Weed Technology

www.cambridge.org/wet

Research Article

Cite this article: Martin LJ, Sellers BA, Devkota P, Ferrell JA, Leon RG, Vendramini JMB (2021) Tolerance of rhizoma perennial peanut to glyphosate and triclopyr. Weed Technol. **35**: 525–531. doi: 10.1017/wet.2020.126

Received: 5 August 2020
Revised: 19 October 2020
Accepted: 30 October 2020
First published online: 6 November 2020

Associate Editor:
Mark VanGessel, University of Delaware

Nomenclature:
Glyphosate; triclopyr; rhizoma perennial peanut; *Arachis glabrata* Benth

Keywords:
Forage crop; herbicide injury; perennial peanut varieties

Author for correspondence:
Brent A. Sellers, Professor and Director, Range Cattle Research and Education Center, 3401 Experiment Station, Ona, FL 33865
Email: sellersb@ufl.edu

Tolerance of rhizoma perennial peanut to glyphosate and triclopyr

Logan J. Martin[1], Brent A. Sellers[2], Pratap Devkota[3], Jason A. Ferrell[4], Ramon G. Leon[5] and João M.B. Vendramini[2]

[1]Former Graduate Research Assistant, University of Florida-Institute of Food and Agricultural Sciences, Department of Agronomy, Range Cattle Research and Education Center, Ona, FL, USA; [2]Professor, University of Florida–Institute of Food and Agricultural Sciences, Department of Agronomy, Range Cattle Research and Education Center, Ona, FL, USA; [3]Assistant Professor, University of Florida–Institute of Food and Agricultural Sciences, West Florida Research and Education Center, Department of Agronomy, Jay, FL, USA; [4]Professor and Director, University of Florida–Institute of Food and Agricultural Sciences, Center for Aquatic and Invasive Plants, Department of Agronomy, Gainesville, FL, USA and [5]Associate Professor, Department of Crop and Soil Sciences, North Carolina State University, Raleigh, NC, USA

Abstract

Rhizoma perennial peanut (RPP) is well adapted to the Gulf Coast region of the United States, but its varietal tolerance to glyphosate and triclopyr is not well defined. The research was conducted to determine the effect of various rates of glyphosate and triclopyr on established RPP, and the response of common RPP varieties to these herbicides. The RPP sward was approximately 7 yr younger at Zolfo Springs than at the Ona location. RPP showed moderate tolerance to glyphosate and triclopyr application, and injury level did not differ with the age of RPP sward. However, biomass production was negatively influenced by the age of the RPP sward. Overall, injury from glyphosate applications did not exceed 40% at either site. The glyphosate rate for 20% biomass reduction was predicted to be 0.53 and 2.17 kg ae ha^{-1} at Zolfo Springs and Ona, respectively. RPP injury from triclopyr was greater at the Zolfo Springs location than at Ona, and the triclopyr rate predicted to result in a 20% biomass reduction was 0.45 and 0.99 kg ae ha^{-1} at the Zolfo Springs and Ona locations, respectively. There was a difference on RPP varieties response to glyphosate and triclopyr application. 'Florigraze' and 'Ona 33' were less tolerant to glyphosate compared to 'UF-Tito' and 'Ecoturf' at 30 d after treatment. Likewise, UF-Tito and Florigraze were less tolerant to triclopyr compared to Ona 33 and Ecoturf. Overall, Florigraze showed highest injury and at least 2-fold reduction on biomass compared to the other three varieties from glyphosate or triclopyr application. Results from this research indicate that glyphosate and triclopyr appear to be safe to apply to long-established RPP stands, but herbicide rate and RPP varieties should be considered if stands are <5 yr old.

Introduction

Pastures in tropical and subtropical environments largely consist of C4 forage species such as bermudagrass (*Cynodon dactylon* L.), bahiagrass (*Paspalum notatum* Flugge), and limpograss [*Hemarthria altissima* (Poir.) Stapf & C.E. Hubb.] (Vendramini 2010). Due to their anatomical and morphological characteristics, these forages are often low in digestibility and crude protein compared to C3 species (Vendramini 2010). Therefore, supplements are added to animal diets to improve digestibility and crude protein of poor-quality forage grasses (Graham and Vance 2003). While supplementation with feedstuffs or molasses is common, legumes are a preferred supplement to meet the dietary needs of livestock (Foster et al. 2017; Williams et al. 2004). Perennial peanut, such as pinto peanut (*Arachis pinto* Krap. and W.C. Greg.) or rhizoma perennial peanut (RPP) is grown in the Gulf Coast region of the United States, and commonly used as supplementation for improving digestibility and nutrient value of C4 grasses (Mislevy et al. 2007; Quesenberry et al. 2010; Villarreal et al. 2005).

