Current and Future Grass Herbicides in Rice

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In the early 1990s, rice weed control in California was simple and heavily dependent on two primary products, molinate and bensulfuron-methyl (Table 1). Other grass materials included thiobencarb (Bolero, Abolish) and propanil in designated areas. By the end of the decade, the pattern of grass herbicide use grew more complex, driven in part by events affecting broadleaf materials. Widespread resistance to bensulfuron among several broadleaf and sedge species stimulated increased phenoxy herbicide use. Subsequently, drift onto cotton in the Sacramento Valley caused a dramatic reduction in use of MCPA and 2,4-D after 1997. Concurrently; thiobencarb and propanil use increased because they are effective on smallflower umbrellasedge.

Table 1. Percent of planted acreage treated with selected rice herbicides, 1993-98.

Year:	1993	1994	1995	1996	1997	1998
			% of planted acres			
phenoxies	23.6	26.9	32.5	54.0	57.7	16.2
bensulfuron	91.7	86.9	85.9	75.4	55.0	41.9
fenoxaprop	--	6.9	5.7	5.1	4.7	3.9
molinate	88.4	78.9	75.4	71.2	61.3	55.4
propanil	1.3	2.1	2.3	4.3	7.6	27.5
thiobencarb	14.9	18.9	27.3	31.7	43.9	38.7

Source: Department of Pesticide Regulation, Pesticide Use Reporting website.

Watergrass resistance to commonly used grass herbicides was first reported in California in 1996 and adds a new layer of complexity. Resistance to commonly-used herbicides was confirmed in approximately forty fields from 1996-98, with the probability of many more. Concurrent with identification of resistant grass biotypes, water soluble formulations of propanil, which have lower drift potential, came on the market. Because propanil controls several broadleaf and sedge weeds in addition to *Echinochloa* species, the rice industry has vigorously supported expanded usage. To manage drift until testing can elucidate the drift risk, most propanil applications have been restricted to ground rigs. Propanil is estimated to have been used on 35.7% of the planted acreage in 1999 (County spray permits, W. Steinke, personal communication). Fenoxyprop use began in 1994 and has been consistently used on approximately 5% of the acres, primarily as a cleanup material for watergrass and sprangletop.

As we begin the 2000 growing season, grass weed control in California rice faces several challenges. Primary among them are the twin spectres of resistance and access to effective materials. Following is a brief discussion of the status of current and candidate products for grass weed control in California rice.

Registered herbicides for grass control in California rice

Molinate. Marketed by Zeneca as Ordram 15G and 8EC, molinate has been a mainstay for *Echinochloa* spp. control for over thirty years. It has a narrow spectrum, good selectivity and can be applied early post plant into the water, preplant incorporated or water run with the first flood. When used correctly, molinate is generally the most consistent watergrass herbicide and performs well on grass seedlings up to the four leaf stage. Molinate has very little residual. Recently, molinate resistant biotypes of watergrass were found in the Sacramento Valley. In addition, for the last several years, molinate has been subjected to a data request relative to Proposition 65. Recent research has demonstrated that molinate in test animals (rats) is metabolized differently than in human males and appears to disprove the evidence that it is a reproductive toxicant. While its usage has declined in response to resistance and use of other products, molinate remains a highly important herbicide in California rice production.

Thiobencarb. Marketed by Valent USA as Bolero 10G and by United Agri Products as Abolish 8E, thiobencarb provides control of *Echinochloa* spp, *Leptichloa fascicularis* and *Cyperus difformis*. Its broader spectrum is the primary reason thiobencarb use has increased. Post plant granule applications should be made before the grass reaches the two leaf stage but after the rice has reached the 1.5 leaf stage. Because the window for rice safety is very narrow, earlier timing may lead to injury and later timing to unacceptable control. The liquid formulation can be applied preflood surface and immediately flooded or post plant on drained fields to slightly larger weeds than with the granule. Thiobencarb is the product of choice when sprangletop and/or umbrellasedge are problems. It provides up to thirty days residual control. In certain low CEC soils along the eastern edge of the Sacramento Valley, a toxic de-chlorinated degradation product of thiobencarb has caused widespread damage following use of thiobencarb. This problem, known as ‘delayed phytotoxicity syndrome’ (DPS), has been identified in at least 56 fields. Specific causes or management procedures have not been entirely identified and thiobencarb use has been discontinued in many of these fields, leaving some of these growers without adequate alternatives. As with molinate, some resistant biotypes of thiobencarb have been identified.

