A Survey of Water Management Practices of California Rice Growers

J. E. Hill, S. M. Brouder,* S. R. Roberts, J. F. Williams, S. C. Scardaci, and C. M. Wick

ABSTRACT

Conventional, continuous flood management for rice (*Oryza sativa* L.) irrigation in California has resulted in off-site movement of rice herbicides and other pesticides. In 1991, the University of California Cooperative Extension and the Soil Conservation Service surveyed rice growers in conjunction with the initiation of a 5-yr project designed to demonstrate and evaluate several feasible, alternative water management systems (alternative WMS). The objective of the survey was to collect baseline information on current water management practices and to identify grower-perceived problems and concerns that may pose barriers to adoption of alternative WMS. Grower respondents accounted for 35% of total California rice hectarage in production in 1991. Fifty-six percent of growers reported exclusive use of conventional WMS, while 23% have tried alternative WMS on a portion of their hectarage. Twenty-one percent of respondents have converted their entire rice production hectarage to alternative WMS. Only 43% of conventional WMS growers described themselves as being highly satisfied with their current practice; the same percentage reported that stricter future water quality regulations will force them to change to an alternative WMS. Growers already fully converted to alternative WMS expressed the highest degree of satisfaction, and 60% classified themselves as being well satisfied with their current system. The primary concern of growers anticipating change to an alternative WMS was the cost of constructing and operating the improved system. Secondary concerns were water availability and the future cost of water. The survey results demonstrate that there is a large audience for extension education efforts focused on cost-effective, alternative WMS that improve water conservation and quality of drainage water.

In California, the conventional WMS used on the 0.2 million ha (0.5 million acres) in rice production is continuous flooding for the 120 d between sowing and harvest (Hill et al., 1992). Water moves serially through interconnected basins with the water depth controlled by irrigation boxes placed in levees between basins. Downstream water supplies become polluted when tailwater—water drained off fields by gravity—containing pesticides and other agricultural chemicals, is spilled from the last basin and cannot be held or *ponded* on fallow hectarage. Documented damage from such pollution includes fish kills and an off-taste of municipal drinking water (Cornacchia et al., 1984).

J.E. Hill and S.M. Brouder, Agronomy and Range Science Dep., Univ. of California, Davis, CA 95616; S.R. Roberts, Oryza Horizons, 721 Falcon Ave., Davis, CA 95616; J.F. Wiliams, Yuba/Sutter County Coop. Ext., Yuba City, CA 95992; S.C. Scardaci, Colusa County Coop. Ext., Colusa, CA 95932; and C.M. Wick, Butte County Coop. Ext., Oroville, CA 95695. Received 15 Oct. 1993. *Corresponding author (smbroude@ucdavis.edu).

Published in J. Nat. Resour. Life Sci. Educ. 23:119-124 (1994).

Since 1984, state regulations have required rice growers to contain pesticide-treated water on their farms until the chemicals dissipate or break down into nontoxic products (Coppock, 1992). As California water quality regulations have become stricter, the length of this mandatory holding period has risen substantially. For molinate (Ordram, S-ethyl hexahydro-*1H*-azepine-1-carbothioate), the primary grass herbicide, the holding period has been extended from 4 d in 1983 to 19 d in 1993, while the maximum acceptable concentrations in drainage water declined from 90 to 20 μg/L during the same period.[1] The current performance goals for molinate are only 10 μg/L. Such restrictions have made it increasingly difficult for growers to manage problems inherent to conventional WMS, such as the buildup of water in lower basins that stresses rice and can jeopardize stand establishment (Hill et al., 1991).

A 5-yr (1990–1995) University of California Cooperative Extension (UCCE) and Soil Conservation Service (SCS) project, entitled the Sacrmaento River Rice Water Quality Demonstration (SRRWQD) Project, was funded by the USDA. The purpose of the SRRWQD is to assist rice growers in voluntarily adopting WMS that provide greater control of water depth in rice culture and reduce pesticide loads in local waterways. The three systems included in the demonstration are (i) the conventional, continuous flood system described above; (ii) a tailwater recirculation system where water collected in a sump at the lowest elevation point in a series of interconnected basins is returned to higher points within the system; and (iii) a static system where flap-gated inlet pipes independently serve each basin from the main supply ditch (Fig. 1). Both alternative water management strategies improve on-farm control of water movement and depth and conserve valuable water resources by eliminating off-farm tailwater loss (Hill et al., 1991).

