20.50	8,756	71.79	63.12
Romeo fb Romeo + Quadris	Tillering fb Heading	0.5 lb fb 0.5 lb + 6 oz	20.23	8,984	71.21	61.43
Regalia + Quadris	Heading	16 oz + 6 oz	20.15	9,261	68.28	55.25
Regalia fb Regalia + Quadris	Tillering fb Heading	16 oz fb 16 oz + 6 oz	20.50	8,981	71.64	62.76
Reyzox	Heading	11 oz	19.60	8,907	71.14	61.82
Reyzox	Heading	14.7 oz	20.68	8,806	70.48	59.92

Table 13. Important dates for azoxystrobin trials at several locations of the Sacramento and San Joaquin Valleys, 2023

Location	Seeding date	Treatment date	Tiller sampling date	Harvest
Glenn	5/18	8/4	9/14	10/21
Yuba	5/24	8/7	9/20	10/30
Sutter	5/25	8/10	9/20	10/28
North Yolo	5/18	8/7	9/19	10/19
South Yolo	6/2	8/25	10/6	11/3
San Joaquin	4/27	8/10	9/26	10/12

Table 14. Pathogens identified in samples with unusual symptoms observed in the field.

Year	County	Variety	Symptoms	Pathogen
2017	Colusa	M-206	Leaf sheath discoloration, panicles stuck on boot	*Nigrospora oryzae*
2021	Yolo	CM-203	Panicle discoloration	*Nigrospora oryzae*
2021	San Joaquin	M-206	Rotting of nodes, neck	*Nigrospora oryzae* *Pantoea ananati*
2022	San Joaquin	M-206	Node and neck blast	*Magnaporthe oryzae*
2022	Butte	M-211	Collar blight	*Nigrospora oryzae*
2023	Butte	M-206	Leaf sheath discoloration	*Nigrospora oryzae*
2023	Colusa	Remy	Leaf sheath discoloration	*Nigrospora oryzae* *Gaeumannomyces graminis*
2023	San Joaquin	M-206	Rotted panicle	*Nigrospora oryzae*

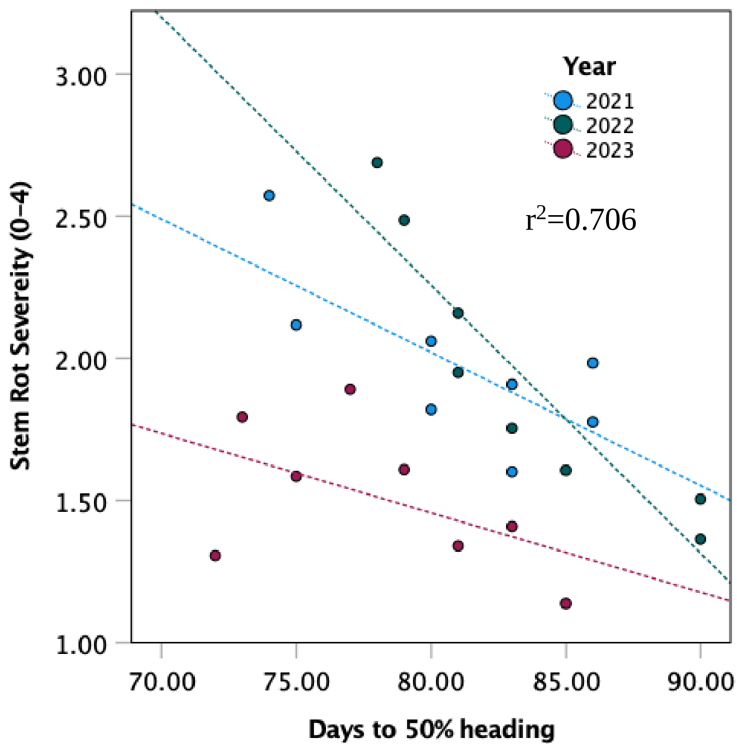


Figure 1. Average stem rot severity and days to 50% heading for varieties tested in stem rot variety trial, Biggs, Butte County, 2021-2023.

