Managing Herbicide Resistance using Alternative Rice Stand Establishment Techniques.

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Justification: Integrating cultural and chemical weed control practices may decrease weed management costs through the reduction of herbicide resistant weed populations, delayed evolution of herbicide resistance, and timely reduction of weed seed banks. Alternative cultural rice establishment techniques such as drill seeding, stale seedbed, or no-till may be used to manipulate weed species recruitment and expand herbicide options for the control of herbicide-resistant weeds. In drill-seeded rice, pendimethalin (Prowl) may be used for soil residual control of many grass species. In stale seedbed systems, weeds that emerge prior to rice planting may be controlled with non-selective herbicides such as glyphosate (Roundup) for which resistance has not evolved in weeds of rice. These herbicides provide alternative mechanisms of action, may be less expensive, and may be more environmentally benign than some of the herbicides used in conventional water-seeded rice systems. No till alternatives discourage weed recruitment and favor seedbank depletion through seed decay. Therefore, a large field experiment was established at the Rice Experiment Station to assess the effectiveness in managing herbicide-resistant weeds by altering weed species recruitment and introducing new herbicides unique to specific rice establishment systems.

RICE ESTABLISHMENT TREATMENTS IN 2007

The following alternative rice establishment systems have been developed and evaluated since 2004: 1) conventional water-seed rice, 2) conventional drill-seeded rice, 3) water-seeded rice after spring tillage and a stale seedbed, 4) water-seeded rice after a stale seedbed without spring tillage, and 5) drill-seeded rice after a stale seedbed without spring tillage. Following is a list of these treatments with a summary of crop establishment practices and herbicides used.

CONVENTIONAL WATER-SEEDED:

Conventional Water seeded:

Crop establishment:

- Spring tillage
- Permanent flood: May 22
- Water seeded: May 31

Herbicides:

- Propanil + Granite SC (6 lb a.i./a + 2 oz/a, respectively) at the 4-5 leaf rice stage (June 27).

CONVENTIONAL DRILL-SEEDED:

Crop establishment:

- Spring tillage
- Drill-seeded May 30

- Flushed for establishment May 31, additional flush June 6
- Permanent flood: June 16

Herbicides:
- Propanil, Prowl, and Clincher (6 lb a.i./a + 2.1 pt/a, 13.3 oz/a, respectively) at the 3 leaf rice stage (June 7).

WATER-SEEDED / STALE SEEDBED:

Crop establishment:
- Spring tillage
- Flushed for weed recruitment May 1 and May 13
- Water seeded June 1

Herbicides:
- Pre-flood: Roundup Weather Max (glyphosate) 1.4 lbs a.e./acre plus 2% ammonium sulfate May 29.
- Post emergence: Propanil + Granite SC (6 lb a.i./a + 2 oz/a, respectively) at the 4-5 leaf rice stage (June 27).

WATER-SEEDED / STALE SEEDBED / NO TILL:

Crop establishment:
- Flushed for weed recruitment May 1 and May 13
- Water seeded June 1

Herbicides:
- Pre-flood: Roundup Weather Max (glyphosate) 1.4 lbs a.e./acre plus 2% ammonium sulfate May 29.
- Post emergence: Propanil + Granite SC (6 lb a.i./a + 2 oz/a, respectively) at the 4-5 leaf rice stage (June 27).

DRILL-SEEDED / STALE SEEDBED / NO TILL:

Crop establishment:
- Flushed for weed recruitment May 1 and May 13
- Drill-seeded May 30
- Flushed for establishment May 31, additional flush June 6
- Permanent flood: June 16

Herbicides:
- Pre-plant: Roundup Weather Max (glyphosate) 1.4 lbs a.e./acre plus 2% ammonium sulfate May 29.
- Propanil, Prowl, and Clincher (6 lb a.i./a + 2.1 pt/a, 13.3 oz/a, respectively) at the 3 leaf rice stage (June 7).

Note: Crop oil concentrate (1.25% v/v) was added to applications of Clincher and Propanil. Ammonium sulfate (2% by weight) was added to applications of Roundup.

