ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
April 1, 2018 – December 31, 2018

PROJECT TITLE: Weedy Red Rice Control in Rice

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OBJECTIVES OF PROPOSED RESEARCH:
1. To assess the current distribution of CA weedy red rice by conducting a survey along with grower interviews, and from the survey, to generate a genetic analysis and morphological analysis of weedy red rice in CA
2. To expand our knowledge of weedy red rice ecology including response to burial in the soil, longevity in the seedbank, and germination and emergence patterns during the season
3. To disseminate pertinent results and best management practices to rice growers and other stakeholders

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

Objective: To survey the distribution of weedy red rice in CA and generate genetic analyses of weedy red rice populations

1.1 **Survey and Grower Interviews.**

Since the beginning of the 2016 season, the UCCE Rice Team has been working together with growers, Pest Control Advisers, and County Agricultural Commissioner's offices to identify weedy rice infestations. By the end of the 2016 season, we had identified 5 distinct ecotypes (populations) (Figure 1). The infested fields covered over 10,000 acres, and were found in every major rice-growing county in California, with the exception of Sacramento County (Figure 2).

The surveys and submissions continued in 2017, with good participation. Many growers, PCA's and County Ag Biologists submitting fields or samples for testing. We had a total of 53 samples submitted for testing, and 15 were confirmed to be weedy rice. The California Crop Improvement Association (CCIA) began their first year of the new seed law and Quality Assurance (QA) Program, and found eight seed fields infested with weedy rice (all were rejected as seed field). Three of the fields were new medium-grain seed fields (never before been in the seed certification program); one field was a previously-certified medium-grain seed field; and four fields were specialty variety seed fields newly submitted to the QA program.

This past year, in 2018, we 25 samples were submitted. 5 were confirmed to be weedy rice, in a total of 4 sites (1 site had 2 types). One new biotype was found, Type 6 (Figure 3). A preliminary phenotypic assessment describes its characteristics as: black-hulled, awned (awns are red in color), and it is tall (similar in height to types 1, 2, 3, and 5). It was found at only one location, in Butte County.

Soil Sampling and Grower Interviews

In fall 2016, nine growers were identified that had large weedy rice infestations. All ecotypes were represented except for ecotype 4, and all counties were represented, except for Yolo county. One field without a weedy rice infestation was also sampled, to ensure the seed extraction methodology was not biased.

After the fields were harvested, soil samples were taken in each field. A 680-foot transect was measured in each field, and soil cores of equal volume were collected at every 20 feet, for a total of 34 samples per field. Soil cores were refrigerated until processing. Cores were processed by dissolving in them in a saline solution to extract the organic matter. Any undissolved soil was then washed through a strainer to ensure maximum seed extraction. All recovered rice seeds were subjected to a potassium hydroxide test (KOH test) to determine if they were red pericarped. All seeds testing positive for the KOH test were assumed to be weedy rice, since the soil samples were all collected from fields that were planted with brown pericarped varieties.

The number of seeds were averaged across the soil samples per field, to determine the amount of seed per meter squared of soil (to a depth of 0.25 meters) and the percentage of samples containing seeds were also calculated. The same fields were again sampled in fall of 2017, after harvest (with the exception of the control field), and again in 2018. In 2018, one grower opted out of participation, so we only had 8 fields.

Results

The number of seeds per volume varied considerably between fields, as did the percentage of cores containing seeds. In general, the longer the length of time that the field was infested, the more weed rice seeds were found in the soil. Growers that were taking steps to reduce the infestation tended to have lower seed counts as well. Some fields had increases in 2017, and some had decreases (Table 1). With just two years of sampling, it is difficult to tell if the differences were due to real changes in the soil seedbank, or simply an artifact of sampling methodology. Once 2018 samples are processed, the trend should become more clear. The average change (over all locations) in both seeds per meter squared and in percentage of samples present increased from 2016 to 2017 (Figures 4 and 5).

Table 1. Weedy rice seed counts from soil samples collected in Fall 2016 and 2017.

County	Biotype	Seeds m^{-2}		Samples Present (%)	
		2016	2017	2016	2017
Butte	1	13.4	12.4	41	38
Sutter	1	1.0	0.0	6	0
San Joaquin	1	9.9	5.4	32	21
Glenn	1	2.0	12.9	9	24
Yuba	2	12.4	0.0	21	0
Sutter	2	2.0	10.4	12	32
Colusa	3	1.0	17.3	6	48
Colusa	3	3.0	38.6	18	76
Sutter	5	16.8	37.1	42	52
Yolo	Control	0.0	--	0	--

Genetic Screening Service. The preliminary results from our weedy rice genetic analysis (2016-2017) made it seem possible that we would find a marker that could distinguish between the biotypes. After 2 years of work, we were not able to identify a marker that could distinguish between the weedy rice biotypes. However, the Rc gene (for red pericarp) can be used to distinguish between red and brown pericarped biotypes. It does not distinguish between weedy and cultivated rice, so determining if a red-pericarped specimen is weedy still requires growing the plant to heading (in the greenhouse), to evaluate shattering and dormancy.

Objective: To expand current knowledge of weedy red rice ecology

Germination Depth and Irrigation. The weedy rice populations were tested to determine the depth of soil from which they germinate, under flooded conditions only. The experiments were conducted outside under field conditions, by Liberty Galvin, Kassim Al-Khatib's PhD student. Results are reported in his RRB report.

