COMPREHENSIVE RESEARCH ON RICE

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PROJECT TITLE: Weed Control in Rice

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OBJECTIVES OF PROPOSED RESEARCH:

I. To investigate the efficacy, timing and compatibility of new herbicides in water-seeded rice (including water management variations of water seeding).

II. To collaborate with plant breeders in developing herbicide-resistant technologies for water-seeded rice.

III. To conduct the research necessary to maintain safe and effective uses of existing herbicides integrated with appropriate cultural practices.

IV. To continue the exploration of rice/weed competition, weed biology and cultural practices to minimize herbicide costs and environmental impacts.

V. To develop an understanding of herbicide resistance in weeds and provide diagnosis and effective alternatives to manage this problem.

OBJECTIVE I. *To investigate the efficacy, timing and compatibility of new herbicides in water-seeded rice (including water management variations of water seeding.)*

Pendimethalin (Prowl) formulations.

Pendimethalin (Prowl) is registered for use in drill-seeded rice. Previous studies have shown that pendimethalin can injure water-seeded rice. We tested pendimethalin and two new formulations (AC 149-469 and AC 147-470) in comparison and in combination with propanil at the Rice Experiment Station (RES) to determine whether or not this product would maintain weed control at rice stages late enough to avoid injury.

Pendimethalin and the formulations were applied at rates of 0.5 and 1.0 lbs/A both alone and in combination with 4 lbs/A of propanil. The adjuvant crop oil concentrate (COC) was mixed with all propanil treatments at 1 pt/A. Treatments were made at the 3-4 leaf stage of rice (lfr) in levee plots that were drained at the time of application. Pendimethalin and the formulations provided weak (Table 1) control of watergrass and smallflower umbrella sedge, while propanil provided fair control of watergrass and good control of smallflower umbrella sedge. When in combination with propanil, herbicide activity was very good or fairly rate responsive, which is reflected by the yield data.

Clodinafop timing and efficacy studies

Clodinafop was tested for the first time at the RES to control watergrass. We tested clodinafop in 8 ft. diameter ring plots at rates of 40, 60, and 80 g/ha at 1-2 and 3-4 lfrs, and at 1-2 tiller (t) timings. Water was completely drained at the time of application for the 1-2 and 3-4 lfr treatments to expose weed leaf surface; and water was lowered to expose at least 70% of weed leaf surface for the tillering treatments.

Assessments of 1-2 lfr treatments demonstrated high rates of injury (Table 2) and poor weed control. Injury was reduced in the 3-4 lfr treatments, however, watergrass control was still not good. In the tillering treatments, rice injury was reduced condsiderably and watergrass control was good. Clodinafop demonstrated the ability to control watergrass effectively in later timed treatments, however, injury was a limiting factor for this herbicide. Clodinafop may have the potential to be an effective grass herbicide, but future work is needed on rate and timing of applications.

Carfentrazone (Shark) foliar and into-the-water applications

Carfentrazone has been tested for several years at the RES, and was permitted to be used by rice growers this season under a Section 18 (emergency registration) by the California Department of Pesticide Regulation. Building on previous research we studied the efficacy of carfentrazone with or without a surfactant under drained conditions, and alone into-the-water or in flooded conditions. Surfactant efficacy was tested by applying carfentrazone at rates of 0.3, 0.5, and 0.7 lbs/A in combination with galactic (0.025% v/v) or X-77 (0.25% v/v) and comparing them to carfentrazone alone at rates 0.5, 0.7, 1.0 lbs/A. Applications were made at 4-5 lf and at 1-2 t on drained 10 X 20 ft staked plots. Into-the-water applications were made at rates of 1.0, 1.5, and 2.0 lbs/A at 3 lf alone, in comparison to, and in split application with 1-2 lf treatments of 4 lbs/A of molinate (Ordram) or 0.6 lbs/A of clomazone (Command).

At the RES carfentrazone foliar applications initially caused slight necrosis and leaf-tip bronzing, however, the plants grew out of the injury. Surfactants increased the level of injury but rice also grew out of the symptoms within 10 to 14 days. In later treatments surfactants appeared to increase the effectiveness (Table 3) of carfentrazone, however, yields were lower than those treatments without the surfactants. Control of broadleaf and sedge species was fair-to-good when the surfactant was added, however, treatments without surfactant had better control. Weed control was also very good with the into-the-water applications. Rice injury was less than foliar applied carfentrazone, but the symptoms were similar. Watergrass pressure was greater in the into-the-water trial (Table 4) and yields were lower. Overall, carfentrazone was an effective herbicide for most broadleaf species. Surfactants were slightly antagonistic to efficacy and yields were lower than with no surfactant, indicating the injury to rice caused some permanent damage.

Clomazone (Command) rate and timing studies

Clomazone was tested for the first time at the RES in 1998 for efficacy as a grass herbicide in rice. We tested clomazone at rates of 0.2, 0.4, and 0.6 lbs/A at three timings, 0.5, 1-2, and 2-3 lf. Clomazone was applied in a granular formulation into 13.5 X 19.5 ft flooded levee plots.

Clomazone was effective (Table 5) and demonstrated control at the 0.5 lf timing. Clomazone injury, however, turned rice leaves white, lasting for seven to ten days afterwhich normal color returned as the plant grew out of the herbicide symptoms. Clomazone at the highest rate and earliest timing provided good control of watergrass and 100 % control of sprangletop. Clomazone also demonstrated fairly good control of watergrass and 100% sprangletop control at the highest rate at the later treatment stages of 1-2 lf.

Cyhalofop (Clincher/DE-537) timing and efficacy studies.

Cyhalofop is a grass herbicide tested for the first time at the RES in 1998. Cyhalofop is widely used in Japanese rice production. This product was tested in two different formulations at the RES. Cyhalofop was applied as a foliar treatment in combination with crop oil concentrate (1.0% v/v) at rates 70, 140, 210, 280, and 510 g/ha at 2-3 and 4-6 leaf stage of watergrass (ℓ_{wg}) timing in 10 x 20 ft plots and compared to propanil (Super Wham) and fenoxaprop (Whip). Water was lowered to expose 50% of the weed leaf surface at each application. Due to a mixing error at the first timing only two rates of cyhalofop are reported. Cyhalofop was also applied in an oil-based granular formulation intoflooded ringed plots at 180 and 255 g/ha at 2 and 4 ℓ_r timings in a separate trial. The active ingredient in this formulation dissolved and floated with the oil released from the granule and contacted the weed as it emerged through a treatment slick at the water surface.

Both formulations of the product resulted in little injury (Tables 6 & 7). Watergrass control in the foliar formulation was better at higher rates and resulted in higher yields (Table 6) at the 2-3 ℓ_r application. The propanil application showed lower watergrass control, but resulted in higher yields at both timings. The granular formulation performed equivalently at both timings. Watergrass control increased at higher rates and performed slightly better (Table 7) at the 2 ℓ_r timing.

IR-5878 efficacy trials

IR-5878 was tested for the first time on the RES in 1998 on a broad spectrum of weeds. We tested IR-5878 in ringed plots at the Hamilton Road facility at rates of 40, 60, and 80 g/ha at 1-2 and 3-4 ℓ_r timings. The surfactant Trend (0.05% v/v) was added in a 1-2 ℓ_r treatment. IR-5878 treatments were compared to azinsulfuron (Gulliver) which is another broad-spectrum herbicide used in European countries for weed control in rice. Water was drained at the time of the applications to expose weed leaf surface to the treatments. These applications resulted in relatively low (Table 8) injury at both timings. Weed control appeared to be improved in the 1-2 ℓ_r treatments at the higher rates when compared to 3-4 ℓ_r treatments. The surfactant showed no benefit to the efficacy of broadleaf and sedge control, however, it did improve watergrass control.

