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Crop Response and Control of Common Purslane (*Portulaca oleraceae*) and Prostrate Pigweed (*Amaranthus blitoides*) in Green Onion with Oxyfluorfen

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Weed management in green onion continues to be a challenge for vegetable growers in Ohio. Field experiments were conducted from 2005 to 2009 to evaluate oxyfluorfen efficacy on common purslane and prostrate pigweed and green onion tolerance when applied POST at 0, 30, 70, 105, and 290 g ai ha^{-1} approximately 3 wk after planting. No crop injury was observed from any of the herbicide rates, except in 2009 when 209 g ha^{-1} oxyfluorfen resulted in 10% injury at 7 d after treatment. The transient injury did not reduce green onion yield. Green onion yield ranged from 1.8 to 2.2 kg plot^{-1} in 2006 and 1.3 to 1.5 kg plot^{-1} in 2009. In 2007 yield increased linearly from 1.9 to 3.0 kg plot^{-1} with oxyfluorfen rates of 0 to 105 g ha^{-1}. Common purslane control increased as the rate of oxyfluorfen increased. Application of oxyfluorfen at 70 to 105 g ha^{-1} provided the best control of common purslane, ranging from 61 to 95% across the years. Similar control results were observed for prostrate pigweed. Prostrate pigweed control with 70 to 105 g ha^{-1} ranged from 40 to 93% from 2005 to 2009. These results suggest that green onion tolerates oxyfluorfen rates of 70 to 105 g ha^{-1}, and these rates provide common purslane and prostrate pigweed control that growers would find acceptable. Registration of the water-based formulation of oxyfluorfen would provide growers an opportunity to control weeds and reduce the need for hand labor.

Nomenclature: Oxyfluorfen; common purslane, *Portulaca oleraceae* L. POROL; prostrate pigweed, *Amaranthus blitoides* S. Wats AMABL; green onion, *Allium* cepa L. ALLCE.
Key words: Crop injury, muck soil, yield.

El manejo de malezas en cebolla verde o inmadura continúa siendo un reto para los productores de vegetales en Ohio. Se realizaron experimentos de campo desde 2005 a 2009 para evaluar la eficacia de oxyfluorfen en el control de *Portulaca oleracea* y *Amaranthus blitoides* y la tolerancia de la cebolla verde, cuando este se aplicó POST a 0, 30, 70, 105, y 290 g ai ha^{-1} aproximadamente 3 semanas después de la siembra. No se observó daño al cultivo con ninguna de las dosis del herbicida, excepto en 2009 cuando 209 g ha^{-1} de oxyfluorfen resultaron en 10% de daño 7 d después del tratamiento. El daño transitorio no redujo el rendimiento de la cebolla verde. Los rendimientos estuvieron entre 1.8 y 2.2 kg plot^{-1} en 2006 y 1.3 a 1.5 kg plot^{-1} en 2009. En 2007, el rendimiento incrementó en forma lineal desde 1.9 a 3.0 kg plot^{-1} con las dosis de oxyfluorfen de 0 a 105 g ha^{-1}. El control de *P. oleracea* incrementó conforme la dosis de oxyfluorfen aumentó. La aplicación de oxyfluorfen de 70 a 105 g ha^{-1} brindó el mejor control de *P. oleracea*, el cual varió de 61 a 95% durante los años evaluados. Resultados de control similares se observaron para *A. blitoides*. El control de esta maleza con 70 a 105 g ha^{-1} varió entre 40 y 93% del 2005 al 2009. Estos resultados sugieren que la cebolla verde tolera dosis de oxyfluorfen de 70 a 105 g ha^{-1}, y que estas dosis proveen control de *P. oleracea* y *A. blitoides* que los productores encontrarían aceptable. El registro para cebolla verde de oxyfluorfen en su formulación basada en agua brindaría a los productores una oportunidad de controlar malezas y reducir la necesidad de deshierba manual.

Approximately 200 ha of green onion (*Allium cepa* L.) are grown on Ohio farms each year. Most production occurs on high-organic-matter muck soils developed from shallow lake bottoms that were ditched and drained more than 100 yr ago. Green onion complements a broad range of salad greens and fruiting vegetables produced by muck farmers adding to the pallet of product that helps them gain and retain market access. Seedings occur every few weeks to provide a continuous supply from early June until October with harvest taking place about 60 d after planting.