At present, little data are available on individual rice grower water management practices, preferences, and concerns. The purpose of our California Rice Growers Survey was to establish an initial database for the SRRWQD project. The specific objectives were: (i) to create grower water management profiles by collecting information on farm size, land tenure arrangements, and system designs; (ii) to quantify the degree of grower satisfaction with current tailwater management practices and

[1] California Regional Water Quality Control Board, Central Valley Region, Resolution no.90-028, Amendment of the Water Quality Control Plan for the Sacramento River (5A), Sacramento-San Joaquin Delta (5B), and the San Joaquin River (5C) Basins, 26 Jan. 1990.

Abbreviations: WMS, water management systems; UCCE, University of California Cooperative Extension; SCS, Soil Conservation Service; SRRWQD, Sacramento River Rice Water Quality Demonstration.

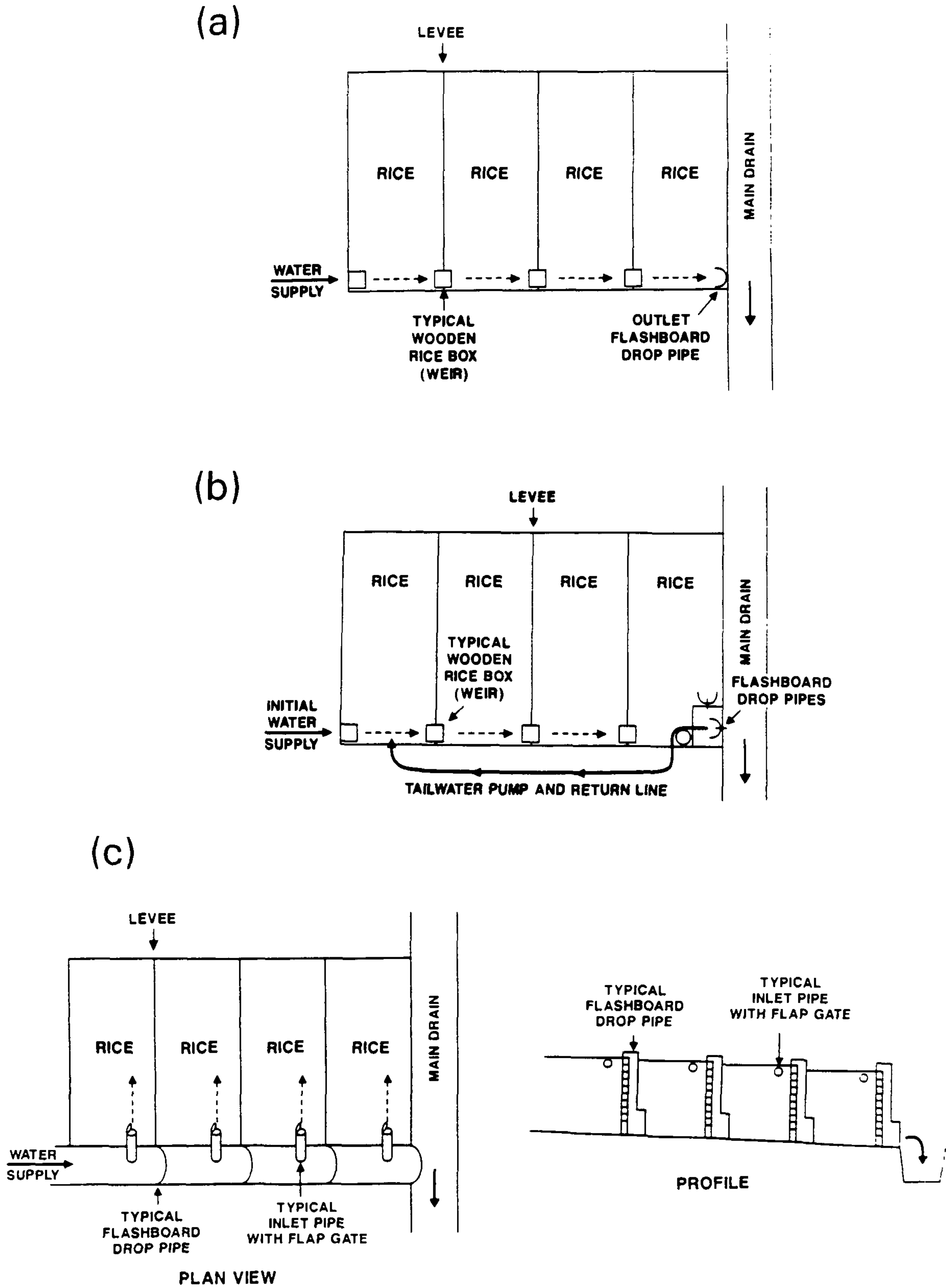

Fig. 1. Illustration of (*a*) the conventional, continuous flow-through water management system used on 59% of California rice production land area; (*b*) a tailwater recirculation system, an alternative water management system that collects water at the lowest elevation point in a series of connected basins and returns it to higher points within the system; and (*c*) a static system (plan view and profile), an alternative water management system that uses flap-gated inlet pipes to independently control water levels in each basin.

to identify problems related to achieving the mandatory water holding requirements for rice pesticides; and (iii) to determine the grower-perceived need to institute change in current management practices and to define the dominant considerations leading to the selection of an alternative system.