IR-5790 efficacy trial

IR-5790 was tested for a second season at the RES in 1998. The 1997 results indicated that IR-5790 was not fully effective on watergrass, but appeared to control broadleaf and sedge weeds. The lack of control of watergrass made the assessment of broadleaf and sedge weeds difficult in 1997. In 1998, grasses were controlled and the chemical was tested for its efficacy on broadleaf weeds in ringed plots at rates of 80 and 160 g/A (10EC formulation) both alone and in combination with 2 lbs/A of propanil at 3 ℓ_r and 5-6 ℓ_r timings. IR-5790 efficacy was compared to the standard 1 oz/A of bensulfuron (1-2 lf) and also to a 2 lbs/A of propanil (3 lf). The experiment received 4 lbs/A of molinate to control watergrass so that broadleaf weeds could be evaluated.

IR-5790 was unable to control broadleaf weeds (Table 9) at the 3 lf stage treatment. It offered better control at the 5-6 lf and was fairly rate responsive. Activity was increased when in combination with propanil and with later treatment timing. The experiment, however, had a high degree of variability due to the rainy establishment conditions (shortened season) which led to a second flush of broadleaf species.

Bispyrabac-sodium (Regiment/V-10029) alone and in combinations

Bispyrabac-sodium has been tested at the RES for over 10 years and is expected to be registered next year. Bispyrabac-sodium is a postemergence herbicide effective on watergrass, barnyardgrass, and ricefield bulrush. Because bispyrabac-sodium is primarily a selective grass herbicide it was tested with broadleaf herbicides to evaluate possible one-shot combinations for broad spectrum weed control in water-seeded rice.

We tested bispyrabac-sodium at a rate of 25 g/ha alone and in combination with carfentrazone (Shark, 112 g/ha), fenoxaprop (Whip, 56 g/ha), trichlopyr (Grandstand, 420 g/ha) and bensulfuron (Londax, 70 g/ha) at the 5-6 lf. These treatments were compared to a standard 1-2 lf molinate (Ordram, 4 lbs/A) and bensulfuron (Londax 1 oz/A) treatment. The test was conducted on the RES on 10 X 20 ft staked plots drained at application to expose 70% of the weed-leaf surface. A kinetic surfactant L-77 (Silwet, 0.125% v/v) was added to all treatments excepting the molinate and bensulfuron combination.

Both bispyrabac-sodium and fenoxaprop alone partially controlled watergrass (Table 10), while sprangletop was controlled best by fenoxaprop. Bispyrabac-sodium and fenoxaprop combinations improved watergrass control. Ricefield bulrush was controlled by carfentrazone and trichlopyr alone and in combination with bispyrabac-sodium. California arrowhead was adequately controlled by carfentrazone and trichlopyr, however, combinations with bispyrabac-sodium improved control. The standard treatment of molinate plus bensulfuron provided fair grass control and excellent broadleaf and sedge control.

Bispyrabac-sodium (V-10029/Regiment) rate and timing alone or in combination with thiobencarb (Abolish)

Bispyrabac-sodium is known to have a weakness in sprangletop control. We repeated our 1997 experiment of thiobencarb and bispyrabac-sodium combinations at the RES. In 1998 we used bispyrabac-sodium at rates of 10 and 12 g/A alone and in combination with thiobencarb at rates 2, 3, and 4 lbs/A at the 3-4 lfs. The surfactant L-77 (Silwet, 0.125% v/v) was used in all applications when bispyrabac-sodium was applied. Water was drained at the time of application to expose weed leaf surface. These treatments were compared to the standard 4 lbs/A molinate and 1 oz/A bensulfuron.

All the bispyrabac-sodium and thiobencarb treatments controlled watergrass (Table 11). Bispyrabac-sodium surpassed the thiobencarb treatments for watergrass control and controlled ricefield bulrush at the highest rate, however, the yields in this test were related more to watergrass than to ricefield bulrush control.

OBJECTIVE II. To collaborate with plant breeders in developing herbicide-resistant technologies for water-seeded rice.

Glufosinate (Liberty) rate and timing.

Glufosinate is a broad-spectrum non-selective herbicide used in genetically altered crops by the insertion of a glufosinate resistant genes. This relatively new technology has been introduced commercially in other crops for only a few years, and is experimental in California rice. Experiments began three years ago at the RES, and Liberty Link M-202 was provided by AgrEvo Corporation in 1998.

Glufosinate was applied postemergence at rates of 162, 202, and 324 g/A at 4-5, 6-7 lf, and in split application plus an application of 162 g/A (t). Glufosinate was also applied in tank-mix combination with pendimethalin at 1 lb/A, thiobencarb at 4 lb/A, bensulfuron 1 oz/A, and propanil at 4 lbs/A at 4-5 lf. These treatmenst were compared to the standard of 4 lbs/A molinate and 1 oz/A bensulfuron applied into the water in ringed 10 X 20 ft plots at the 1-2 lf. Water was lowered for all glufosinate alone and combination treatments.

Weed control was fair to very good (Table 12) with glufosinate treatments. Split applications provided the best results, especially with early applications and split applications (4 - lf fb t). The mid-rate of glufosinate (202 g/A) also resulted in good control. Combinations of glufosinate with other herbicides were less effective than glufosinate alone or in split application. Because glufosinate is a foliar active herbicide good contact is essential, therefore water must be completely drained for early applications.

OBJECTIVE III. *To conduct the research necessary to maintain safe and effective uses of existing herbicides integrated with appropriate cultural practices.*

Trichlopyr (Grandstand) alone or in combination with carfentrazone (Shark).

Trichlopyr and carfentrazone are both broadleaf and sedge herbicides. Carfentrazone was used for the first time by growers in 1998 under a Section 18 (emergency use allocation). We evaluated three rates of carfentrazone and two of trichlopyr both alone and in combination to determine if lower than label rates could effectively control weeds and thus lower total herbicide cost.

We tested carfentrazone at rates of 56, 84, and 112 g/ha alone and in combination with trichlopyr at 280, and 420 g/ha. All treatments were applied with surfactant (Silwet) at 0.25% v/v on 10 X 20 ft plots drained to expose at least 70% of weed-leaf surface at the 6 lf timing.

Trichlopyr, when used alone or in combination (Table 13) stunted rice and reduced yield. Both herbicides and combinations gave excellent control of ricefield bulrush. Carfentrazone controlled monochoria better than trichlopyr, however, in combination monochoria control was excellent.

Propanil (Super Wham SC; Stam EDF) formulations and combinations

Because of problems with herbicide resistance, propanil acreage is expanding in California. We tested two formulations of propanil alone and in combination with other herbicides; Super Wham (SC formulation) and Stam (EDF formulation) at 3 and 4 lbs/A and various combinations at the 4 lf. Both propanil formulations were tested in combination with pendimethalin (Prowl), thiobencarb (Abolish), bensulfuron (Londax), trichlopyr (Grandstand), and carfentrazone (Shark). All propanil treatments were applied with crop oil concentrate (COC) at 1 pt/A to drained rice.

Both propanil formulations and rates provided good (Table 14) watergrass and sedge control, however, sprangletop control was weak to fair when not in combination with another grass herbicide. Carfentrazone and trichlopyr combinations with propanil were the only treatments that caused rice injury, although yield was not reduced by these treatmenst.

Propanil (Super Wham) and thiobencarb (Abolish) combinations and timings.

Propanil and thiobencarb were tested in combination and alone in levee plots at the RES. Thiobencarb was applied preflood and at the 1.5 lf at 4 lbs/A. Propanil was applied at 3 lbs/A at 3 and 5 lf and at 6 lbs/A at 6 lf. Thiobencarb and propanil were applied postemergence in tank-mixes and in split application at 3 + 2, 3, and 6 lbs/A at the 3, 5, and 6 lf. Thiobencarb and propanil applications were compared to the standard molinate and bensulfuron combination of 4 lbs/A plus 1 oz/A at the 1-2 lf. Water was completely drained at time of application at the 1.5 and 3 lf and to expose at least 70% of weed leaf surface for the 5 and 6 lf treatments.

