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Imazethapyr Co-Application Interactions in Imidazolinone-Resistant Rice

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A study was conducted to evaluate interactions of imazethapyr co-application with propanil, thiobencarb, or a prepackaged mixture of propanil plus thiobencarb. At 7, 14, 21, and 49 d after treatment (DAT), synergism occurred for red rice treated with imazethapyr at 70 g ai ha^{-1} mixed with propanil plus thiobencarb at 1,680 and 3,360 g ai ha^{-1}. A synergistic response was also observed with imazethapyr at 70 g ha^{-1} mixed with propanil at 1,680 g ha^{-1}; however, all other co-applications evaluated resulted in a neutral response with no antagonism observed. At 7 DAT, antagonism was observed for barnyardgrass when treated with imazethapyr at 70 g ha^{-1} mixed with propanil plus thiobencarb at 1,680 g ha^{-1}, propanil at 840 g ha^{-1}, or thiobencarb at 840 and 1,680 g ha^{-1}; however, a synergistic response occurred for barnyardgrass control at 14, 21, and 49 DAT with imazethapyr at 70 g ha^{-1} mixed with propanil plus thiobencarb at 3,360 g ha^{-1}. The synergistic response observed for red rice and barnyardgrass control with a mixture of imazethapyr plus propanil plus thiobencarb can benefit producers by increasing control of red rice and barnyardgrass, and this mixture contains three herbicides with three different modes of action, which can be part of an overall resistance-management strategy in imidazolinone-resistant (IR) rice.
Nomenclature: Imazethapyr; propanil; thiobencarb; barnyardgrass, *Echinochloa crus-galli* (L.) Beauv.; red rice, *Oryza sativa* L.; rice, *Oryza sativa* L.
Key words: antagonism, neutral response, synergism.

Se realizó un estudio para evaluar las interacciones de imazethapyr co-aplicado con propanil, thiobencarb, o en mezclas pre-empacadas de propanil más thiobencarb. A 7, 14, 21, y 49 días después del tratamiento (DAT), ocurrió un sinergismo en arroz rojo tratado con imazethapyr a 70 g ai ha^{-1} mezclado con propanil más thiobencarb a 1,680 y 3,360 g ai ha^{-1}. También se observó una respuesta sinérgica con imazethapyr a 70 g ha^{-1} mezclado con propanil a 1,680 g ha^{-1}. Sin embargo, todas las demás co-aplicaciones evaluadas resultaron en una respuesta neutral sin observarse ningún antagonismo. A 7 DAT, se observó un antagonismo en *Echinochloa crus-galli* tratada con imazethapyr a 70 g ha^{-1} mezclado con propanil más thiobencarb a 1,680 g ha^{-1}, propanil a 840 g ha^{-1}, o thiobencarb a 840 y 1,680 g ha^{-1}. Sin embargo, una respuesta sinérgica ocurrió en el control de *E. crus-galli* a 14, 21, y 49 DAT con imazethapyr a 70 g ha^{-1} mezclado con propanil más thiobencarb a 3,360 g ha^{-1}. La respuesta sinérgica observada en el control de arroz rojo y de *E. crus-galli* con mezclas de imazethapyr más propanil más thiobencarb pueden beneficiar a los productores al incrementar el control de estas dos malezas. Además, estas mezclas contienen tres herbicidas con tres modos de acción diferentes, lo que puede ser parte de una estrategia general de manejo de resistencia en arroz resistente a imidazolinone (IR).

Advances in weed management technology have played an essential role in the development of the rice industry (Ashton and Monaco 1991; Carlson et al. 2011). Weed management decisions often drive the overall production system in rice, and numerous herbicides are available for preemergence and postemergence use in rice (Norsworthy et al. 2007; Webster 2014). Imidazolinone-resistance (IR) rice (Clearfield rice, BASF Corporation, Research Triangle Park, NC 27709) provided a major advancement in weed management technology for producers. IR rice allows the use of imazethapyr (Newpath® herbicide label, BASF Corporation, Research Triangle Park, NC 27709) and imazamox herbicides for control of red rice and other troublesome weeds while producing a rice crop (Croughan 1994; Masson and Webster 2001; Pellerin et al. 2004; Webster and Masson 2001). Imazethapyr is labeled for use in IR rice and provides activity when applied as a PRE application and/or as a POST application when applied at rates

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of 70 to 105 g ha^{-1} (Avila et al. 2005; Masson and Webster 2001).

