ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE

Jan. 1, 2010 to Dec. 31, 2010

Project Title: Crop Management, Environmental Conditions, and Storage Insects Effects on Rice Yield and Quality.

Status of Proposal: Continuing

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Level of Funding: $18,880

Objectives:

1. Investigate the crop-environmental interactions affecting yield and quality at a range of soil and grain moisture levels during grain maturation.

2. Evaluate milling quality stability of prominent California public varieties and advanced breeding lines.

3. Determine whether there are measurable water savings when rice fields are drained at different times after 50% heading as compared to the conventional drain time.

4. Assess seasonal occurrence of storage insects and evaluate current management practices in relation to observed infestation patterns.

MATERIALS AND METHODS

FIELD EXPERIMENT

Rice varieties M202, M205, and M206 were planted in a series of hydraulically isolated basins at the RES; each basin was equipped with water intake and drain outlets (Figure 1). The individual drains and the physical separation of the experimental plots allowed for discrete drain times to be imposed without compromising soil water status from the lateral movement of water between basins. Irrigation water was supplied from a common feeder ditch. Field preparation, fertility and pest management followed standard RES procedures. One hundred thirty pounds per acre of nitrogen as aqua ammonia, 50 lb/acre of potassium and 50 lb/acre of phosphorus were applied preplant. The experiment was top dressed with an additional 20 lb/acre N as ammonium sulfate 50 days after seeding. Seeds were dry planted onto a prepared seedbed at a rate of 150 lb/a and irrigation water brought to a depth of 3 to 4 inches during germination and stand establishment. The experiment was planted on May 25.

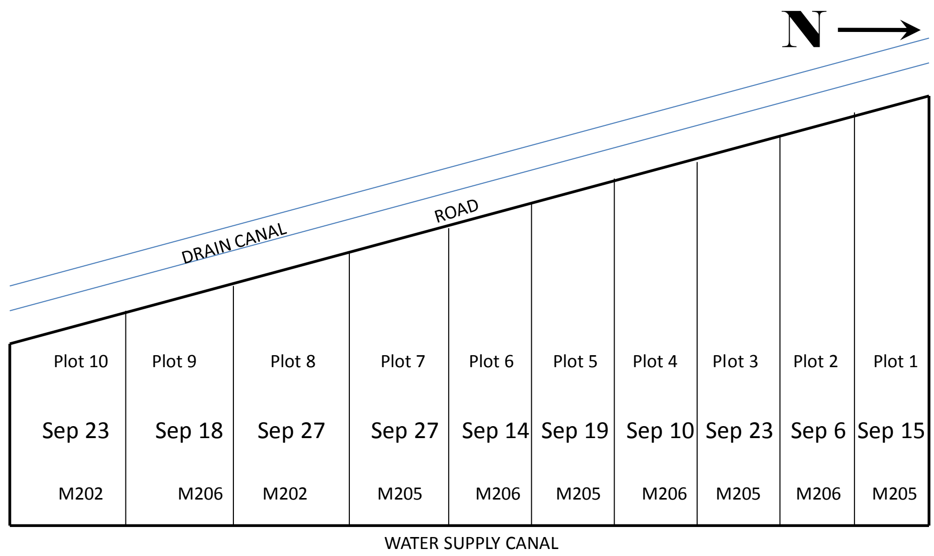


Figure 1. Field map of the experimental field at the RES in 2010.

M205 and M206 were subjected to four drain treatments: 16, 20, 24, and 28 days after 50% heading (DAH, Table 1). Drain time treatments for M202 were 24 and 28 DAH. Previous years' results demonstrated that draining M202 sooner than 20 DAH resulted in some head rice loss but yield was minimally affected. loss. Fifty percent heading was determined by cutting all plants in five randomly located one-foot squares per basin and counting the total of plants and those with emerged heads (panicle stem visible, Table 2). Daily counts ensured when the first heads were visible in each plot and continued until all heads were clear of the boot. Days to 50% heading did not vary within variety, therefore drain dates were uniformly imposed on all plots of a given variety.

Table 1. Days after planting (DAP) to 50% heading for M202, M205, and M206.

Variety	50% heading (DAP)	Date
M202	89	Aug 30
M205	90	Aug 30
M206	86	Aug 20

Environmental conditions were measured from four weeks prior to the first harvest and continued through the final harvest date on November 12. Recording relative humidity and leaf wetness sensors were deployed at canopy level in all plots. To quantify any between basin differences in plant microenvironment as influenced by drain time during the grain ripening period, the experimental site was equipped with a two meteorological station that measure air temperature, relative humidity, and dew point temperature. Single kernel moisture measurements was taken daily at mid-day beginning the third week of September to track the progression in MC starting when kernel reached 30% moisture content and continuing for until the end of the harvest period.

Soil moisture.

Change in soil moisture content was determined using a gravimetic method. Soil samples were taken at four locations and at two depths 0-10 & 10-20 cm (0-4 & 4-8 inch, respectively) twice weekly in all experimental basins over a 5 week and 4 week period, respectively. The samples were immediately taken from the field weighed and dried at 230 °F (110 C) for 24 hours (IS: 2720, Part II – 1973). The difference in the 'wet' and 'dry' weights was used to calculate the soil moisture content expressed as a percentage. As a redundant system, electronic soil moisture probes (Decagon Em5b) were installed in each basin to measure and record soil volumetric water content in the top 15 cm (6 inches) of the soil profile.

Harvest and sample collection at the RES.

The experiment was harvested on October 13, 19, and November 3, 5, 12. Four, 150 square feet plots were harvested from each basin with an Almaco plot combine. Plot grain weights were measured in the combine. Single grain moisture content was determined on samples from each harvested plot (Kett PQ510). Samples were dried with non-heated air to final moisture content of 13 to 14%. Yields are standardized to 14% moisture content and reported on a per acre basis. A 500g subsample was husked (Yamamoto FC-2K) and milled (Yamamoto VP-32T) and whole kernel percentage was measured using a machine grader (Foss Tectator Graincheck).

End of season water use.

Prior to the first drain, the water use in each basin was calculated based on the change in water depth on a daily basis. Three basins, one each for M202, M205, and M206, were equipped with water depth gauges. All drains were closed and the water level in each basin was raised to 5 inches. Water depths were measured daily for 4 days and the basins were refilled and the daily water depth measurements repeated for an additional 4 days. Changes in water depth allow the calculation of water volume used per day. Values presented represent the sum of evaporation, transpiration, and percolation averaged across sampling date. Percolation is assumed to be negligible during the short time period of the study.

Data Analysis

Data was analyzed using a Type III sums of squares ANOVA analysis (Straphgraphics Centurion XVI.I). The contribution of each treatment factor to variety performance was computed having removed the effects of all other factors by partition of error terms. P-values less than 0.05 are statistically significant at the 95.0% confidence level. The separation of the means table applied a multiple comparison procedure to determine which means were significantly different from the others at the 95% confidence level. Fischer's least significant difference (LSD) procedure was used to discriminate among the means.

STORAGE INSECT MONITORING

Stored rice insect populations were followed in six locations of the Sacramento valley during 2010. Two locations were in Richvale, one in Arbuckle and three in Glenn. In Richvale, one location is a dryer and stores dried rice from harvest until spring; the second location is a mill where dried rice is stored for short periods of time in silos before milling. The Arbuckle location is a mill that stores dried rice in silos and warehouses. The Glenn locations are farm bins where rice is stored from harvest until sold to a mill.

Facility description.

Richvale dryer. A flat bed storage warehouse was surveyed. The warehouse contained approximately 20 million lbs of rough rice (a mixture of Calrose varieties). Rice was put in storage in early October 2009 and held until early August 2010. Before being removed from the warehouse, rice was fumigated with aluminum phosphide (Phostoxin). All surrounding areas were treated with ß-cyfluthrin (Tempo) in April, June and July 2010.

Richvale mill. The area surrounding the storage bins was surveyed. Bins varied in size, and grain of different kinds and age were held during the whole time of the survey.

Arbuckle mill. The area surrounding the storage bins was surveyed. The area surveyed included bins and a flatbed warehouse that held rice from October 2009 to March 2010. The bins held several types of rice during the whole time of the survey. All warehouses and silos, and all areas surrounding these buildings, were treated with ß-cyfluthrin (Tempo) before grain was put in storage (August-September 2009).

Glenn farm bins. Three metal farm bins were surveyed. Two of the bins were in the same farm and held seed rice of the varieties M-401 (bin 1) and M-206 (bin 2); the third bin was located in another farm and held rice of the variety M-205 (bin 3). Bins contained between 122,000 and 275,000 lbs of rough rice.

Insect trapping.

Two trap types were used, pheromone and probe traps (Trece, Salinas, CA). Pheromone traps consisted of diamond shaped sticky traps (Storegard II) baited with synthetic pheromone lures and were used to collect insects flying over the grain mass and around the facilities. Insects monitored with pheromones were the Angoumois grain moth (AGM), *Sitotroga cerealella*; the lesser grain borer (LGB), *Rhyzopertha dominica;* and the Indianmeal moth (IMM), *Plodia interpunctella*. Lures were replaced every 4 weeks and traps were replaced when needed. Probe traps (Storegard WB Probe II) consisted of hollow 45 cm long plastic tubes with small openings on their surface and a removable tip where insects that fall into the trap are collected. Probe traps were inserted completely into the grain and used to collect insects moving in the grain mass. All traps were checked every two weeks

Richvale dryer. Traps were set up on 12 February 2010. Pheromone traps were located in the corners and center of the warehouse, approximately 5 ft above the grain mass. Seven probe traps were set up, three at the highest grain surface level, in the center and the grain mass, and in the corners of the warehouse, near the pheromone traps. On 13 August 2010 traps were removed, grain fumigated and moved out of the warehouse.

Richvale mill. Traps were set up on 17 February 2010. Six sets of pheromone traps were located around silos 4 to 5 ft above the ground. Traps were inspected until the end of September 2010.

Arbuckle mill. Traps were set up on 10 February 2010. Seven sets of pheromone traps were located around a flatbed warehouse and concrete silos 4 to 5 ft above the ground. Traps were inspected until the end of September 2010.

Glenn farm bins. Traps were set up on 26 October 2009. One set of pheromone traps were located inside the bins. In bins 1 and 2, two probe traps were inserted into the surface of the grain, and in bin 3, three probes were used. Traps were inspected until grain was removed from the bins. Bin 1 was emptied on 10 December 2009, bin 2 in 5 February 2010, and bin 3 in 20 April 2010.

