ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE: Rice Disease Research and Management

PROJECT LEADER: Luis Espino
Rice Farming Systems Advisor
Colusa, Glenn and Yolo Counties
UC Cooperative Extension
100 Sunrise Blvd, Suite E
Colusa, CA 95948
(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
Ryan Hall, Field Assistant, UCCE
Puja Upadhayay, Lab Assistant, UCCE
Sarah Marsh, Student Assistant, UCCE

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

OBJECTIVE 1) To evaluate current and new fungicides for management of aggregate sheath spot, stem rot, and kernel smut.

Methods

Five fungicide trials were conducted in 2018. Products used, their active ingredient and Fungicide Resistance Action Committee (FRAC) number are listed in table 1. Two trials targeted stem rot, one aggregate sheath spot, and two kernel smut. Locations, variety, and dates are presented in table 2. Treatments were applied to 10x20 ft plots using a CO_2-powered sprayer. All fungicide treatments included the surfactant Dyne-Amic at a rate of 5 pints/100 gal. On the stem rot and aggregate sheath spot trials, sprayes were applied at one of two timings, mid tillering or heading. The mid tillering application coincided with the application of propanil, therefore water was lowered when the applications were made. In the kernel smut trials, the applications were made at the late boot or very early heading stage.

Fields were managed using standard agronomic practices. In the trials targeting stem rot, an extra topdress application 20 lbs/a of N was done at PI in addition to the total N rate used by the grower.

Disease incidence and severity
Stem rot and aggregate sheath spot: To assess disease incidence and severity, tiller samples were taken from each plot right before or after the fields were drained for harvest. Samples consisted of tillers cut below the water level randomly from the front, middle, and back of each plot. A subset of 25 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 = [$\sum$(number of tillers per category*category)] / total tillers

Kernel smut: Six samples of 10 panicles each were examined and the number of smutted kernels per panicle recorded. Additionally, grain samples were taken during harvest and processed using KOH (see objective 2 for details) to determine the number of smutted kernels/25 g.

Grain yield and quality determination
Plots were harvested using a small plot combine. Grain samples from selected treatments were collected at harvest, air dried to 14% moisture content and then stored until milled. Milling was conducted at California Agri Inspections (stem rot and aggregate sheath spot trials) or at the Rice Experiment Station (RES) (kernel smut trials).

Analysis
The experiments were conducted as randomized complete blocks with 4 replications. Analysis of variance was used to detect differences among treatment means for parameters evaluated. Contrasts were used to compare parameter means from treated plots with untreated plots. The level of α used was 0.05.

Results and Discussion

Stem Rot

<u>7 Mile Road Trial</u>
This location has a history of severe stem rot problems. The soil is a heavy clay that remains wet for long in the spring, preventing early field work and delaying planting and harvest. The straw is usually incorporated and the field flooded for duck hunting.

Stem rot incidence was 100% for all treatments (table 4), meaning all tillers sampled had stem rot lesions in them. Average stem rot severity for the trial was 3.21, which is high. None of the treatments significantly reduced the severity of the disease when compared with the control.

Yields were significantly affected by treatments. The application of Quadris at mid tillering, and Sercadis at heading resulted in higher yields than the untreated. In these treatments, yields were 8 and 5% higher than in the untreated plots, respectively.

When regressing the stem rot severity in the plots with yield, a significant relationship was found (fig. 1). This relationship indicates that at the levels of disease severity found in the trial (2.8-3.9), yield reduction due to an increase in disease category is 540 lbs/a.

No significant effect of the treatments was found on milling or head rice yield. Milling yields were good; head rice yields were very poor, about 10 points of what would be considered a good.

Biggs Trial

Stem rot incidence and severity in this trial was moderate to high. Treatments that reduced the severity of stem rot were Quadris applied at heading (49% reduction), Cover XL (57%), Cover XL+ALB 3000 (43%), ALB 4003 (56%), and Sonata applied mid tillering and at heading (23%) (table 5). Grain moisture content, yield, and milling quality were not affected by any of the treatments. The relationship between stem rot severity and yield was not significant.

Aggregate Sheath Spot

Oswald Rd Trial

This field has a history of aggregate sheath spot. Strong symptoms were observed in parts of the field in 2017. The disease reached moderate levels in 2018. Several of the treatments significantly reduced the disease incidence and severity (table 6). Quadris applied at heading, Sercadis applied at heading, and S-2399 gave excellent control of the disease, with reductions in disease severity that ranged from 49 to 90%.

Although good disease control was achieved with some of the treatments, yield and milling quality were not significantly affected. Nevertheless, there was a significant relationship between disease severity and yield, with a yield reduction of 430 lbs/a for every increase in severity category (fig. 2).

Kernel Smut

Kernel smut continues to be an emerging problem. In 2017, several reports of affected fields were received, and one organic field was downgraded due to off-color kernels caused by kernel smut spores. In 2018, reports of affected fields came from several areas including Glenn, Colusa, and Butte counties.

Rd 57 Trial

This trial was set up in a field with a history of kernel smut. However, in 2018 smut was not a problem. The grower used QuiltXcel in the field but skipped the area of the trial.

All treatments were done at the late boot, very early heading stage. No significant effects were observed in any of the parameters measured (table 7). However, the Stratego treatment had the lowest proportion of infected panicles and number of smutted kernels per 25 g of grain sample.

Old Hwy 99 Trial

This field had had a severe kernel smut problem in 2017. However, in 2018, kernel smut levels were very low. This was an organic field, so all treatments made were organic. Treatments were made when rice was at the mid boot stage.