Propanil. Marketed as SuperWham CA by RiceCo through UAP, and Stam 80 EDF by Rhom and Haas, both are water soluble formulations with lower drift hazard than the oil-based formulations. Propanil is primarily a watergrass herbicide which has found popularity as a broadleaf and sedge material. It is active on several species and is helpful in those fields where grass and broadleaf herbicide resistance has developed. Propanil is versatile and relatively selective to the rice, and can be mixed with a number of products to improve efficacy and broaden the spectrum. One promising combination is Duet, a mix of propanil and bensulfuron. Propanil is heavily regulated to prevent offsite movement. Three aerial use zones have been designated which are far from sensitive crops, primarily prunes. However, most propanil is restricted to ground application. No-propanil buffer zones of two mile radius are used throughout the Sacramento Valley to protect prunes, grapes, cotton and other sensitive crops. This results in many growers not having access to propanil. In addition, daily acreage limits of 1500 ac/

county have been established to reduce atmospheric loading. This results in application delays during peak periods. Current UC research appears to support smaller buffer zones and larger daily limits and proposals to ammend the regulations will be made by the Propanil Task Force for 2000. This would provide much greater access to the products and help with timliness of application to improve efficacy. Changes in aerial application zones are not likely although the industry clearly would like to increase this component to decrease reliance on ground rigs which are hard to use in rice fields.

Fenoxaprop. Marketed as Whip 1 EC by Aventis, fenoxyprop is effective for postemergent control of watergrass and sprangletop. Whip is applied from the one tiller stage to panicle initiation. Rates are adjusted according to timing. Whip will control grasses over a wide range of growth stages but has a narrow range of selectivity. Non-uniform application can cause crop injury and result in lower control. This product is useful for cleanup of weed escapes and is especially important for sprangletop control. Some resistant watergrass biotypes have been identified.

Table 2. Site of action of registered grass herbicides for rice and weed susceptibility.

		Weed Susceptibility[1]						
Herbicide	Site of action	ECHCG, ECHPH, ECHOR	LEFFA	CYPDI	SCPMU	SAGMO	AMMCO, AMMAU	ALSPA
molinate	VLCFA[2]	C	N	N	N	N	N	N
thiobencarb	VLCFA	C	C	C	N	N	N	N
propanil	Photosys-tem II	C	N	C	C	P	P	P
fenoxaprop	ACCase	C	C	N	N	N	N	N

[1] 'C' - >90% control; 'P' – partial control at label rate; 'N' - < 50% control at label rate

[2] Very long chain fatty acid inhibitor

Herbicides under development for grass control in California rice

Cyhalofop butyl. Under development by Dow Agro Sciences, cyhalofop will be marketed as 'Clincher'. It is effective for post-emergent control of watergrass and sprangletop but has no broadleaf or sedge activity. It is an ACCase inhibitor like fenoxaprop but has greater selectivity so can be applied to smaller plants. An EC formulation with 2.6 lbs ai/gal and an oil based granule are being tested. In University of California trials in 1999, the granule worked well on watergrass when applied early, but gave better control of sprangletop when applied later. The liquid formulation gave good to very good control at all timings. This material has potential for combinations with molinate, propanil and others. A Sect. 3 label application went in to USEPA in December, 1999 and a Section 18 application was submitted to CalEPA in January, 2000, for use in areas where DPS is a problem and thiobencarb cannot be used safely.

Bispyribac-sodium. This experimental material is under development in the US by Valent USA as 'Regiment' for post-emergent control of barnyardgrass and watergrass and is moderately active on ricefield bulrush. It will suppress or give partial control of ducksalad, umbrellasedge, and arrowhead and is weak on sprangletop. Timing is anticipated to be from early post, 3 leaf stage of the rice (lsr) or later, to the tillering stage, at 10-18 g ai/A. Regiment is an ALS inhibitor and has a wide window of application. Earlier application timing permits lower rates. Regiment will usually cause some stunting of rice at higher rates and later application timings. Because it shares the same mode of action with bensulfuron, which has been used since 1989 in California, resistance management will be important when using Regiment. This product has potential for use in combinations with propanil, Abolish and Grandstand to broaden its spectrum and manage resistance. A Sect. 3 label application went into USEPA in July, 1999 and a Sect. 18 application went to CalEPA in January, 2000, for control of resistant weeds in propanil buffer zones.