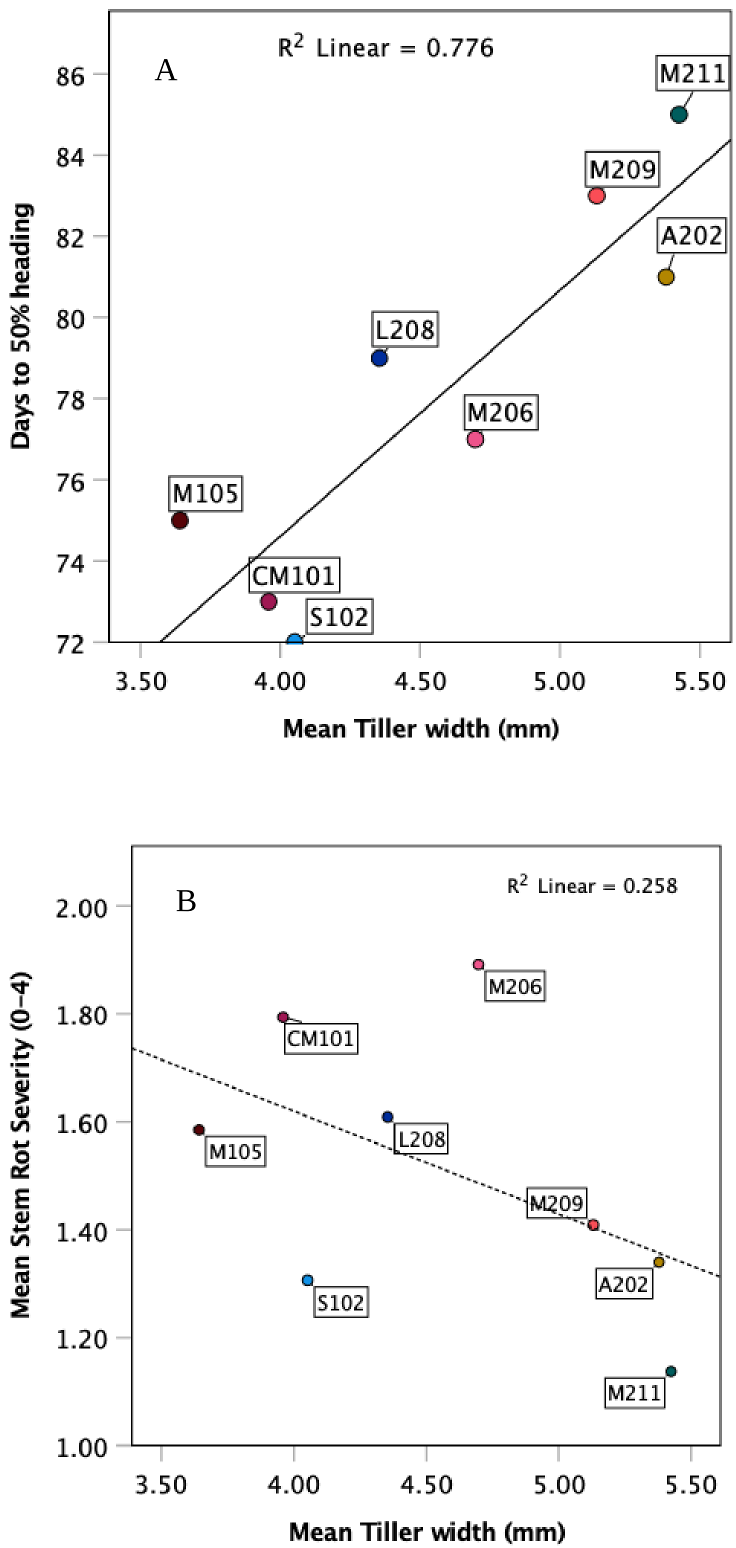


Fig. 2. A. Relationship between tiller width and days to 50% heading recorded at the RES, Biggs, Butte County, 2023. B. Relationship between tiller width and stem rot severity. Biggs, Butte County, 2023.

