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EARLY WATERGRASS (*Echinochloa oryzoides*) AND LATE WATERGRASS (*Echinochloa phyllopogon*) CONTROL WITH FORAMSULFURON

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ABSTRACT

Early watergrass and late watergrass are predominant weeds of rice fields but can also occur in corn fields where it follows rice in rotation. Pot experiments were conducted to evaluate control of early watergrass and late watergrass with foramsulfuron applied alone and in mixture with dicamba, MCPA, sulcotrione, and mesotrione. Foramsulfuron applied at 45 g a.i. ha^{-1} provided 82% of early watergrass and 76% of late watergrass control at 3- to 4-leaf growth stage, whereas efficacy was only 71% for early watergrass and 62% for late watergrass at 5- to 6-leaf growth stage. Increased application rate of foramsulfuron provided better control of both species at any growth stage, with the highest application rate (59 g a.i. ha^{-1}) providing maximum control of both species. Mixtures of foramsulfuron with dicamba or MCPA showed lower control of both species than foramsulfuron applied alone. Moreover, sulcotrione applied in mixture with foramsulfuron improved control of both species, whereas the addition of mesotrione did not affect control of both species compared with foramsulfuron applied alone. Satisfactory control of early watergrass and late watergrass in corn can be achieved with increased application rates of foramsulfuron applied preferably at early growth stage. Mixtures of foramsulfuron with either dicamba or MCPA can reduce considerably the efficacy of foramsulfuron on both early watergrass and late watergrass. On the other hand, mixtures of foramsulfuron with either sulcotrione or mesotrione can be used for broadening spectrum of control without affecting negatively foramsulfuron activity on these grasses.

Key words: Antagonism, herbicide mixtures, early watergrass, late watergrass.

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INTRODUCTION

Early watergrass (*Echinochloa oryzoides*) and late watergrass (*E. phyllopogon*) are considered serious weeds of water-seeded rice in many rice production areas in Europe (Carretero, 1981) and in the United States (Hill *et al.*, 1985). Lately, these species have become serious weeds of rice fields in northern Greece. Early watergrass normally appears with a typically drooping, closed, dense inflorescence (the branches of the panicle are depressed to the main rachis), seeds ovate to almost round with long awn, and shows early flowering with panicle emergence about 62 to 67 d after germination (Damalas *et al.*, 2008). On the other hand, late watergrass normally appears with an erect, closed, dense inflorescence (the branches of the panicle are more or less erect except for the lowermost ones), seeds ovoid to oblong, commonly without awn (or with short awn), and shows late flowering with panicle emergence about 78 to 88 d after germination (Damalas *et al.*, 2008). Dense infestations of early watergrass and late watergrass, if not controlled, have been reported to cause more than 50% yield loss of rice (Hill *et al.*, 1985).

Rice is a small but very important cereal crop in Greece because its production covers the domestic needs and a surplus usually of Indica type is exported too (Ntanos, 1998). It is normally grown using very intensive cropping systems, where rice monoculture and heavy reliance on herbicides for weed control are common agronomic practices. The main crop rotation systems for rice cultivation are rice-rice or rice-fallow rotation. However, there is a significant area (80%) where rotation of three years with rice and one year with corn, sugarbeet, or cotton is normally applied (Ntanos, 1998). Although early watergrass and late watergrass are mostly weeds of rice fields, they can also occur in corn fields particularly where it follows rice in various rotation systems. Thus, these grasses can be a problem in corn. With the low prices for corn grain and silage, pest management issues are becoming increasingly problematic and particularly weed control which is the most important practice and has the greatest lasting effect if not dealt with. Weed control is important in corn to reduce weed competition and minimize yield losses, protect silage feed quality, and reduce the production of weed seeds for the following crops. Despite the existence of several grass herbicides used in corn, the activity of these herbicides has not been evaluated on early watergrass and late watergrass.

Foramsulfuron, a relatively new sulfonylurea herbicide, is used for postemergence control of grasses and some broadleaf weeds in corn (Bunting *et al.*, 2004a, 2005; Prostko *et al.*, 2006; Nurse *et al.*, 2007). Foramsulfuron acts through inhibition of the enzyme acetolactate synthase (ALS) which catalyzes the biosynthesis of the branched-chain amino acids valine, leucine, and isoleucine. These amino acids are necessary components of the growth processes in plant cell division. Inhibition of ALS results in slow or stunted plant growth and ultimate plant death. Visible signs of herbicidal activity after postemergence application of this herbicide are an almost immediate cessation of plant growth, followed by leaf yellowing, promotion of anthocyanin production (leading to a reddish coloration of leaves), and finally, progressive shoot death. Depending on the weed species and the environmental conditions, plant death will usually occur from 1-3 weeks after herbicide application. Selectivity of foramsulfuron in corn crop is due to herbicide metabolism and it depends on corn hybrid and corn growth stage at application (Bunting *et al*., 2004b, 2004c). The objective of the present research was to evaluate control of early watergrass and late watergrass with foramsulfuron applied alone and in mixtures with other herbicides used for broadleaf weed control in corn.