Survey results were intended as a guide in the final development and implementation stages of the SRRWQD project and as an aid in the efficient dissemination of associated educational information to appropriate audiences.

MATERIALS AND METHODS

The joint UCCE/SCS SRRWQD project team designed the survey instrument. The format was an eight-page booklet containing a summary statement for the demonstration project and a detailed description of each WMS. The survey posed 13 questions and provided additional space for individual grower comments. The first eight questions pertained directly to our objectives as stated above (Table 1). The remaining questions addressed conventional cultural practices and associated producer perceptions potentially at odds with general water conservation objectives. Information relating to these issues could be incorporated into the SRRWQD project if grower responses demonstrated the need. The back cover of the survey booklet was addressed permitting its return as a prepaid business reply letter.

The target population was the grower component of the California rice industry. In August of 1991, surveys were sent to all 1200 addresses on a six-county, restricted-access industry mailing list. One month after mailing, growers attending the UCCE sponsored Rice Field Day held annually at the Rice Research Field Station at Biggs, CA, were urged to complete and return the questionnaire. In October of 1991, a final effort to contact nonrespondents was made through the popular agricultural press.

One-third of the surveys were completed and returned. Survey Question 4 (Table 1) concerning type of land tenure was used to separate grower from nongrower respondents. The latter category of respondent included industry members such as landowners who are not operators and accounted for one-third of the returned surveys. Survey

Table 1. The 1991 California Rice Grower Survey of Irrigation Systems conducted by the UCCE/SCS Sacramento River Rice Water Quality Demonstration Project.†