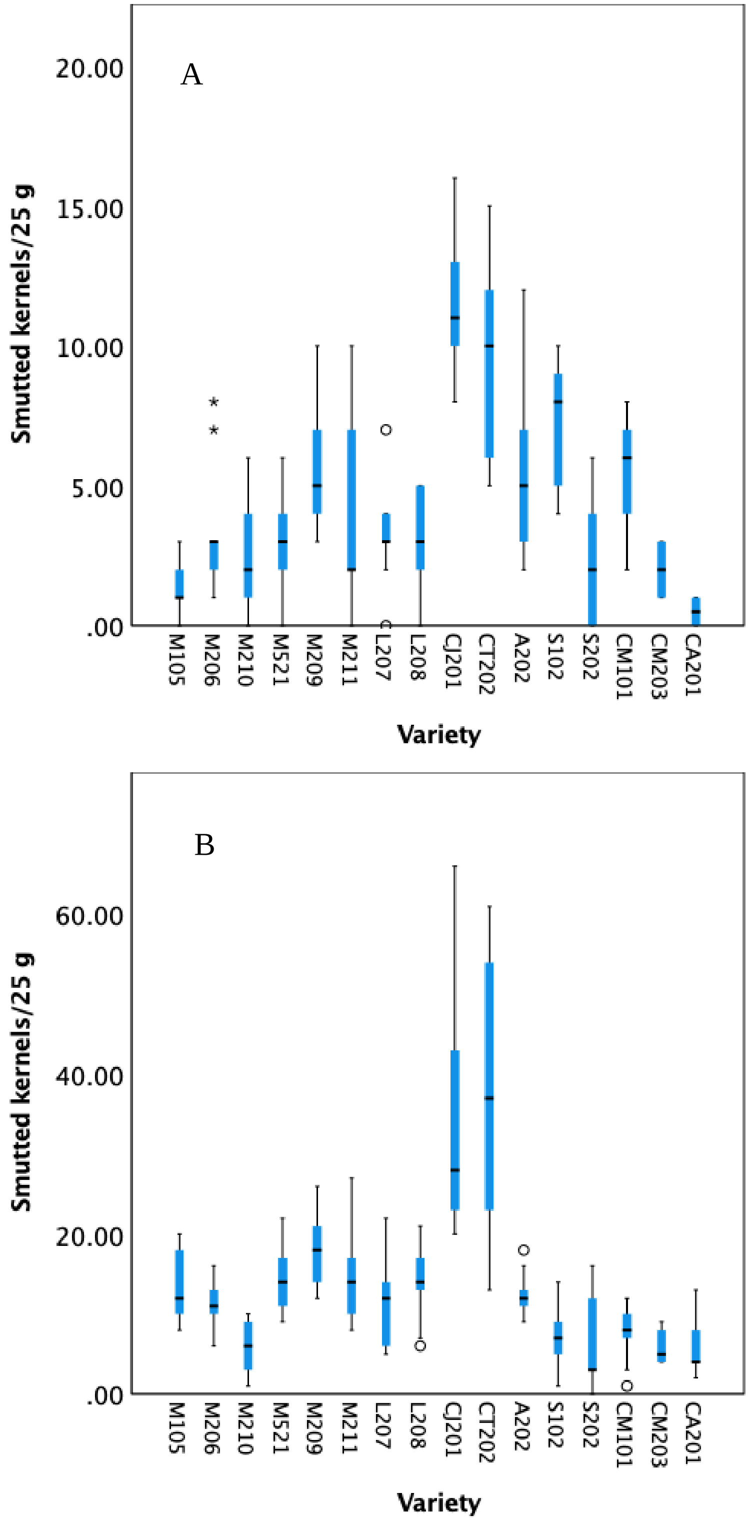


Fig. 3. Boxplot of number of smutted kernels per 25 g of grain. A. Butte County. B. Glenn County. 2023.

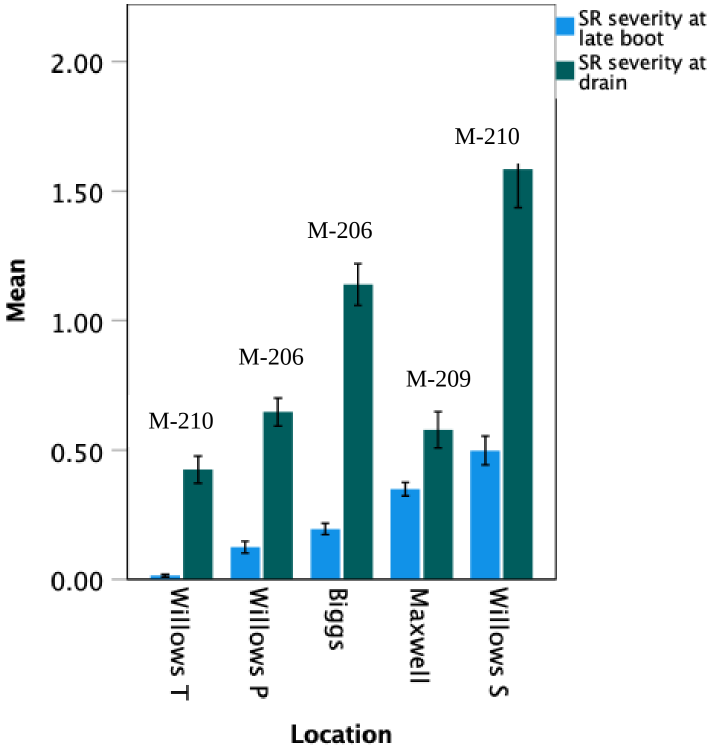


Figure 4. Average stem rot severity in five locations sampled at late boot and drain time.