RESULTS – Drain Date Experiment

Grain Ripening

Surprisingly, there was no striking affect of drain date on the rate of kernel dry down or the time required to reach a harvestable MC. Within each variety, the rate of kernel drying (slope of the lines, Figures 2- 4) were similar for all drain date treatments. On average M202 dried at a rate of 0.35% per day (Fig. 2), M205 at 0.32% per day (Fig. 3) and M206 at 0.26% per day (Fig 4). These rates are slower, but understandably so due to the cool, wet fall, than what observed in 2009. In 2009, M202, M205, and M206 lost 1%, 0.6%, and 0.9% per day, respectively. The 28 DAH treatments delayed the onset of grain dry down in M205 and M206, in that the kernel moistures dropped below 30% several days later than in the 16, 20, and 24 DAH (Figs 3 & 4). A similar trend was observed in 2009, where the MC for all varieties in the 24 DAH treatments remained about 2 points higher than the 12 DAH. The onset of dry down below 30% kernel moisture for M202 was comparable at 24 DAH and 28 DAH. Consequently, the grain in the 28 DAH reached a harvest moisture content of 20% about 3 days later than the other drain date treatments in M205 and M206. In 2009, the 12 DAH treatments reached a target harvest MC of 20% 2 to 5 days sooner than did the 24 DAH treatments. Note that the drop below 30% moisture content in M205 under the 16 DAH treatment was comparable to the response of the 28 DAH treatment (Fig 3). The M205, 16 DAH treatment was inadvertently reflooded on September 23. Rewetting the soil resulted in a rate of moisture loss similar to the 28 DAH. Therefore any conclusions draw from M205's response to the 16 DAH treatment should be cautiously evaluated.

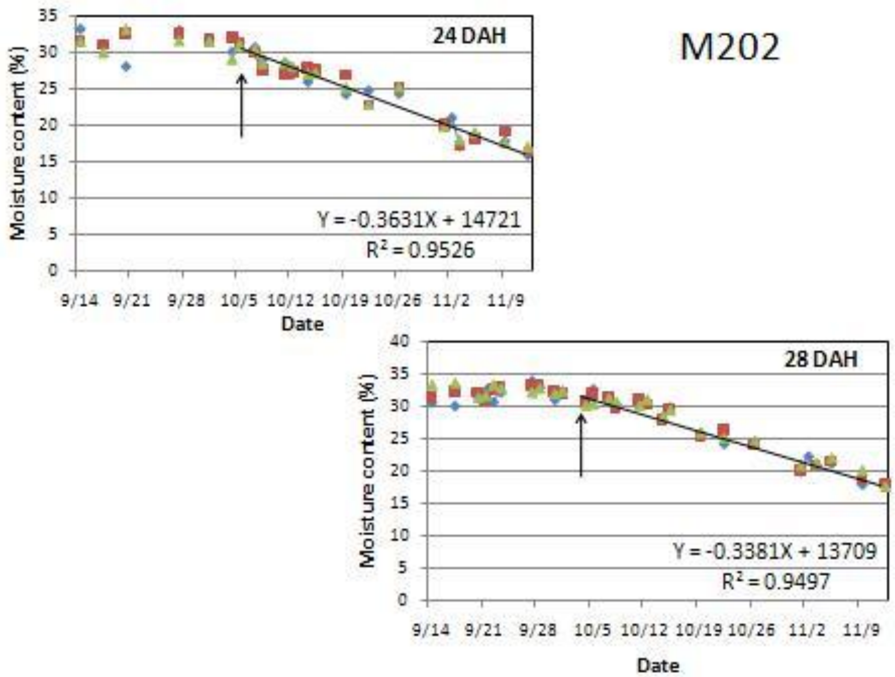


Figure 2. Daily grain moisture loss from ripening M202 subjected to different drain times (16, 20, 24, and 28 days after heading).

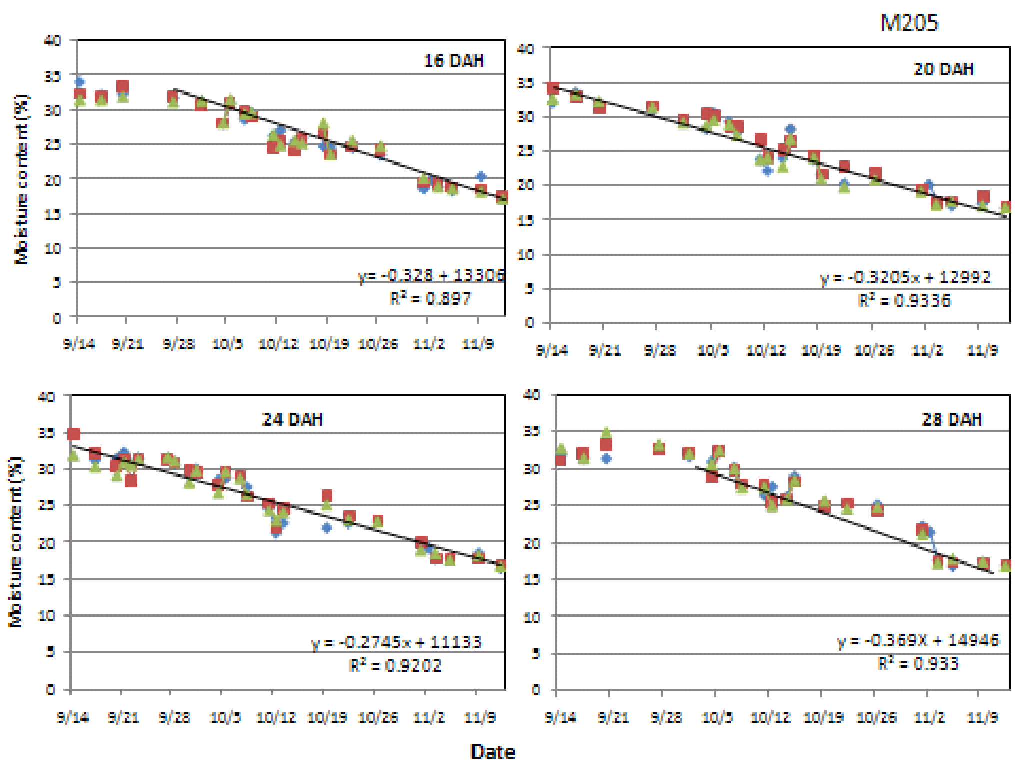


Figure 3. Daily grain moisture loss from ripening M205 subjected to different drain times (16, 20, 24, and 28 days after heading). Note: the 16 DAH basin was inadvertently reflooded on September 23.

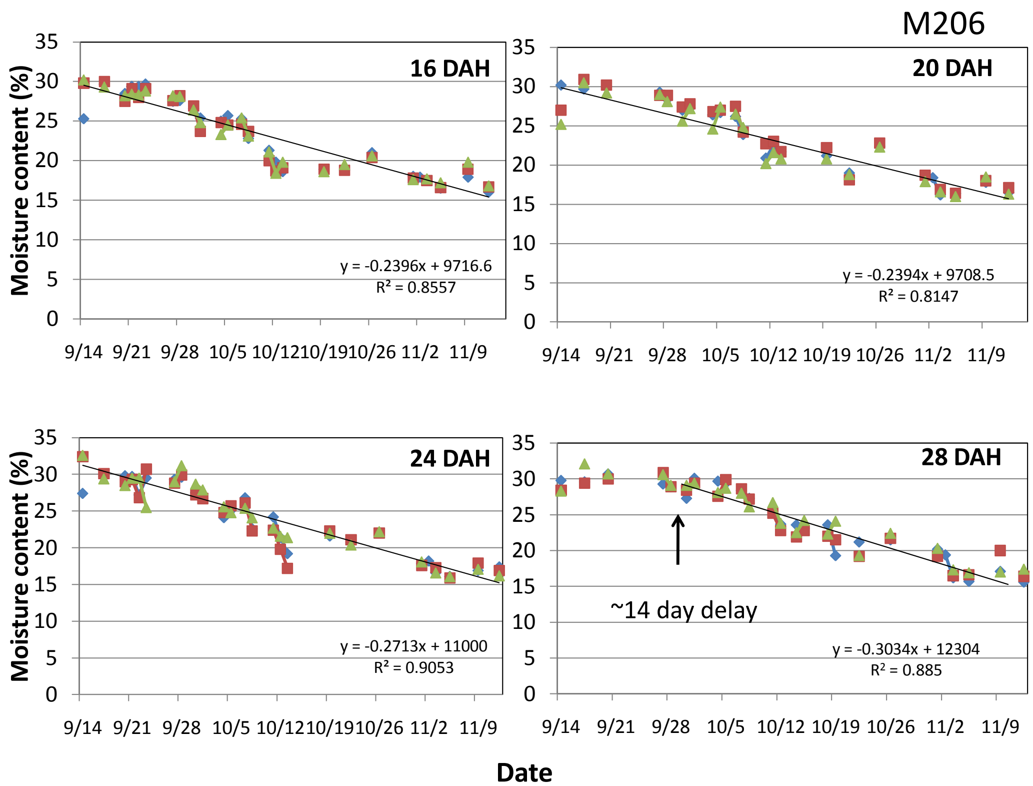


Figure 4. Daily grain moisture loss from ripening M206 subjected to different drain times (16, 20, 24, and 28 days after heading).

Yield and Grain Quality

M202

As was observed in past years and in commercial production settings, the yield of M202 increased significantly when drained at a later date (Table 2). A four day delay in draining from 24 to 28 DAH resulted in over a 1000 lb/a increase in yield (Fig 5). Such as a large discrepancy in yield between drain dates was not observed in previous years. A clear explanation why it was in 2010 remains elusive. Yield also significantly increased at the later harvest date (data not shown), likely attributable to the ripening of late tillers which would have been lost in an early harvest. Head rice yield declined once the harvest moisture content went below about 20% (Fig 6). Data indicate that the head rice yield in the 28 DAH plots was more sensitive to harvest moisture content than the 24 DAH plots, although the reason for the trend is unclear.