RESULTS SUMMARY

The following alternative rice establishment systems have been developed and evaluated since 2004: 1) conventional water-seed rice, 2) conventional drill-seeded rice, 3) water-seeded rice after spring tillage and a stale seedbed, 4) water-seeded rice after a stale seedbed without spring tillage, and 5) drill-seeded rice after a stale seedbed without spring tillage. These systems have demonstrated their potential for manipulating the kinds of weed species that emerge with rice. Thus problematic weeds can be avoided or, alternatively, controlled by new herbicides for which they do not have resistance. Pendimethalin and glyphosate are not used in water-seeded rice, but can control weed biotypes resistant to herbicides used in conventional water-seeded rice. Data averaged across four years show drastic differences in weed recruitment among systems, thus aquatic sedge and broadleaf weeds dominated the water-seeded systems, while the aerobic seedbeds of the drill-seeded systems favored grasses (*Echinochloa* spp. and sprangletop) (Figure 1). The stale seedbed technique (promotion of weed emergence with irrigation flushes, fb. pre-plant burn-down application of glyphosate at 1.2 lbs. a.e./a) had been very useful in depleting weed populations from the upper soil layer and, thus, markedly diminishing the amounts of weeds emerging with the crop. If this technique was followed by no or limited soil disturbance (to prevent new weed recruitment) prior to water-seeding rice, very little weed control was needed thereafter. Thus, the stale-seedbed technique reduced weed recruitment in water-seeded rice by about 40%, and by 70% if spring tillage was eliminated (no-till) (Figure 2). Conventional drill-seeded systems typically result in heavy weed recruitment, and although using stale-seedbed and minimum soil disturbance reduced weed recruitment by 40% (Figure 2), there were still many weeds present in System 5 (no-till drilled rice with a stale seedbed treatment).

Success with the stale-seedbed technique depends on the patterns of weed emergence and, very importantly, upon being able to keep the seedbeds moist and to allow sufficient time for most weeds to emerge prior to glyphosate application. These techniques were successful in suppressing the earlier emerging weeds, particularly *Echinochloa* spp. and smallflower umbrellasedge in dry and water-seeded rice, respectively (Figure 2), since substantial weed emergence was achieved prior glyphosate application, which resulted in very limited weed emergence thereafter (Figures 3 a and 3b). However, aquatic weeds have delayed emergence respect to rice and other weeds and little emergence had occurred by the time glyphosate was applied, thus a substantial proportion of these weeds emerged later in the season in water-seeded rice (Figure 3 b and c). To control these weeds using a stale seedbed technique a longer period of very moist conditions would be required to promote substantial emergence and thus deplete the top layer of soil of germinable weeds. In dry-seeded rice a delayed emergence of sprangletop with respect to *Echinochloa* spp. was also observed Figure 3 a). The patterns of weed infestation over time illustrate how although the mostly grass weed infestations in the no-till drill-seed rice increased over time, the system was successful in reducing recruitment of these grasses everytime the stale seedbed technique was adequately timed such that glyphosate could be applied once most weeds had emerged (Figure 4 a). In water-seeded rice, the stale-seedbed technique was successful in reducing recruitment of the mostly smallflower composed infestations, essentially also because substantial weed emergence was achieved prior to seeding rice (Figure 4 b), which could be eliminated with glyphosate to reduce subsequent weed emergence. Weed dynamics in the no-till systems was different. Although substantial amounts of weeds are eliminated with the glyphosate application, a significant proportion of sprangletop (in no-till drill-seeded rice) and of the aquatics redstem and ducksalad occurs late in the season (Figure 3 c) and infestations by these weeds have gradually increased over time (Figure 4 c). Being able to expose weeds to the action of glyphosate (or other non-selective herbicide for which resistance has not evolved) is an essential aspect of implementing alternative stand establishment techniques in order to control herbicide-resistant weeds.

Subsequently, the drill-seeded systems were treated with Clincher (13 oz/a) + propanil (4 lb a.i./a) + Prowl H_2O (2 pt/a) applied at the 3 lsr, and the water-seeded systems received propanil (lb a.i./a) + Granite SC (2 oz/a) at the 4-5 lsr. Weeds were thus controlled from all plots. Rice yields in previous years did not differ among these establishment systems. Therefore, the alternative rice establishment systems evaluated in this study may be used to effectively manipulate weed species recruitment and enable the use of herbicides that may control weed biotypes resistant to herbicides used in conventional water-seeded systems. Success in weed suppression is maximized if sufficient weed emergence is promoted prior to burn-down in the stale seedbed technique, and if spring tillage is avoided to prevent stirring up new weeds from the soil. Modeling of weed recruitment and growth is being evaluated to identify rotation options that may reduce the seed-banks of problematic weed species. Results from this research will be used to develop innovative integrated weed management programs for California rice by breaking weed life cycles through rotation of stand establishment methods, alternating herbicide modes of action, as well as effective crop interference.

Acknowledgements:

The success of this research was only possible with the cooperation and contributions of numerous people and organizations. The Rice Experiment Station has generously provided use of the large land area necessary to conduct cropping systems research as well as provide access to facilities and equipment and provide technical assistance and support. Equipment loaned by area growers (John Thompson) was greatly appreciated. This research opportunity has generated financial support from public institutions such as CalFed, USDA, and the UC-IPM program. Continued support from the people involved in these institutions and input from growers is greatly appreciated and will be necessary for future progress of this research.