Competition Studies and Growth Potential. A greenhouse experiment was conducted to determine the relative competitive ability of the weedy rice biotypes (1 to 5) in comparison to M-206, as it is the most widely grown rice variety in California. A second experiment, to assess growth potential of each weedy rice biotype was also conducted in the greenhouse.

Methods

For growth potential measurements, ten plants each of M-206 and the five weedy rice biotypes were planted with one plant per pot in a greenhouse set at 33/17 C day/night temperature and 33%/84% relative humidity and ambient light at the Rice Research Station in Biggs, California in October 2017. Pots were kept at water saturation and fertilized as needed. Beginning one week after planting, the height and tiller number of each plant was measured weekly for 12 weeks. At 13 weeks after planting, final yield component measurements were taken for plant height, tiller number, panicle number, seed weight, fresh biomass, dry biomass, root dry weight, and 100 seed weight.

For competition experiments, an additive experimental design was used with complete block randomization. Blocks consisted of four M-206 plants grown in a pot at a density of 32 plants m^{-2}, with varying weedy rice densities of 0, 8, 16, 24, or 40 plants m^{-2} (0, 1, 2, 3, or 5 weedy rice plants per pot) (Figure 6). The five weedy rice biotypes were each tested against cultivated rice in separate pots. The blocks were repeated in time, with four successive plantings two weeks apart in August and September 2017, with the greenhouse conditions listed above. Plant height and tiller number were measured for each M-206 and weedy rice plant weekly for 12 weeks. At 13 weeks after planting for M-206 and weedy rice, final yield component measurements were taken for plant height, tiller number, panicle number, panicle weight, seed weight, fresh biomass, and dry biomass. Hundred seed weight was measured for pooled M-206 from each pot, as individual plants at high weed densities produced small quantities of seeds.

Results

Preliminary results in the growth potential experiments indicate that weedy rice biotypes 1, 2, 3, and 5 are significantly taller than M-206 (Table 2), but type 4 is significantly shorter than M-206. Type 2 tillered at about the same rate as M-206, but Types 1, 3, 4 and 5 had significantly higher numbers of tillers. Types 3 and 4 had more than twice as many tillers per plant as the M-206. The difference in total panicle number was approximately the same as the differences in tiler numbers. Total panicle weight was significantly higher in Type 1, but all other types had similar panicle weight to M-206. Yield per plant (g) was only significantly higher in Type 1. All other biotypes had similar yields to M-206. Fresh and dry biomass was highest in type 2, and lowest in type 4, when compared to M-206. Root biomass was highest in types 1 and 5. 100-seed weight (g) was highest in type 2. M-206 had a higher 100-seed weight than all of the weedy rice biotypes with the exception of type 2.

Table 2. Final yield potential measurements of plant height, tiller number, panicle number, above-ground fresh biomass, above-ground dry biomass, root dry biomass, panicle weight, seed weight per plant, and 100 seed weight for M-206 cultivated rice and five weedy rice biotypes grown in the absence of competition. Letters indicate significant differences between biotypes arranged horizontally.

Biotype	M-206	1	2	3	4	5
Plant Height (cm)	**106.5 a**	**155.0 b**	**146.5 b**	**130.2 c**	**92.3 d**	**124.7 c**
SE	1.6	4.8	2.7	4.7	1.5	1.7
Tiller Number	**11.4 a**	**18.2 b**	**11.5 a**	**23.8 c**	**26.8 c**	**18.4 b**
SE	1.1	0.8	1.2	2.4	2.4	1.9
Panicle Number	**11.2 a**	**18.4 b**	**14.5 ab**	**33.0 c**	**29.1 c**	**16.8 ab**
SE	1.1	0.9	1.2	3.0	3.1	2.0
Total Panicle Weight (g)	**35.23 a**	**49.54 b**	**35.59 a**	**41.44 ab**	**39.37 ab**	**32.64 a**
SE	4.51	3.68	4.97	5.51	5.43	4.61
Yield per Plant (g)	**29.76 a**	**44.06 b**	**30.30 a**	**32.53 a**	**24.99 a**	**28.01 a**

SE	3.84	2.96	4.27	4.59	3.55	4.12
Fresh Biomass (g)	**90.58 a**	**166.64 b**	**116.58 ac**	**132.41 c**	**48.88 d**	**120.23 ac**
SE	7.75	10.66	14.18	17.27	6.66	10.29
Dry Biomass (g)	**24.77 a**	**49.43 b**	**35.26 c**	**36.04 c**	**13.51 d**	**36.16 c**
SE	2.10	3.03	3.52	4.51	1.56	3.70
Root Dry Biomass (g)	**19.05 a**	**43.79 b**	**22.57 a**	**37.31 ab**	**12.63 c**	**47.09 b**
SE	2.79	9.73	5.34	10.72	3.59	17.04
100 Seed Weight (g)	**2.62 a**	**2.00 b**	**2.78 c**	**2.54 d**	**2.45 d**	**2.48 d**
SE	0.03	0.01	0.03	0.02	0.03	0.03

SE: standard error.

