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Pink purslane (*Portulaca pilosa*) control with postemergence herbicides

Nicholas J. Shay[1] and Eric P. Prostko[2]

[1]Graduate Research Assistant, Department of Crop and Soil Sciences, University of Georgia, Tifton, GA, USA and [2]Professor and Extension Weed Specialist, Department of Crop and Soil Sciences, University of Georgia, Tifton, GA, USA

Research Article

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Corresponding author:
Nicholas J. Shay;
Email: nicholas.shay@uga.edu

Abstract

Pink purslane is often ranked as one of the most troublesome weeds in vegetable production systems in Georgia. Pink purslane encroachment along field edges and in-field of agronomic crops has recently increased. Postemergence herbicides are an effective component of agronomic crop weed management. However, little research has addressed pink purslane control in agronomic crops. Therefore, greenhouse and field studies were conducted from 2022 to 2023 in Tifton, Georgia, to evaluate the response of pink purslane to postemergence herbicides commonly used in agronomic crops. Greenhouse screening provided preliminary evidence whereby 13 of the 21 postemergence herbicides evaluated provided ≥80% aboveground biomass reductions. These 13 herbicides were then used for field studies. Results from the field studies, pooled across two locations, indicated that only three of the 13 herbicides provided aboveground biomass reductions of ≥70% compared to the nontreated control. Those herbicides included atrazine at 1,682 g ai ha^{-1}, glufosinate at 656 g ai ha^{-1}, and lactofen at 219 g ai ha^{-1} with 79%, 70%, and 83% biomass reduction, respectively ($P < 0.05$). This research suggests that many of the postemergence herbicides used on agronomic crops will not effectively control pink purslane. Thus, when trying to manage pink purslane with postemergence herbicides in agronomic crops, growers should plant crops or cultivars that are tolerant of either atrazine, glufosinate, lactofen, or a combination of these.

Introduction

Pink purslane is rarely mentioned in university weed control handbooks or on herbicide labels as a resident pest in agronomic crops in the southeastern United States. With a competitive index that is much less than other invasive weed species such as Palmer amaranth (*Amaranthus palmeri* S. Watson), nutsedge (*Cyperus* spp.), common cocklebur (*Xanthium strumarium* L.), and annual morningglory (*Ipomoea* spp.), purslane fecundity is likely reduced by weeds with superior vigor (Finney and Creamer 2008; Singh et al. 2005). As a result, its abundance and distribution in agronomic fields have been suppressed by interspecific competition, and by the influence of common production practices, including preemergence herbicides, tillage, and harvest timing (Singh et al. 2005). This is likely why investigation of methods for controlling pink purslane with common postemergence herbicides in agronomic systems has remained limited. However, pink purslane recently has garnered the attention of growers in Georgia as sightings along field edges have increased.

Pink purslane is a summer annual and is one of seven subspecies of the genus *Portulaca* (family Portulacaceae) found in the southeastern United States (Matthews and Levins 1985). The earliest identified populations are based on detailed descriptions and illustrations published by Commelin (1697) with origins native to South America and the Caribbean islands (Matthews and Levins 1985; Matthews et al. 1992). Introduction into the United States is attributed to one of two routes, either through Florida, or through the Southwest via Mexico. Although timing is uncertain, pink purslane has been included in the southeastern flora since the late 1890s (Matthews and Levins 1985). Populations have been spotted on much of the eastern seaboard beginning in North Carolina to the southern tip of Florida, and across the Gulf Coast into the southwestern United States. Evidence suggests that movement northward into Oklahoma, Missouri, and Arkansas was the result of the expansion of the American railroad (Matthews and Levins 1985). Pink purslane's intracontinental movement highlights its persistence to tolerate a wide range of growing conditions from arid regions of Australia to the subtropics of the southeastern United States (Bair et al. 2006; Kim and Carr 1990; Zimmerman 1976). The aesthetic appeal of purslane's bright flower color and succulent leaves makes it a popular ornamental for home gardens, which could lead to escapes and further regional dispersal (Boas 2011; Hodkinson and Thompson 1997).