High yields correlated with good watergrass control (Table 15), however, most treatments had fairly similar results. Preflood thiobencarb followed by propanil had the best control as well as the highest yield. This is probably due to the early effectiveness of the preflood surface treatment and its residual control plus the combination of the subsequent foliar active propanil treatment. Where propanil was not applied, smallflower umbrella sedge was problematic due to a second flush after the residual activity of thiobencarb was gone. Thiobencarb at preflood followed by propanil had the best control as well as the highest yield.

Trichlopyr (Grandstand) combination and timing.

Trichlopyr was used alone and in combination with propanil and cyhalofop. Trichlopyr was applied at the rate of 420 g/ha at 4-5 lf and at 1-2 t alone and in combination with 3360 and 4480 g/ha of propanil and 210 g/ha of DE-537. Crop oil concentrate (COC, 1.25% v/v) was added to all treatments. Water was completely drained for the 4-5 lf treatments and water was drained to expose at least 70% of the weed foliage for the 1-2 t treatments.

Trichlopyr and propanil combinations provided the best broad spectrum weed control and provided the best yield at the highest rate at the 1-2 t treatment (Table 16). Trichlopyr alone provided good broadleaf control and with some activity on watergrass. Higher yields were associated with the treatments where watergrass control was good.

OBJECTIVE IV. To continue the exploration of rice/weed competition, weed biology and cultural practices to minimize herbicide costs and environmental impacts.

The detection of resistance to herbicides throughout the rice growing areas of California involving most of the herbicides currently available for control in rice imposes a serious problem for rice growers. Low cost practices capable of delaying the selection pressure the development of herbicide resistance as needed. Such management practices must fit easily within growers' current rice cropping practices and herbicide use. Our work in 1998 focused on evaluating the potential for enhancing the competitive ability of rice cultivars in order to develop enhanced weed suppression that could integrate with current weed management practices.

We conducted two major experiments to determine the requirements for weed suppression, and the specific rice traits responsible for exerting such competitive pressure. In the first experiment, we evaluated the response of four weed species (early watergrass. late watergrass, small flower umbrella sedge, and redstem) to shade imposed at different growth stages. Small flower umbrella sedge was most affected by shade followed by redstem, late watergrass and early watergrass. All four species were affected by shading, and their seed production was significantly reduced when shaded at the time of rice canopy closure. However, the results suggested that light must be reduced at much earlier stages of growth to substantially reduce seed production if shade is going to be the only pressure imposed on the weed. Additional experiments conducted in 1998 suggested that rice and watergrass competed strongly for nutrients and that limiting the nitrogen availability to watergrass can significantly reduce its growth. Thus, these experiments clearly suggest that in order to suppress weeds emerging simultaneously with rice, such as herbicide resistant weeds that survive after a herbicide application, the crop must be capable of competing strongly for both light and nutrients. Developing more competitive cultivars will require further research on belowground competition.

In the second experiment, we determined the ability of 11 rice cultivars to compete with watergrass. Five of these cultivars are commercially available, two are obsolete tall varieties, and four were experimental lines. A preliminary analysis of the data indicates that there were substantial differences among the cultivars in their ability to compete with watergrass. There was a fivefold difference among the cultivars in their ability to suppress watergrass seed production and a threefold difference in their ability to tolerate watergrass. Reductions in watergrass seed production were correlated with height and specific leaf area (leaf area/leaf weight) early in the season. Height at maturity was not well correlated with watergrass seed suppression. It may be possible to improve competitive ability without returning to tall lodging-prone cultivars. In this study, the tall obsolete cultivars were no more competitive than the semidwarf varieties. There was no tradeoff in this experiment between competitive ability and yield, and there were significant differences among cultivars in early root growth. The information thus generated is being processed, and relationships between rice plant traits and competitiveness will define what aspects of the rice plant type need to be enhanced to achieve significant weed suppression.

These experiments thus suggest that competitive ability can and should be improved in California rice, as a low cost and environmentally safe component of an integrated weed management approach.

OBJECTIVE V. To develop an understanding of herbicide resistance in weeds and provide diagnosis and effective alternatives to manage this problem.

Testing samples from field survey. When an herbicide is used repeatedly to control a susceptible weed species, a selection pressure is exerted in favor of certain individuals (usually few initially) with the inherited ability to survive and reproduce following exposure to a dose that is normally lethal to that species. Resistance develops in a weed population following the continuous use of the same herbicide or herbicides with the same mode of action (thiobencarb (Abolish and Bolero) and molinate (Ordram) are thiocarbamate herbicides with the same mode of action). Seed samples (accessions) were collected from selected rice fields in late summer of 1997 including accessions of late (*Echinochloa phyllopogon*) and early watergrass (*E. oryzoides*), and barnyardgrass (*E. crus-galli*). Seed samples were germinated and commercial rates of herbicides were applied to these seedlings in the greenhouse: fenoxaprop (Whip) 0.15 lb/ac (grasses at the 4 l_{swg}), thiobencarb (Abolish 8EC) 4 lb/ac (2 l_{swg}), propanil 4EC 4 lb/ac (4 l_{swg}), molinate (Ordram) 15G lb/ac (1 l_{swg}), and bispyrabac-sodium (Regiment/V-10029) 15 g/ac (3 l_{swg}). Spray volume was 15 GPA applied with 8001 nozzles. Fifteen to 20 days after spraying the aboveground fresh biomass of plants was weighed and expressed as percent of the weight of untreated control plants. Data from these tests are summarized in Table 17. Out of the 55 accessions initially collected from 40 farms, many accessions were able to continue growth after treatment with certain herbicides while known susceptible accessions (checks) were killed (Table 15). Also several accessions appeared to be resistant to more than one herbicide, and even to products that differed chemically and in their site of action (Table 17). Although most of the resistant samples were specimens of late watergrass, resistance was also found in early watergrass and in barnyardgrass (Table 17). Most resistant accessions were controlled by at least one product. There were few cases of regrowth after treatment with propanil 4EC, and this was on average lower than for the other herbicides. There was virtually no regrowth (less than 5 % of the untreated check) after treatment with propanil Super Wham SC at 4 lb/ac.

Dose-response studies. Two late watergrass accessions that had shown resistance to the above herbicides were subjected to detailed dose-response studies to conclusively establish the presence of resistance across multiple herbicide mode of actions in watergrass. Each accession was treated separately in the greenhouse with six rates (1/4, 1/2, X, 2X, and 4X; with X approximate to the recommended field rate) of molinate, thiobencarb 8EC, propanil 4EC, bispyrabac-sodium and fenoxaprop. Spray volume was 15 GPA applied with 8001 nozzles, and within three days after spraying plants were flooded to a depth of 4 in (plants treated with molinate were flooded at the time the granules were applied). Each experiment was repeated once. Although accession # 2 was more susceptible to molinate and bispyrabac, results show that the two accessions were resistant to herbicides with three different modes of action (fig. 1). Accession # 1 was not controlled; not even at 4x the normal rate of all the herbicides tested except propanil, which effectively suppressed both accessions (although incipient regrowth of suppressed plants was observed 20 days after spraying plants of accession # 1). This demonstrates that the repeated use of the few herbicides for grass control that have been available in California has led to the development of complex patterns of resistance involving most of these herbicides. Our collected samples appeared more susceptible to propanil, an herbicide discontinuously used in the past. We further investigated the resistance to bispyrabac-sodium, a new compound to which watergrass populations have presumably not yet been exposed to its repeated use (selection pressure). Preliminary tests (data not shown) indicate that resistance to this herbicide can in part be due to an enhanced capacity of the resistant plants to breakdown the herbicide through oxidative reactions, possibly mediated by mixed-function oxidases such as the Cytochrome P_{450} enzyme. Bispyrabac-sodium kills plants by inhibiting the same enzyme (site of action) as bensulfuron, namely the acetolactate synthase (ALS) enzyme. We are now trying to establish if resistance to bispyrabac-sodium (Table 17, fig. 1) could be due to ALS inhibition, resulting from indirect selection pressure by the use of bensulfuron previously in those sites (bensulfuron has some, marginal, activity on watergrass). This information will allow us to establish more accurately safe guidelines for use of this herbicide. This herbicide can become a new tool to control watergrass resistant to other herbicides (Table 17).