MATERIALS AND METHODS

Seeds of *E. oryzoides* and *E. phyllopogon* were collected by hand in September 2006 from mature plants growing in rice fields of the rural area of Thessaloniki in northern Greece. Seeds were collected at the time of natural dispersal and only seeds that fell off carefully shaken plants were used. Distinction between the two *Echinochloa* species was based mainly on morphological traits as morphology of the inflorescence as described by Carretero (1981) and the time of flowering of the species in rice fields. Nonetheless the classification of *Echinochloa* species is difficult because of the existence of numerous intergrading polymorphic complexes with many subspecies and varieties which often lack conspicuous identification characters. Identification key and nomenclature for the species are based on the classification proposed by Carretero (1981). After collection, seeds were dried in the greenhouse, air-cleaned to remove non-viable seeds and waste materials, and stored in plastic bags at 5-6 ^{o}C (in a refrigerator) until the initiation of the experiments.

Seeds of *E. oryzoides* and *E. phyllopogon* were planted in late May in 2-L plastic pots (13.5 cm diameter by 15.5 cm height) filled with a soil mixture (soil and sand 2:1 v/v). The physicochemical characteristics of the soil used in the experiments were clay 32%, silt 56%, sand 12% (silty clay loam), organic matter 1.6%, $CaCO_3$ 7.4%, pH (1:1 H_2O) 7.6 and cation exchange capacity (CEC) 27.7 meq/100 g. Pots were placed outdoors and watered once daily throughout the experiments by irrigating to soil saturation. One week after seedling emergence, plants were thinned to 30 per pot, where necessary, to obtain a uniform plant population in all pots. Plants grew normally throughout the studies without experiencing any particular environmental stress conditions.

Two experiments were conducted. In the first experiment, foramsulfuron was applied alone at 45, 52, and 59 g a.i. ha^{-1} at two growth stages (3-4 and 5-6 leaves) of each *Echinochloa* species. In the second experiment, foramsulfuron was applied alone at 45 g a.i. ha^{-1} and in mixture with dicamba at 288 g a.i. ha^{-1}, MCPA at 600 g a.i. ha^{-1}, sulcotrione at 450 g a.i. ha^{-1}, or mesotrione at 75 g a.i. ha^{-1} at two growth stages (3-4 and 5-6 leaves) of each *Echinochloa* species. A non-treated control for each growth stage was included in each experiment for comparison. There were four replications (pots) for each treatment in a completely randomized design. Herbicide treatments were applied with a propane-pressurized hand-held field plot sprayer at 250 kPa pressure using 300 L ha^{-1} of water. All experiments were repeated in time (two growing seasons) following exactly the same procedure. Environmental conditions during herbicide treatment applications were similar in both study periods.

Echinochloa species were evaluated by determining fresh weight of all live stems remaining at 45 days after herbicide treatments. Fresh weight data were expressed as a percent reduction from the non-treated control and were analyzed separately for each species using a combined over time analysis of variance (ANOVA) with four replications. In particular, for the first experiment the analysis of data was conducted using a 2 by 3 factorial approach (2 growth stages by 3 foramsulfuron rates) combined over time and for the second experiment the analysis of data was conducted using a 2 by 5 factorial approach (2 growth stages by 5 mixture treatments). Before the ANOVA, fresh weight data were log-transformed to stabilize variance. Transformation did not affect data interpretation and therefore original means are presented. Differences between means were compared at 5% level of significance using Fisher's protected LSD test. Because no experiment interaction occurred, fresh weight reduction means were averaged over time.

RESULTS AND DISCUSSION

Foramsulfuron applied alone at 45 g a.i. ha^{-1} provided 82% suppression of fresh weight over control of early watergrass and 76% control of late watergrass at the 3- to 4-leaf growth stage (Table-1). At the 5- to 6-leaf growth stage suppression for early watergrass and late watergrass decreased to 71% and 62%, respectively. For both species higher suppression was recorded with increasing application rate at any growth stage. Greatest control of both species at the early growth stage was observed with two higher rates of foramsulfuron, whereas at the late growth stage suppression was highest with the highest rate applied (Table-1). Early watergrass was more sensitive to foramsulfuron than late watergrass. Variability of these species in tolerance to other rice herbicides tested has been previously reported (Damalas *et al.*, 2006). This variability in tolerance to herbicides could be partially associated with growth rate differences between the two *Echinochloa* species (Damalas *et al.*, 2008), which may be responsible for differences in herbicide metabolism rate. Weed tolerance to herbicides is often associated with metabolic processes that result in herbicide degradation by the target plants (Devine *et al.*, 1993) and thus weed species can exhibit different levels of tolerance to a given herbicide even if they are similarly susceptible at their target site.