None of the treatments applied significantly reduced the proportion of infected panicles with respect to the untreated (table 8). However, some significant differences were observed among some of the treatments. The LSD test showed that Stargus and ThermX70 applied at 14.5 oz/a significantly reduced the proportion of panicles infected with kernel smut when compared to treatment with Regalia and ThermX70 at 7.2 oz/a. A similar result was observed when evaluating the number of smutted kernels per panicle. No significant differences among the treatments were found in the number of smutted kernels in a 25 g of grain; however, treatment with Stargus resulted in the lowest number. Grain moisture content at harvest, yield, and milling quality were not affected by any of the treatments.

For each of the kernel smut trials, no relationship was found between the field evaluation of kernel smut and the KOH method. Most likely, this is because kernel smut levels were very low in both trials.

OBJECIVE 2) Test methods to rate kernel smut and determine the effect of kernel smut on the yield and quality of rice.

Methods

Three fields affected with kernel smut were selected for sampling. Two fields were in Butte County (M105 and M209) and one in Colusa County (M206). In each field, thirty, 1-square yard quadrants were hand harvested between 9/25 and 10/18. After tillers were cut, three samples of ten tillers were randomly selected from each quadrant and inspected for kernel smut. The number of smutted kernels per panicle was recorded. Rice was threshed using a stationary thresher and grain moisture and weight determined. Kernel smut was also evaluated in the lab on grain samples 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 sample over a light.

From each grain sample, 200 g were used for milling. Milling was performed at the RES, using standard equipment and procedures used by the RES to evaluate milling quality. Milling and head rice yield were determined.

Results and Discussion

Levels of kernel smut varied among fields. The proportion of infected panicles was similar for the M105 and M209 fields, and much lower in the M206 field. A similar pattern was found for the average number of smutted kernels per panicle or 25 g of grain, with M209 having higher numbers (fig. 3).

The KOH method to quantify kernel smut has been used by researchers in Arkansas and Texas in the past. This method requires sampling fields or plots during harvest and then processing samples in the lab. A quantification method based on evaluations taken in the field before harvest may facilitate determining the level of smut in a field by growers, PCAs, and researchers.

Based on results from 2017, two measures of kernel smut were calculated from field evaluations. Incidence was determined as the proportion of panicles infected with kernel smut and severity was calculated as the average number of smutted kernels per panicle.

To facilitate sampling, the proportion of infected panicles or the number of smutted kernels per panicle could be used instead of the KOH method. When using the proportion of infected panicles, the relationship to the number of smutted kernels per 25 g of grain after soaking in KOH was good and linear until the number of smutted kernels reached approximately 40 (fig. 4). At higher levels of smutted kernels, all panicles sampled were infected. When using the number of smutted kernels per panicle to quantify the level of kernel smut in the field, the relationship is also good at low levels, but as the number of smutted kernels increases, the variability around the relationship increases (fig. 4).

The data collected comes from three separate fields and three different varieties; therefore aggregating all data is not appropriate. When regressing the proportion of infected panicles, number of smutted kernels per panicle, or number of smutted kernels/25 g (KOH method) against yield, no relationship was found to be significant. This was expected since we are only harvesting a 1-square yard area. In such small area the variability in grain yield can be large. Anecdotal experience indicates that kernel smut incidence is sometimes related to high yields. High levels of N increase the incidence and severity of kernel smut, and therefore fields with high levels of N may also have higher yields and kernel smut. Growers that have seen severe kernel smut infestations in their fields have reported yield losses of up to 10%.

As the proportion of infected panicles increased, milling yield decreased in the three varieties (fig. 5). However, only M206 had a range that allowed for a strong relationship. The other two varieties proportion of infected panicles levels were between 70 and 100%. For M206, milling yields remain around 72% until the proportion of infected panicles reached 40-50%. After that, milling yield declined at a rate of 0.04 percentage points for every percentage point increase in infected panicles. This means that for milling quality to decrease one percentage point, the proportion of infected panicles has to increase by 25.

M206 and M105 had a good relationship between the number of smutted kernels/panicle and milling yield (fig. 5). For M206, milling yield declined 1.3 percentage points for every additional one smutted kernel/panicle. For M105, the decline was not as steep, only 0.3 percentage points for every additional smutted kernel/panicle.

A good relationship exists between the number of smutted kernels per 25 g sample (processed with KOH) and milling yield for the three varieties (fig. 5). When the number of smutted kernels/25 g increased by one, milling yield on average declined by 0.06 percentage points. This means that to reach a one percentage point decline in milling yield, the number of smutted kernels/25 g should increased by 15.

For head rice yield, only the number of smutted kernels/25 g showed a strong relationship for variety M105 (fig. 6).

OBJECTIVE 3) Determine the susceptibility of California varieties to kernel smut.

Methods

Kernel smut was observed in two of the eight statewide variety trials conducted in 2018, Glenn and Butte County trials. In the trials, the advanced lines were evaluated by counting the number of smutted kernels in 10 randomly selected panicles per plot a week before harvest. At harvest, a 400 g grain sample from each plot was taken and later processed using KOH and the number of smutted kernels in three, 25 g subsamples counted, as described in objective 2. For each advanced line, the average proportion of infected panicles, number of smutted kernels per panicle, and smutted kernels per 25 g was calculated and compared using Tukey's test (α=0.05).

Results and Discussion

Smut levels in the Glenn County variety trial were lower than in the Butte County trial (fig. 7). Long grains CJ201, L206, and L207 had the highest levels of smut. Of the medium grains, M209 had significantly higher levels. The number of smutted kernels/25 g in short grains was not significantly different than the number in medium grains (except M209).

