Rice Notes
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In This Issue

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Weeds to Watch Out for in 2021: Watergrass and Weedy Rice (with some management tips)

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Watergrass

We are having more and more difficulties controlling watergrass over the past 20 or so years. We know that as of the early 2000s, we had found multiple-herbicide-resistant late watergrass (also known as mimic), as well as multiple-herbicide-resistant barnyardgrass. For early watergrass, we now have resistant biotypes (to thiobencarb), with none recorded as being multiple-herbicide resistant.

In 2017, two rice fields were identified with an unknown watergrass biotype (or species) that looked very different than the three main known species that infest California rice fields (late watergrass, early watergrass, and barnyardgrass). Both fields had extensive infestations, which were uncontrolled by repeated herbicide applications. The lack of control was coupled with outward characteristics that were not immediately identifiable to one of the known species. After extensive attempts at identification at both the UC Davis Herbarium, and even with the assistance of two Echinochloa experts at two other universities, we were unable to conclusively identify the species. In 2018, 10 more fields were identified, and samples were collected and screened for herbicide susceptibility in 2020. Rates are below (Table 1).

Table 1. *Herbicides and rates utilized for 2020 watergrass screening. Rates are in amount of product per acre.*

Trade Name	Active Ingredient	Rate
Cerano®	Clomazone	12 lb a^{-1}
Bolero®	Thiobencarb	23.3 lb a^{-1}
Butte®	Benzobicyclon + Halosulfuron	7.5 lb a^{-1}
Granite GR®	Penoxsulam	15 lb a^{-1}
Clincher®	Cyhalofop	15 fl oz a^{-1}
Regiment®	Bispyribac-sodium	0.57 oz a^{-1}
SuperWham®	Propanil	6 qt a^{-1}

Results

10 of the 10 unknown watergrass samples were not controlled at 14 Days After Treatment (DAT) (less than 50% by biomass, in comparison to the untreated controls) by Granite GR® or Butte® (Table 2). 9 of the 10 samples were not controlled by Bolero®, and 6 of the 10 were not controlled by Cerano®. SuperWham®, Regiment®, and Clincher® controlled 10 of 10 samples (at least 50% control).

Table 2. *Percent control compared to untreated control by biomass at 14 Days After Treatment of 2 known susceptible late watergrass populations (Susceptible 1 and Susceptible 2), and 10 unknown watergrass populations (identified by county and sample number).*

Control (%) Compared to Untreated Control							
	Granite GR	**Cerano**	**Bolero**	**Butte**	**Propanil**	**Regiment**	**Clincher**
Susceptible 1	68	65	92	49	100	48	92
Susceptible 2	55	63	84	22	98	81	93
Glenn 1	45	80	71	45	100	85	87
Glenn 2	37	74	7	0	98	63	83
Butte 1	45	29	16	41	100	68	86
Butte 2	47	30	17	25	100	87	84
Butte 3	36	93	0	12	100	80	87
Butte 4	19	59	47	47	100	71	78
Sutter 1	47	33	0	0	100	78	89
Sutter 2	32	44	46	0	99	68	92
Sutter 3	26	0	0	7	98	80	81
Yolo	41	68	27	22	100	81	76

For the number of living plants remaining at 14 DAT, 10 of the 10 unknown watergrass samples were not controlled by Granite GR®, Butte®, Bolero®, or Cerano® (50% or more of the plants remained) (Table 3). 10 of the 10 samples were not controlled by Regiment®, 9 of 10 were not controlled by Clincher®. SuperWham® controlled 10 of 10 samples (at least 50% control).

Table 3. *Percent control compared to untreated control by number of living plants at 14 Days After Treatment of 2 known susceptible late watergrass populations (Susceptible 1 and Susceptible 2), and 10 unknown watergrass populations (identified by county and sample number).*

Control (%) Compared to Untreated Control							
	Granite GR	**Cerano**	**Bolero**	**Butte**	**Propanil**	**Regiment**	**Clincher**
Susceptible 1	8	0	42	0	92	8	58
Susceptible 2	8	0	58	0	100	0	33
Glenn 1	0	8	0	0	100	0	8
Glenn 2	0	19	0	8	92	8	42
Butte 1	0	0	0	0	100	0	8
Butte 2	0	0	0	8	100	8	25
Butte 3	0	25	0	0	100	0	33
Butte 4	0	0	0	0	100	0	42
Sutter 1	0	0	0	0	100	0	33
Sutter 2	0	0	33	0	92	0	75
Sutter 3	0	0	0	0	92	0	0
Yolo	0	0	0	0	100	0	25