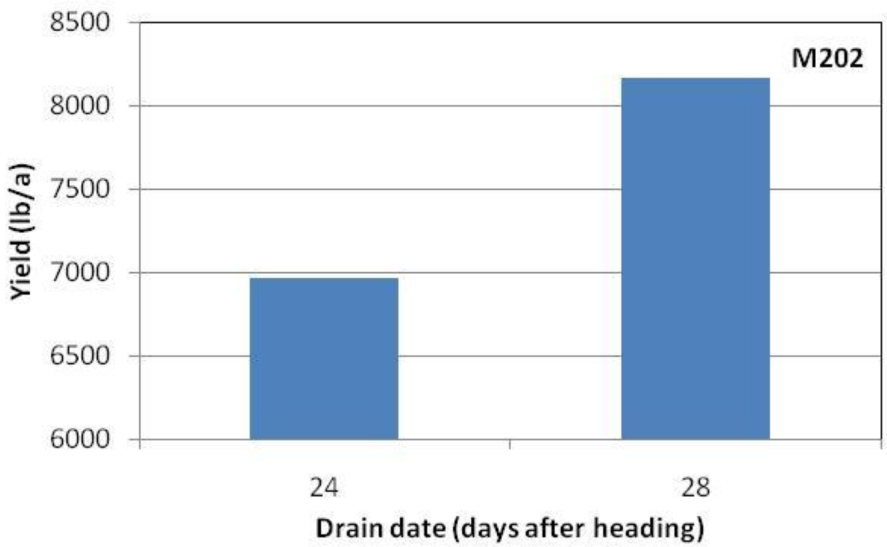


Figure 5. Yield of M202 standardized to 14% MC when drained at 24, and 28 days after 50% heading.

Table 2. Analysis of variance (A) and multiple range tests for harvest date (B, C) and drain date effects on M202 yield.

A: Analysis of Variance – M202 yield

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:M202 2010.Harvest date	6.02759E6	2	3.0138E6	4.93	0.0182
B:M202 2010.Drain date (DAH)	1.67267E7	1	1.67267E7	27.35	0.0000
RESIDUAL	1.22296E7	20	611479.		
TOTAL (CORRECTED)	3.49839E7	23			

All F-ratios are based on the residual mean square error.

B: Multiple Range Tests – Harvest date

Method: 95.0 percent LSD

M202 2010.Harvest date	*Count*	*LS Mean*	*LS Sigma*	*Homogeneous Groups*
11/5/10	8	7417.5	276.469	X
11/3/10	8	7464.63	276.469	X
11/12/10	8	8503.38	276.469	X

C: Multiple Range Tests – Drain date

Method: 95.0 percent LSD

M202 2010.Drain date (DAH)	*Count*	*LS Mean*	*LS Sigma*	*Homogeneous Groups*
24	12	6960.33	225.736	X
28	12	8630.0	225.736	X

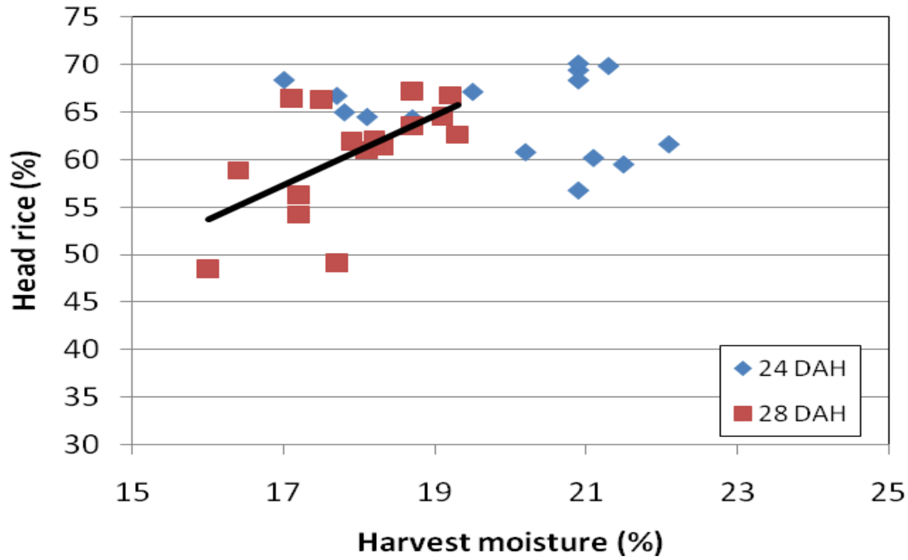


Figure 6. Head rice yield of M202 standardized to 14% MC when drained at 16, 20, 24, and 28 days after 50% heading. Regression line applied to the 28 DAH data.

Table 3. Analysis of variance and drain date effects on M202 head rice yield.

Analysis of Variance for HRY M202

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:Date	69.8834	3	23.2945	0.61	0.6131
B:DAH	71.1028	1	71.1028	1.87	0.1830
RESIDUAL	1027.86	27	38.0688		
TOTAL (CORRECTED)	1168.84	31			

M205

Drain date had no effect on M205 yield, although there was a visible trend in the data that yield peaked at 24 DAH (Fig 7 & Table 4). In 2009, draining at 16 and 20 DAH resulted in lower yield as compared to 24 DAH. The small amount of rain during grain maturation may have contributed to lessening of drain time effects in 2010. While there was no apparent yield penalty or advantage for draining at 28 DAH, this treatment did increase the time required to reach harvestable moisture content when compared to the 24 DAH (Fig 3).

Similar to M202, the yield of M205 increased at the later harvest dates, again presumably due to the more complete ripening of all tillers (Table 4). Yield of M205 remained stable across harvest moisture contents ranging from 16 to 20% regardless of drain date (Fig 8), but was lower at harvest moisture contents from 22% to 25%. Total rice yield declines dramatically when M205 was harvested above about 24% (Fig 10). Total rice yield is an indication of the completeness of grain filling; inadequately developed endosperm is subject to breaking when milled.

Drain date had no significant effect on head rice yield (Table 4). As can be in Figure 9, the head rice values at harvest moistures below 19% form a data cloud where treatment differences are generally indiscernible. There is an indication in the 2010 data that head rice yield declines when harvested below 17%.

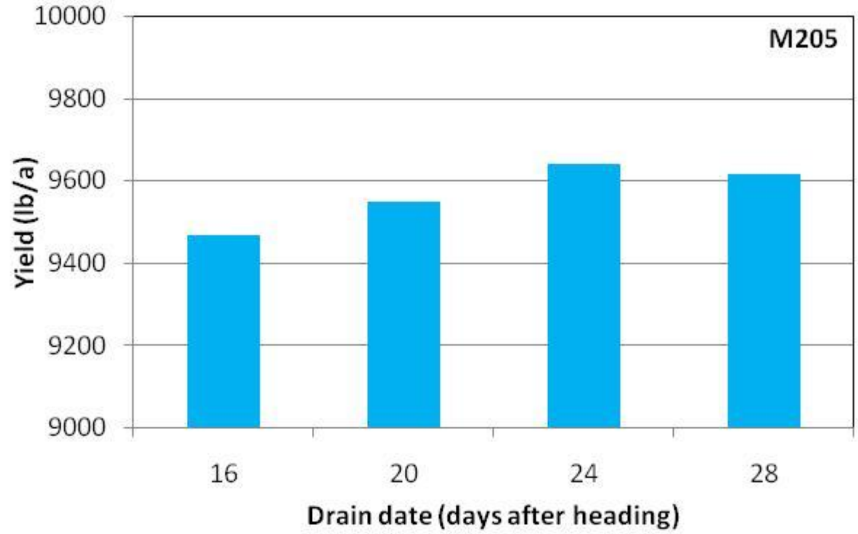


Figure 7. Yield of M205 standardized to 14% MC when drained at 16*, 20, 24, and 28 days after 50% heading. *Unintentionally reflooded.

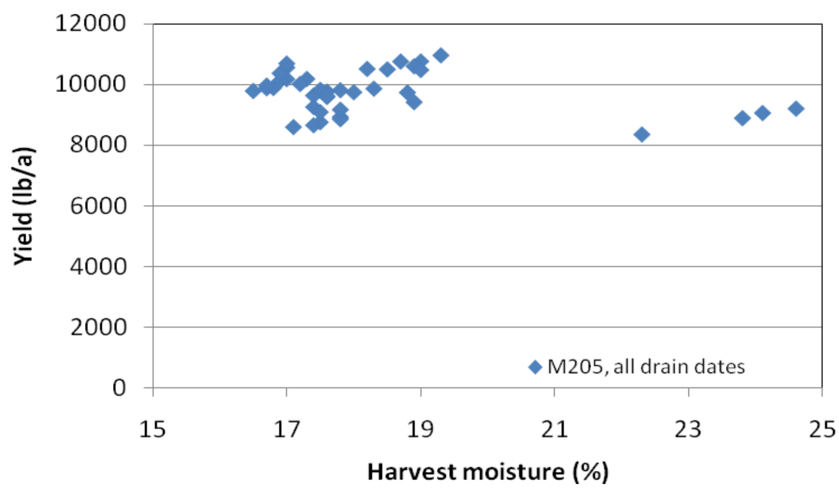


Figure 8. Yield of M205 standardized to 14% MC when harvested at different moisture contents.

Table 3. Analysis of variance (A) and multiple range tests (B) for harvest date and drain date effects on M205 yield.

A: Analysis of variance – M205 yield

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:M205 2010.Harvest date	2.51336E6	2	1.25668E6	3.55	0.0377
B:M205 2010.Drain date (DAH)	2.97295E6	3	990982.	2.80	0.0516
RESIDUAL	1.48719E7	42	354094.		
TOTAL (CORRECTED)	2.03582E7	47			

All F-ratios are based on the residual mean square error.

B: Multiple Range Tests - M205 yield by harvest date

Method: 95.0 percent LSD

M205 2010.Harvest date	*Count*	*LS Mean*	*LS Sigma*	*Homogeneous Groups*
11/3/10	16	9570.63	148.764	X
11/5/10	16	9758.06	148.764	XX
11/12/10	16	10121.8	148.764	X

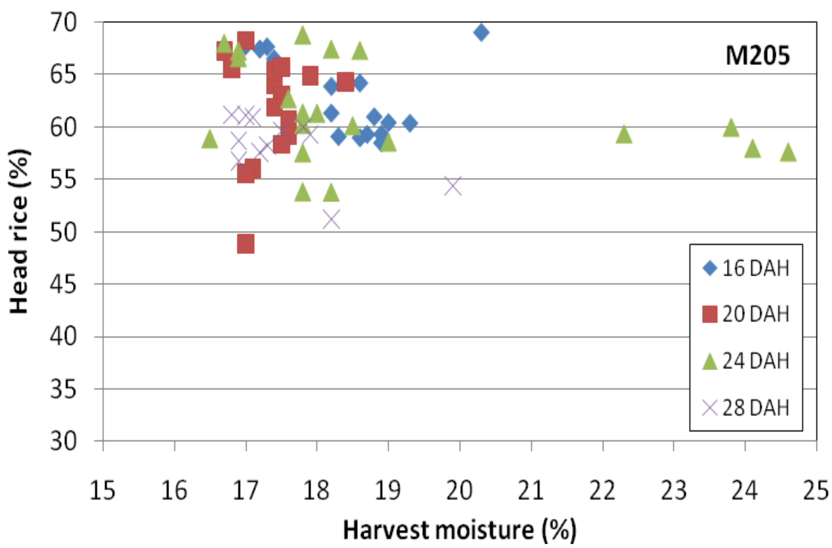


Figure 9. Head rice yield of M205 when drained at 16, 20, 24, and 28 days after 50% heading.