In Butte County, L206, CJ201 and L207 had the highest number of smutted kernels/25 g, between 50 and 90. Medium grains and short grains had similar numbers of smutted kernels/25 g, ranging from 20 to 40. While M209 was not significantly different from other medium grains, it did have numerically more smutted kernels than others.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS

Fungicide trials were conducted against stem rot, aggregate sheath spot, and kernel smut. Azoxystrobin (Quadris, Cover XL) reduced the incidence and severity of stem rot (by 23 to 57%) and aggregate sheath spot (by 73%) when applied during the early heading stage. The new product S-2399 (commercial name Indiflin) and fluxapiroxad (Sercadis) had good activity against aggregate sheath spot when applied at early heading, reducing the incidence of the disease by 90 and 49%, respectively. In one of the trials where the incidence and severity of stem rot was high, no effect of any of the fungicides on the disease was observed.

Although reductions in disease incidence and severity were observed, treatment effects on yield were not found. However, when compiling all data, a significant relationship was found between incidence severity and yield. As severity of stem rot or aggregate sheath spot increased, yields decreased. For selected treatments for which milling quality was analized, no effect of any of the treatments was found.

The stem rot trials did not have enough pressure to produce significant results. However, Stratego resulted in the lowest levels of smutted kernels.

We continued to explore methods to determine the level of kernel smut in the field. Determining the number of infected panicles or the number of infected kernels per panicle could be used to determine the level of kernel smut in the field. This would allow for a quick evaluation by growers or PCAs without having to collect samples during harvest for processing in the lab.

Data generated this year indicates that kernel smut can affect milling yield. While no effects on yields were found, anecdotal evidence suggests that yield reductions are possible. Head rice yield was only affected for M105.

Varietal comparisons in two variety trials showed that long grains are more susceptible to kernel smut than medium and short grains. Of the medium grains, M209 seems to be more susceptible than other medium grains.

Table 1. List of fungicides used in the 2018 fungicide trials.

Product	**Active ingredient**	**FRAC Group**
Quadris	azoxystrobin (22.9%)	11 (strobularin)
QuiltXcel	azoxystrobin (13.5%) + propiconazole (11.7%)	11(strobularin) + 3 (triazole)
Cover XL	azoxystrobin (13.5%) + propiconazole (11.7%)	11 (strobularin) + 3 (triazole)
ALB4003	azoxystrobin (13.5%) + propiconazole (11.7%)	11 (strobularin) + 3 (triazole)
Stratego	trifloxystrobin (11.4%) + propiconazole (11.4%)	11(strobularin) + 3 (triazole)
Sercadis	fluxapiroxad (26.55%)	7 (succinate-dehydrogenase inhibitor)
S-2399 (Indiflin)	inpyrfluxam	7 (succinate-dehydrogenase inhibitor)
Sonata	*Bacillus pumilus* strain QST 2808 (1.38%)	44 (microbial)
Stargus	*Bacillus amyloliquefaciens* strain F727 cells and spent fermentation media (96.4%)	44 (microbial)
Regalia	Extract of *Reynautria sachalinensis* (5%)	P05 (plant extract)
ThermX70	Saponin extract from *Yucca schidigera* (20%)	P05 (plant extract)
MBI-10612	NA	NA
WE 1819-1	NA	NA

Table 2. Trial locations, application and evaluation dates for 2018 fungicide trials.

Location	Target	Variety	Seeding date	Application dates	Evaluation date	Harvest date
7 Mile Rd, Butte County	Stem rot	M-209	17 May	26 June, 3 August	10 Sept	11 October
Biggs, Butte County	Stem rot	M-206	29 May	3 July, 20 August	26 Sept	25 October
Oswald Road, Sutter County	Aggregate sheath spot	M-206	18 May	25 June, 8 August	19 Sept	17 October
Rd 57, Glenn County	Kernel smut	M-206	April 30	18 July	14 Sept	22 Sept
Old Hwy 99, Glenn County	Kernel smut	A-201	April 28	19 July	14 Sept	14 Sept

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. Parameters evaluated for stem rot 7 Mile Road trial.

Treatment	Rate/a	Incidence (%)	Severity	MC	Yield (lb/a)	MY (%)	HRY (%)
Untreated	--	100	3.04	16.94	6,659	71.67	51.00
Quadris mid tillering	15.5 oz	100	3.15	16.94	7,189 *	72.00	55.00
Quadris heading	15.5 oz	100	3.40	16.94	6,520	71.67	48.33
Sercadis mid tillering	6.8 oz	100	3.02	17.19	6,916	72.00	53.33
Sercadis heading	6.8 oz	100	3.26	17.19	7,009 *	71.75	52.25
Stargus heading	2 qt	100	3.09	17.19	6,759	--	--
MBI-10612 heading	2 pt	100	3.32	17.31	6,935	--	--
Sonata mid tillering	1 qt	100	3.23	16.69	6,624	--	--
Sonata mid tillering	4 qt	100	3.23	17.19	6,593	--	--
Sonata mid tillering + heading	4 qt + 4 qt	100	3.57	17.19	6,917	--	--
WE 1819-1 mid tillering	0.68 lb	100	3.20	16.94	6,909	--	--
WE 18191 + Sonata mid tillering	0.68 lb + 1 qt	100	2.99	16.94	6,743	--	--
S-2399 heading	2.01 oz	100	3.18	17.19	6,712	71.67	52.67

MY=Milling yield, HRY=Heard rice yield

* Significantly different from the untreated ($P<0.05$)

Table 5. Parameters evaluated for stem rot Biggs trial.

