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Interaction of Prodiamine and Flumioxazin for Nursery Weed Control

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Both prodiamine and flumioxazin are used in the nursery production and landscape maintenance industries in the southeastern United States for preemergence weed control. Research was conducted to determine whether a tank mixture of these two herbicides would be more effective than either component applied alone. Prodiamine alone, flumioxazin alone, and a 72 : 28 (by weight) prodiamine–flumioxazin mixture were each applied at a series of rates to containers filled with a pine bark–sand substrate that is typical for nursery production in the southeastern United States. Our intent was to have a rate range that hopefully extended from ineffective to lethal for each treatment series. Subsequent to treatment, containers were overseeded with either large crabgrass, spotted spurge, or eclipta. Percent control was determined by comparing treated weed foliage fresh weight to that of the appropriate nontreated control at 6 and 12 wk after application. ANOVA followed by nonlinear regression was used to evaluate the interaction of prodiamine and flumioxazin when combined and to determine the rate of each treatment series required for 95% control (if applicable) for each of the three weed species. Results varied with weed species. The mixture was synergistic and more cost effective than either of the components applied alone in controlling spotted spurge. With respect to large crabgrass control, the mixture was additive and slightly more cost effective than the components. Eclipta could only be controlled with flumioxazin, and this control was antagonized by the addition of prodiamine.

Nomenclature: flumioxazin; prodiamine; eclipta, *Eclipta alba* (L.) Hassk.; large crabgrass, *Digitaria sanguinalis* (L.) Scop.; spotted spurge, *Chamaesyce maculata* (L.) Small.

Key words: herbicide interactions, nonlinear regression, ornamental plant production, soilless growth media.

Tanto el prodiamine como el flumioxazin son utilizados en los invernaderos y en la industria de arquitectura y mantenimiento de jardines en el sureste de los Estados Unidos para el control de malezas en pre-emergencia. Una investigación se llevo al cabo para determinar si las mezclas de estos dos herbicidas serían más efectivas que cada uno de sus componentes aplicados por separado. El prodiamine y el flumioxazin aplicados individualmente y en mezcla a 72 : 28 (por peso), en diferentes dosis a maceteros llenos con un sustrato de arena con corteza de pino, la cual es típica en el cultivo en invernaderos en esa región. Nuestra intención fue obtener un rango de dosis que se extendiera de total in-efectividad hasta la muerte para cada tratamiento. Después del tratamiento, los maceteros fueron hiper-sembrados ya sea con *Digitaria sanguinalis* (L.) Scop., *Chamaesyce maculata* (L.) Small. ó *Eclipta alba* (L.). A las 6 y 12 semanas después de la aplicación, el porcentaje de control fue determinado a través de comparar el peso del follaje de la maleza fresca con el peso de los que no fueron tratados. ANOVA seguida por una regresión no lineal se utilizó para evaluar la interacción de prodiamine y de flumioxazin cuando fueron combinados y para determinar la dosis requerida de cada tratamiento con el fin de obtener el 95% de control (si fuera aplicable) para cada una de las 3 especies de maleza. Los resultados variaron de acuerdo a la especie de maleza. La mezcla fue sinergética y más efectiva en cuanto a sus costos que cualquiera de sus componentes aplicados por separado en el control de *Chamaesyce maculata* (L.) Small. Respecto al control de *Digitaria sanguinalis* (L.) Scop , la mezcla fue aditiva y ligeramente más rentable que los componentes. La *Eclipta alba* (L.) solamente podría ser controlada con flumioxazin, y este control se antagoniza con la adición de prodiamine.

Flumioxazin, a PRE and POST herbicide, is used in the nursery production and landscape maintenance industries. Flumioxazin inhibits protoporphyrinogen oxidase (PPO), an enzyme involved in chlorophyll synthesis (Boger and Wakabayashi 1999; Scalla and Matringe 1994). With respect to its PRE-applied activity in the production of horticultural crops, Richardson and Zandstra (2006) evaluated flumioxazin and several other PRE-applied herbicides for weed control in gladiolus (*Gladiolus* spp.) grown for cut flowers. Flumioxazin applied at rates between 0.11 and 0.56 kg ai ha^{-1} provided a very favorable balance between comprehensive weed control and minimal crop injury. However this PRE-applied activity is considered to be of limited duration since flumioxazin does not persist for extended periods in soils (Ferrell and Vencill 2003). Flumioxazin dissipation from soil is primarily due to microbial degradation (Ferrell and Vencill 2003).