Red rice has been recognized as a weed in U.S. rice fields for over 150 yr, and has become increasingly troublesome in cultivated rice fields throughout the southern United States (Craigmiles 1978; Khodayari et al. 1987; Smith 1981). Since the development and widespread adoption of IR rice across the southern rice belt, red rice control can vary (Carlson et al. 2011, 2012; Webster et al. 2012; Webster and Masson 2001; Zhang et al. 2001). In addition to red rice, a number of grass and broadleaf weeds exist in rice culture (Braverman 1995). The most common weeds in Louisiana rice include broadleaf signalgrass [*Urochloa platyphylla* (Munro ex C. Wright) R. D. Webster], ducksalad [*Heteranthera limosa* (Sw.) Willd.], hemp sesbania [*Sesbania herbacea* (Mill.) McVaugh], spreading dayflower (*Commelina diffusa* Burm. f.), barnyardgrass, alligatorweed [*Alternanthera philoxeroides* (Mart.) Griseb.], and Indian jointvetch (*Aeschynomene indica* L.), and many of these are not controlled with imidazolinone herbicides (Ottis et al. 2002; Richburg et al. 1995; Webster et al. 2012; Webster and Masson 2001; Zhang et al. 2001).

Mixing two or more herbicides into one spray solution can offer producers multiple benefits, such as broader weed control spectrum and reduced application costs (Hydrick and Shaw 1994). This can be accomplished by mixing a herbicide that controls only grasses with a herbicide that is predominantly active on broadleaf weeds (Blouin et al. 2010; Mueller et al. 1989; Rhodes and Coble 1984). Another practice is to mix a herbicide having nonselective postemergence activity on a stale seedbed production system with a herbicide possessing soil-residual activity (Hydrick and Shaw 1994; Lanclos et al. 2002; Webster and Shaw 1997). For both practices, the modes of action of the herbicides are often different, and the use of different modes of action in a single spray mixture can be part of a herbicide-resistance management strategy (Norsworthy et al. 2012).

Synergism is a term that can describe an agrichemical's ability to interact with another agrichemical in such a way that overall weed control is improved compared with the effect of each product applied independently (Hatzios and Penner 1985). Synergistic effects imply that the level of weed infestation is lower after herbicides are applied in mixture than when they are applied alone, and antagonistic effects imply levels of weed infestation are higher after herbicides are applied (Akobundu et al. 1975; Blouin et al. 2010; Colby 1967; Hatzios and Penner 1985; Morse 1978). If herbicide interactions are not significant in either a synergistic or antagonistic way, an additive response can be said to occur. From this point forward, an additive response will be reported as a neutral response.

A generalized expression for expected responses was given by Colby (1967), which, when applied to means, yields the defining contrast for synergism and antagonism (Colby 1967; Flint et al. 1988). Blouin et al. (2004) offered a third strategy employing nonlinear mixed-model methodology (NLMIXED) of SAS to perform tests of hypotheses (SAS Institute 2011), but its implementation became considerably more difficult and inefficient as the experimental design and analysis became more complex. In 2010, Blouin et al. (2010) further refined the methodology for statistically testing herbicide mixture interactions. Blouin's modified Colby's procedure can be used to separate the means of herbicide mixtures to determine if a synergistic, antagonistic, or neutral response occurs when mixing herbicides together in a single application for weed control.

Propanil (RiceShot® herbicide label. RiceCo LLC, Memphis, TN 38137) in a mixture with herbicides with residual activity has been commonly used to broaden weed control spectrum in rice production (Carlson et al. 2011; Crawford and Jordan 1995; Jordan 1997; Jordan et al. 1998; Norsworthy et al. 2010; Pellerin et al. 2003, 2004; Smith and Hill 1990). For many years, weed control programs for rice in the southern United States centered on propanil and propanil-based products (Shaner 2014; Smith 1961; Smith 1965; Smith and Hill 1990). With the development of IR rice, researchers have reported increased weed control spectrum with the use of propanil-based products mixed with imazethapyr (Carlson et al. 2011; Pellerin et al. 2003, 2004). The use of herbicide mixtures with multiple modes of action can also be part of a resistance management strategy, which is very important in a IR rice production system (Norsworthy et al. 2012).