Preliminary results in the competition experiment indicate that regardless of biotype, weedy rice density of 8 plants m^{-2} affected M-206 yield components, including: 1) weight per panicle, which decreased from 2.5 g to 1.5 g (40% reduction) (Figure 7); 2) aboveground dry biomass, which decreased from 24 g per plant to 17 g per plant (30% reduction) (Figure 8); 3) panicle number, which decreased from 7 panicles per plant to 5 panicles per plant (30% reduction) (Figure 9); and 4) yield per plant, which decreased from 19 g per plant to 11 g per plant (40% reduction) (Figure 10).

Regardless of biotype, weedy rice density of 16 plants m^{-2} affected: 1) height, which decreased from about 105 cm to about 98 cm (7% reduction) (Figure 11); and 2) tillering, which decreased from about 9 tillers per plant to about 7 tillers per plant (13% reduction) (Figure 12).

In-Season Field Trials.

The research began in 2018 at the UC Davis Agronomy Field Headquarters. Due to constraints of field setup, the field was divided into three areas, each approximately 2/3 acre (approximately 0.25 ha). Thus the treatments will be un-replicated in space, but will be replicated in time. Treatments will start in 2019, as follows:

1) **Treatment 1 (Control)** will be seeded and maintained as is typical of most CA rice: pre-germinated seed will be broadcast into a flooded field. The plots will be maintained with a 10-cm flood up to approximately 1 month before harvest, when the field will be drained to allow for harvesting equipment to move onto the field. The treatment will remain the same over the three-year project period.
2) **Treatment 2 (Stale Seedbed)** will be managed with a light tillage in the spring, followed by a flush of water to allow weed germination. Approximately 2 weeks after the initial flush, the field will be sprayed with glyphosate. 24-hours after the glyphosate application, the field will be flooded 3-4, and rice will be seeded into the flood. The treatment will remain the same over the three-year project period.
3) **Treatment 3 (Crop Rotation)** will be seeded with sorghum for the first year. Herbicides registered in CA known to control grasses will be utilized. The treatments will also be seeded in sorghum the second year, before being rotated back into rice for the third year.

Within each treatment plot (basin), weedy rice biotypes 1, 2, 3, and 5 were seeded in plots (8 feet by 150 feet). Plots were replicated three times per biotype within each basin, in a Completely

Randomized Design. This year, 2018, was an establishment year for the weedy rice populations. Due to late irrigation (June, 2018), the fields were transplanted with weedy rice plants. Bird damage occurred starting in July. At the end of the season, plants were hand-harvested and seed was shattered onto the soil surface. Where bird damage was severe, plots were overseeded with weedy rice seed that was grown in a greenhouse, at a rate of 20,000 seeds per acre (based on the soil seedbank assessments from grower fields).

Over-Wintering Experiment.
The overwintering experiment will start in fall of 2019. It will be set up in tubs outside at a fenced location at the UCCE Colusa office. It will be set up as a Randomized Complete Block Design (RCBD) with a split-plot design with 3 replications of each main plot treatment. The split-plots will be the four weedy rice ecotypes. Each main plot will be divided into four sections, into which the four weedy rice ecotypes will be randomized.

The four main-plot treatments to be tested are as follows:

1) Control: ambient winter conditions;
2) Flooding: flooded to 3-4 inches above the soil surface in October, and maintained through February;
3) Burning: a slow and hot burn of the rice straw will be conducted in October, and then ambient winter conditions will be maintained through the rest of the experiment; and
4) Flooding x Burning: a slow and hot burn of the rice straw will be conducted in October, and then a 10-cm flood will be maintained through February.

A preliminary (unreplicated) experiment to test experimental methodology will begin in January 2019. Weedy rice seed will be either mixed up into the soil (distributed evenly through the soil profile), or will be placed in mesh bags at pre-determined depths.

Drone Mapping.
Methods
Drone imagery was collected two different flight altitudes of 40 meters and 70 meters above ground level, simultaneously using both red-green-blue (RGB) and multispectral (blue-green-red-red edge, and near infrared) cameras. These cameras were set to trigger along pre-planned autonomous flight paths, so that they had approximately a 85% overlap with each adjacent picture (e.g. equaling approximately 1000 multispectral picture locations for the 40m altitude flight). Additionally, 7 ground control targets were placed in the field, and used a Trimble Geo 7X GPS unit to record their positions to within 5 cm of accuracy. Luis Espino then used the GPS unit to record the positions of 15 patches of weedy rice. Lastly, white target values were recorded before each flight to later calibrate the multispectral imagery into reflectance.

Following the flights, the photogrammetry software (Pix4D Mapper Pro) was used to ‘stitch’ the RGB and multispectral camera images together, at each of the two flight altitudes. The output datasets for these included spatially and spectrally calibrated orthomosaics and digital surface elevation models. Unfortunately, due to the nature of how photogrammetry software functions, wherein it attempts to automatically identify matching high contrast key points between images to tie them together, the 40-meter altitude flight imagery would not process correctly. The problem undoubtedly was that locations within the rice field were too similar to other parts of the field at that low altitude (where homogeneity of the rice between picture frames was more apparent than at the higher 70m flight altitude). Nevertheless, the 70-meter altitude imagery did stitch together nicely, was calibrated to reflectance and precisely geolocated to its correct geographic position using a projected coordinate system. This is important because it allowed the imagery to be exactly matched to the weedy rice sample points recorded by Luis.