RPP is a rhizomatous, prostrate growing, perennial herbaceous legume that grows from a strong tap root and forms a dense mat of stolons (Ball and Hoveland 2015; Williams et al. 2017). Tetrafoliolate leaves are comprised of linear-lanceolate leaflets measuring 4 cm long and 2 cm wide (Cook et al. 2005). RPP is native to Brazil and it is widely used as livestock forage in the tropical and subtropical regions because of its high nutritive value and persistence under a wide range of management conditions (Williams et al. 2017). Various varieties of RPP are grown in Florida, including Florigraze, Ecoturf, UF-Tito, UF-Peace, and Arblick, and newer varieties are continuously introduced and evaluated for potential use.

Because RPP produces few viable seeds, it is propagated primarily by planting rhizomes. Establishment of RPP is typically slow and can take up to 2 yr to achieve a productive sward (Mislevy et al. 2007). During establishment, broadleaf weeds are typically managed by timely

https://doi.org/10.1017/wet.2020.126 Published online by Cambridge University Press

applications of the herbicide imazapic. Mislevy et al. (2007) reported that two applications of imazapic at 70 g ai ha^{-1} at 60 d after planting and 4 mo after the first application provided effective weed control during the first year of establishment. However, with widespread ALS-resistant weed species and limited herbicide registered on RPP, weed management remains as one of the major challenges for successful establishment and production. The presence of weeds can compromise palatability or diminish stands. Likewise, weed interference decreases forage/pasture yield, compromises forage value, and competes with desirable crop species, and has resulted economic loss of about \$180 million to Florida ranchers (Sellers and Ferrell 2018).

Similar to other crops, chemical weed control is a critical tool for reducing weed populations in perennial peanut stands (Valencia et al. 1999). However, few herbicides are registered for use on RPP, and published information on RPP tolerance to postemergence herbicides is limited. Herbicide applied without proper information can cause undesirable injury to RPP, desiccate foliage, and result in total plant loss. Previous researchers have suggested that imazapic use results in minimal RPP injury at any growth stage (Ferrell et al. 2006; Mislevy et al. 2007). RPP was found to be tolerant to 2,4-D (at 0.56 kg ha^{-1}) and hexazinone (at 0.28 kg ha^{-1}) applied at 3 d after clipping (Ferrell et al. 2006). Additionally, RPP has illustrated some level of tolerance to glyphosate and triclopyr (Valencia et al. 1999), but the detail on the rate for RPP tolerance and the varietal differences for tolerance to these herbicides remains unknown.

Currently, imazapic, 2,4-D, and hexazinone are the only herbicides labeled for broadleaf weed control in RPP production in Florida. The labeled rates of 2,4-D and hexazinone often are not adequate for controlling various problematic weeds such as tropical soda apple (*Solanum viarum*), dogfennel (*Eupatorium capillifolium*), licoriceweed (*Scoparia dulcis*), thistles (*Cirsium* sp.), and smutgrass (*Sporobolus indicus*; Sellers and Devkota 2020). Therefore, application of additional herbicides such as glyphosate and triclopyr is necessary to increase the weed control efficacy and spectrum in RPP production. However, expanding herbicide options for RPP must be based on crop tolerance as well as weed control. Therefore, understanding RPP tolerance to glyphosate and triclopyr is necessary so as to apply these herbicides safely and without severely injuring the desirable forage.

Materials and Methods

Herbicide Rate Response on Rhizoma Perennial Peanut

Field studies were conducted to evaluate the response of established RPP to various rates of glyphosate and triclopyr. Studies were conducted at a grower's farm near Zolfo Springs, FL (27.50°N, 81.82°W) in summer of 2015 and 2016. The soil type was St. Lucie fine sand, pH 6. The field was planted with UF-Tito variety in 2012, which indicates that study was conducted on fully established RPP sward. A proportion of the RPP rhizomes were removed from the site to propagate this variety elsewhere approximately 18 mo before the study began.