The objectives of this research were to evaluate the interaction of an imazethapyr mixture with propanil, thiobencarb (Bolero® herbicide label,

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Valent USA Corp, Walnut Creek, CA 94596), or a prepackaged mixture of propanil plus thiobencarb (RiceBeaux® herbicide label, RiceCo LLC, Memphis, TN 38137) on several weeds in IR rice production.

Materials and Methods

A field study was conducted at four locations: (1) the Louisiana State University Agricultural Center Rice Research Station (RRS) near Crowley, LA, in 2011 and 2012 on a Crowley silt loam soil, with pH 6.4 and 1.4% organic matter (OM); (2) the Louisiana State University Agricultural Center Northeast Research Station (NERS) near St. Joseph, LA, in 2012 on Commerce silt loam with pH 6.1 and 2.2% OM; (3) the Louisiana State University Agricultural Center Macon Ridge Research Station (MRRS) near Winnsboro, LA, in 2012 on a Gigger silt loam pH 5.8 and 1.3% OM; (4) the Mississippi State University Delta Research and Extension Center (DREC) near Stoneville, MS in 2012 on a Sharkey clay with a pH of 8.2 and 2.2% OM. Plot size at all locations was 1.5 by 6 m, with eight 20-cm rows.

The experimental design was a two-factor factorial arrangement of treatments in a randomized complete block with four replications. Long grain 'CL-111′ IR rice was planted in 2011 and 2012 at all research locations. Factor A consisted of imazethapyr at 0 and 70 g ai ha^{-1}, Factor B consisted of mixture herbicides, propanil at 840 or 1,680 g ai ha^{-1}, thiobencarb at 840 or 1,680 g ai ha^{-1}, a prepackaged mix of propanil plus thiobencarb at 1,680 or 3,360 g ai ha^{-1}, and no mixture herbicide. Propanil and thiobencarb rates applied alone are equal to the rates found in the two rates of the prepackaged mix of propanil plus thiobencarb evaluated.

Herbicide applications were made with the use of a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} solution at 190 kPa. The spray boom consisted of five flat-fan 110015 nozzles (Flat Fan AirMix® Venturi Nozzle, Greenleaf Technologies, Covington, LA 70434) with a 38-cm spacing. A COC at 1% v/v (Agri-Dex adjuvant label, Helena Chemical Company, Collierville, TN 38017) was added to imazethapyr when applied alone; however, no COC was added to any herbicide mixture that contained propanil and/or thiobencarb. Propanil and thiobencarb used in this research are EC formulations and require no adjuvant when mixed with imazethapyr. The initial treatment containing herbicide mixtures was applied on one- to three-leaf rice. In order to follow the IR rice stewardship program, the entire area at all locations received a second application of imazethapyr at 70 g ha^{-1} applied alone 14 d later to rice in the four- to five-leaf stage.

Data obtained from the studies included visual evaluation of weed control and crop injury based on chlorosis and necrosis of foliage and reduced plant height on a scale of 0 to 100%, where 0 = no injury or control and 100 = plant death. Rice plant height was recorded from the ground to the tip of the extended panicle immediately prior to harvest, and rough rice yield was obtained for the primary crop with a small plot combine harvesting the center four rows of each plot. Grain yield was adjusted to 12% moisture.

Treatments were applied at the RRS in 2011 on red rice at the one- to three-leaf stage, or 2 to 8 cm, and barnyardgrass at the one- to four-leaf stage, or 1 to 8 cm. In 2012, treatments were applied two- to three-leaf, or 5- to 10-cm, red rice and to two- to three-leaf, or 5- to 10-cm, barnyardgrass. In 2012 at the NERS, applications were made on two- to six-leaf, or 1- to 8-cm, barnyardgrass. In 2012, at the MRRS, applications were made on two- to four-leaf, or 3- to 5-cm, barnyardgrass. In 2012, at the DREC applications were made on one- to four-leaf, or 5- to 8-cm, barnyardgrass, and one-to three-leaf, or 3- to 5-cm, barnyardgrass.

Red rice control was evaluated in 2011 and 2012 at the RRS at 7, 14, 21, and 49 d after initial treatment (DAT) and in 2012 at the DREC at 7 and 14 DAT. Barnyardgrass control was evaluated in 2011 and 2012 at the RRS at 7, 14, 21, and 49 DAT, in 2012 at the NERS at 14 and 49 DAT, in 2012 at the MRRS at 21 and 49 DAT, and at the DREC at 7 and 14 DAT. Crop injury was also evaluated at each rating date.