Results
The 70-meter elevation output files were set up in a GIS, and the field sample points for the weedy rice patches were used to train a Random Forest classification model, to attempt to differentiate the weedy rice from other rice areas in the fields. Unfortunately, no matter what subsample of the field data that was used to train the classifications, a model could not be built to separate the two plant types. The reason for this is that when the rice was viewed from an overhead perspective, the stalks of rice (both weedy and regular) were very similar spectrally. Moreover, even at the high spatial resolution of the multispectral imagery (being 1.9 inches horizontal inches on the ground – quality report attached), both types of rice spectrally blended with the other underlying rice, shadows and wet surfaces. A spectral analysis of the field seemed to indicate that the greatest influence on the image spectra was the amount of shadows and wet surfaces that were mixed with the rice spectra at any given point within the field. A simple spectral comparison of one of the weedy plots, against what appeared to be a healthy area in the rice field shows that the spectral plots for each of the two sites are very similar (with 1 = blue, 2 = green, 3 = red, 4 = red edge, and 5 = the near infrared portion of the spectrum) (Figure 11). Note that the image is shown in color infrared, which provides the highest contrast between plant characteristics, with red indicating the most photosynthetic plants.

Objective: To ensure research results and best management practices are available to stakeholders
1.2 Publications and Media. Over the course of the 2016-2018 seasons, a number of extension publications were published through several different channels, including an identification brochure and poster, which were published with the assistance of the California Rice Commission (CRC). Likewise, a weedy rice-specific website, www.caweedyrice.com was also launched at the beginning of the 2017 season (with the CRC). Two videos were created and published on YouTube with the assistance of the CRC: both were focused on weedy rice identification in the field. UCCE launched a weedy rice-specific email listserv, which provided periodic updates of research and other information pertinent to weedy rice, over the course of the 2017 and 2018 seasons. A Weedy Rice Reporter App (for iOS and Android) was developed to allow reporting of weedy rice infestations. In both 2017 and 2018, several blog posts were published on the UCCE Rice blog, as were several updates in the UCCE County Newsletters.

Meetings and Field Days. Our UCCE Winter Rice Grower Meetings featured one talk on weedy rice in January 2017 and two talks on weedy rice in January 2018. We reached approximately 400 attendees over the 2 years, in 5 counties. A weedy rice table with plants and other materials was displayed in 2016, 2017, and 2018 at the Rice Experiment Station's Annual Rice Field Day.

Individual Grower Management Plans. Grower collaborators in the weedy rice seedbank sampling project received individual assessments and recommendation plans specific to their fields (see Appendix 2 for an example).

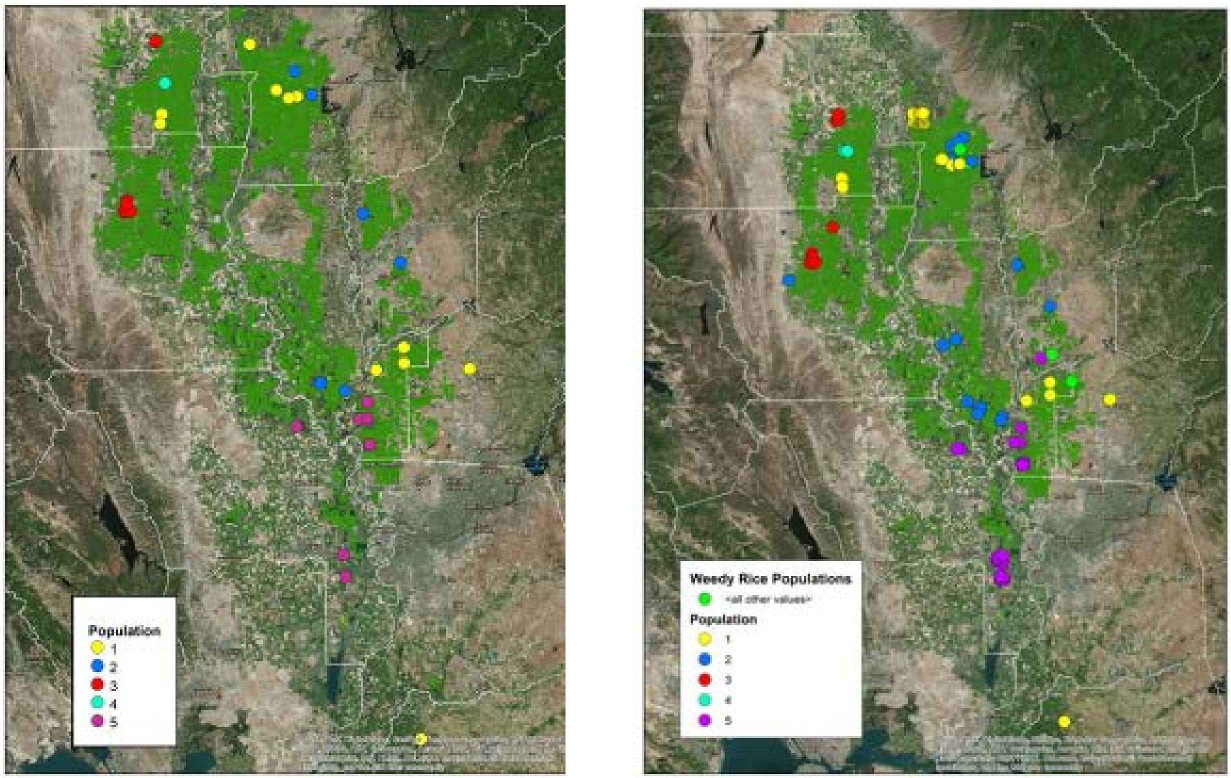
GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:
The past three seasons of work on the weedy rice populations in California yielded information regarding the number of populations as well as the approximate distribution of those populations. Genetic analysis confirmed that the five populations were genetically and morphologically distinct from one another. Comparison to weedy rice populations from around the world has begun to elucidate the possible pathways for introduction of weedy rice into California, as well as giving insight into prevention of its spread. Information on dormancy and shattering has allowed UCCE advisors to begin to give management recommendations based on which population is found in a field. Competition experiments and growth potential experiments in the greenhouse yielded specific reductions in several yield components. A drone flight with the IGIS Center at UC Davis was not able to distinguish between rice weedy rice and other species, including watergrass. Work will continue next year on the drone concept.