Prodiamine is a dinitroaniline herbicide that is used in the nursery and landscape industries. Introduced in the early 1980s (Fretz and Sheppard 1980), prodiamine (PRE-applied) controls annual grasses and various small-seeded broadleaf weeds in a diversity of nursery crops (Altland et al. 2003; Derr 1994; Duray and Davies 1987; Neal and Senesac 1991; Ruter and Glaze 1992; South 1992; Stamps and Neal 1990). Prodiamine, like all other dinitroaniline herbicides, inhibits mitosis within roots tips of germinating seeds. Dinitroaniline-affected roots are distorted and nonfunctional, and consequently the seedling fails to become established. This mode of action has been described and reviewed by Hacskaylo and Amato (1968) and by Parka and Soper (1977).

Flumioxazin is effective in controlling both annual broadleaf and grass weeds, but its control of broadleaves is most valued in the southeastern United States. In contrast, prodiamine is most effective in controlling grasses. Therefore,

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we hypothesized that a mixture may be more cost effective than either component applied alone. In addition, the mixture may control a broader spectrum of weed species. This hypothesis has support from previous research. Ruter and Glaze (1992) reported that prodiamine in combination with another PPO inhibitor, oxadiazon, with both applied at 2.24 kg ai ha^{-1}, resulted in ≥ 95% spotted spurge control in container-grown landscape plants. Oxadiazon alone provide only 43% control; prodiamine alone was not evaluated. Testing the hypothesis that a flumioxazin plus prodiamine mixture would be more effective than either component alone was the objective of this research.

Materials and Methods

Studies were conducted in a nursery production area within the Paterson greenhouse complex of Auburn University, Auburn, AL. Large crabgrass, eclipta, and spotted spurge were selected for evaluation due to their prevalence in the nursery production and landscape maintenance industries of the southeastern United States (Ruter and Glaze 1992; Webster 2003). Individual experimental units consisted of 10-cm square plastic containers, filled with a 6 : 1 (v : v) pine bark plus sand substrate. This substrate was prepared by the authors and was amended with a controlled-release granular fertilizer,[1] dolomitic limestone, and a micronutrient fertilizer[2] at 8.3, 3.0, and 0.9 kg m^{-3}, respectively. Substrate-filled containers were placed in the experimental area 5 d prior to herbicide treatment. Containers received approximately 1.3 cm of irrigation daily.

Three treatment series were included. The first series was prodiamine[3] applied alone at the following seven rates: 0.06, 0.11, 0.22, 0.36, 0.50, 0.76, and 1.12 kg ai ha^{-1}. Prodiamine is registered in nursery crops at 1.7 kg ai ha^{-1}, and the total amount applied during a single growing season is restricted to 4.0 kg ai ha^{-1}. The most common rate for a single application in our area is 1.7 kg ha^{-1} or less because producers prefer to leave open the option of additional applications. Both large crabgrass and spotted spurge, but not eclipta, are identified on the product label[3] as controlled by prodiamine. Stamps and Neal (1990) reported ≥ 83% eclipta control with prodiamine in container-grown landscape plants, but prodiamine had been applied twice during the growing season at 4.5 kg ai ha^{-1} for each application. The second series was flumioxazin[4] applied alone at the following eight rates: 0.02, 0.04, 0.06, 0.09, 0.13, 0.19, 0.29, and 0.43 kg ai ha^{-1}. The registered rate of flumioxazin for PRE-applied control is 0.28 to 0.43 kg ai ha^{-1}, and all three weed species evaluated are identified on the product label[4] as controlled by flumioxazin. The third series was a tank mixture of 1.00 part prodiamine plus 0.38 part flumioxazin by weight of active ingredient, resulting in a prodiamine to flumioxazin ratio of 72 : 28. This ratio was based on the common use rates for a single application in our area. The mixture was applied at the following 12 rates: 0.06, 0.09, 0.12, 0.16, 0.22, 0.29, 0.39, 0.52, 0.67, 0.88, 1.16, and 1.55 kg ai ha^{-1}. A nontreated control was also included with each treatment series. Our intent was to apply each treatment series at rates that extended from no effect to complete kill, which would generate data that could be more accurately described by the log-logistic model (Seefeldt et al. 1995; Streibig and Jensen 2000).