Resistance to new chemistries. Similar dose-response experiments were conducted on the accession # 1 with the following herbicides: Glyphosate, clomazone, pendimethalin, and gluphosinate. Experimental conditions were as above. Each experiment was repeated once. No indication of resistance to any of these herbicides was suggested by these experiments.

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CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

In 1998, several candidate herbicides for use in California rice were evaluated at the Rice Experiment Station (RES). One of these, cyhalofop (Clincher), was particularly promising for watergrass and sprangletop control. Although the mode of action is similar to fenoxaprop (Whip), the safety to rice is improved. Like fenoxaprop, however, cyhalofop will not control resistant watergrass. Bispyrabac-sodium (Regiment) has been tested under several experimental numbers over the past decade, most recently as V-10029. Valent is moving towards registration of bispyrabac as a watergrass/barnyardgrass herbicide which also partially controls ricefield bulrush. Carfentrazone (Shark) evaluation continued at the RES comparing surfactants, combination with other herbicides and into-the-water applications. As in previous studies, carfentrazone controlled broadleaf and sedge weeds with excellent control of ricefield bulrush and good to very good control of smallflower umbrella sedge. Surfactants generally increased rice injury without improving weed control. Foliar applications and into-the-water applications were both effective, but into-the-water applications required approximately twice the rate for similar levels of control. Combinations of carfentrazone with trichlopyr (Grandstand) were very effective at half the normal use rate of each when used alone, thus offering growers an opportunity to reduce the costs of the most expensive herbicide in the mix. Transgenic rice with resistance to glufosinate (Liberty) was evaluated for the third year. For the first time, however, a California variety, M-202, was used. As in previous years, single applications were good, but split applications of glufosinate followed by glufosinate were better. Depending on the weed pressure and initial timing, growers will be able to determine if a second application is needed. Two low drift potential formulations of propanil (Super Wham SC and Stam EDF) were compared for efficacy and safety to rice and found similar in activity.

The repeated herbicide use patterns resulting from the restricted availability of grass herbicides, and the prevailing practice of continuous rice culture have led to the selection of *Echinochloa spp.* biotypes, mostly late watergrass, that can survive treatment by different herbicides. Testing showed that resistance to propanil was infrequent and low, suggesting that this active ingredient will be useful in the short term to deal with resistance. However, overuse of propanil will also soon develop resistance as has already occurred in other areas of the US and the world. It is important watergrass contorl be diversified by preventive, mechanical, and cultural practices aimed at eliminating the survival, seed production, and dispersal of plants that escape herbicide treatment. Herbicides will continue to be the key resource for weed control in rice, and the importance of avoiding the repeated use of herbicides with the same mode of action should help delay the buildup of resistance. This practice will be more difficult to implement when resistance has already developed to more than one herbicide. Some of the fields with resistant watergrass appear clustered together, or in relative proximity, suggesting that dispersal of resistant seed may occur. Knowledge of herbicide modes of actions and patterns of herbicide resistance, through scouting and testing, will provide the rational basis for resistance management. Thiobencarb and molinate belong to the same chemical group and share mechanisms of action; bispyrabac has the same mode of action as bensulfuron. As in 1997, a new set of *Echinochloa spp* seed samples has been collected this past summer from California rice farms. These samples will be tested in the greenhouse for resistance to the currently available grass herbicides for rice.

Table 1. Results of 1998 pendimethalin (Prowl) formulations trial at the RES.

Treatment	Rate(s)	Timing	Injury	Weed Control[1]						Yield[2]
				ECHOR			CYPDI			
			(21-Jul)	(21-Jul)	(10-Aug)	(11-Sept)	(21-Jul)	(10-Aug)	(11-Sept)	
	(g/ha)	(l_{sr})[3]	(%)							(lbs/A)
Untreated	--	--	1.3	45	23	10	3	5	8	2060
pendimethalin	560	3 - 4	0	58	73	60	8	1	25	2980
pendimethalin	1120	3 - 4	0	74	70	64	8	8	25	2300
AC 149-469	560	3 - 4	0	40	53	48	13	5	25	2480
AC 149-469	1120	3 - 4	0	33	68	35	13	34	38	2310
AC 147-470	560	3 - 4	0	35	63	50	0	5	58	2110
AC 147-470	1120	3 - 4	0	25	55	45	8	3	38	2080
propanil	4480	3 - 4	1.3	78	94	74	75	100	88	5560
propanil + pendimethalin	4480 + 560	3 - 4	2.5	93	91	71	100	100	78	6600
propanil + pendimethalin	4480 + 1120	3 - 4	4	94	85	89	100	100	100	6670
propanil + AC 149-469	4480 + 560	3 - 4	8	91	89	87	100	100	100	6380
propanil + AC 149-469	4480 + 1120	3 - 4	0	90	85	76	100	98	75	6700
propanil + AC 147-470	4480 + 560	3 - 4	6.3	99	95	91	95	100	100	6500
propanil + AC 147-470	4480 + 1120	3 - 4	1	96	90	95	95	100	100	6960

[1] ECHOR (watergrass); CYPDI (smallflower umbrella sedge)

[2] Yield adjusted to 14% moisture

[3] (l_{sr}) leaf stage rice

Table 2. Results from the 1998 clodinafop rate and timing trial at the RES.

Treatment	Rate	Timing[2]	Injury	Weed Control[1]		
				ECHOR		
			(22-Jul)	(22-Jul)	(6-Aug)	(16-Sept)
	(g/ha)		---(%)---			
Untreated	--	--	0	7	13	13
clodinafop	40	1 - 2 *lsr*	90	43	47	48
clodinafop	60	1 - 2 *lsr*	96	43	43	43
clodinafop	80	1 - 2 *lsr*	99	47	47	50
clodinafop	40	3 - 4 *lsr*	33	57	70	70
clodinafop	60	3 - 4 *lsr*	30	73	76	73
clodinafop	80	3 - 4 *lsr*	70	60	60	65
clodinafop	40	*t*	23	73	77	75
clodinafop	60	*t*	37	73	90	85
clodinafop	80	*t*	47	67	83	83

[1] ECHOR (watergrass)

[2] (*lsr*) leaf stage rice; (*t*) tiller stage rice

Table 3. Results of 1998 carfentrazone (Shark) efficacy test at the RES

Treatment	Rate(s)	Timing[2]	Injury (4-Aug)	Weed Control[1] SCPMU (4-Aug)	CYPDI (4-Aug)	HELTI (4-Aug)	Yield[3]
	(lbs/A)		---(%)---				(lbs/A)
Untreated	--	4 - 5 *lsr*	0	18	25	23	6530
carfentrazone	0.05	4 - 5 *lsr*	3	78	93	25	6190
carfentrazone	0.07	4 - 5 *lsr*	1	98	100	48	6550
carfentrazone	0.10	4 - 5 *lsr*	0	86	100	45	7130
carfentrazone + galactic	0.03 + 0.025%v/v[4]	4 - 5 *lsr*	4	92	99	13	6050
carfentrazone + galactic	0.05 + 0.025%v/v	4 - 5 *lsr*	0	55	88	40	6380
carfentrazone + galactic	0.07 + 0.025%v/v	4 - 5 *lsr*	1	90	90	26	6290
carfentrazone	0.05	*t*	1	85	98	28	9590
carfentrazone	0.07	*t*	4	83	100	70	6530
carfentrazone	0.10	*t*	4	70	95	80	6990
carfentrazone + galactic	0.03 + 0.025%v/v	*t*	2	96	84	20	6260
carfentrazone + galactic	0.05 + 0.025%v/v	*t*	6	74	78	48	6360
carfentrazone + galactic	0.07 + 0.025%v/v	*t*	3	81	100	23	6470
carfentrazone + X-77	0.05 + 0.25%v/v	*t*	6	83	100	78	6660
propanil	4.0	*t*	2	91	100	89	6800

[1] SCPMU (ricefield bulrush); CYPDI (smallflower umbrella sedge; HETLI (ducksalad)

[2] (*lsr*) leaf stage rice; (*t*) tiller stage rice

[3] Yield adjusted to 14% moisture

[4] (v/v) % volume to volume

Table 4. Results of 1998 carfentrazone (Shark) combinations into water efficacy trial at the RES.