Treatment	Rate/a	Incidence (%)	Severity	MC (%)	Yield (lbs/a)	MY (%)	HRY (%)
Untreated	--	86.00	2.23	16.82	9,550	71.50	61.50
Quadris mid tillering	15.5 oz	71.90	1.76	17.50	9,298	70.25	59.00
Quadris heading	15.5 oz	66.00*	1.14*	16.07	9,206	71.25	59.25
Sercadis heading	6.8 oz	79.00	1.76	15.77	9,673	71.50	60.25
Cover XL heading	21 oz	56.89*	0.95*	16.21	9,693	71.75	59.25
Cover XL+ALB 3000 heading	21 oz + 8 oz	72.58	1.28*	17.50	9,617	70.75	59.50
ALB 4003 heading	21 oz	56.57*	0.98*	15.55	9,788	72.50	62.50
MBI-10612 heading	2 pt	84.53	1.84	16.34	9,313	--	--
Sonata mid tillering	1 qt	83.57	1.86	15.87	9,360	--	--
Sonata mid tillering	4 qt	86.45	2.14	16.30	9,423	--	--
Sonata mid tillering + heading	4 qt + 4 qt	76.46	1.71*	15.84	9,794	--	--
WE 1819-1 mid tillering	0.68 lb	87.08	2.16	15.99	9,355	--	--
WE 18191 + Sonata mid tillering	0.68 lb + 1 qt	86.00	1.97	16.49	9,589	--	--
S-2399 heading	2.01 oz	80.00	1.90	17.69	9,600	70.75	59.75

MY=Milling yield, HRY=Heard rice yield

* Significantly different from the untreated (P<0.005)

Table 6. Parameters evaluated for aggregate sheath spot Oswald Rd trial.

Treatment	Rate/a	Incidence (%)	Severity	MC (%)	Yield (lb/a)	MY (%)	HRY (%)
Untreated	--	94.00	2.01	17.31	8,792	74.00	54.00
Quadris mid tillering	15.5 oz	86.74	1.87	17.31	8,243	74.00	54.00
Quadris heading	15.5 oz	49.00*	0.55*	17.69	8,939	73.75	54.00
Sercadis mid tillering	6.8 oz	86.00	1.92	17.12	8,716	73.75	51.50
Sercadis heading	6.8 oz	70.50*	1.02*	17.69	9,112	74.25	55.00
Stargus	2 qt	86.08	1.96	17.31	8,042	--	--
MBI-10612	2 pt	87.00	1.94	17.12	8,817	--	--
Sonata mid tillering 1 qt	1 qt	93.00	1.97	17.50	8,550	--	--
Sonata mid tillering 4 qt	4 qt	71.00*	1.58	17.31	8,347	--	--
Sonata mid tillering + heading	4 qt + 4 qt	87.00	2.01	17.31	8,260	--	--
WE 1819-1 mid tillering	0.68 lb	91.04	2.14	17.31	8,608	--	--
WE 18191 + Sonata mid tillering	0.68 lb + 1 qt	94.04	1.77	17.69	8,884	--	--
S-2399	2.01 oz	19.00*	0.19*	17.50	8,971	74.25	52.75

MY=Milling yield, HRY=Heard rice yield

* Significantly different from the untreated ($P<0.05$)

Table 7. Parameters evaluated for kernel smut trial at Rd 57, Glenn County.

Treatment	Rate/a	Proportion of infected panicles	Smutted kernels/25 g	MC (%)	Yield (lbs/a)	MY (%)	HRY (%)
Untreated	--	0.02	2.00	18.83	8,420	71.91	58.54
Quadris	15.5 oz	0.02	1.83	18.83	8,704	72.01	57.13
QuiltXcel	21 oz	0.01	1.83	19.22	8,617	72.06	57.65
Regalia	2 qt	0.02	1.58	18.83	8,862	72.08	58.30
ThermX70	7.2 oz	0.01	2.50	18.83	8,478	72.43	58.73
S-2399	2 oz	0.01	1.67	18.64	8,378	72.18	55.66
Stratego	19 oz	0	0.92	18.83	8,390	72.38	56.24

MY=Milling yield, HRY=Heard rice yield

Table 8. Parameters evaluated for kernel smut trial at Old Hwy 99, Glenn County.

Treatment	Rate/a	Proportion of infected panicles	Smutted kernels/ panicle	Smutted kernels/25 g	MC (%)	Yield (lbs/a)	MY (%)	HRY (%)
Untreated	--	0.05	0.07	1.17	19.92	8,306	66.10	48.62
Regalia	2 qt	0.07	0.09	0.83	19.58	7,944	66.42	48.52
Stargus	2 qt	0.03	0.03	0.50	19.37	7,950	66.47	49.48
ThermX70	7.2 oz	0.07	0.08	0.83	19.43	8,057	66.68	49.46
ThermX70	14.5 oz	0.03	0.05	1.42	19.83	7,973	66.47	48.57