Question	Response category
1. Which of the following irrigation systems do you currently use for rice tailwater management to comply with pesticide holding requirements?	• Hold water in conventional system • Ponding on set aside • Tailwater recirculation • Static system • Gravity tailwater recapture • Other
2. If you use a tailwater recovery system, please indicate the nature of the system?	• Individual • Several neighbors • District wide • Gravity tailwater recapture
3. Estimate the percentage (0-100%) of your fields that are laser-leveled?	Comment
4. Of your total rice acreage, indicate the approximate acreage you farm in each of the following tenure categories?	• As an owner-operator • As a cash renter • As a share renter
5. How satisfied are you with your current irrigation system?	• Very satisfied • Fairly satisfied • Not satisfied
6. What problems, if any, have you experienced in meeting mandatory holding requirements for rice pesticides?	• Excessive water depth • Pest problems • Herbicide injury • Gas problems • Other • None
7. Water quality performance goals for Ordram were 30 parts per billion (ppb) in 1990, will be 20 ppb in 1991, and 10 ppb in 1992. Will these regulations necessitate any changes in your future water management practices?	• Yes (Which method would you consider adopting: Tailwater recirculation, Static system, Gravity tailwater recapture?) • No
8. Rank the following considerations in order of importance to you in deciding among irrigation system options.	• Future pesticide water holding requirements • Future water shortages • Cost of constructing and operating the improved system • Future increases in water costs
9. Which of the following water pricing policies do you prefer?	• Unit pricing ($ per acre-foot) • Flat rate ($ per acre) (Please indicate reason(s) for your preferences.)
10. How do you feel about credits on your water bill for reuse of tailwater?	Comment
11. What average water depth do you use during the first 2 mo of your rice production?	• Shallow (less than 4 in.) • Moderate (4-6 in.) • Deep (more than 6 in.)
12. Do you routinely drain your rice fields or allow soil exposure through seepage at any time during the first 1.5 mo of the season?	• Yes (When does it occur? For how many days?) • No
13. For the 1990 season, please check the appropriate lines regarding your herbicide use.	For grass and/or broadleaf herbicides, did you use: • Full labeled rates • Less than full label rate • Multiple applications • More than one product

† The survey is shown here using its original English units. SI units are required elsewhere in this publication. Note: 1 acre = 0.4 ha; ppb = μg/L.

results from these respondents were excluded from all data summary and analyses.

RESULTS AND DISCUSSION

Grower respondents accounted for 35% (48 000 ha; 120 000 acres) of the total California land area in rice production in 1991 and were diverse in terms of size of holdings and type of land tenure. Farm size ranged from 1.2 to 1480 ha (3–3700 acres). Half of the respondents reported growing rice on 120 ha (300 acres) or less, while only 15% farmed 360 ha (900 acres) or more. The predominance of smaller farms indicates UCCE personnel must reach a large total number of growers to successfully promote widespread, voluntary adoption of alternative WMS.

A majority of respondents (56%) farming 59% of the survey land area reported exclusive use of conventional WMS. Twenty-three percent of respondents used some combination of conventional and alternative WMS, while only 21% of respondents, farming a total of 10 400 ha (26 000 acres), have already converted all their land to alternative WMS. No significant relationship was observed between farm size and current WMS, and nearly 87% of all rice hectarage and 85% of rice hectarage in conventional WMS was categorized as *precision-laser graded*. Thus, a portion of the cost associated with improved WMS has already been assumed by most growers, regardless of the size of their enterprise. Comparison of these data with information provided by Sutter and Colusa County Agricultural Commissioner's Office confirmed that survey respondents were representative of California rice producers. The large number of growers who have yet to try an alternative WMS illustrated the need for an educational effort such as the SRRWQD project.

Grower land tenure was divided equally between land area owned (48%) and leased (52%). There was no apparent relationship between the number or proportion of hectares owned by an individual grower and the number or proportion of a grower's hectarage already converted to alternative WMS. These data suggest that renters are no less likely than owner-operators to invest capital in longer-term improvements to WMS. Thus, renting per se, often considered a barrier to changing agricultural practices (Nowak and O'Keefe, 1992),[2] may not be a substantive issue in this situation.

Of the rice hectarage already converted to an alternative WMS, 78% was to tailwater recirculation systems, 12% was to static systems, and 10% was to gravity tailwater recapture systems. Gravity recapture utilizes pipes and gravity flow to divert tailwater from field to field, thus keeping drain water and any accompanying pesticide residue out of public waterways. Tailwater recirculation systems are not new, and their preponderance reflects earlier water conservation efforts made in response to the high cost of irrigation ($125 per hectare [$50 per acre] per season or more) in water districts where, historically, water availability has been limited. In contrast, static and gravity tailwater recapture systems represent newly developed alternatives for water management in rice and, at present, most growers have not had much exposure to these systems. Finally, on large farms and within whole irrigation districts, tailwater recirculation systems provide somewhat better control of water movement than either static or gravity tailwater recapture systems.