Table 4. Analysis of variance (A) and multiple range tests (B) for harvest date and drain date effects on M205 head rice yield.

A: Analysis of variance – 205 HRY

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:Date	332.384	5	66.4769	4.35	0.0018
B:DAH	89.2631	3	29.7544	1.95	0.1312
RESIDUAL	963.183	63	15.2886		
TOTAL (CORRECTED)	1387.0	71			

All F-ratios are based on the residual mean square error.

B: Multiple Range Tests - HRY M205 by Date

Method: 95.0 percent LSD

Date	*Count*	*LS Mean*	*LS Sigma*	*Homogeneous Groups*
10/19/10	4	56.6344	2.13045	X
10/13/10	4	58.2094	2.13045	XX
11/5/10	16	59.1187	0.977517	X
11/3/10	16	60.7188	0.977517	XX
11/9/10	16	62.175	0.977517	XX
11/12/10	16	64.325	0.977517	X

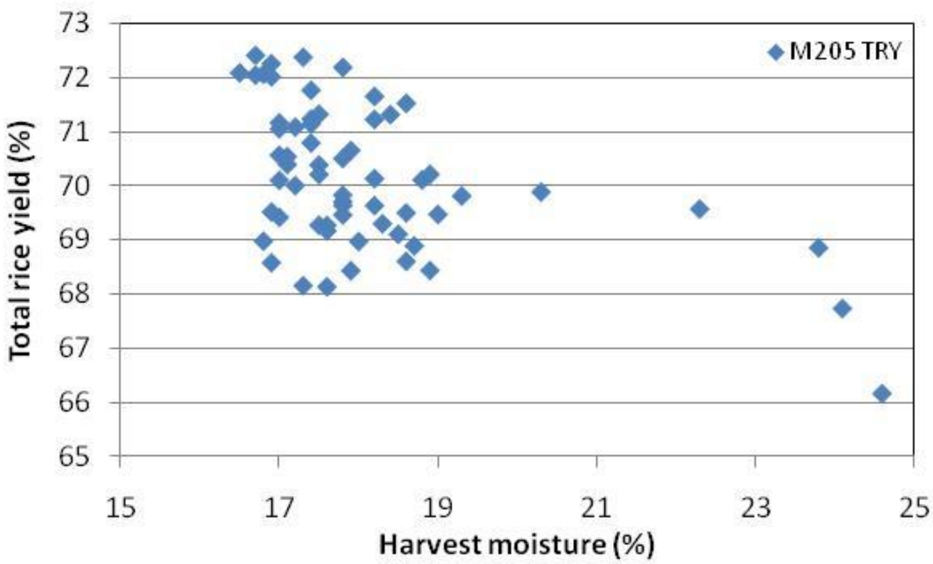


Figure 10. Total rice yield of M205 at different harvest moisture contents. All drain dates.

M206

The 16 DAH treatment significantly reduced yield compared to the other drain date treatments (Fig 11 & Table 5). There was no difference in yield response between the 20 and 24 DAH treatments. Results for the 28 DAH treatment are not presented because plant and stand vigor in the treatment were basin less robust than the comparative basins. Therefore the yield data are suspect. As a matter of note, the yield under 28 DAH was significantly lower than the 20 and 24 DAH treatments. 2010 data confirm findings from previous years that M206 yield plateaus when drained 24 days after heading.

Yield of M206 remained relatively unchanged over the range of harvest moisture contents spanning 17 to 24% irrespective of drain date (Fig 12). However, yield tended to slightly decline at harvest moistures less than 17%. The reduction was attributed to shattering.

Neither harvest date nor drain date had significant effects on head rice yield (Table 5). Head rice yield remained relatively constant for the range of 17 to 24% harvest moisture (Fig 13). Head rice yield tended to decline at harvest moisture contents under 17%. Total rice yield displayed a discernable decline with increasing harvest moisture content (Fig 14). Similar to M205, the data imply that harvesting above 24 to 25% moisture may penalize total rice yield.

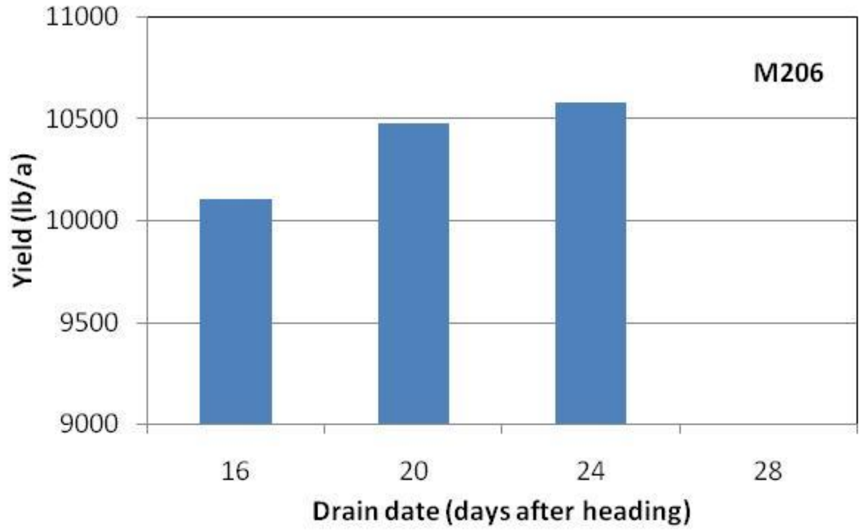


Figure 11. Yield of M206 standardized to 14% MC when drained at 16, 20, 24, and 28 days after 50% heading.

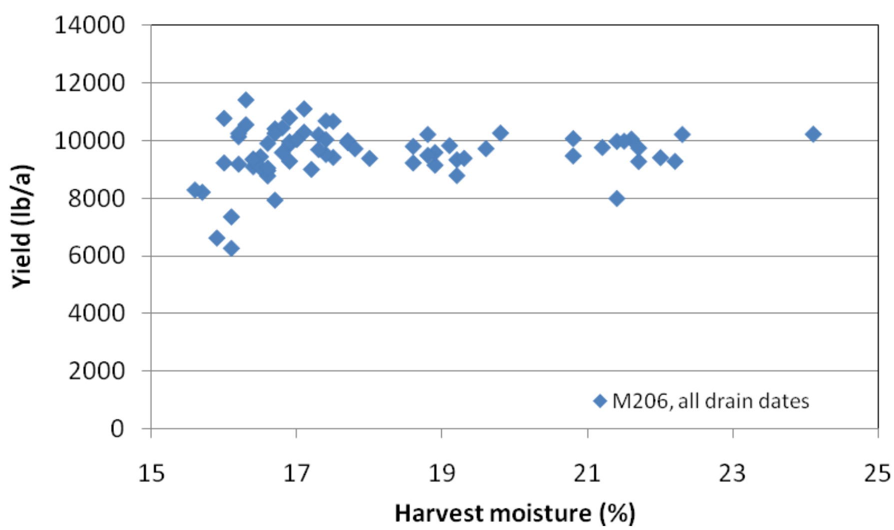


Figure 12. Yield of M206 standardized to 14% MC when harvested at different moisture contents. All drain dates.

Table 5. Analysis of variance (A) and multiple range tests for harvest date (B) and drain date (C) effects on M206 yield.

A: Analysis of Variance – M206 yield

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:M206 2010.Harvest date	1.20792E7	3	4.0264E6	6.63	0.0006
B:Drain date	6.50496E6	3	2.16832E6	3.57	0.0195
RESIDUAL	3.46358E7	57	607645.		
TOTAL (CORRECTED)	5.32199E7	63			

All F-ratios are based on the residual mean square error.

B: Multiple Range Tests – M206 yield by harvest date

Method: 95.0 percent LSD

M206 2010.Harvest date	*Count*	*LS Mean*	*LS Sigma*	*Homogeneous Groups*
11/5/10	16	8943.63	194.879	X
11/3/10	16	9713.19	194.879	X
10/19/10	16	9715.81	194.879	X
11/12/10	16	10149.2	194.879	X

C: Multiple Range Tests – M206 yield by drain date

Method: 95.0 percent LSD

Drain date	*Count*	*LS Mean*	*LS Sigma*	*Homogeneous Groups*
24	16	9235.19	194.879	X
28	16	9406.38	194.879	XX
16	16	9875.63	194.879	XX
20	16	10004.6	194.879	X

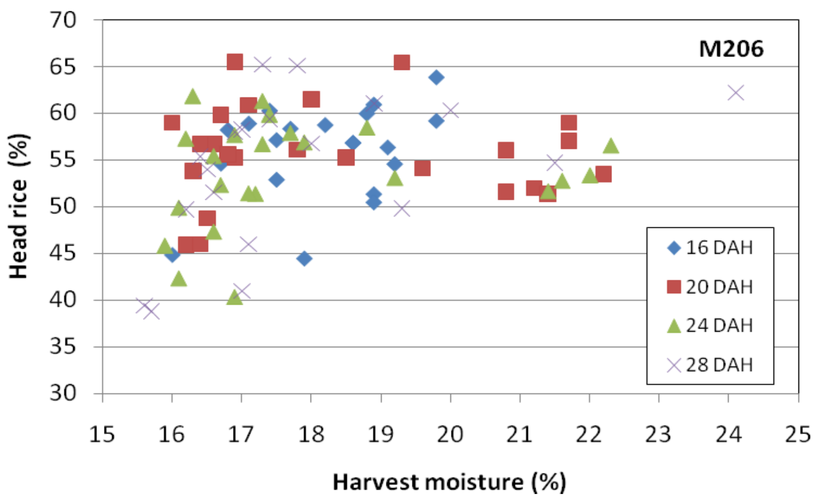


Figure 13. Head rice yield of M206 standardized to 14% MC when drained at 16, 20, 24, and 28 days after 50% heading.

