EVALUATION OF QUIZALOFOP-P-ETHYL MIXED WITH CONTACT HERBICIDES USED IN RICE PRODUCTION

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INTRODUCTION

Imidazolinone-resistant (IR) rice (*Oryza sativa* L.), sold under the name Clearfield® is resistant to imidazolinone herbicides. This herbicide resistant technology was commercialized in 2002, and for the first time rice producers were able to control red rice (*O. sativa* L.) with a herbicide during cultivated rice production. IR hybrid rice was introduced in 2004. Crops are often associated with their respective weedy forms, and for over 150 years red rice has been a troublesome of cultivated rice. Hybrid rice seed has a history of dormancy and becomes weedy when allowed to establish in succeeding growing seasons. A major issue with weedy rice is the ability to outcross with inbred and hybrid IR rice, causing the development of IR weedy rice.

With rising concerns about IR weedy rice and barnyardgrass resistant to several herbicides with different modes of action, BASF is currently developing a new herbicide resistant rice. This rice was developed with resistance to group 1 herbicides, specifically the aryloxyphenoxypropionate herbicides. The herbicide targeted for use is quizalofop, an acetyl coenzyme A carboxylase (ACCase) inhibiting herbicide. ACCase-resistant rice (ACCase-R) will allow the use of quizalofop applied postemergence to control many annual and perennial grasses including the weedy rice complex. The targeted single quizalofop application rate in ACCase-R rice production will be 92 to 155 g ai ha^{-1}, not to exceed 240 g ha^{-1} per year. Quizalofop has been used to substantially reduce red rice infestations during soybean production applied at rates from 35 to 84 g ai ha^{-1} and 84 to 112 g ha^{-1} in non-crop areas for annual or perennial grass control.

Herbicide mixtures have proven to be beneficial for improving efficacy, broadening the weed control spectrum, and maximizing yield and economic returns (Carlson et al. 2011). Herbicide mixtures can have one of three responses: synergistic, antagonistic, or neutral (Blouin 2010). ACCase inhibiting herbicide activity is often antagonized when applied in mixtures with other herbicides. Antagonism of ACCase herbicide activity on barnyardgrass has previously been observed in Louisiana rice production when fenoxaprop activity was reduced when applied in a mixture with halosulfuron, bensulfuron, or carfentrazone; however, fenoxaprop mixtures with bentazon or molinate resulted in a neutral response (Zhang et al. 2005). The objective of this study was to evaluate quizalofop activity when applied independently or in a mixture with contact herbicides

MATERIALS AND METHODS

A study was conducted in 2015 and 2016 at the H. Rouse Caffey Rice Research Station (RRS) near Crowley, Louisiana. Plot size was 5.1 by 2.2 m with eight 19.5 cm drill-seeded rows planted as follows: 4 center rows of ACCase-R 'PVL024B' long grain rice, 2 rows of 'CL-111' long grain IR rice, and 2 rows of 'CLXL-745' hybrid long grain IR rice. The research area is also naturally infested with awnless red rice and barnyardgrass. Each herbicide application was applied when ACCase-R rice was at the three- to four-leaf growth stage. The study was a randomized complete block with a factorial arrangement of treatments with four replications. Factor A was quizalofop applied at 120 g ha^{-1} or no quizalofop (Table 1).

Factor B was bentazon at 1050 g ai ha^{-1}, carfentrazone at 18 g ai ha^{-1}, propanil at

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3360 g ai ha^{-1}, saflufenacil at 25 g ai ha^{-1}, thiobencarb at 3360 g ai ha^{-1}, or no mixture herbicide. A second quizalofop application was applied to all treatments at a rate of 120 g ha^{-1} at 28 days after (DA) the initial quizalofop treatment (DAIT). Visual evaluations for this study included crop injury, barnyardgrass, red rice, CL-111, and CLXL-745 control.

Control data collected were analyzed using the Blouin et al. (2010) augmented mixed model to determine synergistic, antagonistic, or neutral responses for herbicide mixtures by comparing an expected control calculated based on activity of each herbicide applied alone to an observed control.