Many of the *Portulaca* species are nearly indistinguishable, sharing a similar linear-lanceolate, fleshy leaf structure. What separates pink purslane from its close relatives, however, are its densely populated soft white hairs at the leaf axil and bright pink ephemeral inflorescence (Bair et al. 2006; Ekblad 2020; Matthews and Levins 1985). With an extensively branched, prostrate growth pattern reaching 30 cm in length, pink purslane's rapid development of vegetative and reproductive stages occur simultaneously (Bair et al. 2006; Ekblad 2020). Pink purslane is most often found on marginal lands in gravelly or sandy, well-drained soils (Zimmerman 1976). Tolerating a wide range of environmental conditions, moist sunny habitats are most advantageous, and plants can produce upward of 212,000 to 292,000 nondormant seeds per plant with nearly 100% germination within 10 d (Adachi et al. 1979; Bair et al. 2006; Zimmerman 1976). As a result, favorable conditions can amass multiple flushes of progeny from successive life cycles, nearly every 2 mo within one growing season, thus increasing management difficulties (Matthews and Levins 1985).

Pink purslane is also considered a late-emerging weed because it prefers high soil temperatures (30–35 C) for optimum germination, presenting potential challenges for season-long control (Hopen 1972). Typically, cultivation is a broad tactic used in agronomic production for early season and mid-season weed management; however, purslane's fleshy material can resist desiccation when overturned (Finney and Creamer 2008). In fact, vegetative structures can regrow root segments and reestablish, resulting in increased dispersal (Connard and Zimmerman 1931). Even if cultivation was effective at controlling early flushes of pink purslane, this does not safeguard against late-season emergence. By the time the last pass of mechanical cultivation has commenced, crop canopy overlap is thought of as an effective tool for reducing light exposure to the soil surface and minimizing most weed competition. However, field observations have highlighted the persistence of pink purslane beneath orchard canopies, thus revealing its adaptability to tolerate shady environments, potentially including crop canopies (Buckelew 2009).

Previous research on controlling pink purslane in agronomic production systems has been minimal; nevertheless, the weed has consistently ranked as one of the most troublesome weeds in multiple vegetable systems throughout the state of Georgia (Singh et al. 2005; Van Wychen 2022). Common management strategies in vegetable crops such as watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] and bell pepper (*Capsicum annuum*) during early development include cultivation and the use of preemergence and postemergence herbicides including thifensulfuron-methyl (1.6 g ai ha^{-1}), *S*-metolachlor (1.6 kg ai ha^{-1}), imazosulfuron (0.2 kg ai ha^{-1}), fomesafen (0.28 kg ai ha^{-1}), dimethenamid-*P* (0.74 kg ai ha^{-1}), and clomazone (0.24 kg ai ha^{-1}), with control ranging from 88% to 100% (Buckelew 2009; Finney and Creamer 2008; Peachey et al. 2012; Pekarek et al. 2009). However, research also indicates that pink purslane's densely populated trichomes have the potential to negatively influence chemical deposition from postemergence applications (Matthews and Levins 1985).

Many of the herbicides previously mentioned are commonly used in both vegetable and agronomic systems, although herbicide rates and formulation can vary based on their intended use (UGA 2024). A recent assessment of agronomic herbicide labels indicated that pink purslane was not well represented, unlike its close relative, common purslane [*Portulaca oleracea* (L.)] (UGA 2024). Generally, it is assumed that pink purslane will display similar responses to common purslane, but there is potential for intraspecific variation regarding herbicide tolerance between species of the same genus (Hergert et al. 2015). The paucity of research about the response of pink purslane to postemergence herbicides used in agronomic crops makes it difficult to provide science-based control recommendations. Therefore, a thorough investigation into strategies for controlling pink purslane is needed to develop a comprehensive weed management plan for various agronomic production systems in Georgia. Thus, the objective of this experiment was to evaluate the response of pink purslane to various postemergence herbicides commonly used in Georgia's major agronomic production systems, including field corn (*Zea mays* L.), soybean [*Glycine max* (L.) Merr.], and peanut (*Arachis hypogaea* L.) in the greenhouse and field.

Materials and Methods

Description of Research Site

This research was conducted at both the University of Georgia (UGA) Ponder Research Farm near Ty Ty, GA (31.51°N, 83.66°W; 105 m elevation), and the UGA Crop and Soil Sciences greenhouse in Tifton, GA (31.48°N, 83.53°W). Seed collection sites were located in preexisting natural populations of pink purslane in both vegetable production fields and pecan (*Carya illinoinensis*) orchards at the UGA Ponder Research Farm. Seeds were collected on June 14, 2022, during peak bloom season. Extraction methods included hand-picking vegetative structures with visible mature seed capsules (brittle/tan-colored capsules) and brushing capsules across a prime-line gray aluminum screen repair patch wrapped over the opening of a 30-mL test tube. Seeds were then stored one of two ways, either at room temperature (20 C) or refrigerated (4 C), for 2 wk prior to conducting a germination test to further understand potential germination requirements. The initial germination test indicated that refrigeration was not necessary. Seeds were stored at room temperature for the remainder of the study. The field research site is primarily composed of Fuquay loamy sand with 96% sand, 2% silt, 2% clay, and 1.2% organic matter with an average soil pH of 6.0 (USDA-NRCS 2023).