MY=Milling yield, HRY=Heard rice yield

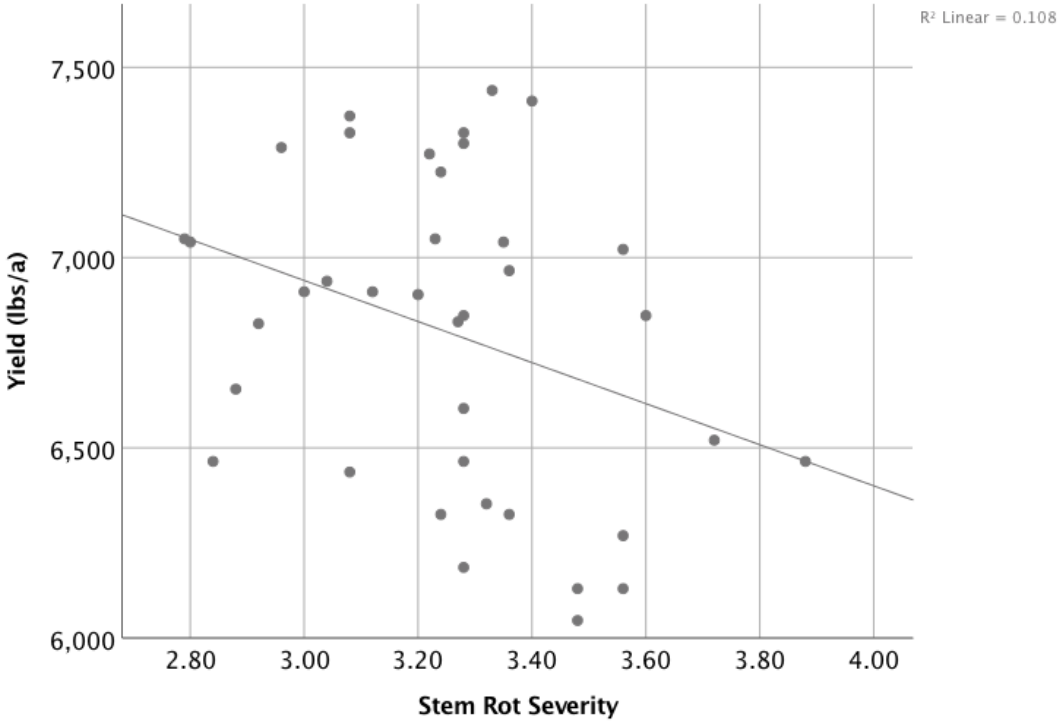

Fig. 1. Linear relationship between stem rot severity and yield for the 7 Mile Rd trial, Butte County. Field variety was M-209.

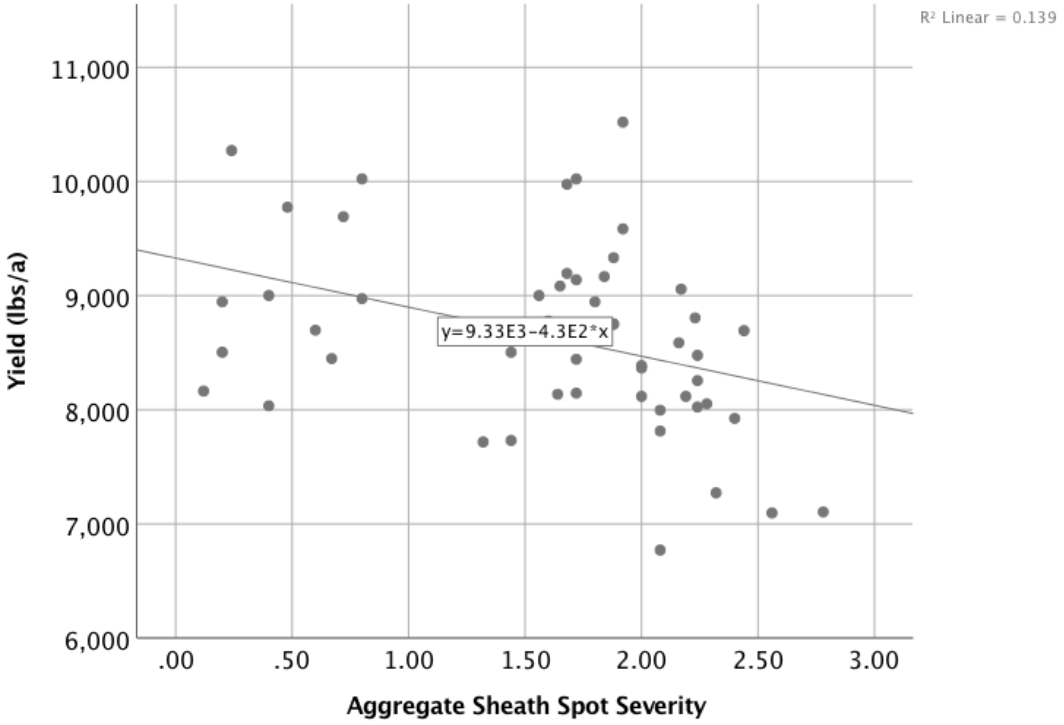

Fig. 2. Linear relationship between aggregate sheath spot severity and yield for the Oswald Rd trial, Sutter County. Field variety was M-206.