RESULTS AND DISCUSSION

Antagonistic responses were observed for red rice control when quizalofop was mixed with propanil at 14, 28, and 42 DAIT (Table 1). At 14 and 28 DAIT, expected control was 95 and 94%, respectively compared with an observed control of 75 and 71%, respectively. At 42 DAIT, an antagonistic response was observed on red rice treated with quizalofop plus propanil with an observed control of 94%, compared with an expected control of 99%. Similar to red rice responses at 14 and 28 DAIT, the addition of propanil to quizalofop resulted in an observed control of CLXL-745 IR hybrid rice 75 and 69%, respectively, compared with an expected control of 94 and 92%, respectively (Table 2). The same treatment at 42 DAIT was still antagonistic with an additional treatment of quizalofop applied alone at 28 DAIT. CL-111 responses were similar to CLXL-745, except a neutral response was observed for quizalofop mixed with saflufenacil at 14 DAIT (Table 3).

Neutral responses were observed for red rice, CLXL-745, CL-111, and barnyardgrass at all evaluation dates when quizalofop was mixed with carfentrazone or thiobencarb, and this may indicate the potential for use as a mixture herbicide with quizalofop in an ACCase-R rice production system.

The only antagonism of quizalofop activity was observed with propanil mixtures at all evaluation dates 14, 28, and 42 DAIT. The addition of a second quizalofop application was not sufficient enough to overcome the antagonism observed at 14 and 28 DAIT when quizalofop was applied mixed with propanil. Propanil antagonized quizalofop activity on barnyardgrass at 14 and 28 DAIT with an observed control of 16 and 38%, respectively, compared with an expected control of 92 to 94% (Table 4). By 42 DAIT, the second quizalofop application at 28 DAIT could not overcome the antagonism observed at earlier evaluations 14 and 28 DAIT, with an observed control of 83% compared with an expected control of 99%. These data indicate propanil should be avoided in an ACCase-R rice production system.

CONCLUSIONS

When comparing all contact herbicides evaluated, these data suggest propanil is least compatible in a mixture with quizalofop on red rice, CLXL-745, CL-111, and barnyardgrass, thus resulting in reduced yield and a negative impact on economic returns. Quizalofop activity can be antagonized when applied on red rice, CLXL-745, CL-111, or barnyardgrass when mixed with propanil, even when quizalofop is applied alone 28 DAIT. Although ACCase-R rice treated with quizalofop plus bentazon or saflufenacil indicated neutral responses at 28 DAIT, antagonized red rice, CLXL-745, CL-111, and barnyardgrass at 14 DAIT can still compete with ACCase-R rice early in the growing season, resulting in a yield reduction

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Table 1. Red rice control with quizalofop applied alone or mixed with various herbicides with contact activity using Blouin's modified Colby's analysis in 2015 and 2016.

Mixture Herbicide[a]	Rate g ai ha^{-1}	Quizalofop (g ai ha^{-1}) 0 Observed	120 Expected	120 Observed[b]
		% of control		
14 DAIT[c]				
None	—	0	—	95
Bentazon	1050	0	95	89
Carfentrazone	18	0	95	90
Propanil	3360	0	95	75-
Saflufenacil	25	0	95	88
Thiobencarb	3360	0	95	91
28 DAIT				
None	—	0	—	94
Bentazon	1050	0	94	89
Carfentrazone	18	0	94	95
Propanil	3360	0	94	71-
Saflufenacil	25	0	94	94
Thiobencarb	3360	0	94	95
42 DAIT[e]				
None	—	0	—	99
Bentazon	1050	79	99	97
Carfentrazone	18	82	99	97
Propanil	3360	79	99	94-
Saflufenacil	25	82	99	98
Thiobencarb	3360	76	99	98

[a]Evaluation dates for each respective herbicide mixture. [b]Observed means followed by a minus (-) are significantly different from Blouin's modified Colby's expected responses at the 5% level indicating an antagonistic response. No (-) indicates an additive response. [c]DAIT, days after initial treatment.