Experimental Design and Treatments

Greenhouse Experiments

Greenhouse trials were conducted twice during the winter of 2022. On the day of study initiation, potting media was placed in planting pot trays (5.7 cm × 7.62 cm × 5.1 cm tapered cells) and seeds were hand scattered over each flat followed by lightly hand-disturbing the soil surface for good seed-to-soil contact. Trays were then irrigated over the top with a common garden shower nozzle by hand delivering 150 mL per cell every other day. Immediately following irrigation, trays were placed under overhead lights (1,621 µmol/s, 130,000 lumens, Philips 1000w; Agrolite XT, Atlanta GA) set to run 16 h daily, with greenhouse temperatures at 28 C throughout the entire study. A 10:10:10 ($N:P_2O_5:K_2O$) fertilizer was applied at planting followed by successive applications every 10 d. Flats were checked daily for emergence. Once averaging 8 to 10 cm in height, two individual plants were randomly selected, and the remaining were removed per cell by cutting the stem at the soil surface.

Postemergence treatments were applied when pink purslane plants were 5 to 10 cm tall, approximately 33 d after planting. Treatments included 21 postemergence herbicides plus a nontreated control and were arranged in a randomized complete block design with six replications (Table 1). The postemergence treatments at the 1× labeled use rates were applied using standard application methods in a spray chamber with a TeeJet TP8004EVS nozzle (Spraying Systems Co., Glendale Heights, IL). A nonionic

Table 1. Greenhouse and in-field postemergence herbicide treatments for controlling pink purslane near Tifton, GA, in 2022

Herbicide	Rate	Trade names
	g ai ha^{-1}	
Nontreated control[d]	——	
2,4-D choline[c]	1,065	Enlist One® 3.8SL
2,4-DB	280[b]	Butyrac® 2SL
Acifluorfen[d]	421[a]	Ultra Blazer® 2SL
Acifluorfen + bentazon[d]	280 + 561[b]	Storm® 4SL
Atrazine[d]	1,682[b]	Aatrex® 4L
Carfentrazone	18[b]	Aim® 2EC
Chlorimuron[d]	9[a]	Classic® 25DG
Dicamba[c]	561	Engenia® 5SL
Diclosulam	18[a]	Strongarm® 84WG
Diuron[d]	841[b]	Diuron® 4L
Fomesafen[d]	421[a]	Reflex®2SL
Glufosinate[d]	656	Liberty® 2.34SL
Glyphosate[d]	1,133	Roundup PowerMax3® 5.88SL
Imazapic[d]	70[b]	Cadre® 2AS
Lactofen[d]	219[b]	Cobra® 2EC
Mesotrione	105[b]	Callisto® 4SC
Paraquat[d]	561[a]	Gramoxone® 2SL
Paraquat + Acifluorfen + Bentazon[d]	210 + 186 + 374[a]	Gramoxone® 2SL + Storm® 4SL
Tembotrione	92[b]	Laudis® 3.5SC
Tolpyralate[d]	29[b]	Shieldex® 3.33SC
Topramezone	31[b]	Impact® 2.8SC

[a]Treatment included a nonionic surfactant at 0.25% vol/vol (Induce®; Helena Chemical Company, Collierville, TN).
[b]Treatment included crop oil concentrate at 1% vol/vol (Agri-Dex®; Helena Chemical Company).
[c]Rates for 2,4-D choline and dicamba are in g ae ha^{-1}.
[d]Greenhouse treatments selected for in-field studies.