Conclusion

The results of this screening closely align with what growers are seeing in the field: the unidentified watergrass is escaping early-season granular control and is then difficult or impossible to control with later-season herbicide applications. Foliar applications in the greenhouse were highly effective (by percent biomass reduction), but since the greenhouse application was conducted at an early timing (1.5 leaf stage of grass), it is possible that later applications in the field may be less effective. Furthermore, some of the herbicides, in particular, Regiment® and Clincher®, although showing biomass reduction at this early stage application (at least 60% in most cases), did not show 100% control of individual plants, which could recover later in the season. Further testing in the field or greenhouse is necessary to determine if that is the case. Again, this matches closely with grower anecdotal evidence in the field, where the unidentified watergrass appears to recover from applications of both Regiment® and Clincher®.

For growers, this preliminary screening implies that control of this new biotype/species will need to be prioritized early in the season, with an aim at overwhelming the plants' ability to metabolize the herbicides, as well as utilizing alternative modes of action. Some possible treatments (note: these have not been field-tested and could cause phytotoxicity) could be: a stale seedbed using a non-selective herbicide; pre-plant Prowl H2O® (pendimethalin) followed by post-emergent herbicide applications; pre-plant Abolish® (thiobencarb) followed by Cerano® or Butte® or Granite GR®; Cerano® followed by Butte® or Bolero® or Granite GR®; or Butte® followed by Granite GR® or Bolero®. There is still a strong likelihood that a follow-up application may still be required later in the season, even with these early-season applications.

Research with this unidentified species or biotype is ongoing, and another larger set of samples was collected in 2020. This larger set will also be subjected to a screening in the greenhouse, and results will be reported in 2021-2022.

Weedy Rice

Although we did not confirm any new biotypes in 2021 (data pending), we want to remain vigilant, as we continue to find new fields and acreage every year. For the latest, most up-to-date reports, please make sure to visit the California Weedy Rice website (caweedyrice.com) website, and subscribe to our Weedy Rice Email Updates (on the CA Weedy Rice website).

If you currently have weedy rice infested acreage, we recommend doing the following in 2021:

1) If possible, fallow or crop rotate (with less water available this year, fallowing may be a good option)
2) Use a pre-plant stale seedbed (flush the field, wait approximately 7-10 days for weedy rice to emerge, then spray with glyphosate or other non-selective herbicide)
3) Once weedy rice can be identified:
    a. Hand rogue (make sure to pull plants completely out of the field and dispose of them)
    b. If plants have fully headed, cut panicles off into bucket to avoid seed shattering
    c. Spot spray (SUPPRESS® can be applied to a drained rice field, with a backpack sprayer). Spray at rice early boot stage. See UC Rice Blog for more specific information. NOTE: no other herbicides are labeled for spot spraying in California rice

In 2021, we would ask that growers and PCA's continue to give us a call if they suspect they have weedy rice in their fields. Please call Whitney Brim-DeForest (Sutter, Yuba, Placer, and Sacramento), Luis Espino (Butte, Glenn), or Michelle Leinfelder-Miles (San Joaquin). For Colusa or Yolo, call either Whitney or Luis.

Fertility considerations going into 2021

Bruce Linquist, CE Rice Specialist

We are experiencing a dry winter and spring. This may affect fertility management considerations in a number of ways. First, if your rice fields were not flooded over the winter and the straw was left in the field (especially if it was not incorporated), there is a strong possibility that the straw did not decompose as much as normal. This might complicate tillage operations; however it will also affect nitrogen management. Straw that has not decomposed will bind up applied fertilizer nitrogen and make it unavailable to the rice early in the season. Therefore, additional nitrogen fertilizer may be necessary in these situations. I am not a big advocate of using a lot of "starter" nitrogen (I tend to push for using as much aqua-N as possible); however in these situations, it might be advisable to add the extra N as part of the starter blend. Importantly, while the fertilizer nitrogen may be bound up early in the season, it will become available later in the season.