Effective teamwork with the rice industry enabled information to be passed on to as many stakeholders as possible. Much information remains to be researched on weedy rice in California, but this first year provided a strong foundation from which to continue research and extension on this important pest.

APPENDIX 1: FIGURES

Figure 1. The five populations of weedy rice found in California in 2016 (L-R), and M-206 (furthest right).

Figure 2. The newest weedy rice biotype, Type 6, found in 1 location in 2018. Preliminary phenotypic characteristic indicate that it is awned, black-hulled, with height similar to types 1, 2, 3, and 5.



2016 2017

Figure 3. Map displaying the locations (by population) for the five weedy rice types found in California in 2016 (Left) and 2017 (Right)

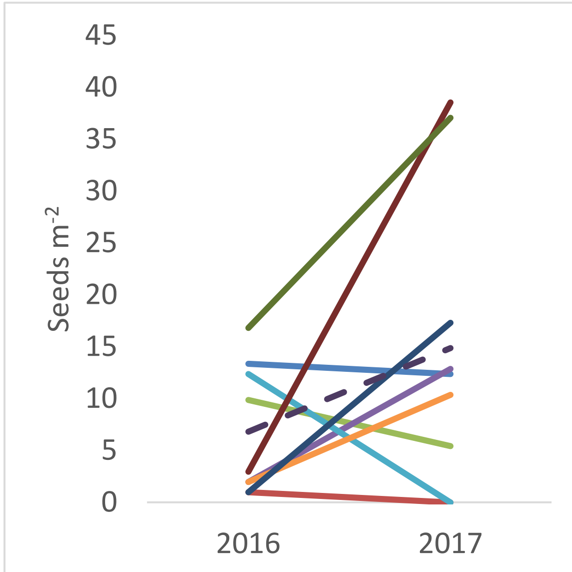


Figure 4. Weedy rice soil seedbank sampling in 2016 to 2017, per field (seeds m^{-2}). Solid lines represent individual fields. Dashed line is an average of all fields.

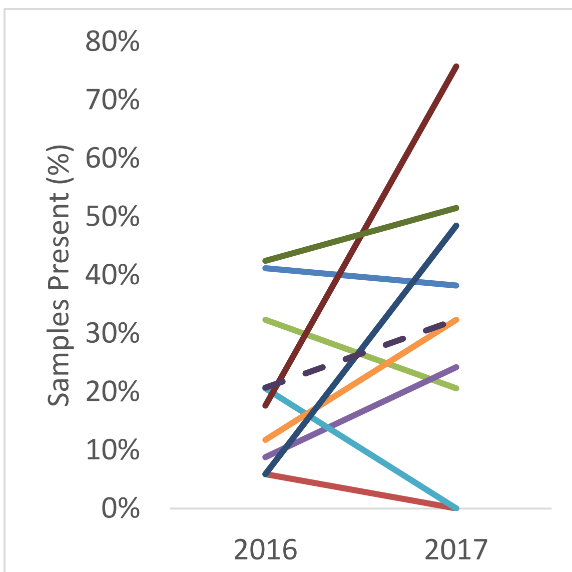


Figure 5. Weedy rice soil seedbank sampling in 2016 to 2017, per field (% samples present). Solid lines represent individual fields. Dashed line is an average of all fields.

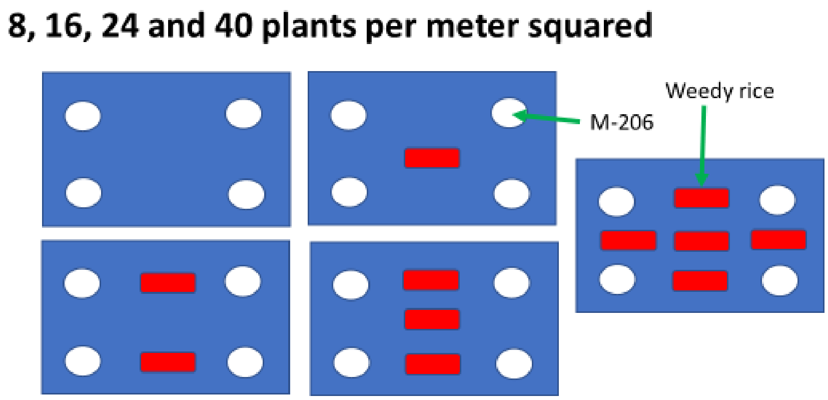


Figure 6. Planting arrangement (8, 16, 24 and 40 weedy rice plants per meter squared) for additive competition experiment with medium rice cultivar, M-206. M-206 plants are represented by white circles and weedy rice plants are represented with red rectangles.