Herbicide-containing treatments were applied within an enclosed-cabinet sprayer calibrated to deliver 280 L ha^{-1} at 193 kPa. Each rate and treatment series combination was applied to 30 containers. After application, 10 containers of each treatment were seeded with 25 seeds of either spotted spurge, eclipta, or large crabgrass, respectively. Seed of spotted spurge and eclipta had been collected by the authors the previous season and stored at 3 C. Seed of large crabgrass was obtained from a commercial source.[5] The herbicide-treated and seeded containers were returned to the experimental area and placed in a completely randomized design. The experiment was repeated in time. The experiment was started on June 20, 2009, and repeated beginning on July 15, 2009.

Six weeks after seeding, five containers of each treatment–weed species combination, plus five containers of the nontreated control were randomly selected for evaluation. Weed foliage was clipped at the soil surface and fresh weight determined. Shoot fresh weight was expressed as a percentage of the nontreated control plants; this value was subtracted from 100 to yield a measure of control. Through this procedure, control was 0% if the foliage of an experimental unit (i.e., a container) weighed equal to or greater than the nontreated; no foliage present equaled 100% control.

The procedure to determine weed control was repeated at 12 wk after seeding with the five remaining containers of each treatment. An additional evaluation at 12 wk would seem to be unwarranted since flumioxazin should be nearly completely dissipated by this time. Ferrell and Vencill (2003) reported that the soil half-life of flumioxazin was approximately 2 wk. However, due to field experiences and the results of a previous study (Wehtje et al. 2010), we are of the opinion that, at least in the nursery environment, flumioxazin may persist much longer than 2 wk. The soil half-life of prodiamine is reported to be approximately 120 d (17 wk) assuming incorporation (Senseman 2007). Furthermore, weed plant numbers were also determined at the 6 wk evaluation so that weed seed germination could be estimated. Germination of spotted spurge, eclipta, and large crabgrass was 21, 16, and 8%, respectively, (average of both experimental repetitions, data not shown). Thus viable seed of all three species, as well as phytotoxic concentrations of both herbicides likely remained after the 6 wk evaluation.

Data were first subjected to ANOVA using the PROC GLM procedure in SAS®.[6] Data for all three weed species were pooled over the two experimental repetitions since no treatment by repetition interactions were detected in this initial ANOVA. Control data for each combination of weed species and herbicide treatment series was subjected to nonlinear regression and modeled with the three-parameter log-logistic model using Prism® software.[7] This model is typically expressed as follows:

$$y = D \Big/ \left[1 + (x/I_{50})^b\right] \qquad [1]$$

where y = the measured response, i.e., control; D = upper limit of the response; I_{50} = rate resulting in 50% of the observed response; b = slope near the I_{50} value; and x = the

Table 1. Results of nonlinear regression (where applicable) and estimates for 95% control for three PRE-applied herbicide treatment series on three weed species.

Weed species/treatment series	Results of nonlinear regression: Parameter estimates (SE) Maximum	LD$_{50}$	Slope	r^2	Estimates for rate and cost for 95% control, i.e. LD$_{95}$	
	% control	kg ai ha^{-1}			kg ai ha^{-1}	\$ ha^{-1}
Spotted spurge 6 WAT (Figure 1, top):						
Prodiamine alone	124 (28)	0.48 (1.62)	1.24 (0.29)	0.78	1.00	207.00
Flumioxazin alone	100 (4)	0.04 (1.03)	3.56 (0.38)	0.89	0.11	56.55
Prodiamine + flumioxazin mix[a]	99 (3)	0.09 (1.02)	4.82 (0.46)	0.87	0.17	37.32
Eclipta 6 WAT (Figure 2, top):						
Prodiamine alone	NA[b]	NA	NA	NA	NA	NA
Flumioxazin alone	97 (6)	0.07 (1.09)	3.45 (0.66)	0.77	0.27	138.78
Prodiamine + flumioxazin mix	79 (4)	0.32 (1.06)	5.84 (1.57)	0.74	NA	NA
Large crabgrass 6 WAT (Figure 3, top):						
Prodiamine alone	101 (6)	0.16 (1.13)	1.91 (0.37)	0.75	0.76	157.32
Flumioxazin alone	97 (4)	0.06 (1.05)	3.58 (0.68)	0.78	0.15	77.10
Prodiamine + flumioxazin mix	99 (2)	0.16 (1.03)	4.48 (0.57)	0.82	0.32	70.24
Large crabgrass 12 WAT (Figure 3, bottom):						
Prodiamine alone	117 (27)	0.34 (1.53)	1.32 (0.38)	0.65	1.10	227.70
Flumioxazin alone	98 (7)	0.10 (1.11)	2.45 (0.45)	0.75	0.36	185.04
Prodiamine + flumioxazin mix	99 (4)	0.20 (1.09)	2.12 (0.34)	0.73	0.84	184.32