Table 2. Monthly rainfall from January to December 2023 at the University of Georgia Ponder Farm in Ty Ty, GA.[a]

	Rainfall	
Month	2023	100-yr average[b]
	mm	
January	149	108
February	108	107
March	73	122
April	88	99
May	77	82
June	184	117
July	134	138
August	160	124
September	77	97
October	35	58
November	25	64
December	152	92
Total	1,262	1,208

[a]Data were obtained from the Georgia Weather Network (http://www.georgiaweather.net).
[b]1923–2016.

surfactant (0.25% vol/vol, Induce®; Helena Chemical Company, Collierville, TN) or crop oil concentrate (1% vol/vol, Agri-Dex; Helena Chemical) was included as required. Visual estimates of pink purslane control were obtained 14 d after treatment (DAT) using a scale of 0% to 100% where 0% = no control and 100% = complete plant death. Aboveground fresh-weight biomass reduction data were also obtained at 14 DAT by hand-harvesting (clipping with scissors) all plant tissue per cell at the soil line. Herbicide treatments that indicated a satisfactory level of pink purslane control (≥80% reduction in aboveground biomass) during the greenhouse study were then selected for further evaluation in field experimentations at the UGA Ponder Research Farm.

Field Experiments

The experiment was arranged in a randomized complete block design with 14 treatments and four replications. Treatments included 13 postemergence herbicides plus a nontreated control, totaling 56 experimental units (Table 1). Field experiments were conducted twice (May and August) during the 2023 growing season. Prior to transplanting, the plot areas were prepared with a ripper/bedder and roto-tilled and maintained weed-free using glyphosate (1,133 g ai ha^{-1}, Roundup PowerMax3®; Bayer CropScience, St. Louis, MO), mechanical cultivation, and hand-weeding.

Transplant establishment in the UGA Weed Science greenhouse followed the protocol previously outlined, however, seeds were planted in 20.32 cm × 40.64 cm Styrofoam tobacco (*Nicotiana tabacum*) transplant trays with 5.08 cm × 5.08 cm × 5.08 cm tapered cells. Prior to transplanting, plants were removed from greenhouse and hardened under shade at Ponder Farm for a period of 7 to 10 d. Pink purslane was then transplanted 30 d after planting into 2 m × 7.62 m field plots at 10 plants plot^{-1} within each replicate. Overhead irrigation was applied at 1.27 cm immediately following transplanting and as needed for the remainder of the study. Rainfall data for this location is presented in Table 2. Weed germination and interference with the study indicated the need for postemergence weed control prior to treatment application. Based on preliminary data from the greenhouse, tolerance to tembotrione (92 g ai ha^{-1}, Laudis®; Bayer CropScience) permitted its use to control unwanted weeds. The postemergence treatments were applied between 15 and 20 d after transplanting using a CO_2-pressurized backpack sprayer and TeeJet AIXR11002 nozzles (Spraying Systems Co.) calibrated to deliver 140 L ha^{-1}. At the time of application, pink purslane plants were 6.4 cm tall and 15.8 cm in diameter. Visual estimates of pink purslane control and aboveground biomass data followed similar methodology as the greenhouse experiments.

Statistical Analyses

Data were subjected to the GLIMMIX procedure with SAS software (v. 9.4, SAS Institute Inc., Cary, NC) (Littell et al. 2006). Conditional residuals for control were used for checking assumptions of normality, independence of errors, homogeneity, and multiple covariance structures. Greenhouse and field experiments were analyzed separately. Fixed effects included postemergence herbicide treatments. Location, trials, and replicates represented random effects. Means were compared using the LSMEANS procedure with a Fisher's protected LSD test, with differences considered significant at $P \leq 0.05$.

Results and Discussion

Greenhouse Screening Study

Visual estimates of control at 14 DAT indicated no differences between experimental runs; therefore data were pooled. When combined over the experimental run, all herbicide treatments provided greater control of pink purslane than the nontreated control except for diclosulam, mesotrione, tembotrione, and

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Table 3. Visible estimates of pink purslane control and aboveground fresh weight biomass reduction 14 d after treatment following postemergence herbicide treatments in the greenhouse located at Tifton, GA, in 2022.[a,e,f]

Herbicide	Rate	Control	Biomass reduction
		14 DAT	14 DAT
	g ai ha^{-1}	%	
Nontreated control	——	0 F	0 h
2,4-D choline	1,065[d]	72 Bc	78 e
2,4-DB	280[c]	43 E	23 g
Acifluorfen	421[b]	97 A	100 a
Acifluorfen + bentazon	280 + 561[c]	79 B	92 abc
Atrazine	1,682[c]	98 A	100 a
Carfentrazone	18[c]	41 E	54 f
Chlorimuron	9[a,b]	62 D	82 cde
Dicamba	561[d]	67 Cd	75 e
Diclosulam	18[b]	8 f	32 g
Diuron	841[c]	96 a	99 ab
Fomesafen	421[c]	79 b	92 abc
Glufosinate	656	98 a	100 a
Glyphosate	1,133	79 b	93 ab
Imazapic	70[c]	77 b	92 abc
Lactofen	219[c]	99 a	100 a
Mesotrione	105[c]	12 f	25 g
Paraquat	561[b]	97 a	99 ab
Paraquat + Acifluorfen + Bentazon	210 + 186 + 374[b]	59 d	80 de
Tembotrione	92[c]	0 f	5 h
Tolpyralate	29[c]	76 b	89 bcd
Topramezone	31[c]	6 f	24 G