Prior to treatment application, the experimental areas were clipped to a height of 7.6 cm and biomass was removed. Plants were allowed to regrow for 2 wk and were approximately 10 cm tall with four to six fully expanded leaves. The individual plot size was 1.5 m by 1.5 m. Treatments consisted of glyphosate (Mad Dog Plus, Loveland Products, Inc., Greeley, CO) at 0.14, 0.28, 0.56, 1.12, and 2.24 kg ae ha^{-1}; and triclopyr (Remedy Ultra, Dow AgroSciences, LLC, Indianapolis, IN) at 0.07, 0.14, 0.28, 0.56, and 1.12 kg ae ha^{-1}. An untreated check was included in the study for treatment comparisons. Herbicide treatments were applied on August 5, 2015, and July 14, 2016. Treatments were applied using a CO_2-pressurized backpack sprayer calibrated to deliver 281 L ha^{-1} at 200 kPa using AirMix 11002 spray nozzles (Greenleaf Technologies, Covington, LA). For trial maintenance, clethodim was applied at 0.28 kg ha^{-1} for grass weed control.

Data Collection and Statistical Analysis

The study was conducted as a randomized complete block design with four replications for each experiment year. Following treatment application, visually assessed crop injury was recorded on a 0% to 100% scale (where 0% = no injury or similar to untreated check and 100% = complete death of the plant) at 15, 30, and 60 d after treatment (DAT). Aboveground RPP biomass was collected from the center 0.25-m^2 of each plot at 60 DAT by clipping plants at the soil surface. Plant samples were placed in a forced air-dryer at 60 C for 4 d, and dry biomass was then recorded.

Data for glyphosate and triclopyr were analyzed separately because the objective of this research was to determine the tolerance of RPP to various rates of these herbicides and not to compare the two herbicides. Data were subjected to ANOVA using the PROC MIXED procedure in SAS (version 9.4, SAS Institute, Cary, NC) to determine the interaction between year and herbicide treatment. Year and herbicide rate were considered fixed effects, whereas replication and its interactions with year were considered as random effects. Effect of year and its interaction with replication was nonsignificant; therefore, data were combined over years for further analysis. Prior to analysis, biomass data were multiplied by 4 to obtain biomass on a square meter basis. Regression analysis was performed to determine the effect of increasing glyphosate and triclopyr rates on RPP injury and biomass. Because trends were most accurately described by either linear or quadratic functions, these models were used to establish the predicted line using Sigma Plot 12.0 software (SPSS Inc., Chicago, IL).

Rhizoma Perennial Peanut Varieties and Herbicide Rate Response

Field studies were conducted at the University of Florida Range Cattle Research and Education Center near Ona, FL (27.39°N, 81.94°W) in mid and late summer of 2016. Response of various rates of glyphosate and triclopyr were evaluated on established RPP varieties. The soil type at this location was an Ona fine sand, pH 6. The experimental site was planted in 2005 with four RPP varieties: Ecoturf, Florigraze, 'PI262833' (hereafter referred to as 'Ona 33', a nonreleased variety), and UF-Tito. The site preparation, plot size, and glyphosate and triclopyr formulation and rates used in this study were the same as those previously mentioned for the Zolfo Springs study. An untreated check was included in the study for treatments comparison. Herbicide treatments were applied on June 23, 2016, and July 19, 2016, as previously described. Clethodim was applied at 0.28 kg ha^{-1} for grass weed control as needed.

Data Collection and Statistical Analysis

For each herbicide, the study was conducted as a 4 × 6 factorial arrangement in a randomized complete block design with four replications and repeated twice. Main factors were RPP varieties and herbicide rates. Following herbicide application, visually assessed

https://doi.org/10.1017/wet.2020.126 Published online by Cambridge University Press

percent RPP injury were recorded on a 0% to 100% scale (where 0% = no injury or similar to untreated check and 100% = complete death of plant) at 15, 30, and 60 DAT. Aboveground RPP and broadleaf weed biomass was collected at 60 DAT by clipping plants at the soil surface, from a 0.25-m^2 area for each plot at the center of each plot to avoid border effects. The broadleaf weed present in the research site were licorice weed and tropical soda apple. RPP and broadleaf weed biomass were separated after clipping. Plant samples were dried in a forced air-dryer at 60 C for 4 d, and dry biomass was then recorded.