[a] Mixture contained prodiamine and flumioxazin in a 72 : 28 ratio by weight, respectively. Herbicide costs: prodiamine \$207 kg^{-1} ai, flumioxazin \$514 kg^{-1} ai, and mix \$219.50 kg^{-1} ai.

[b] Abbreviation: NA, not applicable.

herbicide rate. The log-logistic model, also termed the sigmoid and the dose–response model, has been demonstrated to be effective in modeling herbicide efficacy (Seefeldt et al. 1995). Assuming that the data could be adequately described by the log-logistic model, the rate necessary to provide 95% control (i.e., the LD$_{95}$ value) was calculated for each weed species and herbicide series using the above equation and the parameters as estimated by Prism. The cost (\$ kg^{-1} ai) for the LD$_{95}$ rate was also determined. Herbicide costs were based upon the average of two suppliers within our area and were \$207 kg^{-1} ai for prodiamine and \$514 kg^{-1} ai for flumioxazin. The mixture was calculated to cost \$219.50 kg^{-1} ai.

Comparing the dose–response curve of a fixed-ratio mixture to the response of the components alone can also be used to evaluate the interaction of these herbicides. The precedent has been established in pharmacological research. Tallarida (2001) reported that if two drugs do not interact, i.e., their efficacy when combined is strictly additive, the dose–response curve of a 50 : 50 mixture should fall exactly midway between the response curves of the components administered separately. But if the actual response curve of the mixture is displaced to the left of the theoretical noninteractive curve, the drugs are interacting in a synergistic manner. Conversely, displacement to the right indicates antagonism. We chose this approach to address the interaction of the prodiamine plus flumioxazin mixture. However, the ratio in our mixture was 72 : 28 prodiamine–flumioxazin, not 50 : 50. Therefore, we concluded that the theoretical noninteractive curve would not fall midway between the curves of the two herbicides applied alone, but 22% closer to prodiamine. This curve is presented on the appropriate figures as a dotted line.

Results and Discussion

Control data at 6 wk after treatment (WAT) for nearly all weed species and treatment series could be satisfactorily fitted to the log-logistic model; r^2 values were ≥ 0.74 (Table 1; Figures 1–3). Eclipta control with prodiamine alone was the only exception, in which case control did not exceed approximately 50% (Figure 2; Table 1). At 12 WAT, large crabgrass was the only species for which control from all three treatment series approached 100% and thus could be fitted to the log-logistic model; r^2 values were ≥ 0.65 (Table 1). None of the treatment series controlled either spotted spurge or eclipta more than approximately 80% at 12 WAT. Data that could not be fitted to the log-logistic model were simply plotted.

At 6 WAT, 95% control of both spotted spurge and large crabgrass could be obtained from any of the three treatment series (Figures 1 and 3, respectively). However, 95% eclipta control could only be obtained with flumioxazin alone (Figure 2). Eclipta control with the mixture could also be described by the log-logistic model (r^2 = 0.74; Figure 2; Table 1), but control reached a maximum at approximately 79%. Therefore flumioxazin alone was also the only treatment series that controlled all three species ≥ 95%. The LD$_{95}$ values for flumioxazin alone were 0.11, 0.15, and 0.27 kg ai ha^{-1} for spotted spurge, large crabgrass, and eclipta, respectively (Table 1). Thus spotted spurge and large crabgrass are comparatively sensitive to flumioxazin, while eclipta is more tolerant by a factor of nearly two.