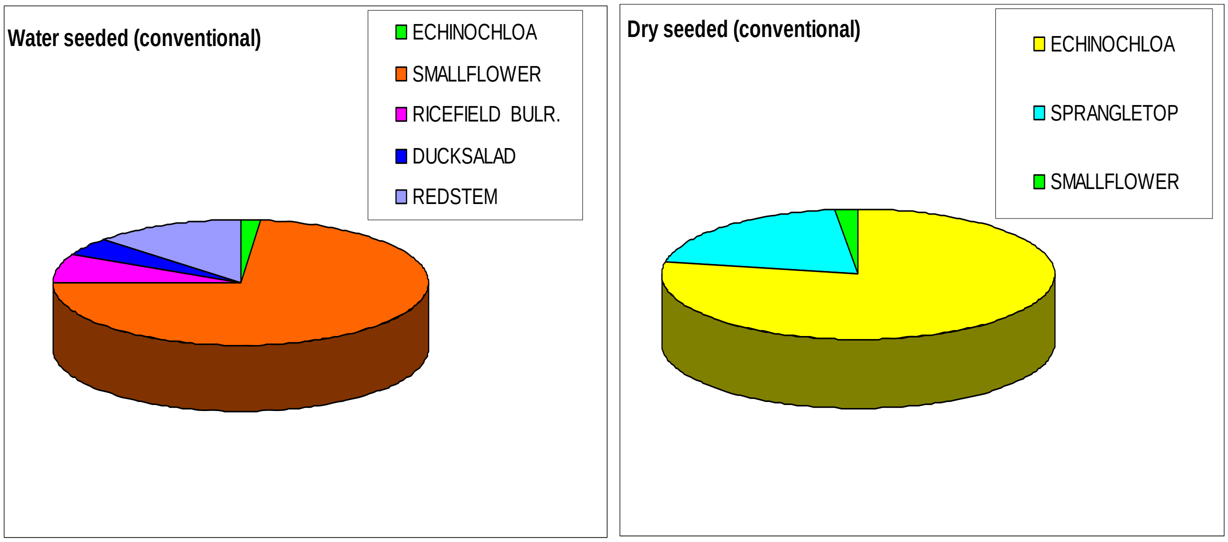

Figure 1. Proportional weed species recruitment in conventionally water-seeded and drill-seeded rice determined 35-40 days after rice emergence in plots where conventional herbicides have not been applied. Data are averages across four years of experiments.