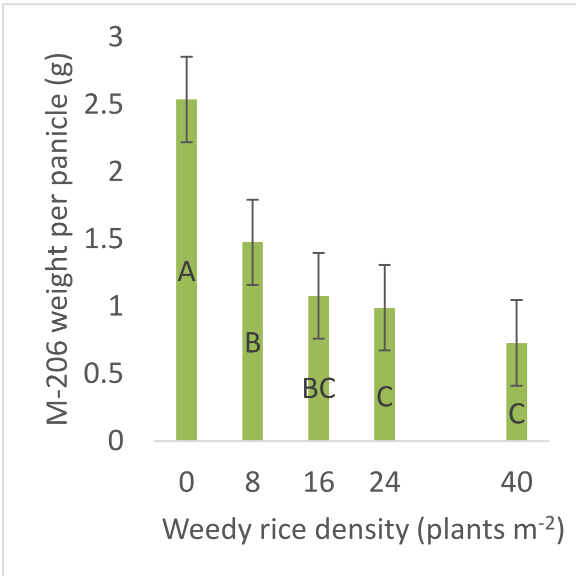


Figure 7. Additive competition experiment with weedy rice biotypes and medium-grain cultivar, M-206. Weedy rice densities are 0, 8, 16, 24 and 40 plants m^{-2}. Letters represent significant differences in weight per panicle (g), using the Tukey Means Separation test. Bars with different letters are significantly different (alpha = 0.05).

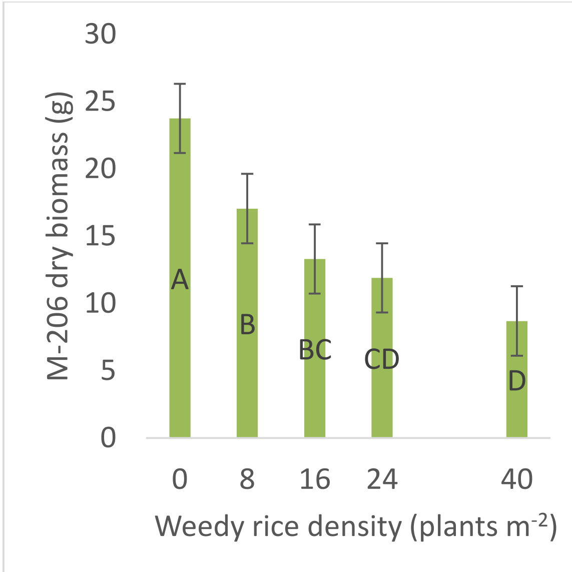


Figure 7. Additive competition experiment with weedy rice biotypes and medium-grain cultivar, M-206. Weedy rice densities are 0, 8, 16, 24 and 40 plants m^{-2}. Letters represent significant differences in dry biomass (g), using the Tukey Means Separation test. Bars with different letters are significantly different (alpha = 0.05).

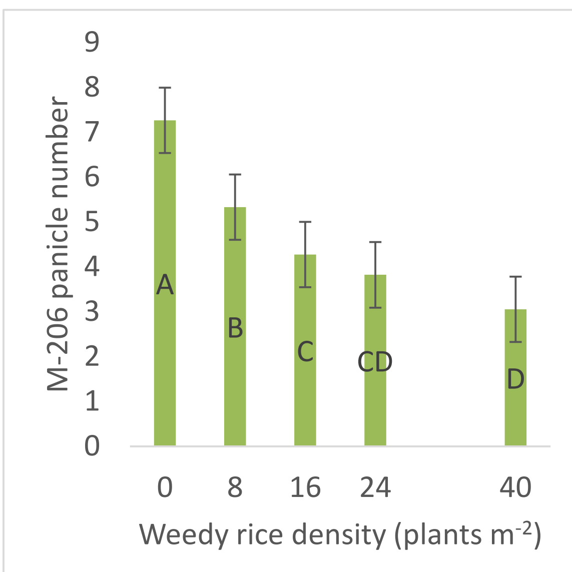


Figure 7. Additive competition experiment with weedy rice biotypes and medium-grain cultivar, M-206. Weedy rice densities are 0, 8, 16, 24 and 40 plants m^{-2}. Letters represent significant differences in panicle number, using the Tukey Means Separation test. Bars with different letters are significantly different (alpha = 0.05).

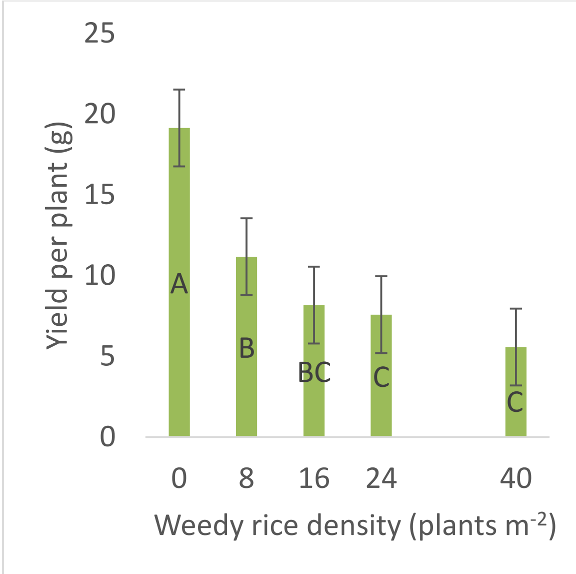


Figure 8. Additive competition experiment with weedy rice biotypes and medium-grain cultivar, M-206. Weedy rice densities are 0, 8, 16, 24 and 40 plants m^{-2}. Letters represent significant differences in yield per plant (g), using the Tukey Means Separation test. Bars with different letters are significantly different (alpha = 0.05).