Treatment	Rate(s)	Timing	Injury	Weed Control[1]				Yield[2]
				ECHOR		SCPMU		
			(20-Jul)	(20-Jul)	(4-Aug)	(20-Jul)	(4-Aug)	
	(lbs/A)	(ℓ_{sr})[3]	----------	----------	(%)	----------	----------	(lbs/A)
Untreated	--	--	0	10	10	47	20	1670
molinate	4.0	1 - 2	0	85	82	63	30	5650
clomazone	0.60	1 - 2	0	73	67	27	0	5260
bensulfuron	0.063	1 - 2	0	33	0	80	17	1880
carfentrazone	0.10	3	0	20	10	93	93	2300
carfentrazone	0.15	3	0	30	13	100	100	2090
carfentrazone	0.20	3	0	53	20	93	93	2730
molinate + carfentrazone	4.0 + 0.10	1 - 2 + 3	0	83	85	100	100	6070
molinate + carfentrazone	4.0 + 0.15	1 - 2 + 3	0	83	83	100	100	6600
molinate + carfentrazone	4.0 + 0.20	1 - 2 + 3	3	88	77	100	100	6420
clomazone + carfentrazone	0.6 + 0.20	1 - 2 + 3	3	80	60	100	100	5460
bensulfuron + molinate	0.063 + 4.0	1 - 2 + 3	3	87	87	100	100	6750

[1] ECHOR (watergrass); SCPMU (ricefield bulrush)

[2] Yield adjusted to 14% moisture.

[3] (ℓ_{sr}) leaf stage rice

Table 5. Results of 1998 clomazone (Command) efficacy test at the RES.

Treatment	Rate	Timing	Weed Control[1] ECHOR (20-Jul)	Weed Control[1] ECHOR (4-Aug)	Weed Control[1] LEFFA (20-Jul)	Weed Control[1] LEFFA (4-Aug)	Yield[2]
	(g/ha)	(ℓ_r)[3]	(%)	(%)	(%)	(%)	(lbs/A)
Untreated	--	--	18	18	23	0	3430
clomazone	0.2	0.5	33	33	100	98	4650
clomazone	0.4	0.5	65	60	100	100	6160
clomazone	0.6	0.5	88	86	100	100	7170
clomazone	0.2	1 - 2	38	53	100	100	4120
clomazone	0.4	1 - 2	75	55	100	100	6840
clomazone	0.6	1 - 2	85	75	100	100	6350
clomazone	0.2	2 - 3	50	48	100	100	4880
clomazone	0.4	2 - 3	63	70	100	100	5310
clomazone	0.6	2 - 3	63	53	100	100	6250

[1] ECHOR (watergrass); LEFFA (sprangletop)

[2] Yield adjusted to 14% moisture

[3] (ℓ_r) leaf stage rice

Table 6.Results of 1998 foliar applied DE-537 EC (Clincher) rate and timing trial at the RES.

Treatment	Rate	Timing	Injury (24-Jul)	Weed Control[1] ECHOR (24-Jul)	Weed Control[1] ECHOR (15-Sept)	Yield[2]
	(g/ha)	(l_{swg})[3]	------------------------	(%)	------------------------	(lbs/A)
Untreated	--	--	2	17	7	2110
DE-537	70	2 - 3	0	17	15	2300
DE-537	140	2 - 3	0	10	10	1850
DE-537	210	2 - 3	0	33	23	4950
DE-537	280	2 - 3	0	47	47	2770
DE-537	560	2 - 3	0	70	76	5290
DE-537 (0.62% v/v COC)[4]	70	2 - 3	0	15	23	2180
DE-537 (0.62% v/v COC)	140	2 - 3	0	60	55	3430
DE-537 (1.00% v/v COC)	210	2 - 3	0	77	83	4950
DE-537 (1.00% v/v COC)	280	2 - 3	3	82	85	4840
DE-537 (1.00% v/v COC)	560	2 - 3	3	85	93	5290
propanil	4480	2 - 3	2	73	70	5600
fenoxaprop	38	2 - 3	0	57	55	3760
fenoxaprop	64	2 - 3	0	67	62	4050
DE-537 (1.00% v/v COC)	70	2 - 3	3	50	27	2150
DE-537 (1.00% v/v COC)	140	2 - 3	3	63	35	2440
DE-537 (1.00% v/v COC)	210	4 - 6	5	70	68	3760
DE-537 (1.00% v/v COC)	280	4 - 6	7	77	68	3580
DE-537 (1.00% v/v COC)	560	4 - 6	7	80	88	4300
propanil	4480	4 - 6	7	77	82	5350
fenoxaprop	38	4 - 6	8	62	68	3560
fenoxaprop	64	4 - 6	8	80	87	4470

[1] ECHOR (watergarss)

[2] Yield adjusted to 14% moisture

[3] (l_{swg}) leaf stage watergrass

[4] crop oil concentrate

Table 7. Results of 1998 1.8G/DE-537/oil-based granular formation (Clincher) rate and timing trial at the RES.

				Weed Control[1]	
			Injury	ECHOR	
Treatment	Rate	Timing	(21-Jul)	(21-Jul)	(6-Aug)
	(g/ha)	(ℓ_{sr})[2]	--------------------(%)--------------------		
Untreated	--	--	0	23	10
DE-537(1.8G)	180	2	0	80	78
DE-537	255	2	5	95	92
DE-537	180	4	1	93	78
DE-537	255	4	2	93	90
DE-537 + bensulfuron[3]	180 + 70	2	80	100	100
DE-537 + carfentrazone[3]	180 + 225	2	20	97	98

[1] ECHOR (watergrass)

[2] (ℓ_{sr}) leaf stage rice

[3] Experiment compromised due to error in bensulfuron rate.

Table 8. Results for 1998 IR-5878 trial at the RES.

Treatment	Rate(s)	Timing	Injury	Weed Control[1]					
				ECHOR		SCPMU		HETLI	
			(22-Jul)	(22-Jul)	(5-Aug)	(22-Jul)	(5-Aug)	(22-Jul)	(5-Aug)
	(g/ha)	(l_{sr})[2]	-----	-----	-----	(%)	-----	-----	-----
Untreated	--	--	0	13	20	3	20	7	3
IR-5878	40	1 - 2	0	27	53	90	87	80	83
IR-5878	60	1 - 2	33	57	83	100	67	83	53
IR-5878	80	1 - 2	0	57	80	100	77	97	87
IR-5878 + Trend	40 + .05% v/v	1 - 2	0	57	80	83	57	53	53
azinsulfuron	20	1 - 2	7	98	100	97	97	80	90
IR-5878	40	3 - 4	2	50	57	100	98	87	70
IR-5878	60	3 - 4	3	50	63	100	98	100	70

[1] ECHOR (watergrass); SCPMU (ricefield bulrush); HETLI (ducksalad)

[2] (l_{sr}) leaf stage rice

Table 9. Results for the 1998 IR-5790 broadleaf control trial at the RES.