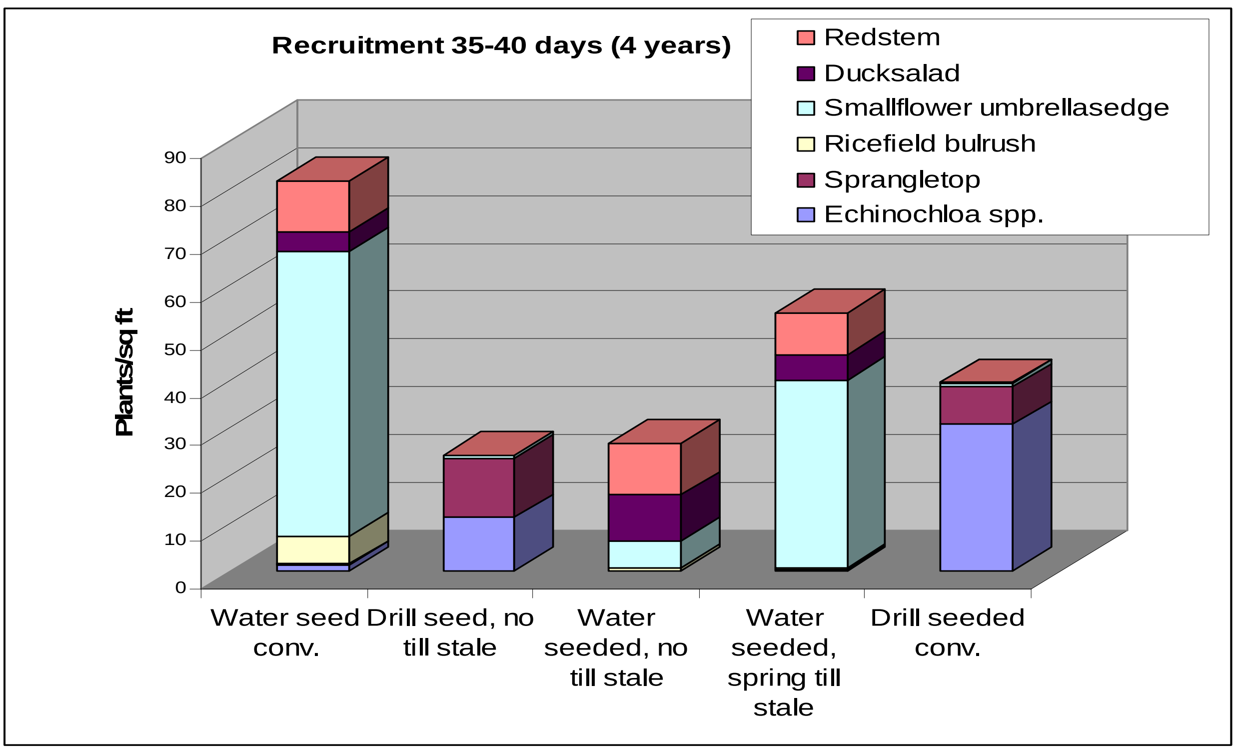

Figure 2. Effect of alternative rice establishment systems on weed species that emerge with rice in plots where conventional herbicides have not been applied (except for glyphosate in the stale-seedbed treatments). Data are averages of four years.

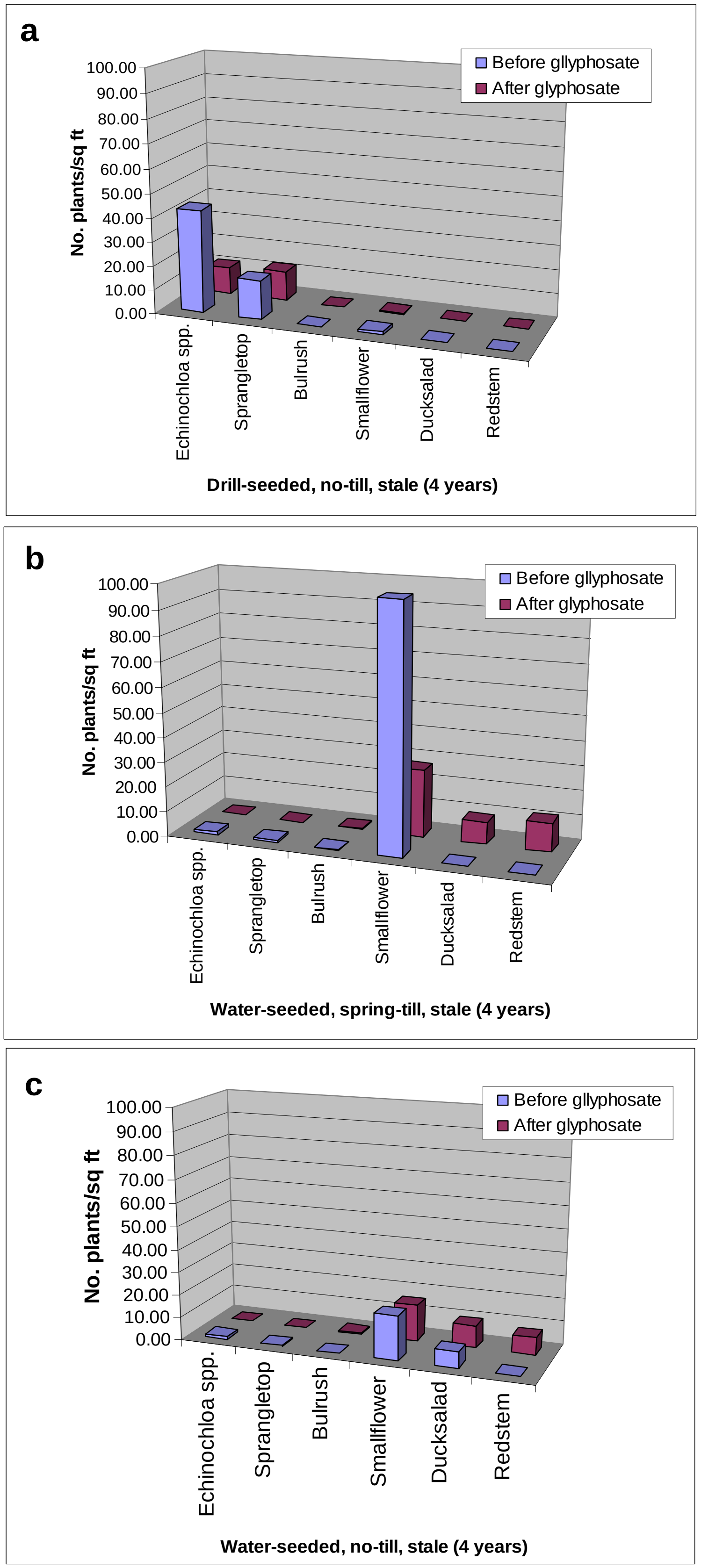

Figure 3. Weed emergence by major species prior glyphosate application in stale-seedbed treatments and the weed infestation present at rice canopy closure (35-40 days after rice emergence) for three alternative rice establishment systems. Data are averages of four years.