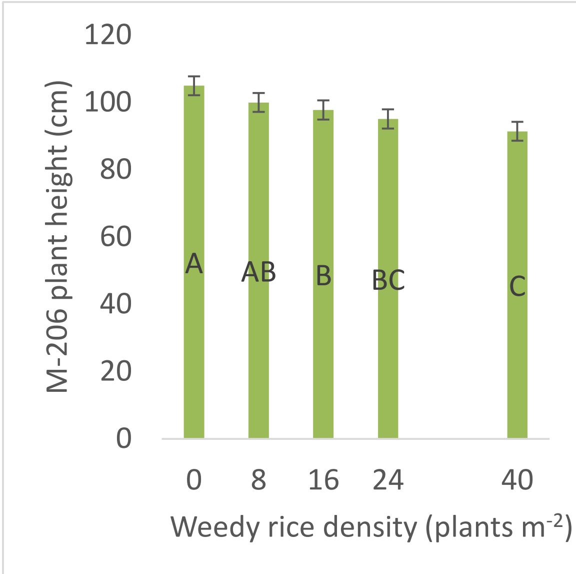


Figure 9. Additive competition experiment with weedy rice biotypes and medium-grain cultivar, M-206. Weedy rice densities are 0, 8, 16, 24 and 40 plants m^{-2}. Letters represent significant differences in plant height (cm), using the Tukey Means Separation test. Bars with different letters are significantly different (alpha = 0.05).

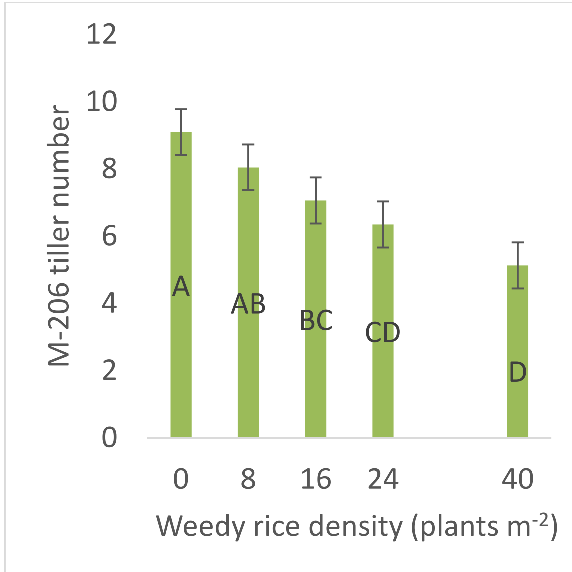


Figure 10. Additive competition experiment with weedy rice biotypes and medium-grain cultivar, M-206. Weedy rice densities are 0, 8, 16, 24 and 40 plants m^{-2}. Letters represent significant differences in tiller number, using the Tukey Means Separation test. Bars with different letters are significantly different (alpha = 0.05).

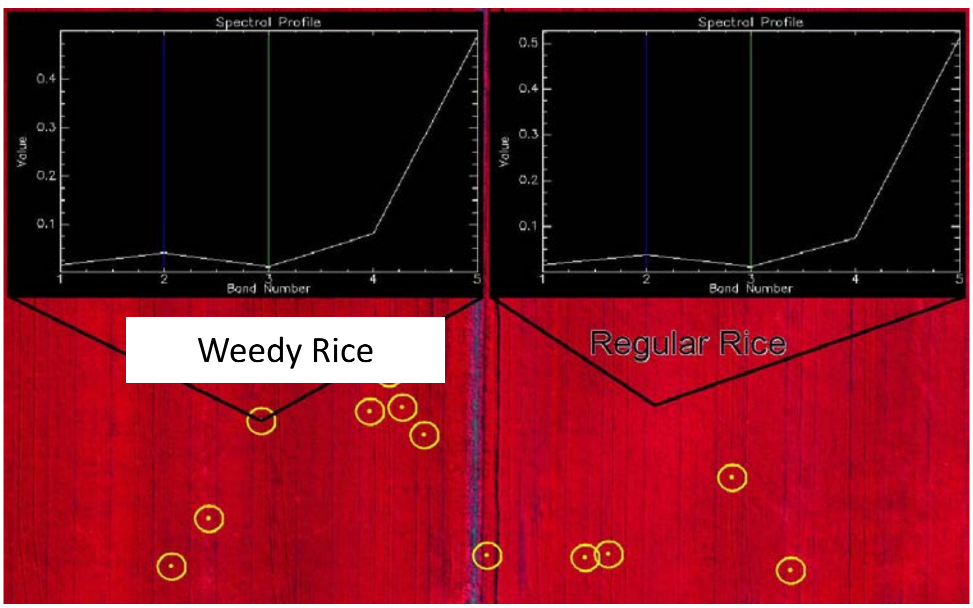


Figure 11. A simple spectral comparison of one of the weedy plots, against what appeared to be a healthy area in the rice field shows that the spectral plots for each of the two sites are very similar (with 1 = blue, 2 = green, 3 = red, 4 = red edge, and 5 = the near infrared portion of the spectrum) (Figure 11). Note that the image is shown in color infrared, which provides the highest contrast between plant characteristics, with red indicating the most photosynthetic plants.