The second consideration is that in the past decade when we have had dry winters, state wide rice yields have tended to be high. High yields could be for a number of reasons including plenty of time for good land preparation and early planting. Given the potentially higher yield potential, higher N rates may be warranted. Thus, at PI, make sure to access the crop for nitrogen status and apply a top-dress if necessary.

I also want to draw your attention to a number of Fact Sheets we have developed on fertility management in rice systems. These can be viewed at http://rice.ucanr.edu/FactSheets/Rice/. We have Fact sheets related to nitrogen, phosphorus and potassium management.

Finally, the Rice Research Board is funding some research to quantify nutrient deficiencies in rice fields other than N, P and K. We will be focusing on sulfur, calcium, magnesium, as well as some micro-nutrients like zinc. We are looking for fields where we can take soil and plant samples this year. The soil samples will need to be taken before any fertilizer has been applied. We also plan on taking plant samples during the season. If you have a field that you would like to have us look at please contact me at my email address (balinquist@ucdavis.edu).

Looking for M-210 fields in Glenn and Butte Counties

Luis Espino, Rice Farm Advisor, Butte and Glenn Counties

If you are growing M-210 in Glenn or Butte counties this year, I would like to hear from you. I plan on selecting several M-210 fields in the northern part of the Valley and monitor them for blast. M-210 is a blast resistant variety; I want to know if the resistance allows for some small lesions to develop or if the blast fungus cannot produce lesions at all on this variety. When M-210 was developed, it was inoculated with the blast fungus in the greenhouse and proven resistant there, but sometimes field reactions to the disease are different. Evidence from last year indicates that M-210 is totally resistant, but this year we want to look closer.

Let me know if you would like to participate (530-635-6234 or laespino@ucanr.edu). Knowing how M-210 reacts to blast in the field will allow us to better manage this disease that caused so many problems last year.

Factors affecting crop rotation for rice growers

Sara Rosenberg, UC Davis Graduate Student, Cameron Pittelkow, UC Davis Professor, Luis Espino, CE Rice Advisor, and Whitney Brim-DeForest, CE Rice Advisor

Crop rotations can decrease herbicide resistance and pest pressure, as well as offer other benefits for cropping systems such as increased yields. However, many rice environments are not considered suitable for other crops, and rotations have not been a major focus in rice research. Until recently, we had little information concerning rotation feasibility and constraints, and little documentation by growers who do rotate about the benefits rotations offer and requirements for rotations to be successful. Most rotations occur in Sutter, Yolo, and parts of Colusa county. However, as California water allotments become less predictable, fallowing is becoming more common beyond these regions and crop rotations may represent an option.

In the summer of 2020, the Rice Research Board funded a project to investigate the perceived benefits and challenges associated with crop rotations in rice systems, while also learning about grower priorities for future research. I interviewed 43 growers throughout Sacramento Valley, both those who rotate and those who are rice only, to better understand what rotations are practiced, the role rotations could play in supporting rice production, and the constraints that exist. The interview major takeaways are below:

- There was strong agreement about the potential benefits for weed control and reduced reliance on herbicides. Growers who rotated described soil health as a primary benefit, important for improving soil tilth, while also decreasing the need for fertilizer and pesticide inputs.
- Constraints include soil limitations such as heavy clay, shallow soil depth, or alkali soils. Altogether, growers felt like the combination of soil/environmental barriers with marketing difficulties meant they were left with no profitable options for rotational crops.
- Rice-only growers felt like rotations were not profitable because of expensive land payments, lacking proper equipment for rotation crops, and not having enough land or labor for alternative crops.
- Contrasting this, those who rotate said that rotations increased profitability through crop diversification and increased economic resilience.
- Conditions required for successful rotations were lighter soils which support drainage; ability to hire contractors to grow alternative crops, access to diverse markets, flexible land payments or ownership of land; appropriate equipment and land size; and raising rice in locations where rotations are already occurring, which increases access to information.
- Overall, the majority of rice-only growers expressed major challenges with weeds and anticipated they may have to change systems in future, but there was a range of urgency on this issue.
- For common crops rotated with rice, we compared preliminary information on profitability level, production costs, soil tolerance, equipment, water usage, and rotation benefits offered (Table 1)

Table 1: Summary of grower comments for common rotation crops comparing profitability level, production costs, soil tolerance, equipment, water usage, and rotation benefits.