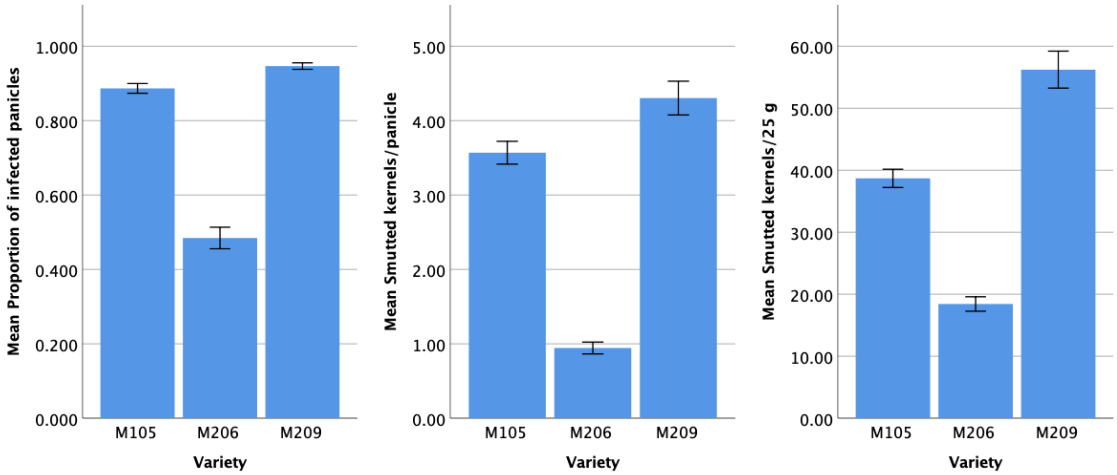

Fig. 3. Levels of kernel smut in sampled fields. Field sampling consisted on inspecting three, 10 panicle samples per 1 square yard quadrant. To determine the number of smutted kernels per 25 g of grain, three samples were soaked on KOH overnight and then inspected over a light.

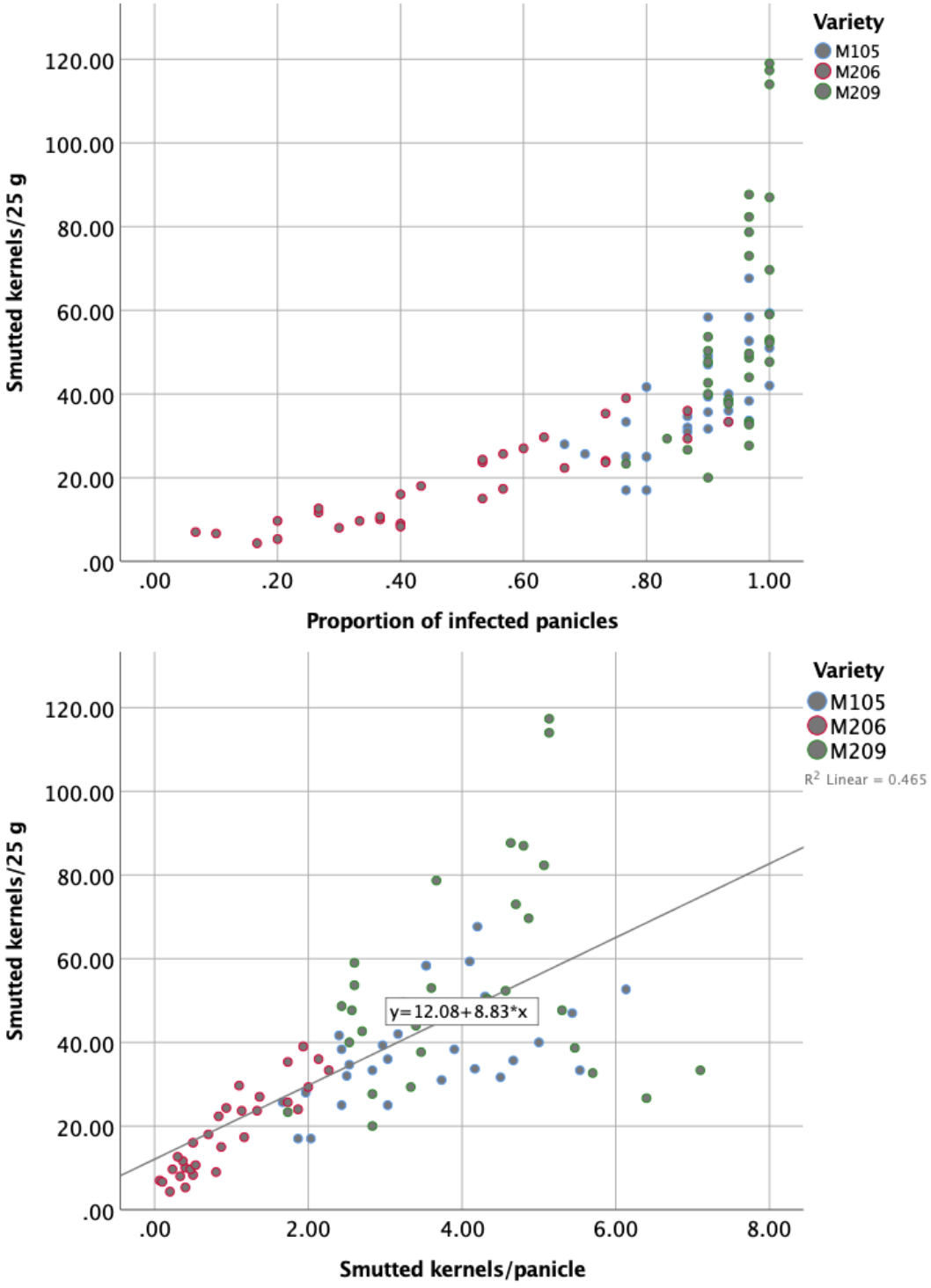

Fig. 4. Relationship between laboratory and field measurements of kernel smut.