With large crabgrass at 6 WAT (Figure 3), the response curve of the mixture nearly paralleled the predicted additivity curve in the range of rates where acceptable (≥ 70%) control was obtained. However the mixture was antagonistic with

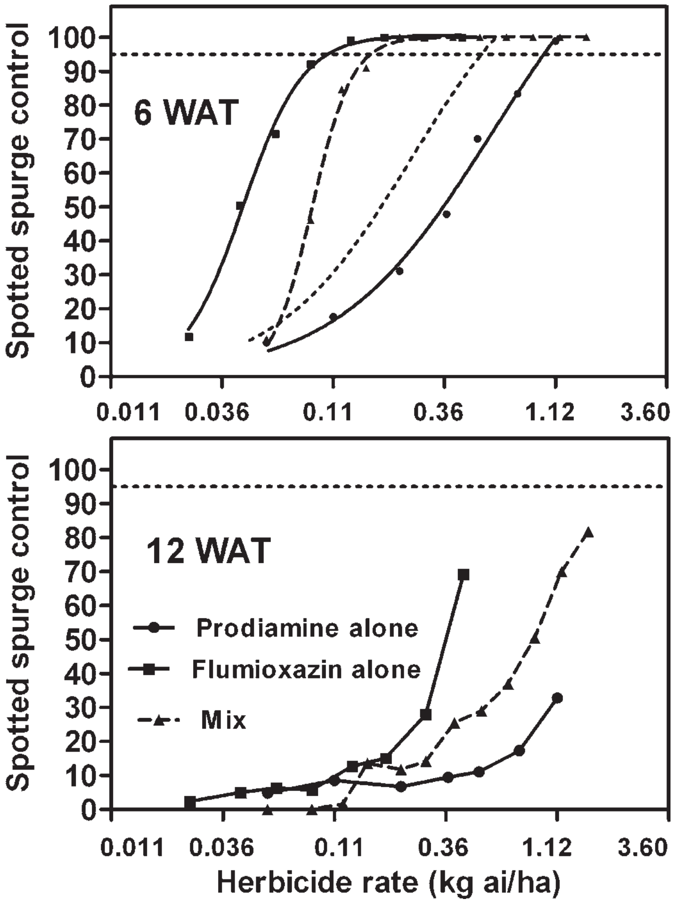

Figure 1. Spotted spurge control as influenced by a rate progression of flumioxazin, prodiamine, and a 72 : 28 mixture by weight, respectively, at 6 (top) and 12 (bottom) wk after treatment (WAT). Responses were fitted to the three-parameter log-logistic model if applicable (Table 1). The dotted line in the top graph that is not associated with any data points represents the theoretical expected response assuming that the mixture was noninteractive or that the components behaved strictly in an additive manner.