Crop	Profitability	Production costs	Contracts available	Rotation Benefits	Equipment requirement	Soil tolerance	Irrigation requirements	Growing season
Sunflower	High	High	Yes	Intermediate crop	Different harvester and planter	May tolerate heavier soil as long as not waterlogged	Low to no irrigation required	Spring-summer
Safflower	Low	Low	No	Intermediate crop	Same	May tolerate heavier soil as long as not waterlogged	Low to no irrigation required	Spring-summer
Tomato	High	High	Yes	Rice following tomatoes does well	Different harvester and planter	Perception need lighter ground	High irrigation, drip tape	Spring-summer
Beans	Variable	Low	Yes	Can tolerate growing after rice & planted later into planting season	Same	May tolerate heavier soil as long as not waterlogged	Low to no irrigation required	Can be planted later into summer
Vine seed	Variable	High	Yes	Small market	Different harvester and planter	Requires lighter soils	Drip	Summer
Vetch	Low	Low	No	Provides nitrogen and breaks down rice straw, offers wildlife habitat	Same	May tolerate heavier soils	No irrigation required	Fall-winter
Rye	Low	-	No	May do better in rice ground compared to wheat.	Same	May tolerate heavier soils	Flood irrigation tolerant	Fall-winter
Barley	Low	Low	No	May do better in rice ground compared to wheat.	Same		Flood irrigation tolerant	Fall-winter
Wheat	Low	-	No	Can be grown as a winter or summer crop. Tomato growers like to follow wheat.	Same	Growers report poor yields and drowning out in rice environments		Fall-winter or summer
Alfalfa	Moderate	Low	No	Growers who have rotated alfalfa with rice report a high rice yield from nitrogen.	Same			
Oats	Low	Low	No	Can be mixed with vetch or hay for a forage crop	Same	May do well in combination with vetch or other forage crops	If grown with vetch no irrigation required	Fall or summer

Grower research priorities

Evaluating the economic advantages and disadvantages of crop rotation was a major area of research prioritized by growers. Growers also requested further analysis of how rotations support weed control and soil health, while potentially lowering input costs and increasing crop productivity. Research that investigates the impacts of rotations on input use and economics would be very valuable for understanding the feasibility and benefits rotations provide. In line with this, organic growers felt like there wasn't enough information for best management options with cover crops as well as how much additional nitrogen they added to soil, or how well they impacted weed pressure when used with a fallowing program.

Our next steps

This project is an important first step to determine grower priorities and concerns regarding crop rotations. I want to say thank you to all the growers who participated in the interviews last summer, without your insights and willingness to contribute this research would not have been possible. This year (2021) and in subsequent years, we intend to address some of the priorities mentioned and further refine which rotation crops are most promising for different soils and production environments. This summer, we will conduct on-farm research comparing rotated fields to non-rotated fields and investigating the economic concerns and soil health impacts of crop rotations. **If you would like to be involved with this project, please contact Sara Rosenberg (** Srosenberg@ucdavis.edu **)** before the start of the growing season. Simultaneously, and related to the on-farm research, we intend to organize focus groups to gain feedback from last year's interviews and learn the basic costs for switching over to different crops from rice. These meetings will be organized under a new project funded by the Western IPM (Integrative Pest Management) Center for creating an IPM Workgroup to tackle some of the evolving pest problems rice systems encounter.

Research team consists of- Cameron Pittelkow, Assistant Proffessor at UC Davis, Whitney Brim De-Forest, Bruce Linquist, Luis Espino, Michelle Leinfelder, Kassim Al-Khatib, and Sara Rosenberg-MSc Candidate, UC Davis.

IPM Work Group Project, Summer 2021

The California rice IPM Workgroup strives to bring together a wide range of diverse stakeholders; including rice growers, extension specialists, PCA's, industry leaders, and UC Davis faculty and student members, to explore the feasibility and impact of crop rotations and other IPM solutions as they relate to California rice production systems. Our collaborative team aims to improve and develop management options and tools for pest and disease control which will increase long-term sustainability of rice production, through conducting interdisciplinary research and outreach.