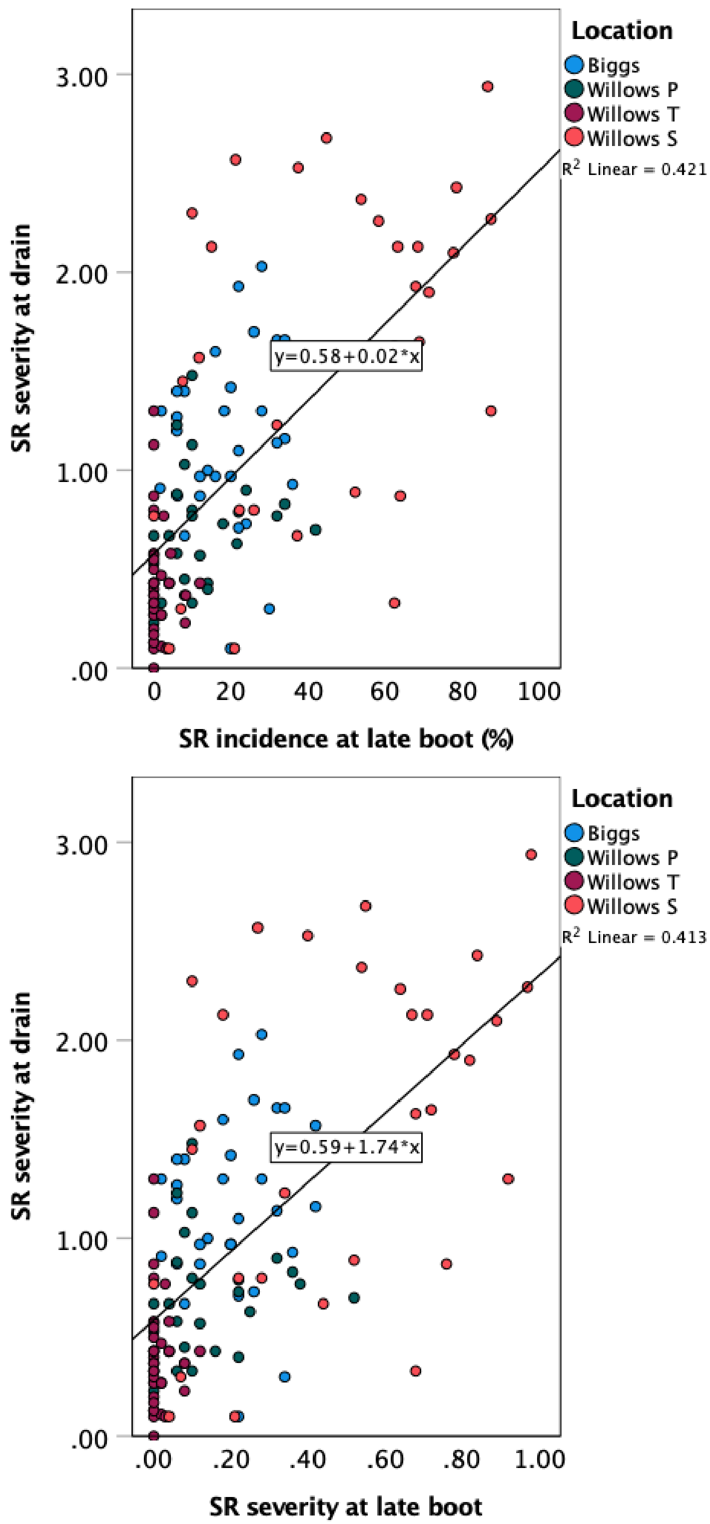


Figure 5. Relationship between stem rot incidence or severity at the late boot stage and severity at drain time, when up to 50% of kernels in panicles had turned yellow. Butte and Glenn Counties, 2023.