Table 6. Analysis of variance (A) for harvest date and drain date effects on M206 head rice yield.

A: Analysis various – M206 HRY

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:Date	174.631	5	34.9261	1.00	0.4222
B:DAH	82.936	3	27.6453	0.79	0.5014
RESIDUAL	2894.98	83	34.8792		
TOTAL (CORRECTED)	3157.71	91			

All F-ratios are based on the residual mean square error.

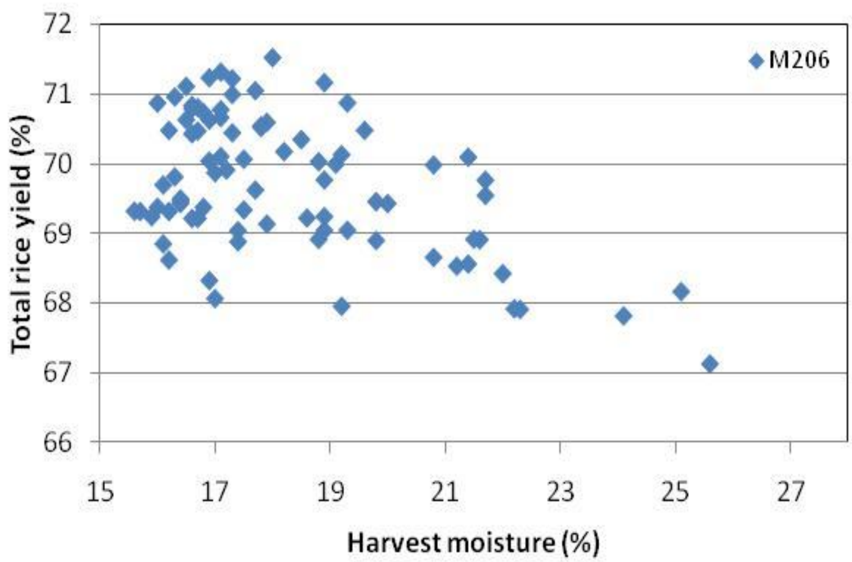
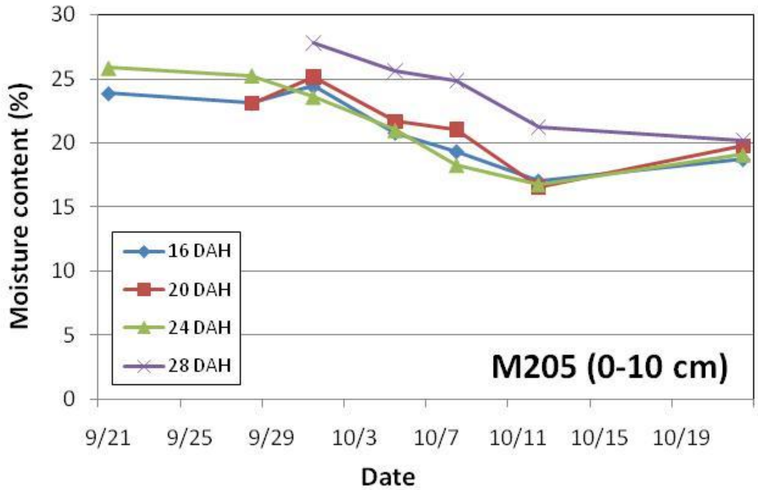


Figure 14. Total rice yield of M206 at different harvest moisture contents. All drain dates.

<u>Soil moisture</u>

M205

Under saturated conditions the soil moisture content in all basins was around 25% when gravimetrically quantified (Figure 15). Upon draining, the soil moisture declined at a similar rate in all drain date treatments at both the 0-10 cm and 10-20 cm depths (Figs 15-16). The soil moisture content for in M205 basins significantly declined over time (Fig 15, Table 7), although there were not statistically significant difference in water content associate with drain date. There was a trend, albeit non-significant, for higher soil moisture content in the 28 DAH treatment. There was no difference in soil moisture due to either sampling date or drain date at the 10-20 cm depth. Rain events did not appreciably increase soil moisture content as evidenced by the lack of large ‘spikes’ in content at either the 0-10 or 10-20 cm depths.



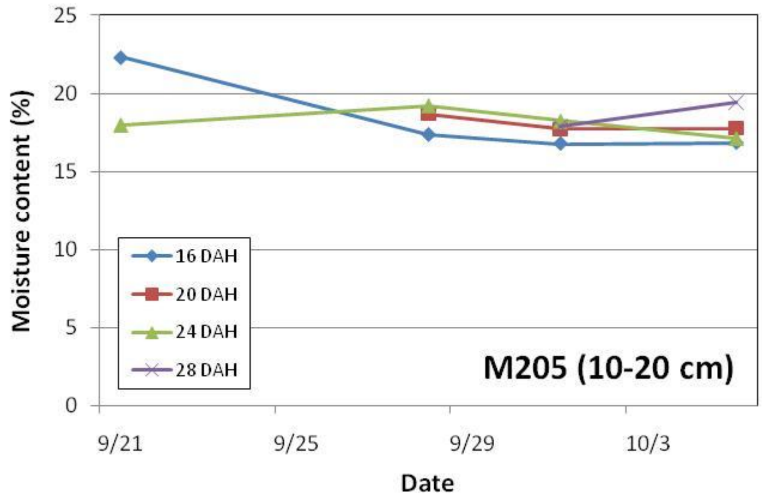


Figure 15. Soil moisture content over time in the different drain time treatments for M206.

Table 7. Analysis of variance for effects of sample date and drain date on soil moisture content at 0-10 cm (A) and 10-20 cm (B) depths for M205.

A: Analysis of Variance - M205 0-10 cm.

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:Soil Samples M205 0-10 cm.Date	4.26389	2	2.13194	6.06	0.0060
B:Soil Samples M205 0-10 cm.Drain date	0.877222	2	0.438611	1.25	0.3013
RESIDUAL	10.9011	31	0.351649		
TOTAL (CORRECTED)	16.0422	35			

B: Analysis of Variance - M205 10-20 cm

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:Soil Samples M205 10-20 cm.Date	93.7924	4	23.4481	7.06	0.0002
B:Soil Samples M205 10-20 cm.Drain date	20.0351	3	6.67837	2.01	0.1261
RESIDUAL	146.042	44	3.31913		
TOTAL (CORRECTED)	241.961	51			

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M206

Soil moisture contents for M206 were significantly affected by both sampling date and drain date at the 0-10 cm depth, while at the 10-20 cm depth only sampling date influenced moisture content (Fig 14 & Table 8). There was less water available in the 0-10 cm zone at the 16 and 20 DAH treatments as compared to the 24 and 28 DAH treatments, which had higher water content throughout the sampling period. There was no difference between 24 and 28 DAH treatments. At the 10-20 cm depth moisture content varied over sampling date, but drain date had no effect (Table 9). As was the case in the M205 basins, moisture content at the deeper depth remained constant over time and unaffected by drain date.

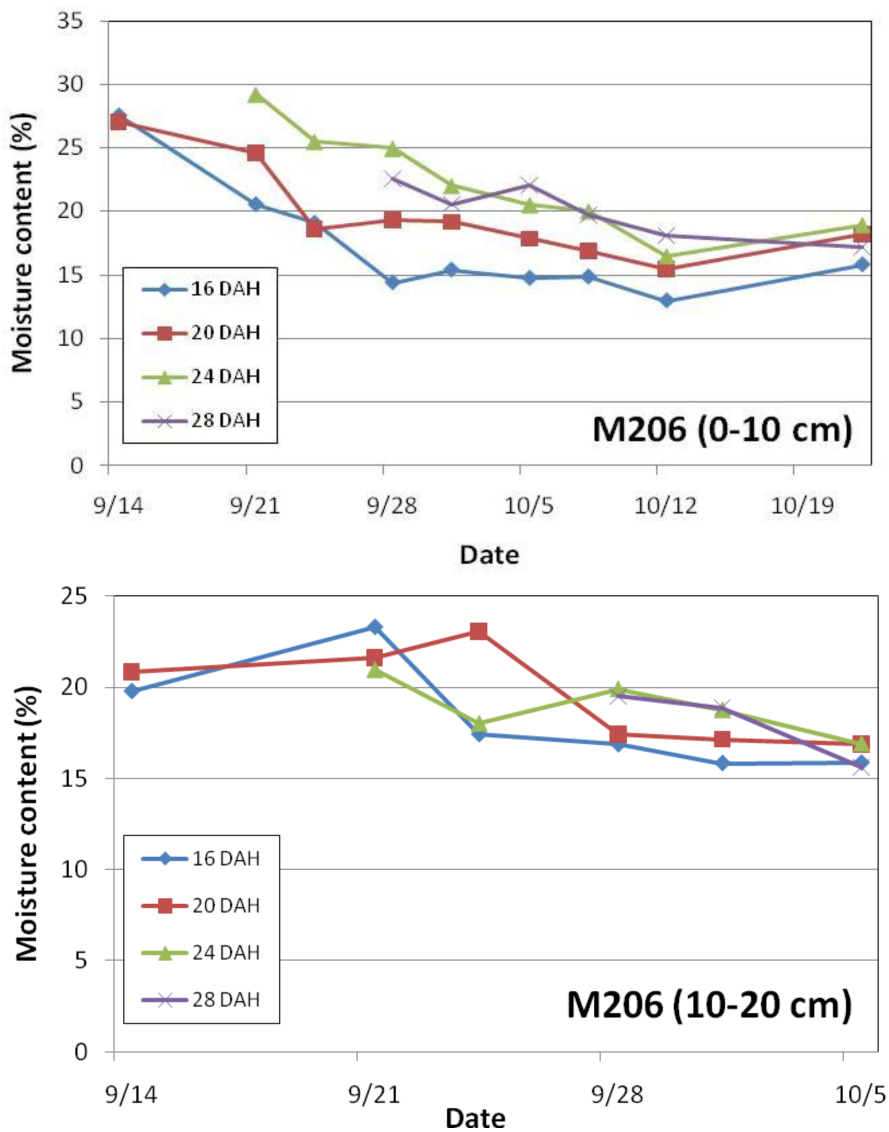

Figure 14. Soil moisture content over time in the different drain time treatments for M206.