This summer's plan includes developing the overall group and organizing meetings to investigate the economic costs of switching over from rice to rotation crops. We are also going to be organizing a meeting to discuss last summer's interview findings and allow for feedback and contributions from stakeholders in expanding the list of constraints for rotations. If you would like to be involved in this work group, please **reach out to Whitney Brim-DeForest (wbrimdeforest@ucanr.edu) or Luis Espino (**laespino@ucanr.edu**)**

Herbicide Trial in Delta Drill-Seeded Rice

Michelle Leinfelder-Miles, Delta Farm Advisor

Weeds are important pests of California rice systems, and weed management can account for roughly 17 percent of total operating costs (Espino et al., 2016). Integrated weed management uses cultural and chemical practices where herbicides are important tools. Certain conditions in California rice production systems, however, increase the likelihood of developing herbicide resistance. Herbicide resistance is the ability of certain weed biotypes to survive certain herbicide treatments when the weed species is usually killed by that herbicide (Al-Khatib et al., 2019). Such conditions include, but are not limited to, lack of crop rotation, the efficacy of certain herbicides on certain weeds causing them to get frequently used, and not having diverse chemistries available.

In 2019 and 2020, trials were conducted to evaluate the efficacy of a new herbicide product called Loyant (florpyrauxifen-benzyl; group 4 herbicide; Corteva Agriscience) in drill-seeded rice in the Delta region. Loyant is registered in rice growing states in the southern US but would be a new chemistry in California. Corteva Agriscience is currently working on getting the product registered in California. The objective of the trials, by assessing different rates and treatment combinations, was to understand the efficacy and crop tolerance of Loyant for weed control in drill-seeded rice in California. This article highlights select results of the 2020 trial. Complete information from both years – including methods, herbicide rates, and full results – is available from my website (https://ucanr.edu/sites/deltacrops/Rice/).

Methods. Rice variety M.206 was drilled-seeded to moisture on April 13th. Herbicide treatments were applied on May 8th, when the rice was approximately at the 3rd leaf stage. The permanent flood was established within a few days after treatment.

Crop injury. We made crop injury observations and weed counts on 7-day intervals for about two months following treatment. We observed tip burning in several of the treatments, but the symptoms were no longer apparent by 21 days after treatment (DAT). We observed leaf curling in the Loyant treatments until about 56 DAT. Corteva Agriscience has observed this symptom with Loyant in other trials where environmental stressors impact crop health, such as extreme cold or heat, drought, or poor fertility. We observed this symptom on the side of the plots closest to the field edge. We observed no stunting, stand reduction, or differences in heading with any treatments.

Weed control. Overall weed pressure was relatively low, with about one weed per square foot in an untreated strip next to the trial. The prominent weeds in the field were *Echinochloa* species (i.e. watergrass, barnyardgrass; Figure 1). We did not have a completely untreated control but instead considered the pre-emergent only treatment (i.e. Prowl) the control. There was a trend for the Prowl treatment to have the highest weed counts. The treatments that had the best weed control were the grower standard and Loyant/SuperWham herbicide programs (Table 1).

Yield. We found no differences in yield, but there was a trend for the grower standard and the Loyant/SuperWham herbicide programs to have slightly higher yields (Table 2). Measured yields were uncharacteristically high for the region. Our explanation of the data is that we hand-harvested in the early morning hours when there was a heavy dew, and this likely inflated the weights. There was, however, low variability across the plots, which suggests that our results are a robust comparison of the treatments.

Conclusions. The purpose of the trial was to learn the efficacy and crop tolerance of Loyant (florpyrauxifen-benzyl) for weed control in California drill-seeded rice. We observed Loyant to have good activity on watergrass and barnyardgrass, which were the predominant weeds in the trial. We observed Loyant treatments to have similarly low weed counts compared to the grower standard, and a Loyant/SuperWham herbicide program appears to provide comparable weed control to the grower standard under this composition of weeds. Tank mixes may be needed when a broader array of weeds are present. The results demonstrate that Loyant could be used in drill-seeded rice herbicide programs, providing a different chemistry for herbicide resistance management.

The aforementioned information on products and practices is for educational purposes only and does not constitute an endorsement or recommendation by the University of California.