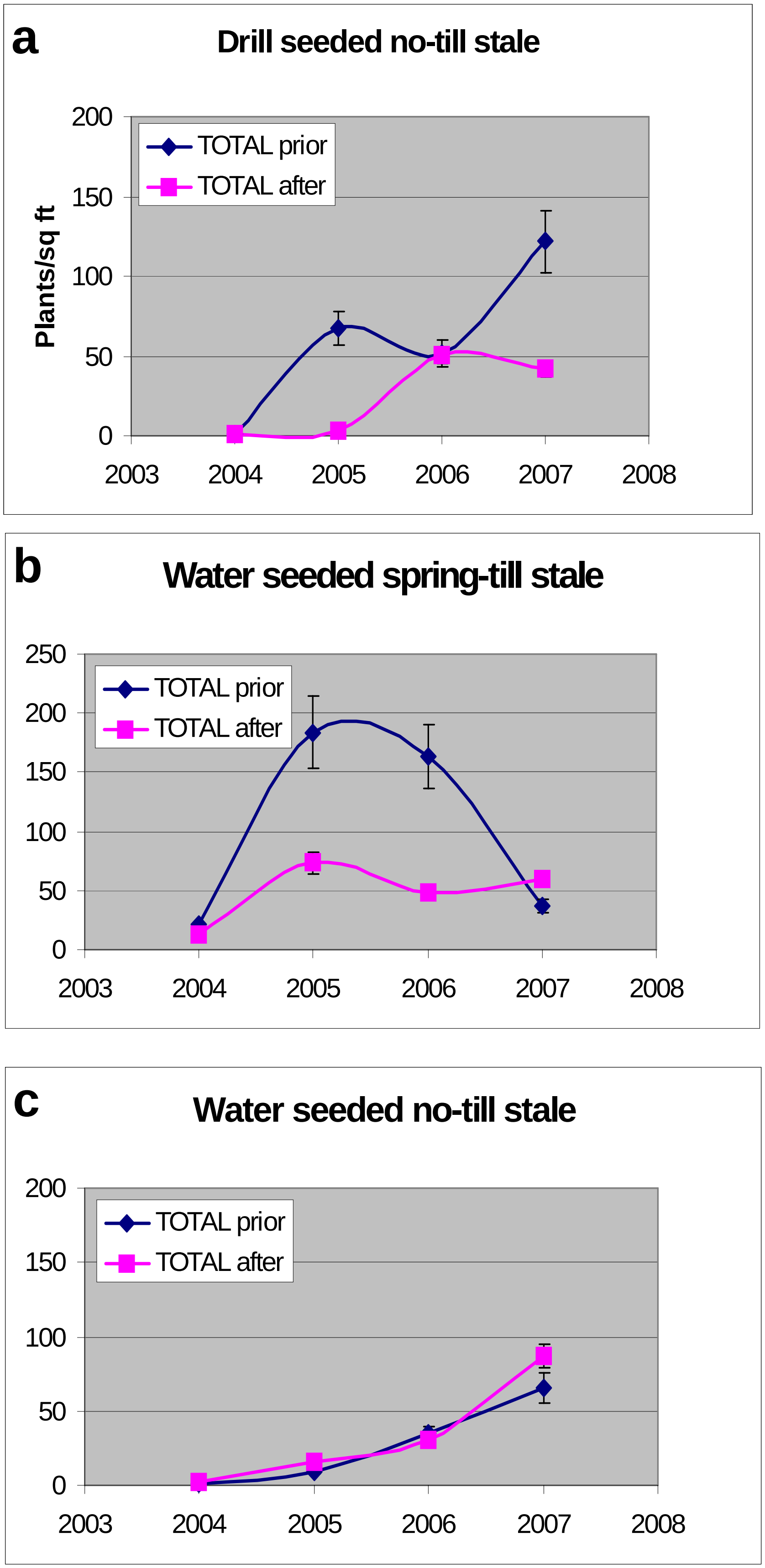

Figure 4. Total weed emergence prior and after (35-40 d after rice emergence) glyphosate application in stale-seedbed treatments determined yearly for three alternative rice establishment systems.