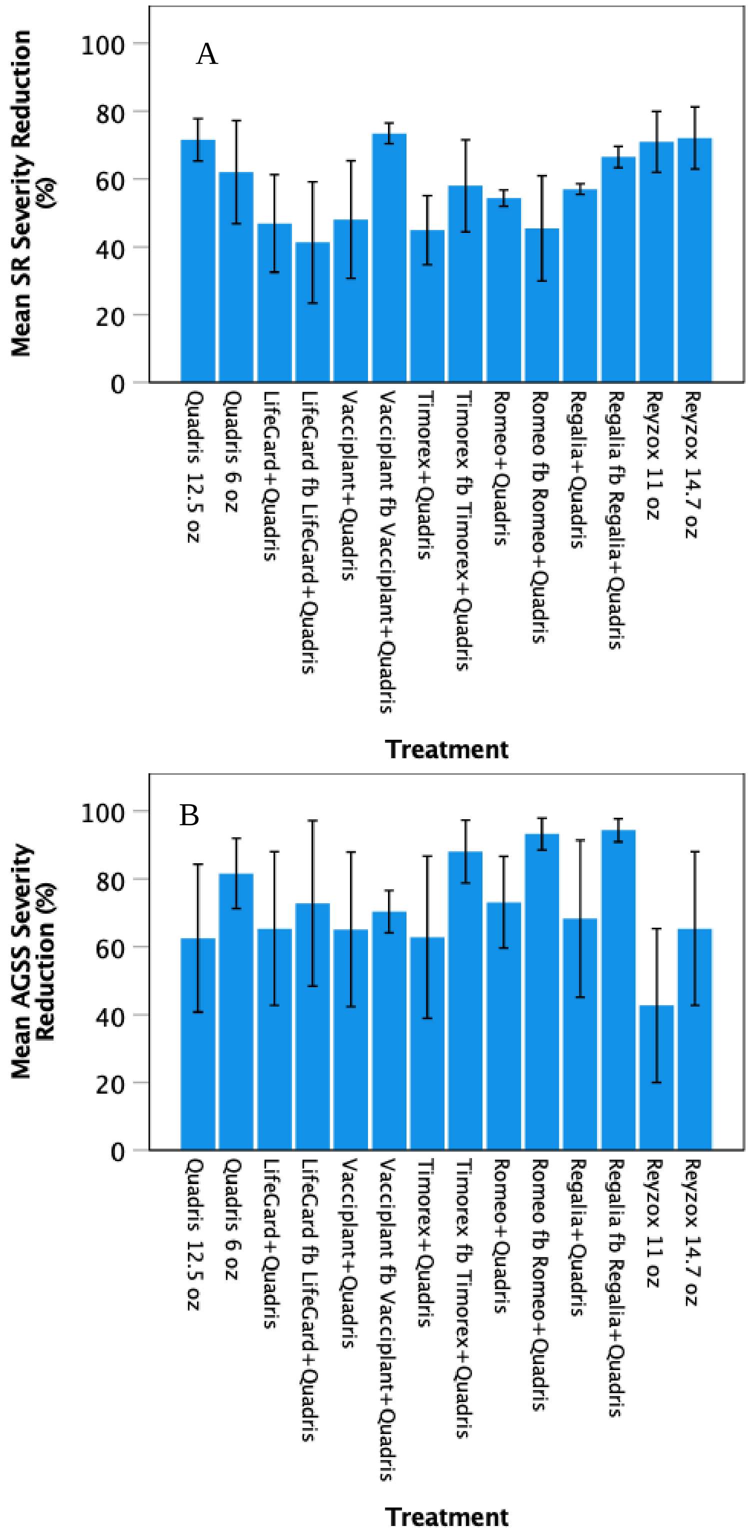


Figure 6. Average stem rot (A) and aggregate sheath spot (AGSS) (B) severity reduction with respect to untreated plots. Biggs, Butte County, 2023.