			Weed Control[1]			
Treatment	Rate	Timing	MOOVA (17-Jul)	SCPMU (17-Jul)	MOOVA (31-Jul)	SCPMU (31-Jul)
	(g/ha)	(l_{sr})[2]	(%)			
Untreated	--	--	53	38	50	53
bensulfuron	64	1 - 2	50	73	59	25
propanil	2400	5	37	84	78	57
IR-5790	200	3	50	55	50	15
IR-5790	400	3	68	70	40	38
IR-5790	200	5 - 6	67	65	76	28
IR-5790	400	5 - 6	75	63	45	10
IR-5790 + propanil	200 + 2400	3	87	74	66	69
IR-5790 + propanil	400 + 2400	3	38	74	38	48
IR-5790 + propanil	200 + 2400	5 - 6	75	81	65	53
IR-5790 + propanil	400 + 2400	5 - 6	77	84	73	74

[1] MOOVA (monochoria); SCPMU (ricefield bulrush)

[2] (l_{sr}) leaf stage rice

Table 10. Results from the 1998 bispyrabac-sodium (V-10029/Regiment) and combinations trial at the RES.

Treatment	Rate	Timing	Injury (23-Jul)	Weed Control[1] ECHOR (23-Jul)	LEFFA (23-Jul)	SCPMU (23-Jul)	SAGMO (23-Jul)	Yield[2]
	(g/ha)	(ℓ_{sr})[3]	----------	----------(%)	----------	----------	----------	(lbs/A)
Untreated	--	--	0	23	23	18	0	2450
V-10029	25	5 - 6	4	73	48	98	68	5380
carfentrazone	112	5 - 6	0	25	53	95	75	2690
fenoxaprop	56	5 - 6	1	73	100	63	23	4730
trichlopyr	420	5 - 6	0	35	98	93	88	2120
bensulfuron	70	5 - 6	0.5	54	55	100	73	3700
V-10029 + carfentrazone	25 + 112	5 - 6	1	70	45	84	98	4910
V-10029 + fenoxaprop	25 + 56	5 - 6	1	86	95	100	98	5480
V-10029 + trichlopyr	25 + 420	5 - 6	1	83	79	81	100	5760
V-10029 + bensulfuron	25 + 70	5 - 6	1	88	44	98	98	5030
molinate + bensulfuron	4480 + 70	1 - 2	1	71	79	98	100	5560

[1] ECHOR (watergrass); LEFFA (sprangletop) SCPMU (ricefield bulrush); SAGMO (California arrowhead)

[2] Yield adjusted to 14% moistrure

[3] (ℓ_{sr}) leaf stage rice

Table 11. Results of 1998 trials with bispyrabac-sodium (Regiment/V-10029) and thiobencarb (Abolish) combinations at the RES.

Treatment	Rate	Timing	Injury	Weed Control[1]						Yield[2]
				ECHOR		LEFFA		SCPMU		
			(21-Jul)	(21-Jul)	(4-Aug)	(21-Jul)	(4-Aug)	(21-Jul)	(4-Aug)	
	(g/ha)	(L_r)[3]	(%)							(lbs/A)
Untreated	--	--	0	58	13	22	10	33	20	1770
V-10029	25	3--4	5	58	23	13	0	75	63	2180
V-10029	30	3--4	10	65	55	0	0	100	88	3510
thiobencarb	2240	3--4	2.5	65	30	100	85	48	40	2940
thiobencarb	3360	3--4	3	43	35	100	100	33	33	3280
thiobencarb	4480	3--4	6	35	43	100	85	45	38	3600
V-10029 + thiobencarb	25 + 2240	3--4	13	94	88	88	80	100	83	4910
V-10029 + thiobencarb	25 + 3360	3--4	13	94	78	95	55	100	90	5180
V10029 + thiobencarb	25 + 4800	3--4	11	94	86	90	95	98	88	4900
V10029 + thiobencarb	30 + 2240	3--4	11	88	83	53	65	81	83	4930
V10029 + thiobencarb	30 + 3360	3--4	8	93	81	100	95	99	100	5380
V10029 + thiobencarb	30 + 4480	3--4	16	98	85	100	100	100	98	5270
molinate + bensulfuron	4480 + 70	1--2	8	83	85	100	100	100	98	4990

[1] ECHOR (watergrass); LEFFA (sprangletop); SCPMU (ricefield bulrush)

[2] Yield adjusted to 14% moisture

[3] (L_r) leaf stage rice

Table 12. Results from the 1998 glufosinate Liberty Link/transgenic/M-202 trial at the RES.

Treatment	Rate(s)	Timing[3]	Injury (28-Jul)	Weed Control[1] ECHOR (28-Jul)	ECHOR (5-Aug)	ECHOR (1-Sept)	SCPMU (28-Jul)	SCPMU (5-Aug)	Yield[2]
	(g/ha)		(%)						(lbs/A)
Untreated	--	--	5	10	13	25	5	48	2450
pendimethalin	1120	4-5 *lf*	4	54	53	20	48	43	2720
thiobencarb	4480	4-5 *lf*	4	70	60	28	53	33	3490
bensulfuron	70	4-5 *lf*	0	43	33	0	89	100	2750
molinate	4480	1-2 *lf*	4	68	61	45	43	45	3850
propanil	4480	4-5 *lf*	9	78	73	43	73	75	4160
glufosinate	400	4-5 *lf*	5	83	83	70	60	58	5150
glufosinate	500	4-5 *lf*	11	80	68	45	73	63	4850
glufosinate(NT)[4]	500	4-5 *lf*	91	83	45	15	75	63	1280
glufosinate	800	4-5 *lf*	8	90	85	78	69	88	4760
glufosinate	400	6-7 *lf*	0.5	79	80	65	48	95	4480
glufosinate	500	6-7 *lf*	2	73	83	68	56	88	4340
glufosinate(NT)	500	6-7 *lf*	61	60	60	28	58	100	2920
glufosinate	800	6-7 *lf*	18	88	98	83	71	100	4770
glufosinate + glufosinate	400 + 400	4-5 *lf* + 3-4 *t*	11	81	90	80	83	88	5340
glufosinate + glufosinate	500 + 400	4-5 *lf* + 3-4 *t*	6	91	91	85	88	100	5260
glufosinate + glufosinate	800 + 400	4-5 *lf* + 3-4 *t*	13	93	93	88	88	100	5250
glufosinate + glufosinate	400 + 400	6-7 *lf* + 3-4 *t*	3	89	95	88	74	100	5050
glufosinate + glufosinate	500 + 400	6-7 *lf* + 3-4 *t*	3	98	95	90	71	93	4720
glufosinate + glufosinate	800 + 400	6-7 *lf* + 3-4 *t*	7	96	99	100	91	99	5440
glufosinate + pendimethalin	500 + 1120	4-5 *lf*	18	81	73	55	78	93	4370
glufosinate + thiobencarb	500 + 4480	4-5 *lf*	11	78	75	58	83	98	4690
glufosinate + bensulfuron	500 + 70	4-5 *lf*	11	75	73	33	95	100	3930
glufosinate + propanil	500 + 4480	4-5 *lf*	20	80	73	53	95	100	4040
molinate + bensulfuron	4480 + 70	1-2 *lf* +4-5 *lf*	3	73	63	45	63	38	3740

[1] ECHOR (watergrass); SCPMU (ricefield bulrush)

[2] Yield adjusted to 14% moisture

[3] (*lf*) leaf stage rice; (*t*) tiller stage rice

[4] (NT) nontransgenic rice

Table 13. Results from the 1998 trichlopyr (Grandstand) and carfentrazone (Shark) efficacy test at the RES.