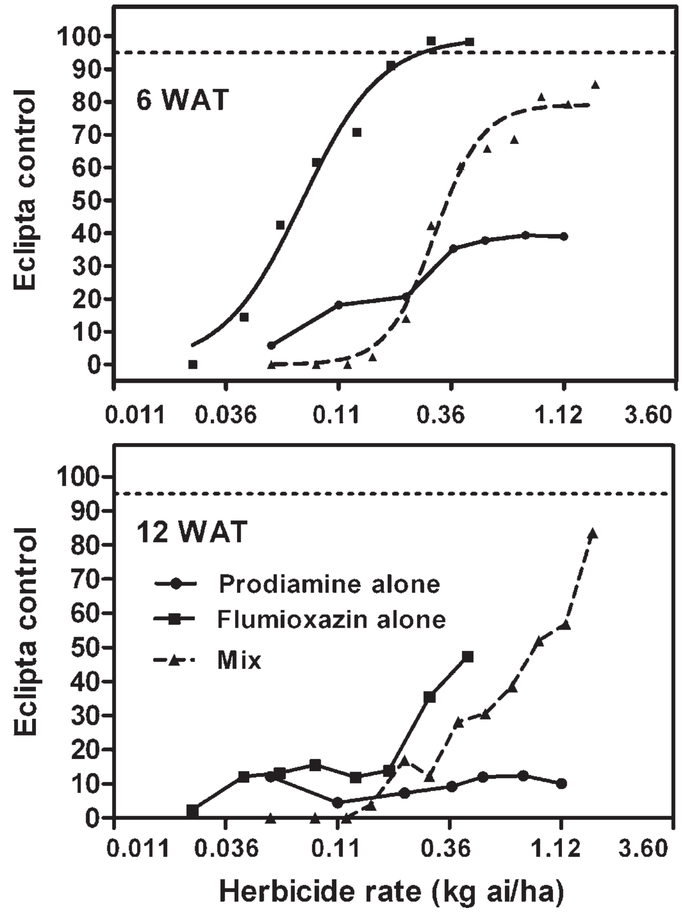

Figure 2. Eclipta control as influenced by a rate progression of flumioxazin, prodiamine, and a 72 : 28 mixture by weight, respectively, at 6 (top) and 12 (bottom) wk after treatment (WAT). Responses were fitted to the three-parameter log-logistic model if applicable (Table 1).

rates that provided less than acceptable (< 70%) control. At 12 WAT, the response curve of the mixture consistently paralleled the predicted additivity curve. Thus at this evaluation, flumioxazin and prodiamine responded independently of each other with respect to large crabgrass control. With spotted spurge at 6 WAT (Figure 1), the response curve of the mixture was consistently to the left of the predicted additivity curve. Therefore the mixture was synergistic in respect to spotted spurge control.

Our primary objective as previously mentioned was to utilize nonlinear regression (when applicable) to estimate for each of the three weed species the rate and the cost required for 95% control from each treatment series. Spotted spurge at 6 WAT and large crabgrass at both 6 and 12 WAT were the only cases in which all three treatment series were able to provide 95% control; therefore, a cost comparison becomes relevant (Table 1). The most economical option for 95% control of spotted spurge at 6 WAT was the mixture at 0.17 kg ai ha^{-1} (i.e., 0.12 kg ha^{-1} prodiamine plus 0.05 kg ha^{-1} flumioxazin), at a cost of \$37.32 ha^{-1} (Table 1). The mixture was 34% more economical than flumioxazin alone, for which 95% control was obtained with 0.11 kg ha^{-1}, at a cost of \$56.54 ha^{-1}. As mentioned above, the mixture was deemed to be synergistic with respect to spotted spurge control, and this synergism is reflected in a cost savings. The most economical option for 95% control of large crabgrass at 6 WAT was also the mixture applied at 0.32 kg ha^{-1} at a cost of \$70.24 ha^{-1} (Table 1). However the mixture was only 8% more economical than flumioxazin alone. Flumioxazin alone and the mixture were nearly identical with respect to the cost required for 95% control of large crabgrass at 12 WAT. Thus with spotted spurge and large crabgrass, two species that could be controlled with all three treatment series, the mixture was frequently but not consistently more cost effective. Another potential benefit of the mixture that is not reflected in a cost comparison is that it challenges the target weeds with two different modes of actions, which can delay and/or prevent the emergence of herbicide-resistant weed biotypes (Gressel and Segal 1982).

Eclipta control presented an interesting situation (Figure 2; Table 1). Prodiamine alone was nearly ineffective in controlling eclipta. Control with flumioxazin alone reached 95% with 0.27 kg ha^{-1}. In contrast, the highest rate of the mixture, i.e., 1.55 kg ai ha^{-1} (1.12 kg ha^{-1} prodiamine plus