Table 8. Analysis of variance (A) and multiple range tests (B) for effects of sample date and drain date on soil moisture content at 10-20 cm depth for M206.

A: Analysis of Variance - M206 0-10 cm

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:Soil Samples M206 0-10 cm.Date	1342.64	8	167.83	30.74	0.0000
B:Soil Samples M206 0-10 cm.Drain date	730.92	3	243.64	44.63	0.0000
RESIDUAL	633.266	116	5.45919		
TOTAL (CORRECTED)	2438.49	127			

B: Multiple Range Tests for Soil Samples M206 0-10 cm by drain date

Method: 95.0 percent LSD

Soil Samples M206 0-10 cm.Drain date	*Count*	*LS Mean*	*LS Sigma*	*Homogeneous Groups*
16	36	17.0139	0.389415	X
20	36	19.6806	0.389415	X
28	24	22.3502	0.505865	X
24	32	23.1894	0.424355	X

Table 9. Analysis of variance (A) and multiple range tests (B) for effects of sample date and drain date on soil moisture content at 10-20 cm depth for M206.

A: Analysis of Variance - M206 10-20 cm

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:Soil Samples M20610-20 cm.Date	259.155	5	51.8311	10.39	0.0000
B:Soil Samples M20610-20 cm.Drain date	25.1183	3	8.37276	1.68	0.1794
RESIDUAL	349.094	70	4.98706		
TOTAL (CORRECTED)	634.516	78			

B: Multiple Range Tests - M20610-20 cm by drain date

Method: 95.0 percent LSD

Soil Samples M20610-20 cm.Drain date	*Count*	*LS Mean*	*LS Sigma*	*Homogeneous Groups*
16	23	18.1985	0.466261	X
24	20	19.1776	0.519835	XX
20	24	19.5	0.455844	X
28	12	19.6486	0.70219	XX

M202

Soil moisture decline over time (data not shown) in both the 24 and 28 DAH treatments, but there was no significant difference between the two treatments for M202 (Table 10).

Table 10. Analysis of variance for effects of sample date and drain date on soil moisture content at 0-10 cm (A) and 10-20 cm (B) depths for M202.

Analysis of Variance - M202 0-10 cm

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:Soil Samples M202 0-10 cm.Date	333.162	5	66.6323	15.86	0.0000
B:Soil Samples M202 0-10 cm.Drain date	13.8063	1	13.8063	3.29	0.0780
RESIDUAL	155.42	37	4.20054		
TOTAL (CORRECTED)	490.468	43			

Analysis of Variance - M202 10-20 cm

Source	*Sum of Squares*	*Df*	*Mean Square*	*F-Ratio*	*P-Value*
MAIN EFFECTS					
A:Soil Samples M202 10-20 cm.Date	1.52604	2	0.763021	0.16	0.8534
B:Soil Samples M202 10-20 cm.Drain date	19.5806	1	19.5806	4.11	0.0597
RESIDUAL	76.2456	16	4.76535		
TOTAL (CORRECTED)	99.108	19			

Table 11. End of season water use in inches per day. Evapotranspiration + percolation.

Year	M202	M205	M206
2010	0.33	0.44	0.33

Estimated water savings

Keep in mind that purpose of draining based on a stage of plant development (i.e. heading) is to improve management efficiency without any detrimental effects on yield. The time to drain a field could be determined in a few weeks in advance to operational efficiency in preparation for harvest. A small amount of water savings may be an added benefit. Of course, the amount of potential water savings depends on how early a field is drained as compared to the traditional practice (Table 4). For example, if a field that was traditionally drained 28 days after heading (about 116 days after planting for M206) was drained at 24 DAH, then the end of season water savings would be about 1.4 inches in 2010. The potential water savings were about 70% of those observed in 2009. These should be considered preliminary results that need to be confirmed.

Table 12. Comparative water savings (inches) when field were drained at different times after 50% heading (DAH).

Water savings (inches)		Traditional drain (DAH)				
		12	16	20	24	28
New drain (DAH)	12	0	1.43	2.14	4.28	5.71
	16		0	1.43	2.14	4.28
	20			0	1.43	2.14
	24				0	1.43
	28					0

DISCUSSION – GRAIN QUALITY

2010 data confirmed previous years observations that M205 and M206 can be drained at 24 to 28 DAH without detrimental effects of productivity. The observed differences in yield and head rice yield were not associated with soil moisture content although the early drain dates (16 and 20 DAH) lowered yields. The less synchronous flower characteristics of M202 when compared to M206 may account for the great sensitivity to late season soil moisture content. The broader span of flowering within a head and between panicle on the same plant results in the grain transitioning through critical stages of physiological and agronomic maturing at different times. Lower soil moisture levels during the final stages of maturation apparent are less significance to performance of M205 and M206 than it is for M202.

Furthermore, there is no evidence that the presence or absence of standing water altered the canopy microclimate (e.g. occurrence of dew and temperature, data not shown). It is possible that the observed yield and quality differences associated with drain date may be associated with the presence or absence of flooded conditions rather than soil moisture level per se. The lack of relationship between drain date, soil moisture, and canopy conditions suggests that plant response is attributable to an unidentified factor, such as anaerobic or oxidative state of the soil. Exploration of such questions is beyond the scope of the current project.

Harvest date and harvest moisture content had negligible overall impact on yield. High HMCs did reduce yield this season. However when M205 and M206 were harvested below about 22% MC there is little effect on yield. The results reaffirm previous observations and confirm the stability of M205 and M206 over a range of conditions. The stability is not without limitation, however. Total rice yield declined at harvest moisture above 25% and head rice yield declined below 17%. When comparing the behavior of M205 and M206 to M202, the data suggests that breadth of the optimal moisture range (high and low) has not expanded; it has shifted downscale. To put it another way, the optimal operation range for harvesting M202 is about 20% to 26%. This maintains yield and milling performance. In contrast, the optimal range for M205 and M206 is about 17% to 24%. Furthermore unlike M202, there is no apparent advantage to draining the fields beyond 24 to 28 DAH. While it has become apparent to grower and dryer operator alike that M205 and M206 behave differently at the lower harvest moistures, they also behave differently in terms of grain maturation and late season water management. Although arguably subtle, there is a distinct and quantifiable shift in the management paradigm for M205 and M206 as compared to the way Calrose varieties have been managed for the past three decades.

RESULTS & DISCUSSION – Insect Monitoring

Arthropods caught on pheromone and probe traps during the surveys are listed in Table 13. Some of the species found were grouped by family because their importance as pests of stored grains is limited. Their presence in each facility sampled is discussed below. From the insects collected, two are internal feeders, three external feeders, and the other six are scavengers or feed on molds. Booklice and mites were found in all probe samples; however, they were not quantified. These arthropods are very common and not likely causing grain damage. They seem to be abundant under high moisture conditions.

In the Richvale dryer, pheromone traps inside the flat bed storage warehouse captured AGMs, LGBs and IMMs (Fig. 15). AGM adults were first detected toward the end of March, and numbers increased steadily to 3.7 moths/trap/day by mid June. From then, numbers increased rapidly and reached 8 moths/trap/day and remained at that level until the end of sampling. The steep increase in AGM population coincides with increasing ambient temperatures in summer.

Few LGBs and IMMs were caught with pheromone traps. Three peaks of LGBs were detected; in late March (0.01 beetles/trap/day), mid May (0.01 beetles/trap/day) and early July (0.04 beetles/trap/day). After the July peak, populations remained at 0.03 beetles/trap/day until the end of sampling. IMMs were caught in mid June and late July only, and numbers were never higher than 0.02 moths/trap/day.

Probe traps in grain in the flat bed warehouse caught several beetles and AGM adults (Fig. 16). Among the beetles caught, the red flour beetle, an external feeder, was the most abundant (11.4 beetles/trap during the whole trapping period). LGBs were found only in two sampling dates in July and August, for a total of 0.7 beetles/trap. Number of other beetles collected ranged from 1 to 0.1 beetles/trap; most of these beetles feed on mold developing on grain. AGM adults caught in probe traps were first found in early April and numbers increased steadily until the end of sampling, when the number caught reached 5.1 adults/trap/day.

Table 13. Arthropods caught with pheromone and probe traps in stored rice from various in northern California.

Arthropod	Feeding habits
Lepidoptera (moths)	
Angoumois grain moth, *Sitotroga cerealella* (Gelechiidae)	Grain, internal feeder
Indianmeal moth, *Plodia interpunctella* (Pyralidae)	Grain, external feeder
Coleoptera (beetles)	
Lesser grain borer, *Rhyzopertha dominica* (Bostrichidae)	Grain, internal feeder
Foreign grain beetle, *Ahasverus advena* (Silvanidae)	Scavenger, mold
Grain beetle, *Cryptolestes sp.* (Laemophloeidae)	Grain, external feeder
Red flour beetle, *Tribolium castaneum* (Tenebrionidae)	Grain, external feeder
Silken fungus beetle, *Cryptophagus spp.* (Cryptophagidae)	Mold
Minute brown scavenger beetles (Lathridiidae)	Mold
Paratenetus spp. (Tenebrionidae)	Mold
Hairy fungus beetle, *Typhaea stercorea* (Mycetophagidae)	Mold
Spider beetles (Ptinidae)	Scavenger
Psocoptera (booklice)	Scavenger, mold
Mites	Scavenger, mold

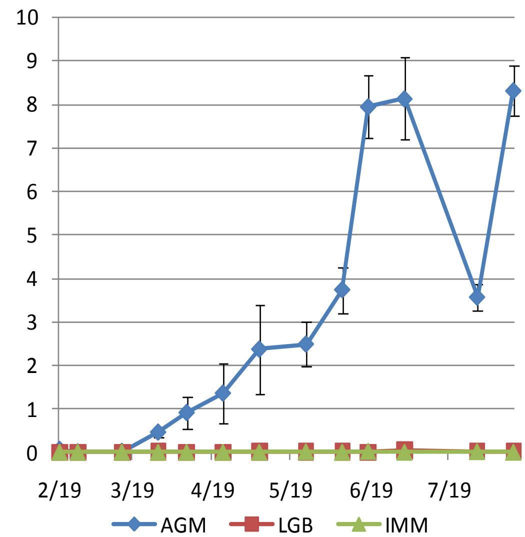

Fig. 15. Number of Angoumois grain moth (AGM), lesser grain borer (LGB) or Indianmeal moth (IMM) adults/trap/day in pheromone traps in a flatbed warehouse, Richvale 2010

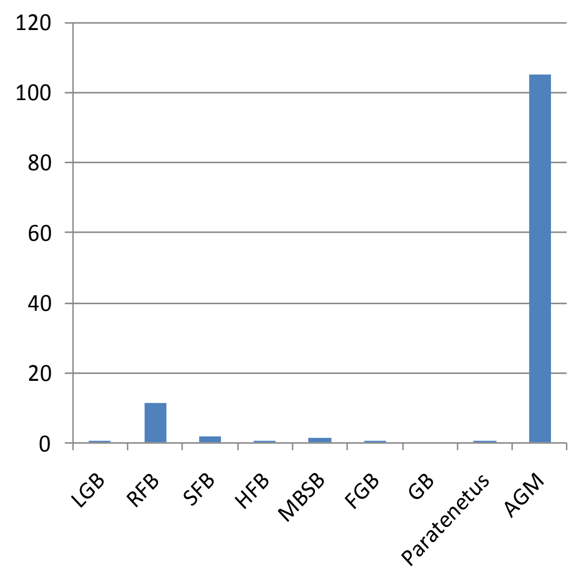

Fig. 16. Number of insects captured per probe trap from 19 February to 13 August in a flatbed warehouse, Richvale 2010. LGB = lesser grain borer, RFB = red flour beetle, SFB = silken fungus beetle, HFB = hairy fungus beetle, MBSB = minute brown scavenger beetle, FGB = foreign grain beetle, GB = grain beetle, AGM = Angoumois grain moth.