There was no significant correlation between current WMS and grower satisfaction. Growers, however, with 75 to 100% of their farm hectarage in alternative WMS had the highest satisfaction rating with 60% describing themselves as *highly satisfied* (Fig. 2). Furthermore, a majority of growers employing only alternative WMS reported having no problems meeting the state-mandated water holding requirements for rice pesticides, and only 20% anticipated having to change their current WMS to meet future, stricter molinate performance goals (Table 2). In contrast, growers with less than 25% of their hectarage in alternative WMS expressed the highest degree of dissatisfaction, and 65% of growers using combined WMS and 43% of strictly conventional WMS growers thought future water quality regulations would necessitate change in their current practice.

Presenting a favorable cost-benefit analysis will be cru-

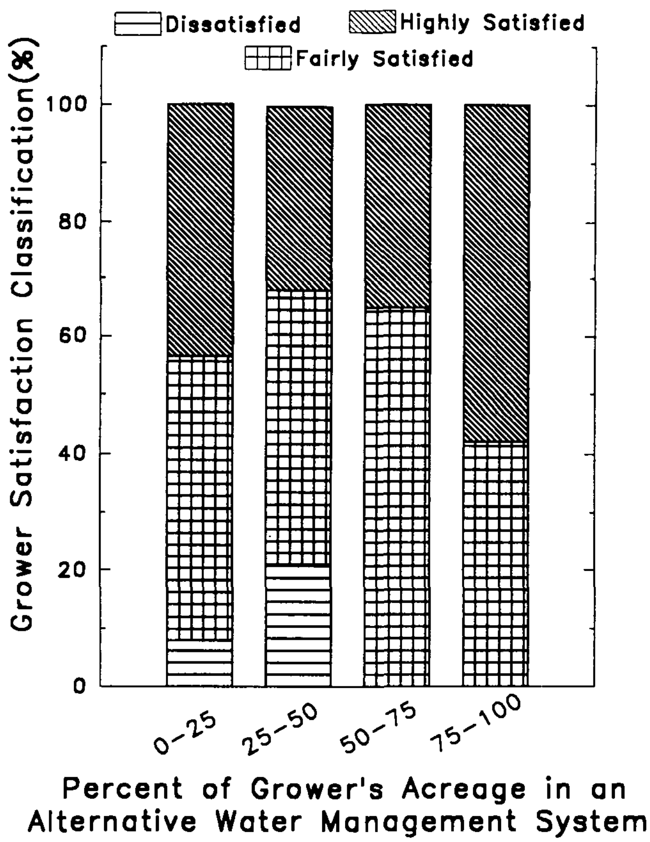

Fig. 2. The relationship between the percent category of a grower's land area already converted to an alternative water management system (0-25, 25-50, 50-75, and 75-100%) and the percent of growers in each category who described themselves as *dissatisfied, fairly satisfied*, or *highly satisfied* with their current water management system.

[2] P.J. Nowak and G.J. O'Keefe. 1992. Evaluation of producer involvement in the United States Department of Agriculture 1990 water quality demonstration projects. Unpublished rep. USDA, Washington, DC.

cial to achieving high levels of voluntary adoption of alternative WMS. The primary concern cited by growers who have not converted any hectarage to alternative WMS was the cost of constructing and operating the improved system (Fig. 3). Similarly, conventional WMS growers are likely to lose 20% of applied water to spillage (Hill et al., 1991) and thus the majority (58%) preferred flat rate pricing for water ($ per acre), citing lower costs as the basis for their choice. In contrast, 56% of alternative WMS growers preferred unit pricing ($ per acre foot). The most common reason given for selecting unit pricing was water conservation promotion. A tailwater credit system involving monetary reimbursement for recycling of drainage water was viewed positively by 56% of all respondents. Clearly, unit pricing and a tailwater credit system present opportunities for off-farm water policy decisions to favorably influence the cost-benefit analyses of alternative compared with conventional WMS.