Interaction for control data were analyzed under the guidelines described by Blouin et al. (2010), and rough rice yield data were analyzed with the use of the MIXED procedure of SAS (SAS 2008). The fixed effects for all models were the treatment mixtures from the two rates of imazethapyr in combination with mixture herbicides. The random effects for the model were location by year,

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replication within location by year, and treatment-by-replication interactions. The formulation of the model was detailed by Blouin et al. (2011). The dependent variables in separate analyses were red rice control, barnyardgrass control, and rice yield. The analyses for control were by DAT. The analysis for yield used the Fisher's protected LSD ($P = 0.05$) to compare treatment means. Normality of plot effects over all DAT was checked using the UNIVARIATE procedure of SAS (SAS 2011). Significant normality problems were not observed.

Results and Discussion

At 7 d after treatment (DAT), synergism occurred for red rice when treated with imazethapyr at 70 g ha^{-1} mixed with propanil plus thiobencarb at 1,680 and 3,360 g ha^{-1}, with an observed control of 66 and 71% compared with an expected control of 59 and 61%, respectively (Table 1). At 14 DAT, red rice, treated with imazethapyr mixed with propanil plus thiobencarb at 1,680 and 3,360 g ha^{-1}, or with propanil at 1680 g ha^{-1}, control was synergistic by increasing control from an expected 78% to an observed 87, 91, and 85% control, respectively. At 21 and 49 DAT, the same synergistic response occurred with the co-application of imazethapyr mixed with propanil plus thiobencarb at 7 and 14 DAT. This indicates that the propanil and thiobencarb prepackaged mixture consistently provides synergism when mixed with imazethapyr for red rice control. This increased control of red rice over the expected control may be due to increased uptake and translocation of imazethapyr when mixed with propanil plus thiobencarb compared with imazethapyr applied alone. The propanil plus thiobencarb prepackaged mixture is an EC formulation, and this formulation may be working as a better adjuvant compared with a crop oil concentrate by allowing more efficient uptake and translocation of imazethapyr. A neutral response occurred for all other mixtures at all other rating dates. No antagonism for red rice control was observed for any herbicide mixture evaluated. These data suggest that the addition of the prepackaged mixture can be beneficial for red rice control when mixed with imazethapyr. Carlson et al. (2011) reported increased red rice control, higher rice yield, and increased profits when using propanil mixed with imazethapyr in an IR weed management program.

At 7 DAT, antagonism was observed for barnyardgrass with imazethapyr mixed with propanil plus thiobencarb at 1680 g ha^{-1}, propanil at 840 g ha^{-1}, or thiobencarb at 840 and 1,680 g ha^{-1} by decreasing control from an expected control of 93, 91, 89, and 90% to an observed control of 86, 85, 77, and 79%, respectively (Table 2). These data suggest a 7 DAT rating may be too early to evaluate the potential benefits of these co-applications for barnyardgrass control. Although no synergism was observed, a neutral response was observed on barnyardgrass with the high rate of the prepackaged mixture and the high rate of propanil mixed with imazethapyr at 7 DAT.

The high rate of the prepackaged mixture resulted in a synergistic response for barnyardgrass control at 14, 21, and 49 DAT, and the low rate of propanil plus thiobencarb was synergistic at 21 DAT and neutral at 49 DAT. As observed for red rice control, imazethapyr plus the prepackaged mixture of propanil plus thiobencarb applied at 3360 g ha^{-1} can consistently increase barnyardgrass control over the products applied alone. At 14, 21, and 49 DAT, barnyardgrass treated with propanil at 840 or 1,680 kg ha^{-1} and thiobencarb at 840 or 1,680 kg ha^{-1} mixed with imazethapyr resulted in a neutral response; although no synergism was observed, a neutral response suggests no negative impact with these mixtures. The synergism observed for barnyardgrass control is probably due to imazethapyr. The prepackaged mixture of propanil plus thiobencarb both have activity on barnyardgrass when applied separately, and by applying the products in a single spray mixture, the control may be enhanced. This indicates that the propanil and thiobencarb prepackaged mixture consistently provides synergism when mixed with imazethapyr for red rice control. As mentioned in the red rice discussion, the increased control of barnyardgrass over the expected control may be due to increased uptake and translocation of imazethapyr when mixed with propanil plus thiobencarb compared with imazethapyr applied alone. The propanil plus thiobencarb prepackaged mixture is an EC formulation, and this formulation may be working as a better adjuvant compared with a crop oil concentrate by allowing more efficient uptake and translocation of imazethapyr.