In the Richvale and Arbuckle mills, AGM, LGB and IMM populations were monitored using pheromone traps located outside grain bins in the storage area of the mill. More AGMs were caught in the Richvale mill than in the Arbuckle mill (Fig. 17A). In Richvale, AGMs were found from the beginning of sampling, although numbers were very low (less than 0.02 moths/trap/day). Numbers increased in both locations starting in late April. The area surveyed in both locations was similar; however, the Richvale location is surrounded by rice fields and weedy vegetation while the Arbuckle location is surrounded by tree orchards and a major highway. The presence of vegetation and rice residue from surrounding fields may provide more refuge and food for AGM populations near the Richvale mill and may explain the higher number of AGMs trapped there. In both locations, LGBs were first detected in late April-early May (Fig. 17 B). Numbers trapped in both locations were similar, except during the last four sampling dates, when more LGBs were found in Richvale than Arbuckle. Number of IMMs caught was very low in both locations. Starting in May, less than 0.03 and 0.1 moths/trap/day were caught in Richvale and Arbuckle, respectively.

In the farm bins, the silken fungus beetle and the hairy fungus beetle were the most common beetles caught (Fig. 18). *Paratenetus* spp., a darkling beetle not considered a pest of stored rice, was commonly found as well. Bins 1 and 2 had higher populations that bin 3. Bins 1 and 2 were located in the same farm. Probe traps from bin 1 caught the highest number of insects. This bin had the smallest capacity, was the oldest of the sampled bins and had a history of insect problems. Insects from previous years surviving inside this bin or in surrounding areas may explain the high insect population.

Number of hairy fungus beetles and silken fungus beetles captured were at their highest right after harvest when the rice was put in the bins (Fig. 19). In bins 2 and 3, where rice was stored for more than three months, beetle populations dropped to less than 0.1 beetles/trap/day towards the end of the storage period.

The silken fungus beetle and the hairy fungus beetle feed on fungi. They are likely feeding on mold growing on the grain. Rice stored in farm bins after harvest has a moisture content between 18 and 24%. This moisture content may allow mold development soon after rice is stored. As the rice is aerated, grain is dried and mold development decreased, reducing the population of fungus feeding beetles. Ambient temperatures may also have reduced the number of beetles trapped. Probe traps were located on the surface of the grain mass. When ambient temperatures are low, grain insects tend to go deeper into the grain mass, where temperatures are higher.

AGM, LGB and IMM pheromone traps inside the farm bins did not detect any of these insects. Temperatures during the time of the year when bins were sampled (November – March) may not have been adequate for these insects to develop in the grain mass.

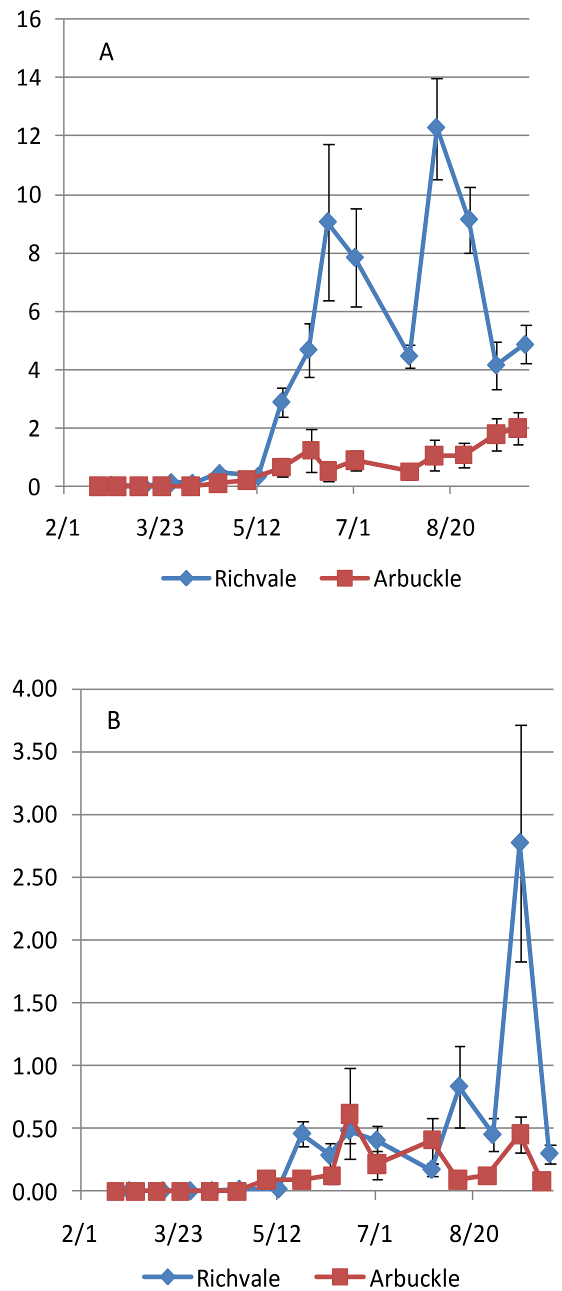

Fig. 17. Average number of Angoumois grain moths (A) and lesser grain borers (B) adults/trap/day caught in pheromone traps around rice mills in Richvale and Arbuckle, 2010

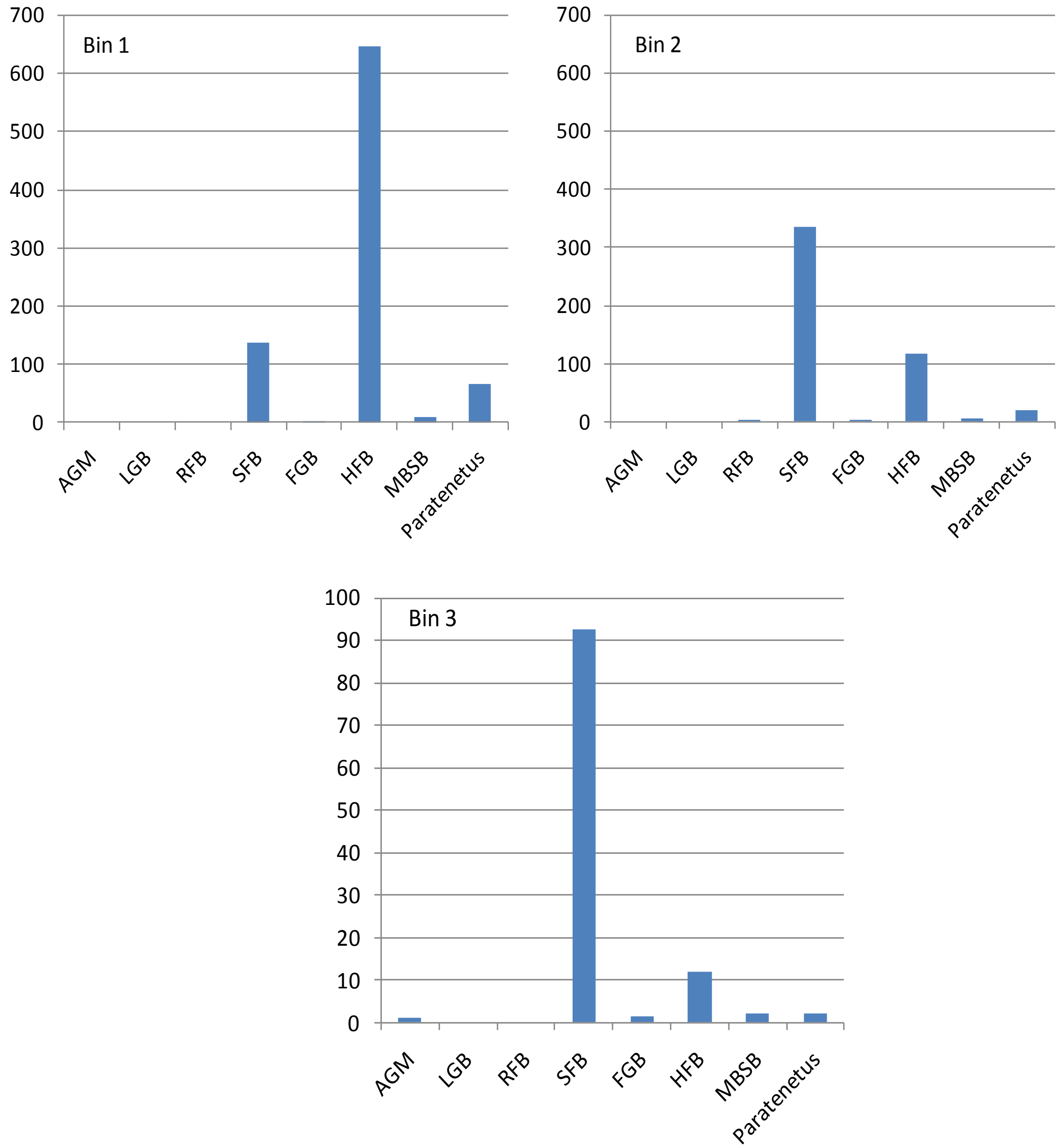

Fig. 18. Number of insects captured per probe during sampling in farm bins in Glenn, 2010 AGM = Angoumois grain moth, LGB = lesser grain borer, RFB = red flour beetle, SFB = silken fungus beetle, FGB = foreign grain beetle, HFB = hairy fungus beetle, MBSB = minute brown scavenger beetle.