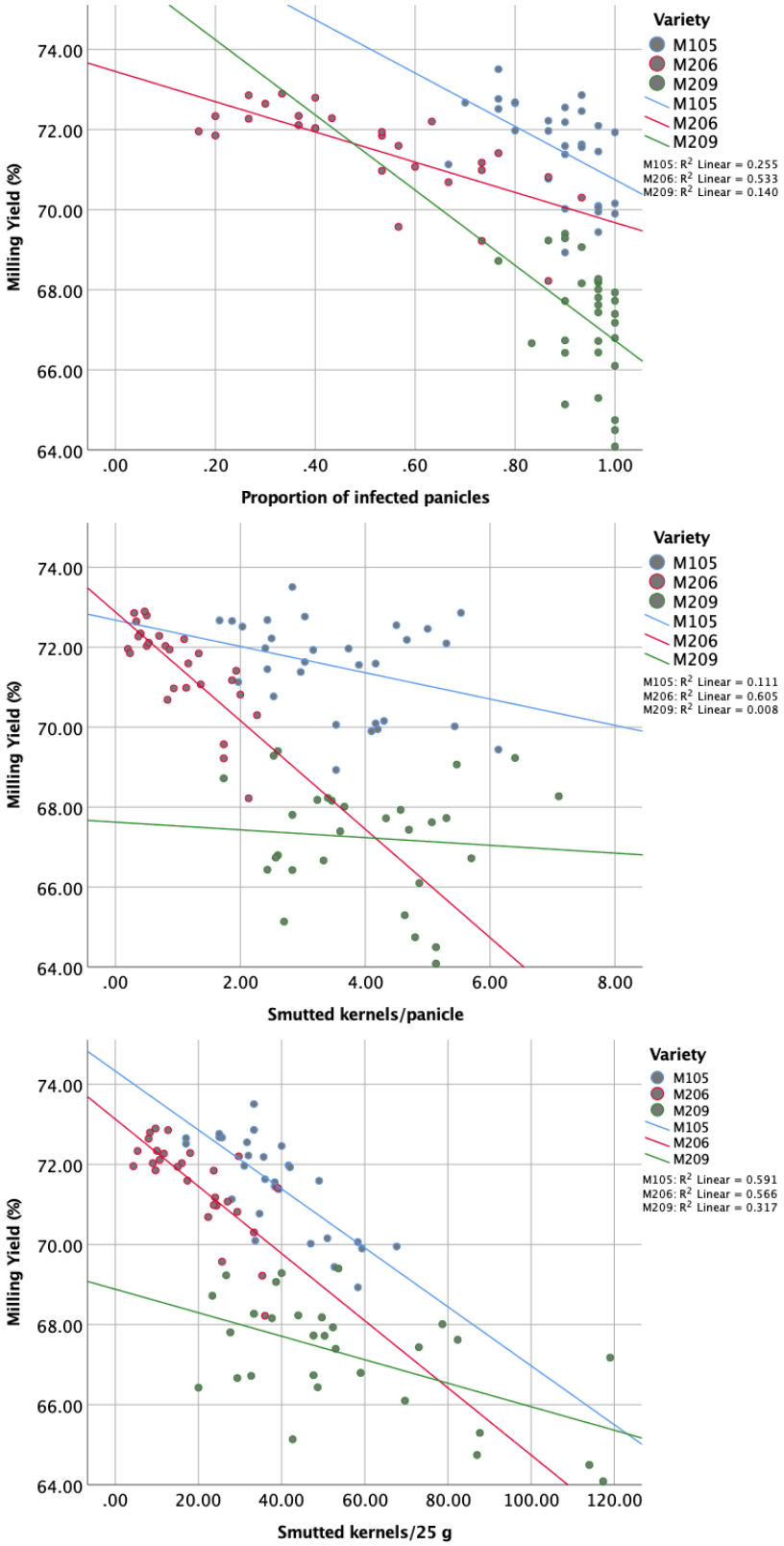

Fig. 5. Relationship between measures of kernel smut and milling yield.