Weed control is one of the most costly practices required to produce the crop. A standard weed control program used by most growers in Ohio consists of dimethenamid-p applied PRE, or PRE followed by POST at the two-leaf crop stage; cultivation; and up to three hand-weedings. Cultivation and hand-weeding are required because of the limited efficacy of the few herbicides registered for use on muck soil. Binding of herbicides with organic matter and the intense microbial degradation characteristic of muck compromises efficacy of soil-active herbicides. Crop loss from mechanical injury during cultivation is estimated to be 25% and each year about 10% of the hectares are plowed under because of uncontrolled weed growth that renders the crop nonharvestable (B. Buurma, personal communication). Cost of hand-weeding of specialty crops increased 35% in Ohio in a single year (Comis 2007) and has continued to rise since then. Herbicides registered for use on green onion include dimethenamid-p, sethoxydim, DCPA, fluazifop, and *S*-metolachlor (Precheur et al. 2011). None of these herbicides adequately control emerged common purslane (*Portulaca oleraceae* L.) and prostrate pigweed (*Amaranthus blitoides* S. Wats), species found in virtually every field of green onion in Ohio. Pesticide manufacturers have shown little interest in

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registering herbicides for muck crops because the market is small and the potential risk of lawsuits arising from crop injury is high.

Other herbicides registered for dry bulb onions should control emerged weeds in green onion but are not licensed because of registrant concern that the short crop cycle does not provide sufficient time for crop recovery from potential leaf-spotting and burn caused by POST herbicides (B. Bret, personal communication; W. Haddad, personal communication). Norsworthy et al. (2007) found that green onion growing in mineral soils of South Carolina had tolerance to POST ethalfluralin, oxyfluorfen, and *S*-metolachlor but noted that additional research was needed to determine the optimum timing and rate for each. Green onion yields following treatment with oxyfluorfen, ethalfluralin, or *S*-metolachlor were equivalent to the nontreated control (Norsworthy et al. 2007). Ghosheh (2004) reported that single POST applications of oxyfluorfen, oxadiazon, and bentazon controlled weeds but caused excessive crop injury. Of the POST herbicides tested by Ghosheh (2004), oxyfluorfen at 1,200 g ai ha^{-1} provided the best weed control but caused the most severe crop injury.

Oxyfluorfen is of particular interest to Ohio's green onion producers because it has been used for many years on dry bulb onion and provides rapid burn-down of grasses and many broadleaf weeds, including common purslane and prostrate pigweed (Precheur et al. 2011). Experience with the emulsifiable concentrate formulation in dry bulb onions suggested that the liability concerns of the registrant could be managed by using not more than 105 g ha^{-1} and restricting application to not less than 15 d before harvest (B. Buurma, personal communication). When the water-based flowable formulation GoalTender^{TM}, touting superior crop safety (Anonymous 2011), became available approximately 10 yr ago, Ohio growers prioritized oxyfluorfen labeling for green onion as a primary objective within the IR-4 Project (Comis 2007; IR-4 Project 2011). The objective of this research was to characterize green onion response to the water-based formulation of the herbicide and gather data needed to support registration.

Methods and Materials

Field experiments were conducted at the Ohio Agricultural Research and Development Center, Muck Crops Research Station near Celeryville, OH (41°00′37.38″N, 82°43′52.82″W) from 2005 to 2009. Soil was a Linwood muck; mixed euic, mesic, Terric Halosaprist (Elder and Lal 2008) with approximately 50% organic matter and a pH of 5.4. The field was moldboard-plowed and disked twice to create a smooth seedbed for green onion production. The experimental design was a randomized complete block with four replications. Plots were 7.6 m long and 1.5 m wide. Each plot was a single raised bed (10 cm high) with three rows of onion 10 cm apart and 2.54 cm within the row. Experiments were established in August each year except in 2005 when green onions were seeded at the end of June. Green onion ('Ishikura') was seeded at a rate of 36 viable seeds m^{-1} of row each year. Dimethenamid-p was applied PRE the same day to provide a base level of weed control in all plots. Other pest management practices and fertilizers were those recommended for green onion production by Ohio State University Extension (Precheur et al. 2011). Oxyfluorfen treatment rates of 0, 35, 70, 105 and 209 g ha^{-1} were applied when green onion seedlings had two to three leaves, approximately 3 wk after seeding. The 209 g ha^{-1} rate was included as a 2× rate of the herbicide to characterize crop response to spray overlap. Herbicides were applied with a handheld sprayer equipped with four 8002EVS flat fan nozzles (Spraying Systems Co., P.O. Box 7900, Wheaton, IL). Spray volume and pressure were 234 L ha^{-1} and 275 kPa, respectively with CO_2 used as a propellant. Crop tolerance and weed control were evaluated visually 7, 14, and 21 d after treatment (DAT), except in 2009 when evaluations were at 7 and 14 DAT only. Yield was determined each year except 2005 by harvesting onions from 2 m of the center row. In 2006 and 2007, green onion harvest was 67 d after seeding whereas in 2009, harvest was 52 d after seeding. Visual estimates of crop injury and weed control were based on the 0 to 100% scale, where 0% indicates no crop injury or weed control and 100% indicates complete weed control or total crop death.