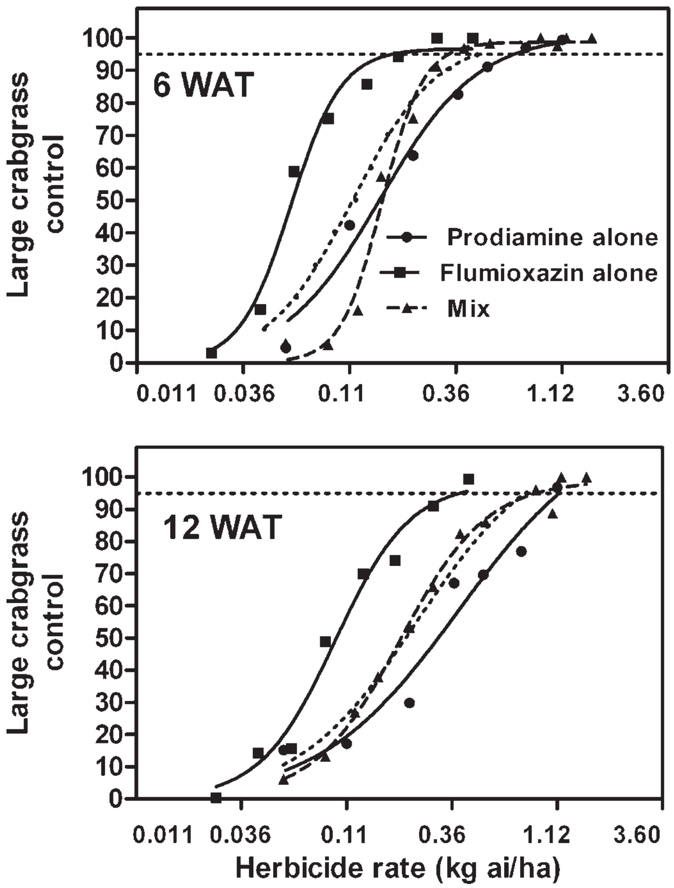

Figure 3. Large crabgrass control as influenced by a rate progression of flumioxazin, prodiamine, and a 72 : 28 mixture by weight, respectively, at 6 (top) and 12 (bottom) wk after treatment (WAT). Responses were fitted to the three-parameter log-logistic model if applicable (Table 1). The dotted lines in both graphs that are not associated with any data points represent the theoretical expected responses assuming that the mixture was noninteractive or that the components behaved strictly in an additive manner.

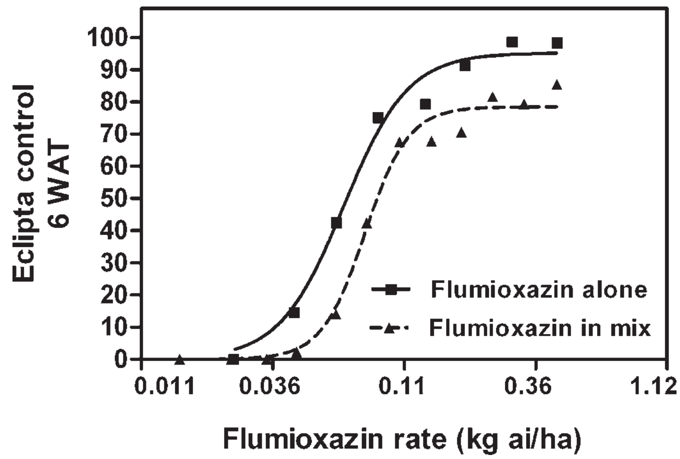

Figure 4. Eclipta control with flumioxazin as influenced by whether flumioxazin was applied alone or in a mixture with prodiamine. Mixture contained flumioxazin and prodiamine in a 28 : 72 ratio by weight, respectively. Responses were fitted to the three-parameter log-logistic model, and parameter estimates (Table 2) were compared by the goodness of fit test as described by Motulsky and Christopoulos (2004) and by Seefeldt et al. (1995).

0.43 kg ha^{-1} flumioxazin), only controlled eclipta approximately 80% (Figure 2). Since the mixture was less effective than flumioxazin alone, we suggest that prodiamine is antagonistic toward flumioxazin. Since flumioxazin and prodiamine are effective and nearly ineffective, respectively, in controlling eclipta, the log-logistic model that compares herbicide activity with and without a potential antagonist as described by Seefeldt et al. (1995) and by Streibig and Jensen (2000) was employed. Data from flumioxazin alone and the mixture were again subjected to nonlinear regression, but with eclipta control presented as a function of the flumioxazin rate (Figure 4; Table 2). The lack of fit test as described by Motulsky and Christopoulos (2004) and by Seefeldt et al. (1995) was then utilized to determine which (if any) of the model parameters were significantly different. This analysis revealed that both the maximum (*D* value) was 20% less (79 vs. 99% control), and the LD_{50} was 35% greater (0.088 vs. 0.065 kg ha^{-1}) when flumioxazin was applied in combination with prodiamine compared to when applied alone (Table 2). Thus it can be concluded that prodiamine was antagonistic toward the PRE activity of flumioxazin. The parameter estimate for maximum control with the mixture was only 79% (Table 2). This indicates that the antagonism likely cannot be overcome even with exorbitant rates of the mixture. But it must also be noted that this antagonism was only detected in one of the three species evaluated, a species that was flumioxazin-sensitive but prodiamine-tolerant.