[a]Means within columns followed by the same letter are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$. Means were averaged over two experimental runs with six replications per treatment.
[b]Treatment included a nonionic surfactant at 0.25% vol/vol (Induce® Helena Chemical Company, Collierville, TN).
[c]Treatment included a crop oil concentrate at 1% vol/vol (Agri-Dex®; Helena Chemical Company).
[d]Rates for 2,4-D choline and dicamba are in g ae ha^{-1}.
[e]Pink purslane plants were 5–10 cm tall at the time of application.
[f]Abbreviation: DAT, days after treatment.

Table 4. Visible estimates of pink purslane control and aboveground fresh weight biomass reduction 14 d after treatments following postemergence herbicide treatments in field experiments at Ty Ty, GA, in 2023.[a,d,e]

Herbicide	Rate	Control	Biomass Reduction
		14 DAT	14 DAT
	g ai ha^{-1}	%	
Nontreated control	——	0 g	0 g
Acifluorfen	421[b]	54 cde	44 def
Acifluorfen + bentazon	280 + 561[c]	49 def	35 ef
Atrazine	1,682[c]	88 a	79 ab
Chlorimuron	9[b]	55 cde	49 de
Diuron	841[c]	63 bcd	61 bcd
Fomesafen	421[b]	44 ef	43 def
Glufosinate	656	64 bc	70 abc
Glyphosate	1,133	56 cde	43 def
Imazapic	70[c]	71 b	53 cde
Lactofen	219[c]	86 a	83 a
Paraquat	561[b]	63 bcd	54 cde
Paraquat + acifluorfen + bentazon	210 + 186 + 374[b]	36 f	25 f
Tolpyralate	39[c]	54 cde	53 cde

[a]Means within columns followed by the same letter are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$. Means were averaged over two experimental runs and four replications/treatment.
[b]Treatment included a nonionic surfactant at 0.25% vol/vol (Induce®; Helena Chemical Company, Collierville, TN).
[c]Treatment included crop oil concentrate at 1% vol/vol (Agri-Dex®; Helena Chemical Company).
[d]Pink purslane plants were 6.35 cm tall and 15.75 cm in diameter at the time of application.
[e]Abbreviation: DAT, days after treatment.

topramezone (Table 3). All other treatments provided >70% control of pink purslane except for 2,4-DB (43%), carfentrazone (41%), chlorimuron (62%), dicamba (67%), and paraquat + acifluorfen + bentazon (59%). Treatments that exceeded 95% control of pink purslane included acifluorfen (97%), atrazine (98%), diuron (96%), glufosinate (98%), lactofen (99%), and paraquat (97%).

Similar results were observed with pink purslane aboveground biomass reductions. All herbicide treatments improved control compared with the nontreated control except for tembotrione. Among the treatments, five herbicides provided <55% biomass reduction: carfentrazone (54%), diclosulam (32%), mesotrione (25%), topramezone (24%), and 2,4-DB (23%) (Table 3). All remaining herbicide treatments reduced pink purslane biomass by at least 75%. Interestingly, tolpyralate caused greater biomass reductions (76%) of pink purslane than the other hydroxyphenylpyruvate dioxygenase (HPPD) inhibitors (categorized as Group 27 herbicides by the Weed Science Society of America) in these trials. Similar trends were also observed in previous studies when annual grass and broadleaf weed responses varied significantly between Group 27 HPPD herbicides applied postemergence (Metzger et al. 2018; Tonks et al. 2015).