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Table 1. Observed and expected red rice control and interactions with imazethapyr mixed with propanil and/or thiobencarb, in 2011 and 2012 at the RRS and the DREC in 2012.[a]

		Imazethapyr (g ha^{-1})			
		0	70		
Mixture herbicide[b]	Rate[c]	Observed	Expected	Observed[d]	P value
	g ha^{-1}	% of control			
7 DAT					
None	–	0	–	58	–
Propanil + thiobencarb[d]	1,680	3	59	66+	0.0069
Propanil + thiobencarb	3,360	8	61	71+	0.0003
Propanil	840	1	58	63	0.1071
Propanil	1,680	4	59	64	0.0897
Thiobencarb	840	0	58	58	1.0000
Thiobencarb	1,680	0	58	61	0.1768
14 DAT					
None	–	0	–	78	–
Propanil + thiobencarb	1,680	0	78	87+	0.0001
Propanil + thiobencarb	3,360	0	78	91+	0.0000
Propanil	840	0	78	80	0.3050
Propanil	1,680	0	78	85+	0.0033
Thiobencarb	840	0	78	79	0.5378
Thiobencarb	1,680	0	78	82	0.0949
21 DAT					
None	–	0	–	82	–
Propanil + thiobencarb	1,680	0	82	94+	0.0000
Propanil + thiobencarb	3,360	2	82	96+	0.0000
Propanil	840	2	82	83	0.6641
Propanil	1,680	1	82	83	0.5900
Thiobencarb	840	0	82	83	0.7676
Thiobencarb	1,680	0	82	83	0.5548
49 DAT					
None	–	0	–	81	–
Propanil + thiobencarb	1,680	0	81	89+	0.0168
Propanil + thiobencarb	3,360	3	81	91+	0.0026
Propanil	840	2	81	79	0.4867
Propanil	1,680	3	81	80	0.7293
Thiobencarb	840	2	81	79	0.4867
Thiobencarb	1,680	1	81	79	0.5373

[a] RRS, Louisiana State University AgCenter Rice Research Station near Crowley, LA; DREC, Mississippi State University Delta Research and Extension Center near Stoneville, MS.

[b] Evaluation date and respective herbicide mixture.

[c] Propanil and thiobencarb applied alone are equivalent to rates found in prepackaged mixtures.

[d] Observed means followed by a plus (+) or a minus (–) are significantly different from Blouin's Modified Colby's expected responses at the 5% level indicating a synergistic or an antagonistic response. No (+) or (–) indicates a neutral response.

Crop injury was less than 10%, and no difference in crop height occurred at harvest across all locations, treatments, and ratings (data not shown). Rice treated with mixtures containing imazethapyr resulted in a higher yield than those without imazethapyr (Table 3). Although no yield increase was observed for co-application of imazethapyr plus propanil, thiobencarb, or the prepackaged mixture, yield increases and increased profits have been reported when other herbicides, such as propanil, are mixed with imazethapyr (Carlson et al. 2011; Pellerin et al. 2003, 2004; Webster et al. 2012).

In conclusion, the addition of a prepackaged mixture of propanil plus thiobencarb in mixture

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Table 2. Observed and expected barnyardgrass control and interactions with imazethapyr mixed with propanil and/or thiobencarb, in 2011 and 2012 at the RRS and 2012 at the RRS, NERS, MRRS, and DREC.[a]