Table 2. Hybrid CLXL-745 IR rice control with quizalofop applied alone or mixed with various herbicides with contact activity using Blouin's modified Colby's analysis in 2015 and 2016.

Mixture Herbicide[a]	Rate g ai ha^{-1}	Quizalofop (g ai ha^{-1}) 0 Observed	120 Expected	120 Observed[b]
		% of control		
14 DAIT[c]				
None	—	0	—	94
Bentazon	1050	0	94	89-
Carfentrazone	18	0	94	90
Propanil	3360	0	94	75-
Saflufenacil	25	0	94	88-
Thiobencarb	3360	0	94	91
28 DAIT				
None	—	0	—	92
Bentazon	1050	0	92	87
Carfentrazone	18	0	92	88
Propanil	3360	0	92	69-
Saflufenacil	25	0	92	84
Thiobencarb	3360	0	92	88
42 DAIT[e]				
None	—	0	—	99
Bentazon	1050	82	99	97
Carfentrazone	18	81	99	96
Propanil	3360	73	99	92-
Saflufenacil	25	80	99	98
Thiobencarb	3360	76	99	97

[a]Evaluation dates for each respective herbicide mixture. [b]Observed means followed by a minus (-) are significantly different from Blouin's modified Colby's expected responses at the 5% level indicating an antagonistic response. No (-) indicates an additive response. [c]DAIT, days after initial treatment.

Table 3. CL-111 IR rice control with quizalofop applied alone or mixed with various herbicides with contact activity using Blouin's modified Colby's analysis in 2015 and 2016.

Mixture Herbicide[a]	Rate g ai ha^{-1}	Quizalofop (g ai ha^{-1}) 0 Observed	120 Expected	120 Observed[b]
		% of control		
14 DAIT[d]				
None	—	0	—	94
Bentazon	1050	0	94	82^{-}
Carfentrazone	18	0	94	86
Propanil	3360	0	94	71-
Saflufenacil	25	0	94	86
Thiobencarb	3360	0	94	87
28 DAIT				
None	—	0	—	92
Bentazon	1050	0	92	89
Carfentrazone	18	0	92	93
Propanil	3360	0	92	71-
Saflufenacil	25	0	92	91
Thiobencarb	3360	0	92	91
42 DAIT[e]				
None	—	0	—	99
Bentazon	1050	78	99	97
Carfentrazone	18	80	99	96
Propanil	3360	79	99	92-
Saflufenacil	25	77	99	98
Thiobencarb	3360	77	99	98

[a]Evaluation dates for each respective herbicide mixture. [b]Observed means followed by a minus (-) are significantly different from Blouin's modified Colby's expected responses at the 5% level indicating an antagonistic response. No (-) indicates an additive response. [c]DAIT, days after initial treatment.

Table 4. Barnyardgrass control with quizalofop applied alone or mixed with various herbicides with contact activity using Blouin's modified Colby's analysis in 2015 and 2016.

Mixture Herbicide[a]	Rate g ai ha^{-1}	Quizalofop (g ai ha^{-1}) 0 Observed	120 Expected	120 Observed[b]
		% of control		
14 DAIT[d]				
None	—	0	—	89
Bentazon	1050	0	89	82
Carfentrazone	18	0	89	82
Propanil	3360	27	92	38-
Saflufenacil	25	17	91	81^{-}
Thiobencarb	3360	20	91	85
28 DAIT				
None	—	0	—	92
Bentazon	1050	0	92	87
Carfentrazone	18	7	92	94
Propanil	3360	32	94	16-
Saflufenacil	25	12	93	93
Thiobencarb	3360	15	93	92
42 DAIT[e]				
None	—	0	—	99
Bentazon	1050	79	99	98
Carfentrazone	18	77	99	95
Propanil	3360	77	99	83-
Saflufenacil	25	80	99	98
Thiobencarb	3360	80	99	97

[a]Evaluation dates for each respective herbicide mixture. [b]Observed means followed by a minus (-) are significantly different from Blouin's modified Colby's expected responses at the 5% level indicating an antagonistic response. No (-) indicates an additive response. [c]DAIT, days after initial treatment.