APPENDIX 2.

SAMPLE:

Grower Report: Weedy Rice Soil Sampling

In fall 2016, nine growers were identified that had large weedy rice infestations. All ecotypes were represented except for ecotype 4, and all counties were represented, except for Yolo county. One field without a weedy rice infestation was also sampled, to ensure the seed extraction methodology was not biased.

After the fields were harvested, soil samples were taken in each field. A 680-foot transect was measured in each field, and soil cores of equal volume were collected at every 20 feet, for a total of 34 samples per field. Soil cores were refrigerated until processing. Cores were processed by dissolving in them in a saline (salt) solution to extract the organic matter. Any undissolved soil was then washed through a strainer to ensure maximum seed extraction. All recovered rice seeds were subjected to a potassium hydroxide test (KOH test) to determine if they had red pericarp. All seeds testing positive for the KOH test were assumed to be weedy rice, since the soil samples were all collected from fields that were planted with brown pericarped varieties.

The number of seeds were averaged across the soil samples per field, to determine the amount of seed per meter squared of soil (to a depth of 0.10 meters) and the percentage of samples containing seeds were also calculated. The same fields were again sampled in fall of 2017, after harvest.

Results
The type of weedy rice in this field was: **Type 1**. Type 1 is high shattering and high dormancy. This means that a high number of seeds fall easily off the panicle before harvest. The high dormancy indicates that the seeds are likely to last a long time in the soil (possibly up to 10 years, based on information about weedy rice types from the southern United States).

The number of seeds per volume varied considerably between fields, as did the percentage of cores containing seeds. In general, the longer the length of time that the field was infested, the more weed rice seeds were found in the soil. This particular field saw a decrease both in the number of seeds per m^2 (Table 1, Figure 1), and percentage of soil cores containing seeds (Table 2, Figure 1).

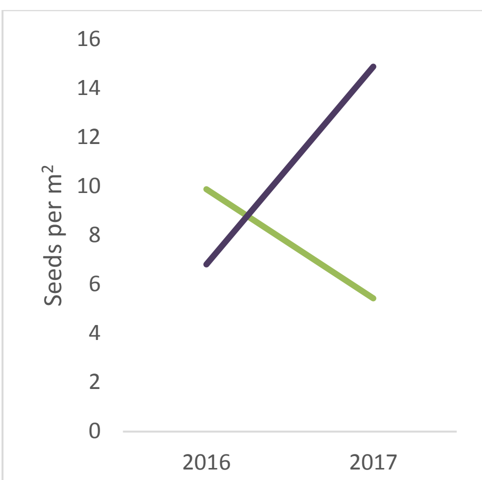
Table 1. The number of weedy rice seeds per m^2, in the top 10 cm of soil for each of the nine weedy rice fields in 2016 and 2017, as well as the average number of weedy rice seeds per m^2 overall in all fields combined. The red text (3rd line) is this particular field (JM).

Fields	**Seeds per m^2**	
Type	**2016**	**2017**
1	13.35	12.36
1	0.99	0.00
1	9.89	5.44
1	1.98	12.86

2	12.36	0.00
2	1.98	10.39
3	0.99	17.31
3	2.97	38.57
5	16.81	37.09
Average	**6.81**	**14.89**

Table 2. The number of samples containing weedy rice seed (%) in all 9 weedy rice fields in 2016 and 2017, as well as the average number of samples containing weedy rice (%) across all fields. The red text (3rd line) is this particular field (JM).

Fields	**Samples Containing Seeds (%)**	
Type	**2016**	**2017**
1	41%	38%
1	6%	0%
1	32%	21%
1	9%	24%
2	21%	0%
2	12%	32%
3	6%	48%
3	18%	76%
5	42%	52%
Average	**21%**	**32%**



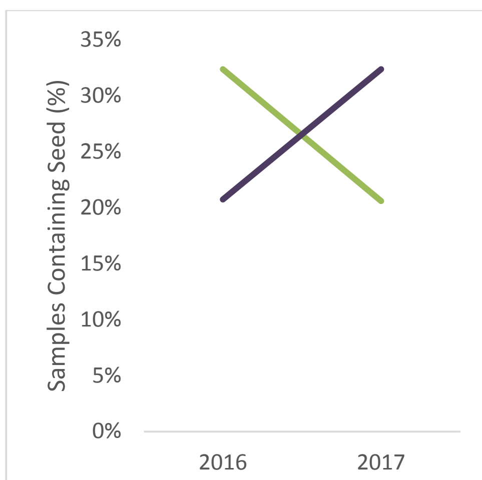


Figure 1. Seeds per m^2 (left) and samples containing seed (%) (right) for this particular field (JM: grey line) and overall average of all weedy rice fields (brown line).

Recommendations:

- Since Type 1 is high shattering, it is recommended that plants be rogued out early in the season.
- Type 1 also has high dormancy, so it is likely to remain in the soil for a long amount of time. Less tillage, or shallow tillage is recommended.
- Using crop rotation or a fallow (no-till) is also recommended to maximize seed deterioration in the soil.
- Lastly, this grower should continue to follow his current practices, as the practices appear to be reducing the weedy rice soil seed bank.