Currently, there has been little research on the response of pink purslane to various herbicides in a greenhouse setting. The wide array of treatments in the greenhouse study was designed to capture as many options for the weed management toolbox as possible. Treatments included many different sites of action including a 5-enolpyruvylshikimate-3-phosphate synthase inhibitors (glyphosate), a photosystem I electron diverter (paraquat), a glutamine synthetase inhibitor (glufosinate), photosystem II inhibitors (diuron, atrazine, and bentazon), acetolactate synthase inhibitors (chlorimuron and imazapic), protoporphyrinogen oxidase (PPO) inhibitors (fomesafen, acifluorfen, and lactofen), and HPPD inhibitors (mesotrione, tembotrione, tolpyralate, and topramezone). In summary, the greenhouse results provided preliminary evidence and identified several different sites of action for potential management options of pink purslane in agronomic systems. As a result, herbicide treatments that exhibited ≥80% aboveground biomass reduction were selected for in-field trials.

In-field Study

There was no location-by-herbicide treatment interaction; therefore, data were pooled across locations. With all herbicide treatments, pink purslane control differed from the nontreated control ($P < 0.05$) (Table 4). Atrazine (88%), lactofen (86%), and imazapic (71%) were the only herbicides that provided satisfactory control of purslane. Control with all remaining treatments was less than 64%. Lactofen provided the greatest level of biomass reduction (83%), but it was not statistically different when compared to atrazine (79%) and glufosinate (70%) (Table 4). Biomass reductions for the remaining treatments were <61%. Interestingly, overall biomass reductions declined for all herbicide treatments in the field when compared to the greenhouse. Similar trends were observed in previous research in which differences in testing conditions (field vs. greenhouse) influenced herbicide response (Fletcher et al. 1990). It is common knowledge that greenhouse conditions provide favorable and highly controllable environments for conducting research. However, field environmental factors such as the inability to manage temperature, light, and precipitation can influence plant growth and herbicide deposition, and these factors can reduce the efficacy of herbicides with enhanced sensitivity to environmental degradation, and therefore increase the variable responses to chemical treatment (Fletcher et al. 1990).

A final assessment of all herbicide treatments indicated that lactofen, glufosinate, and atrazine provided >70% biomass reductions of pink purslane under field conditions. Leaf surface characteristics can significantly influence herbicide deposition, foliar uptake, and permeability (Hess and Falk 1990; Schonherr and Baur 1994; Stagnari 2007). Although the specific features of pink purslane's leaf surface are unknown, purslane is hypothesized to have a similarly thick, waxy epicuticular layer as other succulent species, which may contribute to limited herbicide effectiveness (Evans 1932; Hess and Falk 1990). Studies have indicated that the use of surfactants can have a marked influence on herbicide distribution across the leaf surface and penetration through the cuticle layer (Hess and Falk 1990). Adjuvants were used according to label recommendations to maximize herbicide effectiveness, however, many of the herbicide treatments that failed to provide satisfactory control included either a nonionic surfactant or a crop oil concentrate. This suggests that although adjuvants may increase herbicide efficacy, additional factors may influence the varied responses across treatments, including within the same herbicide classification.

The PPO-inhibiting and PS II-inhibiting modes of action were represented by multiple herbicide treatments in the experiment, including lactofen (a PPO inhibitor) and atrazine (a PS II inhibitor). Results indicated that lactofen was the most effective herbicide treatment with 83% biomass reduction, whereas applications of acifluorfen, fomesafen, and acifluorfen + bentazon resulted in significantly lower biomass reductions (44%, 43%, and 35%, respectively) among the remaining PPO inhibitors. Conversely, Higgins et al. (1988) found that absorption of acifluorfen in pitted morningglory (*Ipomoea lacunosa* L.) was significantly greater than that of lactofen. However, studies have shown that weed maturity and temperature, especially colder temperatures (16 C at application) can significantly influence acifluorfen efficacy whereby temperature was not a significant factor for lactofen (Ritter and Coble 1981, 1984; Wichert et al. 1992). Because plant species is a major contributing factor to varied responses of acifluorfen and lactofen, pink purslane's differing responses to similar herbicides, even within the same family, suggests that minute differences in chemical composition can have a significant influence on absorption, translocation, and metabolic activity (Higgins et al. 1988; Stagnari 2007; Svyantek et al. 2016; Wichert et al. 1992). Furthermore, the reduced efficacy of acifluorfen + bentazon (35% biomass reduction), supports previous studies suggesting that this tank-mixture can be antagonistic, especially when tank-mixed with paraquat (Colby 1967; Wehtje et al. 1992).