All data were subjected to a normality test. Because analysis of square root-transformed data did not change the results of ANOVA, the nontransformed data were used in the final analysis. Data were analyzed using the generalized linear mixed model (GLIMIX) procedure in SAS (Version 9.2. SAS Institute, Inc., NC; SAS 2008) because of nonconstant variability. Orthogonal contrasts were calculated and the least square means method was used to separate treatment affects.

Results and Discussion

Crop Response. Visual assessments of green onion response to oxyfluorfen rates evaluated in these experiments indicated that crop tolerance was excellent (data not shown). Crop injury was not noted with any treatment except in 2009 when the 2× rate (209 g ha^{-1}) resulted in 10% injury at 7 DAT. Green onion injury was characterized by slightly shorter plants compared to onions in control plots and those treated with lower rates of the herbicide. Yield was not affected by the transient injury in 2009 (Table 1). Differences in green onion yield were observed only in 2007 when there was a significant linear response to rates between 30 and 105 g ha^{-1} indicating an increase in yield with better weed control. Yield at 209 g ha^{-1} was lower compared with 105 g ha^{-1} indicating that yield reduction had occurred with the 2× rate in 2007.

Green onion tolerance to oxyfluorfen was expected because the herbicide is registered in dry bulb onion (Anonymous 2011) and applications made at the two- to three-leaf stage have been previously reported to be safe (Westra et al. 1990). Our results partly corroborate Norsworthy et al. (2007) who reported only slight injury (3%) when green onions were treated at the two- to three-leaf growth stage with a single application of oxyfluorfen at 134 g ha^{-1}, a rate slightly higher than the 1× rate used in our experiments. However, higher rates of oxyfluorfen are likely to cause unacceptable injury as reported by Ghosheh (2004). Given the extreme sensitivity of onion to weed competition (Bond and Burston 1996), it is likely that some level of injury caused by oxyfluorfen would be

Table 1. Green onion yield (kg plot^{-1}) in response to oxyfluorfen rate and weed pressure at Celeryville, OH in 2006, 2007, and 2009.

	Green onion yield[a]		
Oxyfluorfen	2006	2007	2009
g ai ha^{-1}	kg plot^{-1}		
0	1.8 a	1.9 c	1.5 a
30	2.2 a	2.5 ab	1.5 a
70	1.8 a	2.9 ab	1.4 a
105	1.8 a	3.0 a	1.4 a
209	2.1 a	2.2 b	1.3 a
Contrasts			
Linear (30 vs. 105)	NS[b]	0.0058	NS
Quadratic (70 vs. 0 and 30)	NS	NS	NS

[a] Means within a column followed by the same letter are not significantly different according to LSD P = 0.05.[b]

[b] Abbreviation: NS, not significantly different.

more than compensated for by better onion growth resulting from adequate weed control. However, under conditions of very low weed pressure low rates of oxyfluorfen should be used or crop injury may be detected. This was the case in another experiment similar to the one reported here (Doohan and Koch 2008). That year a weed-free control was used instead of a weedy control, and the density of common purslane, prostrate pigweed, and other species was low throughout the experiment. Shorter plants were observed 7 DAT in plots treated with 209 g ha^{-1} and yields were lower in oxyfluorfen-treated plots than in the weed-free control even though crop injury was not visually apparent at harvest time.