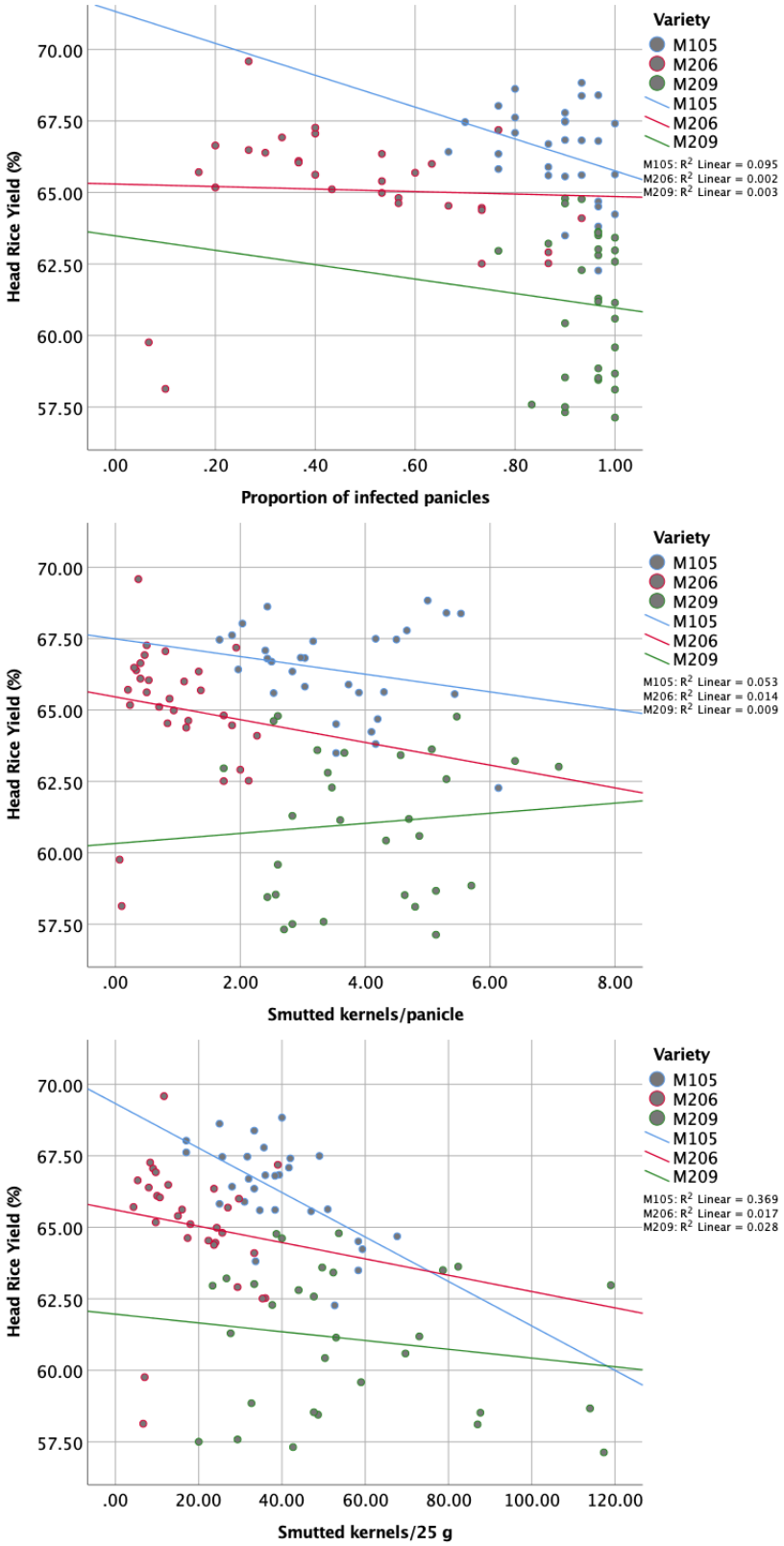

Fig. 6. Relationship between measures of kernel smut and head rice yield

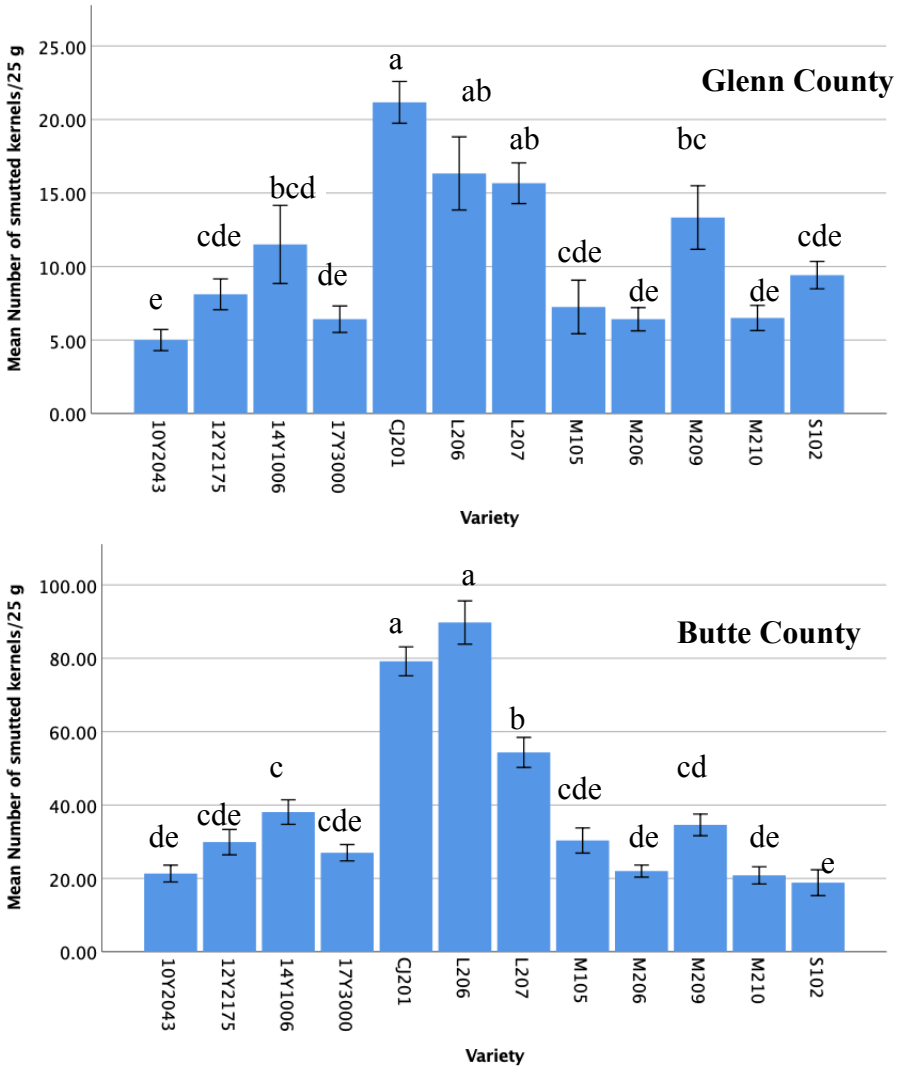

Fig. 7. Number of smutted kernels/25 g of grain in advanced entries in the Glenn and Butte County variety trials.