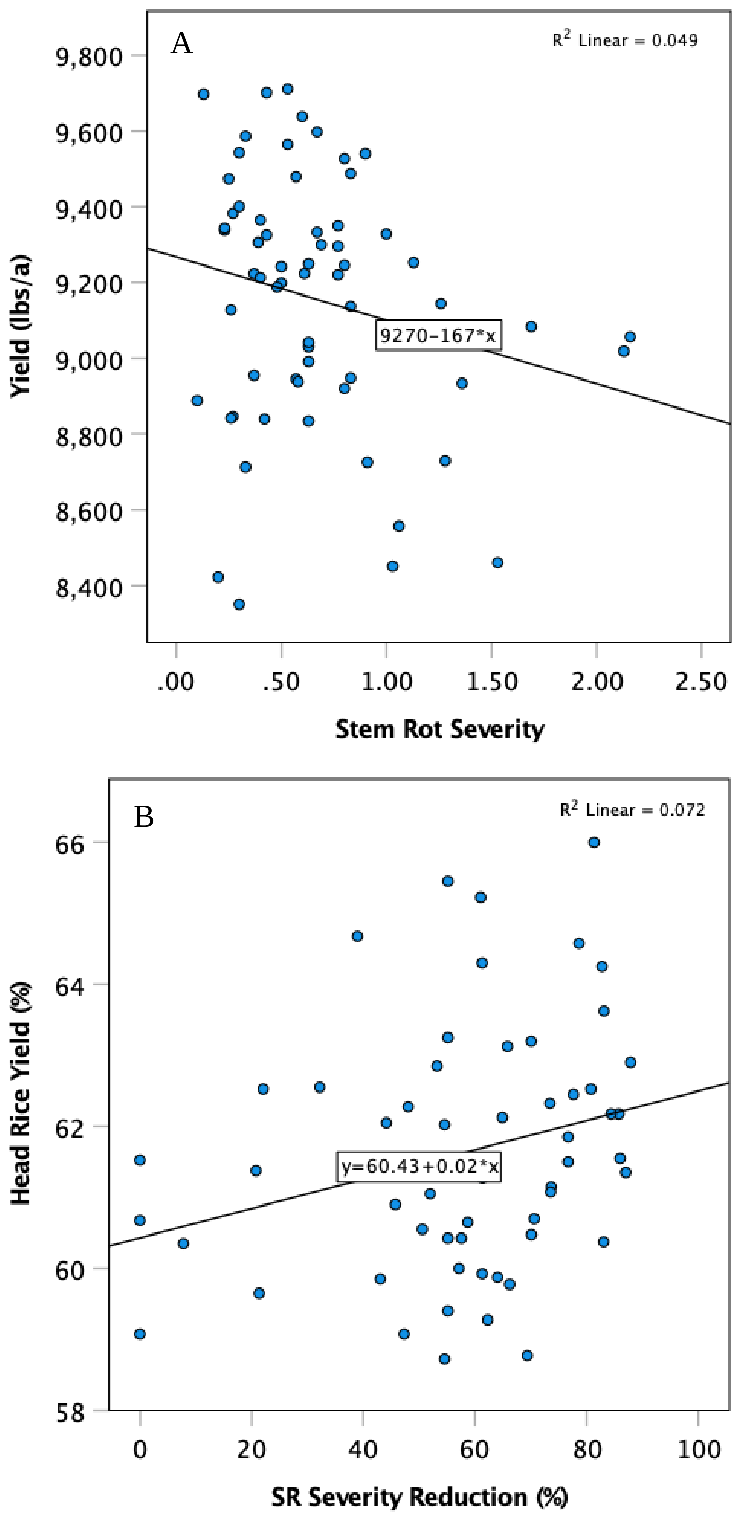


Fig. 7. Relationship between stem rot severity and yield (A) and stem rot severity reduction and head rice yield (B).