Weed Control. Because ANOVA indicated yearly differences in weed control levels, the data for each year are presented separately (Tables 2 and 3). Control of common purslane improved with increasing rate of oxyfluorfen (Table 2). Control with 30 g ha^{-1} was unacceptable but higher rates provided control that growers would likely deem acceptable. At 70 g ha^{-1} and higher, oxyfluorfen provided good weed control ranging from better than 80% at 70 g ha^{-1} to 90% or better control at 209 g ha^{-1} over the 4-yr period. Oxyfluorfen at 70 to 105 g ha^{-1} appeared to be an optimum rate range within which yield was not impacted adversely and weed control averaged better than 80% across the rating intervals. In 2005, 2006, and 2009, oxyfluorfen at 209 g ha^{-1} provided better weed control than 105 g ha^{-1} at one or more rating intervals; however, control was similar to that with 105 g ha^{-1} at all rating intervals in 2007 and at 14 DAT in 2005 and 2006. Results in 2005 differed from other years in that even the 2× rate of 209 g ha^{-1} oxyfluorfen did not provide acceptable weed control. This was almost certainly due to seeding more than 1 mo earlier in the growing season (late June) than in the 2006, 2007, and 2009 experiments. Broadleaf weed germination and growth is much more intense in midsummer than in late summer on the muck soils used in these experiments. Under such conditions herbicides alone are unlikely to provide complete control; the 105 g ha^{-1} rate of oxyfluorfen should be used and hand-weeding should be anticipated. In 2005 all of the plots were hand-weeded after completing the 14 DAT rating and remained weed-free until harvest. Common purslane response to oxyfluorfen rate was largely linear as indicated by significant orthogonal contrasts. However, a quadratic response was noted in 2005 at 7 DAT, at 21 DAT in 2007, and at both rating intervals in 2009, sometimes with a diminished rate of increase in common purslane control at 209 g ha^{-1}. Prostrate pigweed required higher rates of oxyfluorfen to achieve acceptable control than did common purslane as indicated by fewer instances of a significant linear contrast between 30 and 105 g ha^{-1} (Table 3). Oxyfluorfen at 30 g ha^{-1} rarely provided more than 50% control. Application of 209 g ha^{-1} was required to achieve prostrate pigweed control that was significantly better than observed with 70 g ha^{-1}. In contrast, common purslane was generally well controlled at 70 g ha^{-1}.

These results indicate that the water-based flowable formulation of oxyfluorfen at the rates of 70 to 105 g ha^{-1} can provide commercially acceptable control of common purlsane and prostrate pigweed in green onion. However, need for supplemental cultivation, hand-weeding, or both should always be anticipated with onions, especially when weed densities are high. The 105 g ha^{-1} rate is needed for prostrate pigweed control. The 70 g ha^{-1} rate may be

Table 2. Effect of oxyfluorfen rate on common purslane control in green onion at Celeryville, OH, in 2005, 2006, 2007, and 2009.

	Common purslane control[a]										
	2005			2006			2007			2009	
Oxyfluorfen	7 DAT[b]	14 DAT	21 [c] DAT	7 DAT	14 DAT	21 DAT	7 DAT	14 DAT	21 DAT	7 DAT	14 DAT
g ai ha^{-1}	(%)										
0	0 d	0 c	99	0 c	0 d	0 d	0 d	0 b	0 d	0 d	0 d
30	13 c	11 b	99	79 b	70 c	71 c	51 c	54 a	40 c	60 c	79 c
70	61 b	44 a	99	88 b	86 b	81 b	88 bc	88 a	76 b	85 b	93 b
105	61 b	69 a	99	88 b	88 ab	84 b	94 ab	93 a	80 ab	89 b	95 ab
209	74 a	71 a	99	93 a	96 a	92 a	95 a	94 a	89 a	100 a	99 a
Contrasts											
Linear (30 vs. 105)	0.0003	0.0047		0.0013	0.0001	0.0002	0.0259	0.0449	0.0041	0.0001	0.0001
Quadratic (70 vs. 0 and 30)	0.0079	NS		NS	NS	NS	NS	NS	0.0484	0.0104	0.0001

[a] Means within a column followed by the same letter are not significantly different according to LSD P = 0.05.

[b] Abbreviations: DAT, days after treatment; NS, not significantly different.