				Weed Control[1]		
			Injury	SCPMU	MOOVA	
Treatment	Rate(s)	Timing	(28-Jul)	(28-Jul)	(28-Jul)	Yield[2]
	(g/ha)	(ℓ_{lr})[3]	----------	(%)	----------	(lbs/A)
Untreated	--	--	1	35	8	6840
carfentrazone	56	6	6	94	80	7000
carfentrazone	84	6	5	99	88	6850
carfentrazone	112	6	5	99	89	7140
trichlopyr	280	6	23	100	76	5910
trichlopyr	420	6	23	99	70	6120
carfentrazone + trichlopyr	56 + 280	6	11	96	100	6400
carfentrazone + trichlopyr	56 + 420	6	20	97	100	6400
carfentrazone + trichlopyr	84 + 280	6	15	99	98	6690
carfentrazone + trichlopyr	84 + 420	6	20	99	100	6390
carfentrazone + trichlopyr	112 + 280	6	16	100	100	6470
carfentrazone + trichlopyr	112 + 420	6	21	99	99	6510
Untreated	--	--	0	47	10	6520

[1] SCPMU (ricefield bulrush); MOOVA (monochoria)

[2] Yield adjusted to 14% moisture

[3] (ℓ_{lr}) leaf stage rice

Table 14. Results for the 1998 propanil (Super Wham, Stam) formulations, combination, and efficacy trial at the RES.

Treatment	Rate(s)	Timing	Injury	Weed Control[1]								Yield[2]
				ECHOR		LEFFA		SCMPU		CYPDI		
			(23-Jul)	(23-Jul)	(14-Sept)	(23-Jul)	(14-Sept)	(23-Jul)	(4-Aug)	(23-Jul)	(4-Aug)	
	(g/ha)	(*L*)[3]	(%)									(lba/A)
Untreated	--	--	0	22	30	23	50	38	8	23	13	3500
propanil (EDF)	3360	4	6	73	83	53	58	99	98	99	98	6670
propanil (EDF)	4480	4	1	93	88	60	73	100	100	100	100	7550
propanil (SC)	3360	4	1	88	85	23	25	100	98	100	98	6600
propanil (SC)	4480	4	6	97	91	35	68	100	100	100	98	6850
pendimethalin	1120	4	0	70	70	60	84	25	28	33	10	3470
thiobencarb	3360	4	0	63	58	72	98	70	38	73	35	4640
bensulfuron	70	4	0	75	58	15	65	100	100	100	98	5700
trichlopyr	420	4	8	60	28	43	63	89	70	80	66	3960
carfentrazone	112	4	0	5	28	3	80	100	100	100	98	3820
propanil (EDF) + pendimethalin	4480 + 1120	4	3	91	91	92	91	100	100	100	96	7450
propanil + thiobencarb	4480 + 3360	4	5	100	100	99	100	100	100	100	95	7110
propanil + bensulfuron	4480 + 70	4	1	95	90	55	69	100	100	100	100	7210
propanil + trichlopyr	4480 + 420	4	33	98	96	91	83	100	100	100	100	7350
propanil + carfentrazone	4480 + 112	4	11	80	85	58	70	100	100	100	100	7150
propanil (SC) + pendimethalin	4480 + 1120	4	9	96	95	88	94	100	95	100	9	7710
propanil + thiobencarb	4480 + 3360	4	8	95	91	85	92	100	100	100	100	7700
propanil + bensulfuron	4480 + 70	4	6	96	90	43	61	100	100	100	100	7070
propanil + trichlopyr	4480 + 420	4	38	98	95	90	78	100	100	100	100	7580
propanil + carfentrazone	4480 + 112	4	14	89	86	50	53	100	98	100	100	7030

[1] ECHOR (watergrass); LEFFA (sprangletop); SCPMU (ricefield bulrush): CYPDI (smallflower umbrella sedge)

[2] Yield adjusted to 14% moisture

[3] (*L*) leaf stage rice

Table 15. Results of 1998 propanil and thiobencarb (Abolish) combination and efficacy trial at the RES.

Treatment	Rate	Timing	Injury (24-Jul)	Weed Control[1] ECHOR (24-Jul)	Weed Control[1] LEFFA (24-Jul)	Weed Control[1] CYPDI (24-Jul)	Yield[2]
	(lbs/A)	(ℓ_{sr})[3]	--------------(%)	--------------	--------------		(lbs/A)
Untreated	--	--	0	10	10	10	1310
thiobencarb	4	1.5	3	70	90	90	5910
propanil	3	3	3	85	87	80	6610
propanil	3	5	7	68	60	100	6540
propanil	6	6	10	75	27	100	5880
thiobencarb + propanil	4.0 + 4.0	PFS[4] + 6	10	78	97	100	7610
thiobencarb + propanil	4.0 + 4.0	1.5 + 6	12	87	100	97	6710
thiobencarb + propanil	3.0 + 2.0	3	5	95	90	78	7420
thiobencarb + propanil	3.0 + 3.0	3	5	95	100	100	7340
thiobencarb + propanil	3.0 + 3.0	5	7	50	73	67	5580
thiobencarb + propanil fb propanil	3.0 + 3.0 fb 4.0	3 fb 6	5	93	100	100	7510
propanil fb propanil	3.0 fb 4.0	3 fb 6	5	87	77	100	7050
molinate + bensulfuron	4.0 + 0.063	1--2	5	73	96	100	6060

[1] ECHOR (watergrass); LEFFA (sprangletop); CYPDI (smallflower umbrella sedge)

[2] Yield adjusted to 14% moisture

[3] (ℓ_{sr}) leaf stage rice

[4] Preflood surface treatment

Table 16. Results from the 1998 trichlopyr (Grandstand) combinations and timing trial at the RES.

Treatment	Rate	Timing[3]	Injury	Weed Control[1]				Yield[2]
				ECHOR	SCPMU	CYPDI	HETLI	
			(27-Jul)	(27-Jul)	(27-Jul)	(27-Jul)	(27-Jul)	
	(g/ha)		(%)					(lbs/A)
Untreated	--	--	0	8	10	5	5	1870
propanil	3360	4-5 ℓ	0	68	98	100	90	4600
propanil	4480	4-5 ℓ	5	73	100	100	95	5270
trichlopyr	420	4-5 ℓ	8	68	90	95	90	1930
DE-537	210	4-5 ℓ	0	73	28	15	33	3880
propanil + trichlopyr	3360 + 420	4-5 ℓ	15	81	100	100	100	5030
propanil + trichlopyr	4480 + 420	4-5 ℓ	16	85	100	100	98	6070
DE-537 + trichlopyr	210 + 420	4-5 ℓ	0	68	28	23	33	3130
propanil	3360	1-2 t	4	65	100	100	75	4290
propanil	4480	1-2 t	6	75	100	100	90	5480
DE-537	210	1-2 t	0	63	33	38	53	2680
propanil + trichlopyr	3360 + 420	1-2 t	15	73	98	100	98	4680
propanil + trichlopyr	4480 + 420	1-2 t	5	78	100	100	95	6300
DE-537 + triclopyr	210 + 420	1-2 t	6	75	83	80	75	3470

[1]ECHOR (watergrass); SCPMU (ricefield bulrush); CYPDI (smallflower umbrella sedge); HETLI (ducksalad)

[2]Yield adjusted to 14% moisture

[3] (ℓ) leaf stage rice; (t) tiller stage rice

Table 17 Response of *Echinochloa spp* accessions collected in California rice fields to conventional herbicide treatments. The herbicide effect is measured as the plant fresh weight 20 days after treatment, expressed as percent of the fresh weight of an untreated control; thus, 100%=unaffected by herbicide, 0%=killed.