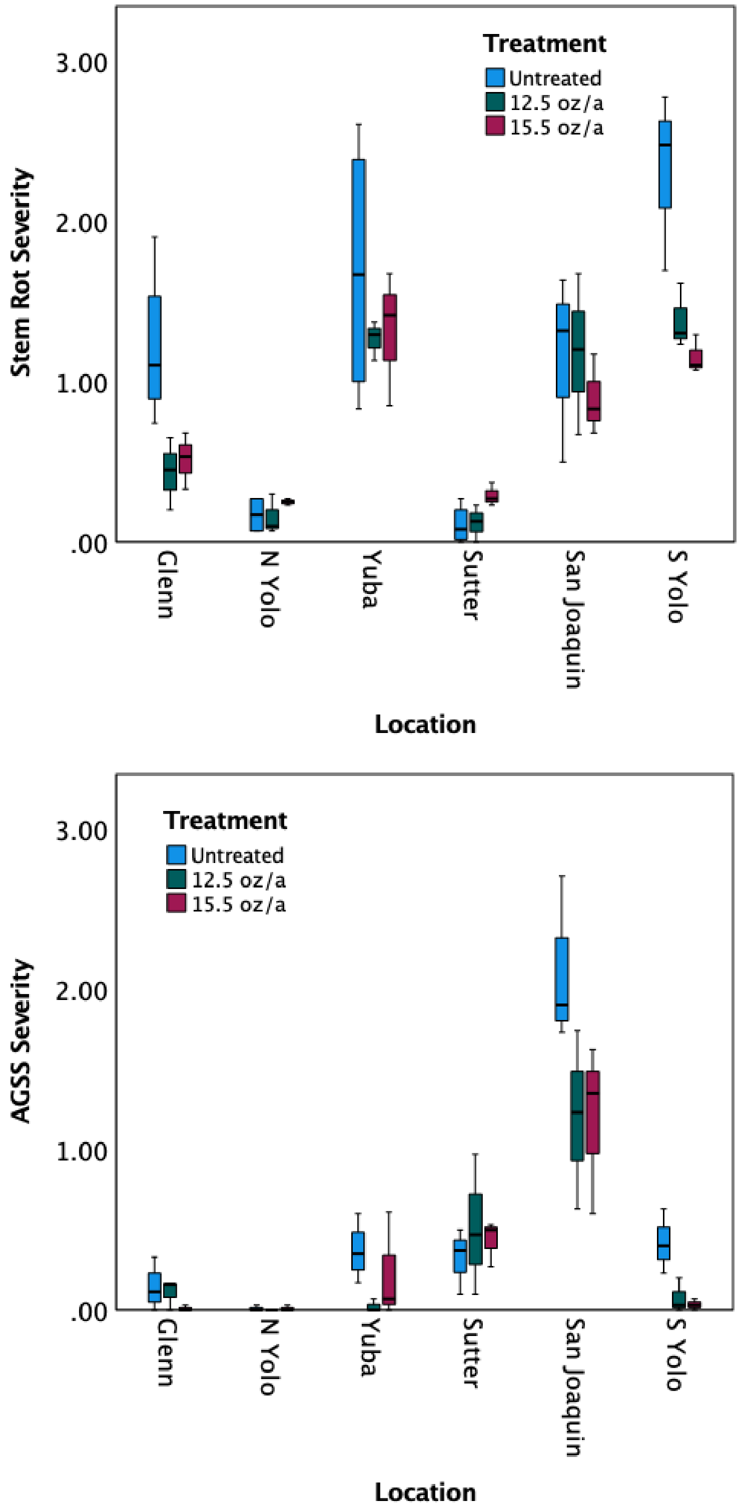
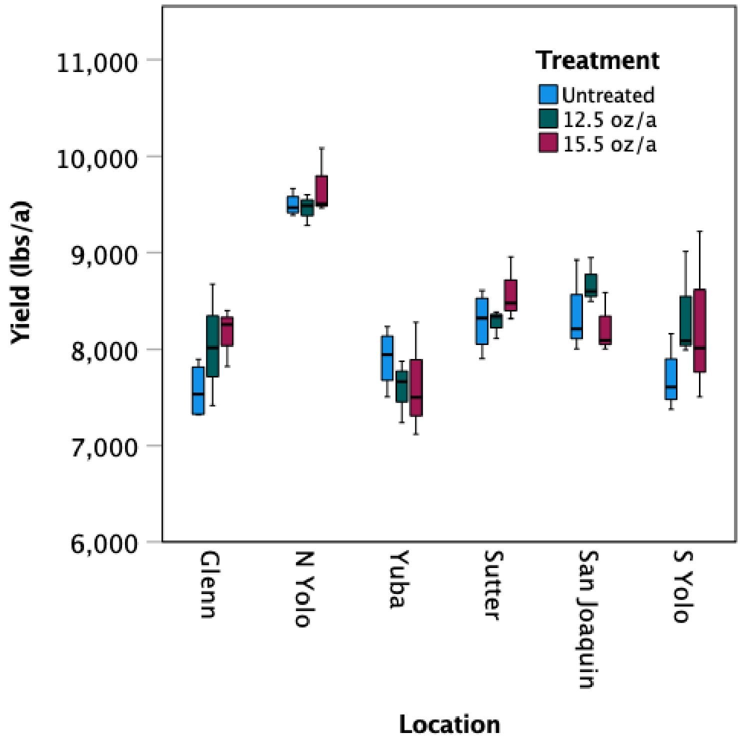


Fig. 8. Boxplot of stem rot and aggregate sheath spot (AGSS) severity from azoxystrobin trials conducted at six locations. 2023.