Figure 1. *Predominant weeds in the trial were watergrass and barnyardgrass.*

Table 1. *Weed counts on 7-day intervals from 14 DAT to 42 DAT. Data represent total number of weeds in the 400-ft^2 plot and are the means across four replicates.*

Herbicide Program (Treatment)	14 DAT	21 DAT	28 DAT	35 DAT	42 DAT
Loyant	3	5	2ab	3 ab	4 c
Loyant, Prowl H2O, MSO	2	3	1ab	3 ab	5 bc
Loyant, Clincher, Prowl H2O, MSO	4	3	1 b	9 ab	15 ab
Loyant, Granite SC, Prowl H2O, MSO	2	3	1ab	4 ab	9 abc
Loyant, RebelEX CA, Prowl H2O, MSO	1	1	1 b	2 b	4 c
Regiment, Sandea, Prowl H2O, SuperWham, MSO, UAN-32	3	0	8a	15 a	21 a
Prowl H2O	1	2	1 b	2 b	3 c
Loyant, Prowl H2O, SuperWham, MSO	2	2	2	5	9
Coefficient of Variation (%)	113	74	154	119	95
Significance of treatment effect (P value)	0.1757	0.2314	0.0191	0.0085	0.0011

Table 2. *Yield adjusted to 14 percent moisture. The grower reported that harvest moisture was around 18.5 percent. The trial was hand-harvested on Sept. 29, measuring one 10.8-ft^2 (1-m^2) quadrat per plot.*

Herbicide Program (Treatment)	Yield (lbs/ac)
Loyant	12575
Loyant/Clincher	12431
Loyant/Granite	13064
Loyant/RebelEX	12210
Grower standard	13438
Prowl	12335
Loyant/SuperWham	13534
Average	12798
Coefficient of Variation (%)	8
Significance of treatment effect (P value)	0.3755

Tadpole shrimp: How resistant are they to pyrethroids? We are looking for fields.

Ian Grettenberger (CE Specialist), Luis Espino (CE Rice Advisor), and Madi Hendrick (UC Davis Graduate Student)

Pyrethroids have been the go-to material of choice for tadpole shrimp management. Because they are widely used, there is a real concern that resistance to one or multiple active ingredients in this class (e.g., lambda cyhalothrin and zeta-cypermethrin). As many of you may have heard, resistance appears to have cropped up in a few areas already, although it is fairly localized. Tadpole shrimp don't move a lot across the landscape (lack of wings contributes to that!), so any resistance or "lack of susceptibility" issues likely will be localized to given fields or farms. We are conducting laboratory bioassays to measure resistance as part of our CA Rice Research Board-funded research.

We were able to gather soil/eggs from some fields last year, although some samples didn't produce any shrimp when we flooded up soil and some of this work was delayed with the changes with lab work due to Covid. Nevertheless, we noted some differences in susceptibility with the populations that we have assayed, with a roughly 25-fold difference in susceptibility between the most and least susceptible populations. We use laboratory bioassays to expose shrimp to a range of lambda-cyhalothrin concentrations to determine how susceptible they are to this material (and likely most pyrethroids).

What we could use and if you are interested/able to help:

If you have fields that have tadpole shrimp and that we can gather some soil from, please let us know. We ideally will gather soil from fields before they are flooded but after they are prepped. If fields are untreated, we can also gather shrimp from the fields. Fields where resistance is suspected would great, but any fields work. All we need is access and a place to go. Since sampling is straight-forward, we would just need a map or a map pin to go to. If you are interested, please email Ian and Madi at imgrettenberger@ucdavis.edu and mlhendrick@ucdavis.edu. Madi Hendrick is the UCD graduate student that will be working on tadpole shrimp resistance. You can also call Ian at (530) 752-0473 and he will return your call (likely not in the office).

We are also willing to check out any possible resistance issues once fields are flooded and shrimp are present. If you made an application and control seems limited, please reach out and we can try to measure lambda-cyhalothrin susceptibility in that field.

Managing Rice with Limited Water

Background

During drought years water deliveries are often restricted. In these situations, how can you use the least amount of water to grow rice without reducing yields? Based on past studies, the amount of water delivered to rice fields varies widely (i.e. 4 to 7.7 ft). This water is lost as evapotranspiration, percolation and seepage, and tailwater drainage (Figure 1).