Table-1. Fresh weight reduction (% of non-treated control) of *E. oryzoides* and *E. phyllopogon* with foramsulfuron as affected by application rate and growth stage.

Treatment	Rate (g a.i. ha^{-1})	% Fresh weight reduction a, b	
		E. oryzoides	*E. phyllopogon*
		3-4 leaves	3-4 leaves
Foramsulfuron	45	82 c	76 cd
Foramsulfuron	52	88 ab	83 ab
Foramsulfuron	59	92 a	88 a
		5-6 leaves	5-6 leaves
Foramsulfuron	45	71 d	62 e
Foramsulfuron	52	79 c	71 d
Foramsulfuron	59	87 b	80 bc

a Means are pooled over two experiments.
b Different letters within each column indicate statistically significant differences at P=0.05.

Addition of dicamba and MCPA in mixture with foramsulfuron resulted in reduced efficacy on both species (Table-2). The reduced control with those mixtures was evident at both growth stages and it was more pronounced for the mixtures with MCPA. The reduced control of both species with the mixtures of foramsulfuron with MCPA or dicamba indicates some kind of herbicide interaction which alters the expected behavior of foramsulfuron. It seems possible that the presence of these herbicides in mixtures with foramsulfuron reduces the amount of foramsulfuron that is absorbed by the foliage of the treated plants or the amount of foramsulfuron that is translocated to the site of action of the treated plants, resulting in reduced grass control.

On the contrary, addition of sulcotrione in mixture with foramsulfuron resulted in increased efficacy on both species at both growth stages compared with foramsulfuron applied alone (Table-2). Addition of mesotrione in mixture with foramsulfuron did not affect control of both species compared with the single application of foramsulfuron (Table-2). Previous research indicated no antagonistic interactions for the control of large crabgrass with tank mixtures of foramsulfuron plus mesotrione (Schuster *et al.*, 2007). Conversely, Schuster *et al.*, (2007) showed that similar tank mixtures caused 20 to 30% antagonism for the control of yellow foxtail and green foxtail. Previous findings also showed a reduction in the efficacy of nicosulfuron in mixture with mesotrione which was attributed to decreased absorption and translocation of nicosulfuron in green foxtail and decreased absorption in yellow foxtail (Schuster *et al.*, 2007). However, tank mixtures of rimsulfuron with mesotrione did not result in reduced absorption or translocation of rimsulfuron in green foxtail, whereas in yellow foxtail the absorption decreased by 11% at 7 days after treatment. In a controlled environment, the addition of mesotrione in mixture with sulfonylurea herbicides had no adverse effects on the control of large crabgrass or velvetleaf. Tank mixing mesotrione with nicosulfuron or foramsulfuron, however, resulted in reduced control of green foxtail and shattercane by nicosulfuron and foramsulfuron (Schuster *et al.*, 2008). On the contrary, antagonistic interactions were not observed with foramsulfuron in tank mixtures with either topramezone or mesotrione for the control of large crabgrass, barnyardgrass, yellow foxtail, and green foxtail (Kaastra *et al.*, 2008).

Table-2. Fresh weight reduction (% of non-treated control) of *E. oryzoides* and *E. phyllopogon* with foramsulfuron (at 45 g a.i. ha^{-1}) as affected by mix partner herbicide and growth stage.

Treatment	**Rate (g a.i. ha^{-1})**	**% Fresh weight reduction a, b**			
		E. oryzoides		***E. phyllopogon***	
		3-4 leaves		**3-4 leaves**	
Foramsulfuron	45	82	b	76	bc
(+) dicamba	(+) 288	66	d	58	e
(+) MCPA	(+) 600	52	e	42	f
(+) sulcotrione	(+) 450	96	a	88	a
(+) mesotrione	(+) 75	84	b	80	b
		5-6 leaves		**5-6 leaves**	
Foramsulfuron	45	71	c	62	de
(+) dicamba	(+) 288	53	e	42	f
(+) MCPA	(+) 600	39	f	26	g
(+) sulcotrione	(+) 450	83	b	72	c
(+) mesotrione	(+) 75	73	c	66	d

a Means are pooled over two experiments.
b Different letters within each column indicate statistically significant differences at *P*=0.05.

It is concluded that satisfactory control of early watergrass and late watergrass in corn can be achieved with increased application rates of foramsulfuron applied preferably at early growth stage. Mixtures of foramsulfuron with either dicamba or MCPA can reduce considerably the efficacy of foramsulfuron on early watergrass and late watergrass. Mixtures of foramsulfuron with either sulcotrione or mesotrione can be used for broadening spectrum of control without affecting negatively foramsulfuron activity on these grasses.

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