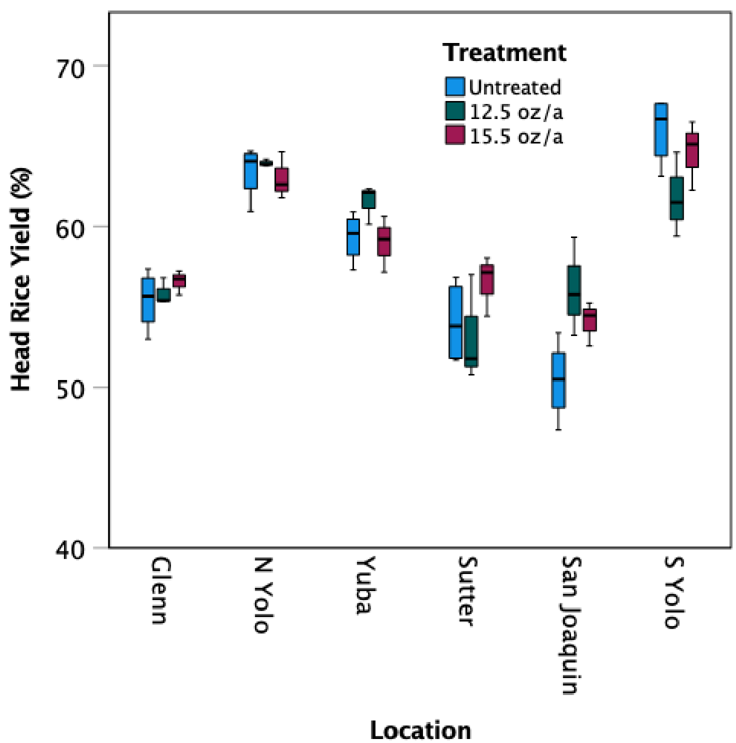


Fig. 9. Boxplot of yield and head rice yield from azoxystrobin trials conducted at six locations. 2023.

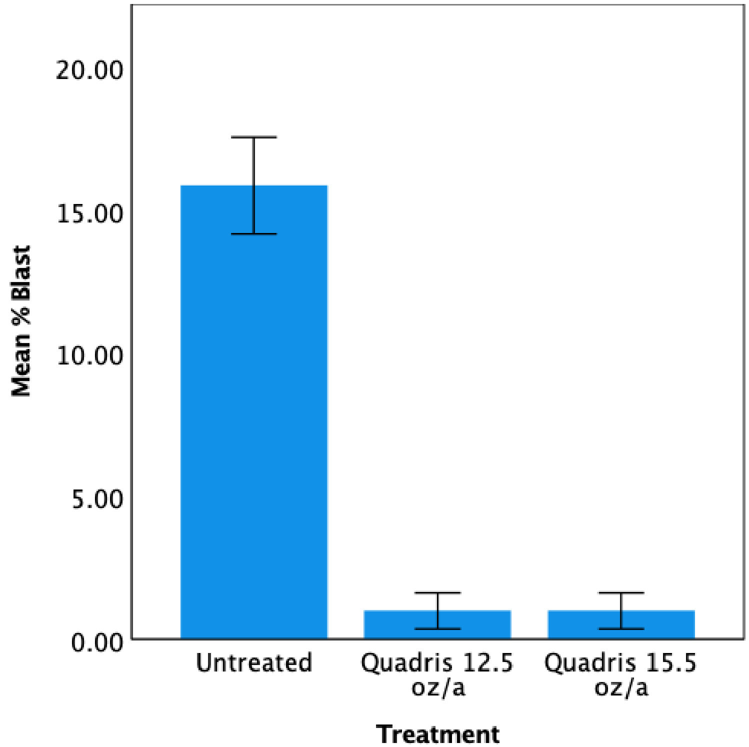


Fig. 10. Average percentage neck and node blast after treatment with Quadris at two rates, Glenn County, 2023.

Figure 11. Leaf sheath discoloration (A) and panicle rot (B) caused by *Nigrospora oryza*. 2023.