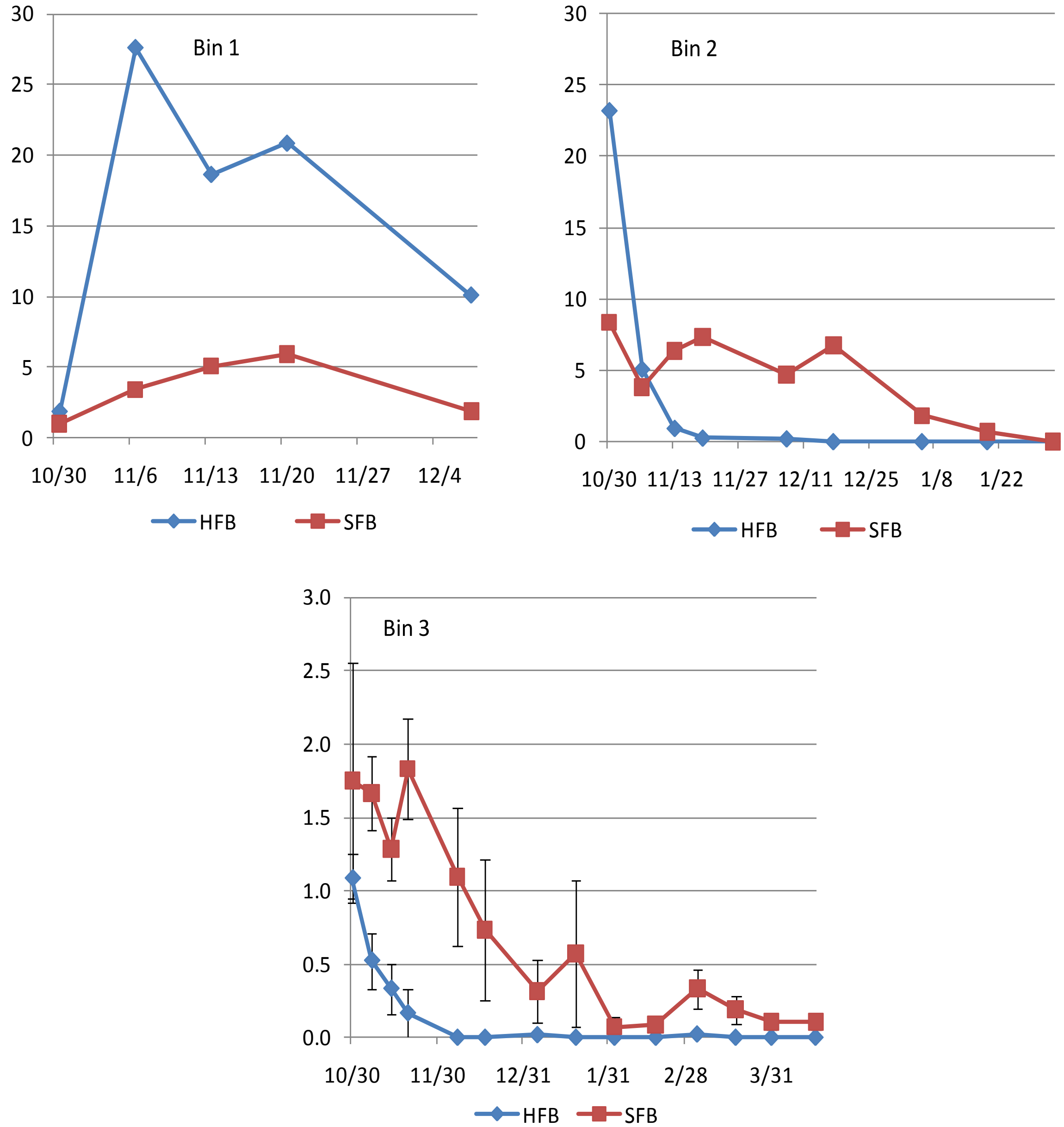

Fig. 19. Average number of hairy fungus beetle (HFB) and silken fungus beetle (SFB) adults/trap/day caught in probe traps in farm bins, Glenn, 2010.

In summary, monitoring of insects in grain, storage spaces, and farm bins showed that the type of insects found varied with location, grain moisture content at the time of storage, and weather conditions. The AGM, an internal grain feeder, was prevalent during spring and summer in grain and around storage facilities. Mold feeding beetles were prevalent in farm bins where rice was stored after harvest and decreased in number as ambient temperature dropped and grain dried. In farm bins, AGM, LGB and IMM pheromone traps did not catch any insects.

SUMMARY OF 2010 RESEARCH

Field Experiment-Grain Quality

Accumulated results over several years of study indicate that it is not advisable to harvest M205 and M206 below 17% or above 25% moisture content due to loss in head rice and total rice yield, respectively. The data suggest, though not actually measured in the present study, that the kernels of M205 and M206 reach physiological maturity at a lower moisture content that does M202. The data suggest that the improvement in milling stability at lower moisture contents resulted in a reduction in upper limit of acceptable harvest moisture to preserve total rice yield. To put it another way, the acceptable moisture range for harvesting M205 and M206 in terms of percentage points shifted down scale compared to M202; the range did not expand in absolute terms.

Within each variety, the rate of kernel drying below 25% MC was similar for all drain date treatments. The rate of moisture loss averaged across varieties was about 0.4 percentage points per day. The 16, 20, and 24 DAH treatments reached harvestable moisture content 3 to 5 days sooner than the 28 DAH treatments. On the whole, yields increased as the drain date was delayed. There was no apparent advantage to postponing field drainage beyond 24 DAH in M205 and M206. However, the yield of M202 was higher at a 28 DAH when compared to 24 DAH. Based on this year's results and those from previous tests, draining sooner than 20 DAH is not advised. To varying degrees, total rice yield (TRY) and head rice yield (HRY) of all varieties were unaffected by drain date. TRY for M205 and M206 were particularly sensitive to harvest moisture contents above 24%. All test varieties showed a comparable level of sensitivity to environmental conditions during agronomic maturity phase as evidenced by the HRY. The HRY was unaffected by harvest moisture contents above 17%. Soil moisture content over the course of the harvest was not affected by drain date at the 10-20 cm soil depth. Soil moisture at the 0-10 cm depth significantly declined over time as would be expected. Only the soil moistures at this in the M206 basins were influenced by drain date. No discernible differences in the M205 or M202 basin were attributable to drain date.

Observed differences in HRY were not associated with soil moisture content. The observed differences in yield and quality are not attributable to drain time treatments (i.e. soil moisture) during the latter stage of grain maturation. The productivity of the three test varieties may be adversely affected by the loss of flooded conditions; in that yield and grain quality are unfavorably compromised when the soil transitions from an anaerobic to an aerobic state. Results from trials at the RES in 2009 suggest that the yield and quality performance of the test varieties were most sensitive to reduced soil moisture when grain moisture was above 27% (physiological maturity stage).

End of season water-use averaged across varieties was about 0.35 and about 0.8 inches per day in 2010 and 2009 (data not shown), respectively. Shifting the drain date by a few days would result in nominal water savings at the individual field level.

General Conclusions – Grain Quality

Based on this year's results and those from the previous three, late season management guidelines for M205 and M206 are as follows.

1. Field drainage. Fields can be drained 24 to 28 days after heading without any loss in yield or milling quality in the heavy basin soils.
2. Total rice yield. Harvest when the grain moisture content is below 24%. Harvesting at higher moisture contents reduces the total rice yield.
3. Head rice yield. Harvest between 17 and 24% moisture for maximum milling yield. Head rice yield declines if harvested at less than 17%. Head rice yield can be lost if the rice remains in the field at around 17% for extended periods of time. Recurring drying-rehydration cycles are most detrimental when rice is at this moisture level or less.
4. Harvesting at moisture contents above 24% requires aeration within a few hours to prevent off-odor development, the cost of drying is higher, and total rice yield may be reduced.
5. No information is available describing head rice, total rice, and yield performance of the other important California varieties with regard to drain date, late season soil moisture conditions, or across a range of harvest moisture contents.

Storage Insect Survey

A survey of several facilities that store rice was conducted using pheromone and probe traps. Grain, storage spaces, and farm bins were monitored. In grain stored in a flat bed warehouse, the most prevalent insect caught in pheromone and probe traps was the Angoumois grain moth (AGM), an internal grain feeder. The AGM appeared at the beginning of spring and number of moths captured increased during the summer until grain was fumigated. In pheromone traps located around storage bins in two mills, the AGM and lesser grain borer (LGB) were caught during spring and summer. Number of Indianmeal moths (IMM) caught was very low. In farm bins, mold feeding beetles were prevalent. Their numbers decreased as ambient temperature dropped and grain dried. AGM, LGB and IMM pheromone traps inside farm bins did not catch any insects.

PUBLICATIONS OR REPORTS:

Espino, L., R. Mutters, and J. Thompson. 2010. Monitoring pests of stored rice in California. Poster abstract. Rice Field Day, Rice Experiment Station, Biggs, CA.

Espino, L., R. Mutters, and J. Thompson. 2010. Monitoring pests of stored rice in California. Poster presented at the 2010 Annual Meeting of the Entomological Society of America, Dec.13-15, San Diego, CA.

REFERENCES

Bousquet, Y. 1990**.** Beetles associated with stored products in Canada: An identification guide. Canadian Governement Publishing Centre, Ottawa.

Cogburn, R. R. 1980**.** Insect pests of stored rice, pp. 289-310. *In* B. S. Luh [ed.], Rice: production and utilization. AVI Publishing Company, Inc., Westport.

Gorham, R. J. 1991**.** Insect and mite pests in food. United States Department of Agriculture, Agricultural Research Service and United States Department of Health and Human Services, Washington, D. C.

Howell, T. A. 2003. Rice storage, pp. 545-566. *In* C. W. Smith and R. H. Dilday [eds.], Rice. Origin, history, technology and production. Wiley, New Jersey.

Pedersen, J. R. 1992. Insects: Identification, damage, and detection, pp. 435-489. *In* D. B. Sauer [ed.], Storage of cereal grains and their products. American Association of Cereal Chemists, Inc., St. Paul.