In contrast to these results, pink purslane has been controlled with postemergence applications of glyphosate at 3,092 g ha^{-1} and paraquat at 1,549 g ha^{-1} in vegetable production systems (preplant and row middles), but these application rates are much higher than rates used in agronomic crops (UGA 2024). Renton et al. (2011) highlighted that herbicide rate can be a limiting factor in providing adequate control of targeted weeds. Therefore, future pink purslane control research in agronomic crops should investigate higher application rates, however, many of the herbicides used in these studies were applied at the maximum labeled rates for agronomic production systems.

In conclusion, pink purslane is likely not a significant threat to agronomic production compared to other highly competitive weed species. This research suggests that many of the postemergence herbicides used in agronomic crops will not effectively control pink purslane. Current assessments indicate that cultural and mechanical agronomic practices are likely limiting the abundance and distribution of pink purslane within the field. Thus, a systems approach is the most effective way to achieve satisfactory control. Growers can now have confidence in their integrated weed management plan with the addition of proven and effective postemergence herbicides when pink purslane becomes problematic in agronomic production systems.

Practical Implications

Currently, observations of pink purslane have been limited to field edges and occasional in-field treatable populations in agronomic production systems. Growers of agronomic crops who need to use postemergence herbicides for pink purslane control should plant crops and cultivars that are tolerant of atrazine, lactofen, or glufosinate. Fortunately, growers have many preemergence herbicide options that can provide effective control of pink purslane including *S*-metolachlor (Dual Magnum®; Syngenta, Greensboro, NC), flumioxazin (Valor®; Valent, Walnut Creek, CA), dimethenamid-*P* (Outlook®; BASF, Research Triangle Park, NC), and pendimethalin (Prowl H_2O®; BASF) (UGA 2024). Thus, using a fully integrated weed management plan, including cultural practices and both preemergence and postemergence herbicides for controlling pink purslane, is paramount.

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References

Adachi T, Kushima H, Nakazono K, Nagatomo T (1979) Some features on genetic diversity of seed dormancy and germination in the genus *Portulaca*. Bull Faculty Agr Miyazaki Univ 26:57–64

Bair A, Howe M, Roth D, Taylor R, Ayers T, Kiger RW (2006) Portulacaceae Purslane Family. Canotia 2:1–22

Boas S (2011) Pink purslane is a weed but a pretty one with many benefits. *Orlando Sentinel*, July 25. https://www.orlandosentinel.com/2011/07/25/pink-purslane-is-a-weed-but-a-pretty-one-with-many-benefits/. Accessed: February 14, 2024

Buckelew JK (2009) Orchard floor management in young peach [*Prunus persica* (L.) Batsch.]: Effects of irrigation, vegetation-free width, and certain PRE herbicides [Ph.D. dissertation].North Carolina State University

Colby SR (1967) Calculating synergistic and antagonistic responses of herbicide combinations. Weeds 15:20–22

Commelin C (1697) *Horti Medici Amstelodamensis*. 9 p

Connard MH, Zimmerman PW (1931) Origin of adventitious roots of *Portulaca oleracea* L. Contrib Boyce Thomps 3:337–346

Ekblad M (2020) *Portulaca pilosa* var. *mandala*: Drought resistant succulent thrives in the rockiest of gardens. https://conservancy.umn.edu/bitstream/handle/11299/225168/Portulaca%20pilosa%20var.%20mundala%20by%20Marena%20Ekblad.pdf?sequence=1. Accessed: November 28, 2023

Evans BH (1932) The physiology of succulent plants. Biol Rev 7:181–211

Finney DM, Creamer N (2008) Weed management on organic farms. https://content.ces.ncsu.edu/weed-management-on-organic-farms. Accessed: August 20, 2023

Fletcher JS, Johnson FL, McFarlane JC (1990) Influence of greenhouse versus field testing and taxonomic differences on plant sensitivity to chemical treatment. Environ Toxicol Chem 9:769–779

Hergert HJ, Mealor BA, Kniss AR (2015) Inter- and intraspecific variation in native restoration plants for herbicide tolerance. Ecol Manag Restor 33:74–81

Hess FD, Falk RH (1990) Herbicide deposition on leaf surfaces. Weed Sci 38:280–288

Higgins JM, Whitwell T, Corbin FT, Carter GE Jr, Hill HS Jr (1988) Absorption, translocation, and metabolism of acifluorfen and lactofen in pitted morningglory (*Ipomoea lacunosa*) and ivyleaf morningglory (*Ipomoea hederacea*). Weed Sci 36:141–145

Hodkinson DJ, Thompson K (1997) Plant dispersal: the role of man. J Appl Ecol 34:1484–1496

Hopen HJ (1972) Growth of common purslane as influencing control and importance as a weed. Weed Sci 20:20–23

Kim I, Carr GD (1990) Reproductive biology and uniform culture of *Portulaca* in Hawaii. Pac Sci 44:123–129

Littell R, Milliken G, Stroup W, Wolfinger R, Schabenberger O (2006) SAS for mixed models, Second Edition. Cary, NC: SAS Institute Inc.