Clomazone. Under development by FMC, 'Command' is being tested in 3 ME and 1.9 G formulations for watergrass and sprangletop control. In 1999 UC trials, both foliar and granular formulations were applied into standing water at 0.2 to 0.6 lb ai/A, at the 0.5 to 2 lsr. Granules applied early at the higher rate give the best results but increased injury compared to the micro-encapsulated formulation. Some crop injury in the form of leaf bleaching and delayed growth was noted in trials, but disappeared after 15 days. Command is a carotinoid biosynthesis inhibitor and represents a new form of chemistry not currently in use in California rice, so may be very useful for resistance management programs. The product was used in Texas in 1999 under a Sect. 18 exemption. Because it causes bleaching on sensitive plants, drift management will be a consideration for this product.

Glufosinate. 'Liberty' is a broad spectrum, non-selective product under development by Aventis for use on transgenic rice which will carry the name 'Liberty-Link.' The product is contact active and is currently used on Liberty-Link corn, soybean and canola. It provides excellent control of watergrass and sprangletop, good control of redstem and arrowhead and partial control of bulrush and sedge. Sequential applications and mixtures with propanil Grandstand and Shark improved control but increased crop injury. Coverage is very important so water level will have to be adjusted to expose plants. Water management protocols, and rate, timing and combinations need refining. Drift management, especially when planted near non-resistant rice, will be vital. Liberty resistance genes have been inserted into the public variety M-202, the most widely grown variety in California, and seed is under production. Aventis is actively pursuing development of this technology for California for possible commercial use in 2001. The California Rice Commission is developing policies to appropriately integrate this technology in California markets to satisfy the needs of its various customers some of whom have announced they will not purchase genetically modified rice or will require labeling.

Glyphosate. Well known as 'Roundup,' Monsanto is also developing transgenic rice which will be called 'Roundup Ready.' This technology is currently widely used in the US in corn, soybeans, cotton and other crops. Roundup is broadspectrum and has systemic activity, and has a similar weed control spectrum as glufosinate. Similarly, sequential applications and possibly combinations will be beneficial to improve control and broaden the spectrum. Water management to expose weeds and drift management will be important with this product. Monsanto is also using M-202 and is in early stages of development of the transgenic rice and are proceeding cautiously while the industry and markets decide what they want to do with this new technology.

Table 3. Mode of action of candidate grass herbicides for rice and weed susceptibility.

		Weed Susceptibility[1]						
Herbicide	**Site of action**	**ECHCG, ECHPH, ECHOR**	**LEFFA**	**CYPDI**	**SCPMU**	**SAGMO**	**AMMCO, AMMAU**	**ALSPA**
Cyhalofop	ACCase	C	C	N	N	N	N	N
bispyribac	ALS	C	N	N	P	P	N	N
Clomazone	Carotenoid biosynthesis	C	C	N	N	N	N	N
glufosinate	Glutamine synthase	C	C	P	P	C	C	--
glyphosate	EPSP synthase	C	C	P	P	C	C	--

[1] 'C' - >90% control; 'P' – partial control at label rate; 'N' - < 50% control at label rate

Summary

Several key issues and trends will shape the future of grass weed control in California rice. Drift management is one of the issues because many of the current and future products will be applied as liquids. Ground rig application will likely increase as the primary drift management tool, in response to widespread use of materials which have high biological activity and broad spectrum at low dosage rates and which are applied as liquids. The California rice industry has responded to the need for ground application by fabricating a fleet of rigs capable of operating in flooded fields. In the near future, expect to see innovations in application methods that will combine the speed of air application with the drift control of ground rigs. One such example is the Australian SQIIRT technology which meters material into the field via gravity from a moving platform (either ground or air) with drop nozzles. The system depends on migration of the concentrated product to achieve control, but reduces drift because the material is not put out under pressure.

Another key issue is the need to control resistance through rotation and combinations of modes of action, in addition to cultural practices. Alternative materials with differing modes of action must be available for this to be a reality. Several new products are on the horizon but not all are new chemistry so they, too will require stewardship to prevent resistance from developing. They may be best in combinations, which will likely make crop injury more prominent, and growers will need to be able to assess the risk, cost and benefit of these combinations. As new chemistry, including herbicide tolerant technologies, becomes available, resistance management programs should become more effective.

In future, we expect grass weed control to become more complex as more modes of action come on the market, combination and sequential application becomes the norm, and new technologies emerge. Growers will probably spend more for rice weed control, will assume more risk and will need to be more knowledgeable about the alternatives. The days of simple weed control are gone.

Selected References

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