[c] In 2005 all plots were weeded after the 14 DAT rating and kept weed-free until harvest.

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Table 3. Effect of oxyfluorfen rate on prostrate pigweed control in green onion at Celeryville, OH, in 2005, 2006, 2007, and 2009.

	Prostrate pigweed control[a]										
	2005			2006			2007			2009	
Oxyfluorfen	7 DAT[b]	14 DAT	21 [c] DAT	7 DAT	14 DAT	21 DAT	7 DAT	14 DAT	21 DAT	7 DAT	14 DAT
$g\ ai\ ha^{-1}$	%										
0	0 c	0 d	99	0 d	0 d	0 d	0 c	0 b	0 d	0 d	0 c
30	10 b	26 c	99	23 c	13 c	71 c	47 b	51 a	40 c	41 c	76 b
70	44 ab	75 b	99	40 b	60 b	81 b	70 ab	68 a	76 b	64 bc	91 b
105	60 a	79 ab	99	58 ab	70 ab	84 b	74 ab	80 a	80 ab	79 ab	93 ab
209	75 a	91 a	99	83 a	89 a	92 a	99 a	99 a	89 a	96 a	96 a
Contrasts											
Linear (30 vs. 105)	0.0015	0.0366	—	0.0056	0.0017	0.0001	NS	NS	0.0015	0.0037	NS
Quadratic (70 vs. 0 and 30)	NS	0.0456	NS	NS	0.0396	0.0163	NS	NS	NS	NS	NS

[a] Means within a column followed by the same letter are not significantly different according to LSD P = 0.05.

[b] Abbreviations: DAT, days after treatment; NS, not significantly different.

[c] In 2005 all plots were weeded after the 14 DAT rating and kept weed-free until harvest.

appropriate for infestations consisting mainly of purslane or when overall weed pressure is very low. Green onion injury was only observed in 1 of 3 yr, and then only at 209 g ha^{-1}, which is two times the proposed maximum use rate. Yield of green onion was not affected by herbicide treatments in 2006 or 2009. This is not surprising as weed density and growth were suppressed by declining temperatures and day length. In 2007, there was a linear increase in green onion yield as oxyfluorfen rate increased from 30 to 105 g ha^{-1}, indicating a positive crop response to weed control. Registration of the water-based formulation of the herbicide would provide green onion growers with a more effective means of controlling emerged weeds than currently available and reduce grower reliance on hand labor.

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Literature Cited

Anonymous. 2011. Goal Tender® herbicide label. Dow AgroSciences Publication No. D02-204-005. Indianapolis, IN: DowAgroSciences LLC. Document1.

Bond, W. and S. Burston. 1996. Timing the removal of weeds from drilled salad onions to prevent crop losses. Crop Prot. 15:205–211.

Comis, D. 2007. Specialty crops: more vulnerable than you think. Agric. Res. 55:4–6.

Doohan, D. and T. Koch. 2008. Green Onions—Weed Control and Crop Tolerance with Goaltender and Prowl H2O. Weed Management in Horticultural Crops. Research Results 2008. Horticulture and Crop Science Series No. 762. Pp. 63–65.

Elder, J. W. and R. Lal. 2008. Tillage effects on physical properties of agricultural organic soils of northcentral Ohio. Soil Tillage Res. 98:208–210.

Ghosheh, H. Z. 2004. Single herbicide treatments for control of broadleaved weeds in onion (*Allium cepa*). Crop Prot. 23:539–542.

IR-4 Project. 2011. General Search of Food Use Request Database. http://ir4.rutgers.edu/FoodUse/food_Use2.cfm?PRnum=03574. Accessed: October 28, 2011.

Precheur, R. J., C. Welty, D. Doohan, and S. Miller (eds.). 2011. Ohio Vegetable Production Guide. OSUE Bulletin 672. 285 p.

Norsworthy, J. K., J. P. Smith, and C. Meister. 2007. Tolerance of direct-seeded green onions to herbicides applied before or after crop emergence. Weed Technol. 21:119–123.

SAS. 2008. SAS/STAT® 9.2 User's Guide. Cary, NC: SAS Institute Inc.

Westra, P., C. H. Pearson, and R. Ristau. 1990. Control of Venice mallow (*Hibiscus trionum*) in corn (*Zea mays*) and onions (*Allium cepa*). Weed Technol. 4:500–504.

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