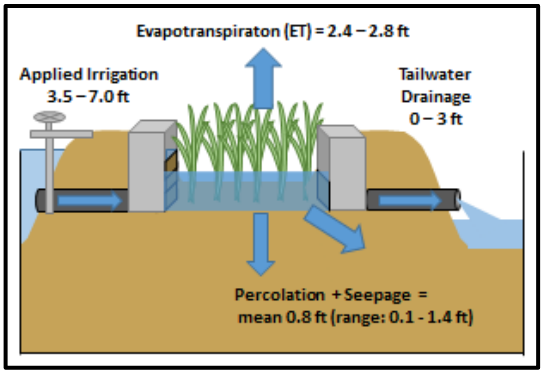

Figure 1. Ranges in water inputs and potential losses from California rice fields.

Best Practices to Conserve Water while not Reducing Yields

Avoid fields that have high percolation. In most California rice soils, water percolation rates are low due to the high clay soils that rice is typically grown on. However, some soils may have high percolation rates due to a highly permeable layer or old creek bed that runs through the field. When water is in short supply, consider fallowing these fields.

Avoid early planting. Planting early increases water use because planting occurs during a cooler time of the year. Since crop duration is dependent on temperature (growing degree days), early planting extends the duration of the crop, thus needing to be irrigated for longer and increasing ET and percolation/seepage losses.

Short duration varieties. Choose shorter duration varieties which reduce the time the field has to be flooded. Rice typically needs to be flooded from planting to reproductive stage R7 (R7, when one kernel on the main panicle is yellow; about 3 weeks after heading). Table 2 gives an indication of the differences flooding period by variety.

Table 1. Days to from planting to R7 for different varieties grown in California

Variety	Days to reach R7*
M-105, S-102, CM-101	99-102
M-206, M-210	105
M205, M-209, M-211	108-112
M-410, M-402	124-128

* *Days from planting to R7 (typically when it is time to safely drain) for different California rice varieties at the Rice Experiment Station. These days are to be used for comparison among varieties. Actual days to R7 will vary depending on year and location in the Sacramento Valley.*

Don't spill. Rice can be grown using 3.5 to 4 ft of water (depends on the percolation and seepage characteristics of the field) if there is no tailwater drainage (Figure 1). Tailwater drainage results from lowering the water for herbicide applications, maintenance flow, and draining the field at the end of the season for harvest. No-spill (no tailwater) practices require closer management of irrigation water and planning for upcoming events where water may need to be lowered. With no-spill management, yields can be maintained as long as the irrigation water has relatively low salinity (<0.6 dS/m) and soils are not saline. Most California rice fields receive irrigation water that has low salinity.

Fix leaks. Leaks around outlet boxes or in levees can result in significant water loss. These leaks can be caused by water erosion, crayfish, or rodents. Fields should be routinely monitored for such leaks and leaks repaired.

Figure 2. Leak near outlet caused by crayfish.

Don't drain at the end of the season. It is common to pull outlet boards at the end of the season to drain the field in preparation for harvest, resulting in significant tailwater drainage losses. Instead, growers should turn off irrigation before needing to drain and allow the water to naturally subside rather than drain the field. Determining when the irrigation water can be turned off depends on how much water is in the field, climate, and soil properties. Fields with heavy clay soils can safely have no standing water 21 to 24 days after 50% heading without risking yield loss and grain quality.

Dry- versus water-seeding. While it may seem counter intuitive, dry/drill seeding does not necessarily require less water than water-seeding. In California, dry seeding usually requires two or three flushes of irrigation water to establish the crop before a permanent flood is established. These flushes require a lot of water. Once the field is flooded the water has to be drained resulting in high tailwater losses. Dry seeding can use less water if rice seed is planted to moisture which reduces the need to flush the field (or number of times field is flushed) in order to germinate the seed and establish the crop.

Figure 4. Drill seeded rice field before permanent flood.

For more on this topic:

- ✓ Agronomy Research and Information Center-Rice: rice.ucanr.edu
- ✓ View video at http://ucanr.edu/insights.
- ✓ Linquist, B.A. et al. (2015) Water balances and evapotranspiration in water- and dry-seeded rice systems. Irrigation Science 33:375-385.
- ✓ Montazar, A. et al. (2017) A crop coefficient curve for paddy rice from residual of the energy balance calculations. Journal of Irrigation and Drainage Engineering. 143(2) doi: 10.1061/(ASCE)IR.1943-4774.0001117.
- ✓ Marcos, M, et al. (2018) Spatio-temporal salinity dynamics and yield response of rice in water-seeded rice fields. Agricultural Water Management 195:37-46.

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