We conclude that this is the first report of the PRE activity of flumioxazin being antagonized by another PRE-active herbicide. However, the ability of dinitroaniline herbicides to antagonize triazine herbicides, which are also PRE active, has been established by previous research. Ladlie et al. (1977) reported that metribuzin-induced injury to soybean [*Glycine max* (L.) Merr.] was reduced by concomitant application with the dinitroaniline herbicide trifluralin. Malefyt and Duke (1981) reported that both pendimethalin (also a dinitroaniline) and trifluralin reduced injury in soybean from both atrazine and metribuzin. Similarly O'Donovan and Prendeville (1976) reported that applying trifluralin in combination with either simazine, atrazine, or prometryne to the upper 5-cm root region of vetch (*Vicia sativa* L.), pea (*Pisum sativum* L.), and soybean was less injurious than when the trifluralin was omitted. These authors concluded that dinitroaniline-induced inhibition of lateral root development near the soil surface reduced triazine uptake, and in turn triazine phytotoxicity. Ladlie et al. (1977) and O'Donovan and Prendeville (1976) proved this hypothesis by monitoring the uptake of ^{14}C-triazines with and without the dinitroaniline herbicide. We speculate that this explanation also applies to the antagonism of flumioxazin by prodiamine with respect to eclipta control.

Another interesting aspect of our study is that the data indirectly provide a measure of flumioxazin longevity. Germination of large crabgrass in the nontreated control was 8 and 19% at 6 and 12 wk after planting (average of both experimental repetitions; data not shown). Thus viable seed likely remained in the media during the duration of the experiment. The LD_{50} and LD_{95} at 6 WAT for flumioxazin

Table 2. Comparison of parameter estimates as derived from nonlinear regression for flumioxazin whether applied either alone or as a mixture with prodiamine for eclipta control at 6 wk after treatment.

Flumioxazin application	Parameter estimates		
	Maximum	LD_{50}	Slope
	% control	kg ai ha^{-1}	
Alone	99	0.065	3.46
Mixture[a]	79	0.088	5.83
P value[b]	0.003	0.037	NS[c]

[a] Mixture contained flumioxazin and prodiamine in a 28 : 72 ratio by weight, respectively.

[b] P values are for the comparison between parameter estimates and were derived using the lack of fit test as described by Motulsky and Christopoulos (2004) and by Seefeldt et al. (1995).

[c] Abbreviation: NS, not significant.

applied alone on large crabgrass was 0.06 and 0.15 kg ha^{-1}, respectively (Table 1), and averaged 0.105 kg ha^{-1}. Comparable values at 12 WAT were 0.10 and 0.36 kg ha^{-1}, averaging 0.23 kg ha^{-1}. Therefore, flumioxazin activity likely decreased approximately 55% during the 6-wk period between the two harvesting dates. This rate of loss in activity appears unexpectedly slow in light of the previously mentioned report that flumioxazin has a soil half life of only about 2 wk (Ferrell and Vencill 2003).

Results in toto do not present a compelling argument for routinely applying flumioxazin and prodiamine as a tank mixture. The interaction of the mixture varied with the species evaluated. With spotted spurge, the mixture was synergistic and more cost effective than either prodiamine or flumioxazin applied alone. With large crabgrass, the mixture was predominately additive and only marginally more cost effective than flumioxazin alone. The mixture was antagonistic with respect to eclipta control.

Sources of Materials

[1] Granular, slow-release fertilizer, Polyon® 17N-6P-12K, Harrell's Fertilizer, Inc., 203 West 4th Street, Sylacauga, AL 35105.

[2] Micronutrient fertilizer, Micromax®, O. M. Scott Corp., 14111 Scotts Lawn Road, Marysville, OH 43401.

[3] Prodiamine, Barricade® 65WG, Syngenta Turf and Ornamental Products, P.O. Box 18300, Greensboro, NC 27419.

[4] Flumioxazin, SureGuard® 51WG, Valent U.S.A. Corporation, P.O. Box 8025, Walnut Creek, CA 94596.

[5] Azlin Seed Service, P.O. Box 914, Leland, MS 38756.

[6] SAS® Statistical Analysis System software, Release 8.3, SAS Institute, Inc., Box 8000, SAS Circle, Cary, NC 27513.

[7] Prism® GraphPad Software, Inc., 2236 Avenida de la Playa, La Jolla, CA 92037.

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