Finally, our survey identified several cultural practices associated with water management, quality, and conservation that require new or more intensive educational efforts. Regardless of WMS, at least half of all respondents used full label rates of molinate (Fig. 4). Full label application of bensulfuron (Londax, 2-[[[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]methyl] benzoic acid), the primary broadleaf herbicide, ranged from 59% of strictly alternative WMS growers to over 75% of growers using combined WMS. Yet, studies conducted by UCCE have demonstrated that lower rates of both herbicides can be used with equivalent effectiveness,

Table 2. Number and percentage of growers using conventional (holding and ponding), alternative (tailwater recirculation, gravity recapture, and static), or a combination of systems, grower difficulty in meeting mandatory water holding requirements associated with the current system(s), and anticipated change to an alternative system.

	Current water management system			
	Conventional	Alternative	Combined	Total
Number of growers (%)	144 (54.3)	54 (20.4)	58 (25.3)	256 (100)
Problems meeting mandatory water holding requirements:				
Excessive water depth	68 (47.2)	18 (32.1)	33 (56.9)	119 (46.5)
Pesticide problems	24 (16.7)	4 (7.4)	13 (22.4)	41 (16.0)
Herbicide injury	24 (16.7)	4 (7.4)	18 (31.0)	46 (18.0)
Gas problems	10 (6.9)	3 (5.6)	4 (6.9)	17 (6.6)
Other	29 (20.3)	3 (5.6)	13 (19.0)	45 (17.6)
No problems	41 (28.5)	28 (51.9)	14 (24.1)	83 (32.4)
Growers who will change current system	62 (43.1)	11 (20.4)	38 (65.5)	110 (43.0)
Preferred new system:				
Tailwater recirculation	35 (56.5)	3 (27.3)	21 (55.3)	59 (53.6)
Static system	20 (32.3)	6 (54.6)	14 (36.8)	40 (36.4)
Gravity tailwater recapture	10 (16.1)	1 (9.1)	10 (26.3)	20 (18.2)
Other	7 (11.5)	3 (27.3)	2 (5.3)	12 (10.9)

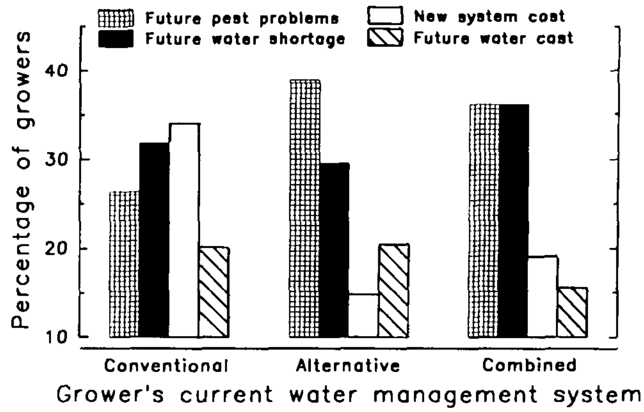

Fig. 3. The percent of growers using conventional (N = 144), alternative (N = 54), or a combination of conventional and alternative (N = 58) water management systems who identified future pest problems, future water shortages, cost of new system installation, or future water cost as their primary concern when evaluating alternative water management systems.

especially when applied in conjunction with increased water depth (Williams et al., 1990).

It should be noted that while early season deep-water culture can provide some direct control of rice weeds, the practice does have documented negative effects on rice seedling root development and early plant growth and tillering (Hill et al., 1992). Growers appear to consider these risks prohibitive. Only 3% of all respondents reported intentionally keeping more than 15 cm (6 in.) of water in basins (data not shown). Indeed, growers, especially those using conventional WMS, perceived excessive water as the primary obstacle to meeting mandatory water hold-