		Imazethapyr (g ha^{-1})			
		0	70		
Mixture herbicide[b]	Rate[c]	Observed	Expected	Observed[d]	P value
	g ha^{-1}	% of control			
7 DAT					
None	–	0	–	71	–
Propanil + thiobencarb	1,680	76	93	86–	0.0376
Propanil + thiobencarb	3,360	83	95	90	0.1425
Propanil	840	69	91	85–	0.0475
Propanil	1,680	74	92	88	0.1636
Thiobencarb	840	63	89	77–	0.0000
Thiobencarb	1,680	67	90	79–	0.0004
14 DAT					
None	–	0	–	69	–
Propanil + thiobencarb	1,680	45	83	86	0.4363
Propanil + thiobencarb	3,360	54	86	93+	0.0447
Propanil	840	32	79	80	0.9018
Propanil	1,680	42	82	85	0.4200
Thiobencarb	840	29	78	79	0.8528
Thiobencarb	1,680	43	83	81	0.6455
21 DAT					
None	–	0	–	72	–
Propanil + thiobencarb	1,680	32	81	91+	0.0220
Propanil + thiobencarb	3,360	51	86	96+	0.0248
Propanil	840	39	83	77	0.1326
Propanil	1,680	43	84	81	0.4373
Thiobencarb	840	25	79	78	0.7964
Thiobencarb	1,680	37	82	79	0.4408
49 DAT					
None	–	0	–	61	–
Propanil + thiobencarb	1,680	28	71	78	0.2486
Propanil + thiobencarb	3,360	40	76	92+	0.0024
Propanil	840	24	70	68	0.6416
Propanil	1,680	29	72	78	0.2967
Thiobencarb	840	30	73	69	0.5380
Thiobencarb	1,680	30	72	71	0.7263

[a] Abbreviations: RRS, Louisiana State University AgCenter Rice Research Station near Crowley, LA; NERS, Louisiana State University AgCenter Northeast Research Station near St. Joseph, LA; MERS, Louisiana State University AgCenter Macon Ridge Research Station near Winnsboro, LA; and DREC, Mississippi State University Delta Research and Extension Center near Stoneville, MS.

[b] Evaluation date and respective herbicide mixture.

[c] Propanil and thiobencarb applied alone are equivalent to rates found in prepackaged mixtures.

[d] Observed means followed by a plus (+) or a minus (–) are significantly different from Blouin's modified Colby's expected responses at the 5% level, indicating a synergistic or an antagonistic response. No (+) or (–) indicates a neutral response.

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Table 3. Rough rice yields of rice treated with imazethapyr mixed with propanil and/or thiobencarb, in 2011 and 2012 at the RRS.[a]

Mixture herbicide[b]	Rate[c]	Imazethapyr (g ha^{-1})	
		0	70
	g ha^{-1}	kg ha^{-1}	
None	–	3,460 e[d]	5,210 abcd
Propanil + thiobencarb[c]	1,680	4,450 bcde	5,620 abc
Propanil + thiobencarb	3,360	4,680 bcde	6,250 a
Propanil	840	4,400 bcde	5,370 abcd
Propanil	1,680	3,990 de	5,750 ab
Thiobencarb	840	3,580 e	4,960 abcde
Thiobencarb	1,680	4,120 cde	5,400 abcd
Standard error		2,340	

[a] RRS, Louisiana State University AgCenter Rice Research Station near Crowley, LA.

[b] Evaluation date and respective herbicide mixture.

[c] The products applied alone are equivalent to rates found in prepackaged mixtures.

[d] Means followed by the same letter were not statistically different according to the Fisher's protected LSD on difference of least-square means at P = 0.05 with the use of PROC MIXED.

with imazethapyr is synergistic for control of red rice and barnyardgrass. These results are similar to other research from Louisiana reporting increased control of red rice, barnyardgrass, Texasweed [*Caperonia palustris* (L.) St. Hil.] and alligatorweed with imazethapyr mixed with propanil-containing herbicides (Carlson et al. 2012; Pellerin et al. 2003, 2004; Webster et al. 2012). The addition of multiple herbicide modes of action per individual application can help prevent or reduce the development of herbicide-resistant weeds, and can be part of an overall strategy to help manage the development of herbicide resistance (Norsworthy et al. 2012). Researchers have also reported herbicide programs containing co-applications of imazethapyr plus a propanil-containing herbicide resulted in higher rough rice yields and higher profits than programs including only imazethapyr applications (Carlson et al 2011; Webster et al. 2012). There are multiple weed species that infest rice fields and rarely is there a single weed monoculture in rice production (Braverman 1995; Webster 2004). The IR rice production system is often infested with Indian jointvetch, hemp sesbania, and alligatorweed, and these weeds can be difficult to control, or a resistance management program may be needed when barnyardgrass and red rice infests rice. The combination of imazethapyr plus propanil plus thiobencarb provides a mixture with three different modes of action, and provides an excellent opportunity to broaden the weed control spectrum (Carlson et al. 2011, 2012; Masson and Webster 2001; Norsworthy et al. 2007; Pellerin et al. 2004; Webster et al. 2012). This will also offer growers with a herbicide resistance management program in IR rice production (Norsworthy et al. 2012).

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