Matthews JF, Ketron DW, Zane SF (1992) The reevaluation of *Portulaca pilosa* and *P. mundula* (Portulacaceae). SIDA, Contributions to Botany 15:71–89

Matthews JF, Levins PA (1985) The genus *Portulaca* in the southeastern United States. Castanea 50:96–104

Metzger BA, Soltani N, Raeder AJ, Hooker DC, Robinson DE, Sikkema PH (2018) Tolpyralate Efficacy: Part 2. Comparison of three Group 27 herbicides applied POST for annual grass and broadleaf weed control in corn. Weed Technol 32:707–713

Peachey E, Doohan D, Koch T (2012) Selectivity of fomesafen based systems for preemergence weed control in cucurbit crops. Crop Prot 40:91–97

Pekarek RA, Monks DW, Hoyt GD, Creamer NG, Jennings KM (2009) Evaluation of a 'Caliente' Mustard Cover Crop, S-Metolachlor, Imazosulfuron, and Thifensulfuron-Methyl for Weed Control in Bell Pepper [master's thesis]. North Carolina State University

Renton M, Diggle A, Manalil S, Powles S (2011) Does cutting herbicide rates threaten the sustainability of weed management in cropping systems? Theor Biol 283:14–27

Ritter RL, Coble HD (1981) Influence of temperature and relative humidity on the activity of acifluorfen. Weed Sci 29:480–485

Ritter RL, Coble HD (1984) Influence of crop canopy, weed maturity, and rainfall on acifluorfen activity. Weed Sci 32:185–190

Schonherr J, Baur P (1994) Modelling penetration of plant cuticles by crop protection agents and effects of adjuvants on their rates of penetration. Pestic Sci 42:185–208

Singh BP, Granberry DM, Kelley WT, Boyhan G, Sainju UM, Phatak SC, Sumner PE, Bader MJ, Webster TM, Culpepper AS, Riley DG, Langston DB, Fonsah GE (2005) Sustainable vegetable production. J Food Agric Environ 3:1–38

Stagnari F (2007) A review of the factors influencing the absorption and efficacy of lipophilic and highly water-soluble post-emergence herbicides. Eur J Plant Sci Biotechnol 1:22–35

Svyantek AW, Aldahir P, Chen S, Flessner ML, McCullough PE, Sidhu SS, McElroy JS (2016) Target and nontarget resistance mechanisms induce annual bluegrass (*Poa annua*) resistance to atrazine, amicarbazone, and diuron. Weed Technol 30:773–782

Tonks D, Grove M, Kikugawa H, Parks M, Nagayama S, Tsukamoto M (2015) Tolpyralate: an overview of performance for weed control in US corn. Abstract 276 *in* Proceedings of the Weed Science Society of America Annual Meeting. Lexington, Kentucky, February 9–12, 2015

[UGA] University of Georgia (2024) Georgia Pest Management Handbook. https://ipm.uga.edu/georgia-pest-management-handbook/. Accessed: February 19, 2024

Van Wychen L (2022) Survey of the most common and troublesome weeds in broadleaf crops, fruits & vegetables in the United States and Canada. Weed Science Society of America National Weed Survey Dataset. https://wssa.net/wp-content/uploads/2022-Weed-Survey-Broadleaf-crops.xlsx. Accessed: February 14, 2024

[USDA-NRCS] U.S. Department of Agriculture–Natural Resources Conservation Service (2023) Web Soil Survey. http://websoilsurvey.sc.egov.usda.gov/. Accessed: November 27, 2023

Wehtje G, Wilcut JW, McGuire JA (1992) Influence of bentazon on the phytotoxicity of paraquat to peanuts (*Arachis hypogaea*) and associated weeds. Weed Sci 40:90–95

Wichert RA, Bozsa R, Talbert RE, Oliver LR (1992) Temperature and relative humidity effects on diphenylether herbicides. Weed Technol 6:19–24

Zimmerman CA (1976) Growth characteristics of weediness in *Portulaca oleracea* L. Ecology 57:964–974