Field #	Species	Herbicide	Percent growth after treatment (%)	Field #	Species	Herbicide	Percent growth after treatment (%)
1	LWG*	Abolish	35	12	LWG	Regiment	55
1	LWG	Ordram	12	12	LWG	Whip	32
1	LWG	Regiment	15				
1	LWG	Whip	45	13	LWG	Abolish	65
				13	LWG	Ordram	56
2	EWG	Propanil**	19	13	LWG	Regiment	30
				13	LWG	Whip	38
3	LWG	Abolish	53				
3	LWG	Whip	40	14	LWG	Abolish	81
				14	LWG	Ordram	64
4	LWG	Abolish	33	14	LWG	Whip	59
4	LWG	Whip	20				
				15	EWG	Ordram	17
5	LWG	Abolish	73				
5	LWG	Ordram	31	16	EWG	Abolish	37
5	LWG	Whip	24	16	EWG	Ordram	61
6	LWG	Abolish	80	17	BYG	Abolish	54
6	LWG	Ordram	43	17	BYG	Ordram	60
6	LWG	Regiment	45	17	BYG	Propanil	13
6	LWG	Whip	70	17	BYG	Regiment	26
7	LWG	Abolish	86	18	BYG	Abolish	68
7	LWG	Ordram	68	18	BYG	Ordram	70
7	LWG	Whip	86				
				19	LWG	Abolish	30
8	LWG	Abolish	62				
8	LWG	Ordram	19	20	LWG	Abolish	54
8	LWG	Regiment	16	20	LWG	Ordram	52
				20	LWG	Regiment	41
9	LWG	Abolish	75	20	LWG	Whip	34
9	LWG	Ordram	23				
9	LWG	Regiment	15	21	EWG	Ordram	90
9	LWG	Whip	68	21	EWG	Propanil	9
10	LWG	Abolish	85	22	BYG	Abolish	68
10	LWG	Ordram	68	22	BYG	Ordram	51
10	LWG	Propanil	18				
10	LWG	Regiment	48	23	LWG	Abolish	75
10	LWG	Whip	59	23	LWG	Ordram	66
				23	LWG	Whip	43
11	LWG	Abolish	70				
11	LWG	Ordram	73	24	EWG	Ordram	41
11	LWG	Propanil	12	24	EWG	Propanil	21
11	LWG	Regiment	58				
11	LWG	Whip	70	25	LWG	Ordram	61
				25	LWG	Regiment	35
12	LWG	Abolish	31	25	LWG	Whip	76
12	LWG	Propanil	14				

* Classification based on preliminary evaluation of pressed panicles and seeds; BYG, barnyardgrass; EWG, early watergrass; LWG, late watergrass.

** Propanil 4 EC

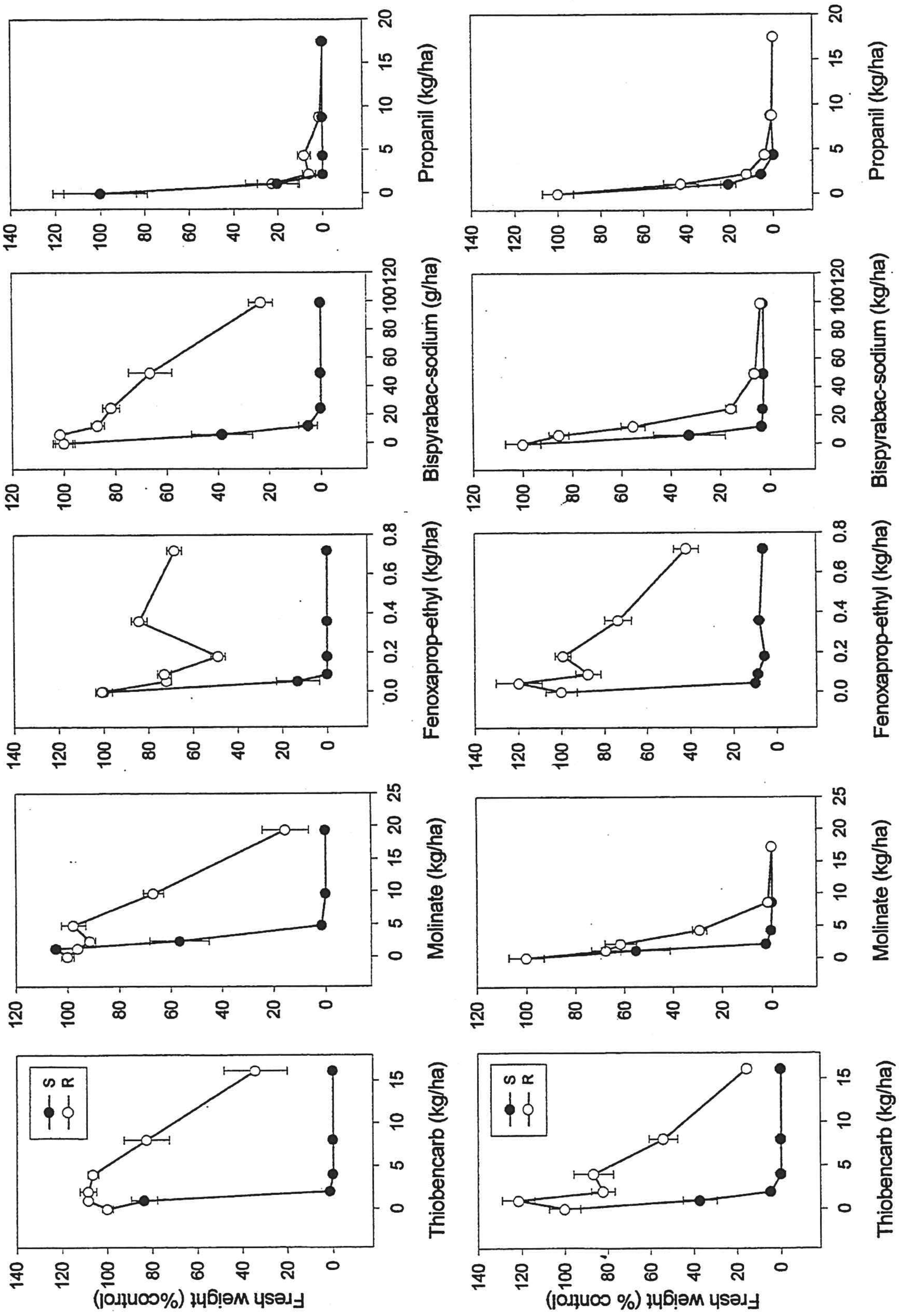

Figure 1. Growth of two herbicide-resistant (R) late watergrass accessions (# 1: top row, # 2: bottom row) compared to that of a susceptible (S) accession 20 days after treatment with six rates of either thiobencarb (Abolish 8EC), molinate (Ordram 15G), fenoxaprop-ethyl (Whip), bispyrabac-sodium (Regiment), and propanil (Propanil EC). Rates are in kg active ingredient/ha, and vertical bars are standard errors of the means.

Appendix A

Trade Names, Common Names, and Manfacture of Herbicides.

Trade Name	Common Name	Manfacturer
Abolish	thiobencarb	United Agri Products
Bolero	thiobencarb	Valent
Clincher	DE-537	Dow AgroSciences
Command	clomazone	FMC
Grandstand	trichlopyr	Dow AgroSciences
Gulliver	azimsulfuron	DuPont
IR-5790		Isagro
IR-5878		Isagro
Liberty	glufosinate	AgrEvo
Londax	bensulfuron	DuPont
Ordram	molinate	Zeneca
Prowl	pendimethalin	American Cyanamid
Regiment	V-10029	Valent
Shark	carfentrazone	FMC
Stam	propanil	Rohm and Haas
Super Wham	propanil	RiceCo
Whip	fenoxaprop	AgrEvo

Appendix B

Additives used with Herbicides

Trade Name	Type	Manufacturer
Agri-Dex	crop oil concentrate	Dow AgroSciences
Kenetic	organo silicone surfactant	Helena
Silwett	organo silicone surfactant	Loveland
X-77	non-ionic surfactant	Valent