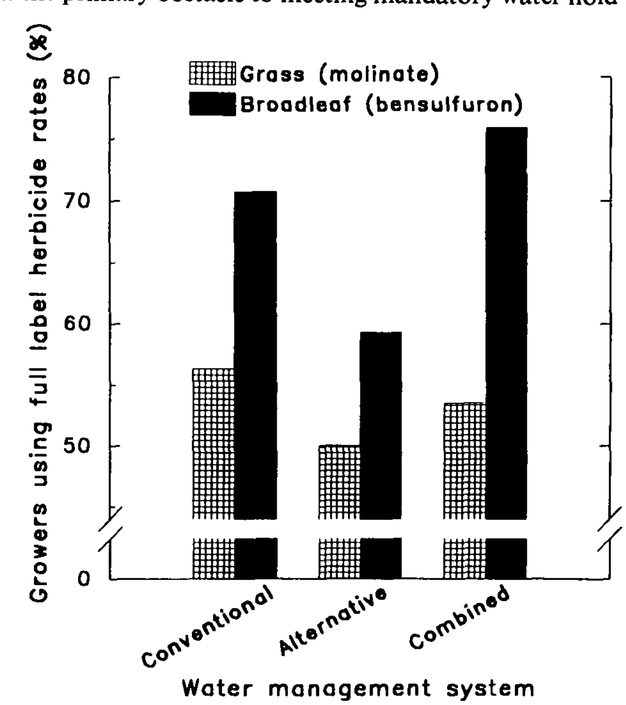

Fig. 4. The percent of growers using conventional, alternative, or a combination of conventional and alternative water management systems who apply full label rates of molinate (Ordram), the primary grass herbicide, and belsulfuron (Londax), the primary broadleaf herbicide.

ing requirements for pesticides (Table 2). Furthermore, 40% of respondents indicated that they drain fields at some point during the first 6 wk of the season. This water management practice contradicts current recommendations of UCCE who report that draining the field early in the season is largely unnecessary in terms of stand establishment and seedling vigor and is wasteful, particularly in drought years (Williams et al., 1990). Educational efforts incorporated into the SRRWQD project that present a more balanced assessment of the risks and advantages associated with deep-water culture appear necessary. The successful demonstrations of both greater precision in water depth management afforded by the alternative WMS and weed control with less than full label herbicide rates will likely improve water conservation in rice production systems and decrease herbicide usage.

CONCLUSIONS

This survey of rice growers produced information essential to the development of the SRRWQD project. The majority of California rice producers are still using conventional WMS, but many anticipate changing to an alternative WMS that will allow them to conserve water and meet state water quality standards. The survey found cost concerns to be the primary barrier to adoption and identified grower views on deep water culture and herbicide usage as closely associated issues that need to be addressed by the SRRWQD project to achieve successful adoption of alternative WMS.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Dr. Lisa Kitinoja of Extension Systems International, Woodland, CA, with the development of the survey instrument and preparation of the manuscript. John Tiedeman of the Soil Conservation System reviewed the survey prior to mailing. This study was supported, in part, through the USDA's Water Quality Initiative Program under special project no. 90-EWQD-1-9501 and the University of California Cooperative Extension.

REFERENCES

Coppock, R. (ed.). 1992. Maintaining the competitive edge in California's rice industry. Univ. of California Agric. Issues Center, Davis, CA.

Cornacchia, J.W., D.B. Cohen, G.W. Bowes, R.J. Schnagl, and B.L. Montoya. 1984. Rice herbicides: Molinate and thiobencarb. Special Proj. Rep. 84. State Water Resources Control Board, Sacramento, CA.

Hill, J.E., S.R. Roberts, D.M. Brandon, S.C. Scardaci, J.F. Williams, C.M. Wick, W.M. Canevari, and B.L. Weir. 1992. Rice production in California. Publ. 21498. Dep. of Agric. and Natural Resour., Univ. of California, Oakland, CA.

Hill, J.E., S.C. Scardaci, S.R. Roberts, J. Tiedeman, and J.F. Williams. 1991. Rice irrigation systems for tailwater management. Publ. 21490. Dep. of Agric. and Natural Resourc., Univ. of California, Oakland, CA.

Nowak, P.J., and G.J. O'Keefe. 1992. Evaluation of producer involvement in the United States Department of Agriculture 1990 water quality demonstration projects. Baseline rep. Submitted to the U.S. Department of Agriculture.

Williams, J.F., S.R. Roberts, J.E. Hill, S.C. Scardaci, and G. Tibbits. 1990. Managing water for weed control in rice. Calif. Agric. 44(5):7–10. ■