Data for glyphosate and triclopyr were analyzed separately. Data were subjected to ANOVA using the PROC MIXED procedure in SAS to determine the interaction between experimental run and herbicide rate. Run, herbicide rate, and variety were considered fixed effects, whereas replication and its interactions with run were considered as random effects. Because there was no significant effect of replication and its interaction with run, data were combined over experimental runs for further analysis. Herbicide rate, variety, and interactions were considered fixed effects, whereas replication was considered a random effect. Prior to analysis, biomass data were multiplied by 4 to obtain biomass on a square meter basis. Means separation was performed using Fisher's protected LSD at $P \leq 0.05$. Regression analysis was used to determine the effect of increasing glyphosate and triclopyr rates on RPP injury and biomass using either linear or quadratic equations in Sigma Plot 12.0 software. In addition, ratio analysis was used to determine the herbicide rate for optimum RPP biomass with providing maximum weed control. Ratios were square root–transformed prior to regression analysis and were back-transformed for reporting results in percentage units.

Results and Discussion

Herbicide Rate Response on Rhizoma Perennial Peanut

RPP injury followed a quadratic response to glyphosate rates at 15, 30, and 60 DAT (Figure 1). The glyphosate I_{20} (rate for 20% injury, which is considered to be acceptable by most RPP producers) was estimated to be 0.72, 0.77, and 0.78 kg ae ha^{-1} at 15, 30, and 60 DAT, respectively. The RPP biomass also followed a quadratic response to glyphosate rate (Figure 2), but a 20% reduction in biomass was estimated at 0.53 kg ae ha^{-1} at 60 DAT. RPP injury followed a linear response to increasing triclopyr rates at 15, 30, and 60 DAT (Figure 3). Estimated I_{20} values for triclopyr were 0.47, 0.45, and 0.39 kg ae ha^{-1} at 15, 30, and 60 DAT, respectively. Perennial peanut biomass also followed a linear response to increasing triclopyr rate, and a 20% reduction in biomass was estimated at 0.45 kg ae ha^{-1} at 60 DAT (Figure 4). Unlike glyphosate, visual estimations of plant injury may provide a relationship to potential yield loss with using triclopyr. Other forage legume species including blue pea (*Clitoria ternatea* L.) and perennial soybean (*Neonotonia wightii* L.) have shown a relatively high tolerance to glyphosate with ED_{50} values for at 0.6 and 0.33 kg ae ha^{-1}, respectively (Cruz-Hipolito et al. 2011).

Rhizoma Perennial Peanut Varieties and Herbicide Rate Response

Glyphosate Study

The interaction between variety and glyphosate rate, and the main effect of variety, was significant at 30 DAT; however, only the effect of glyphosate rate was significant at 15 and 60 DAT. The general trend observed between varieties at 30 DAT indicated that

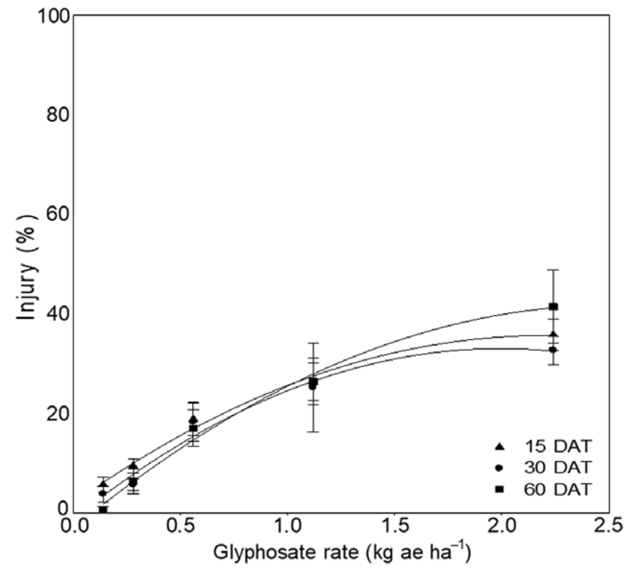

Figure 1. Rhizoma perennial peanut injury as a function of glyphosate rate for data combined across 2015 and 2016 at the Zolfo Springs, FL, location. Predicted line is plotted with mean and standard error. The predicted model for 15 DAT is $y = -6.9x^2 + 30.4x + 2.0$ ($R^2 = 0.99$); 30 DAT, $y = -8.6x^{-2} + 34.1x - 1.2$ ($R^2 = 0.98$); and 60 DAT, $y = -7.0x^2 + 35.4x - 3.1$ ($R^2 = 0.99$), where y = injury (%) and x = glyphosate rate (kg ae ha^{-1}).

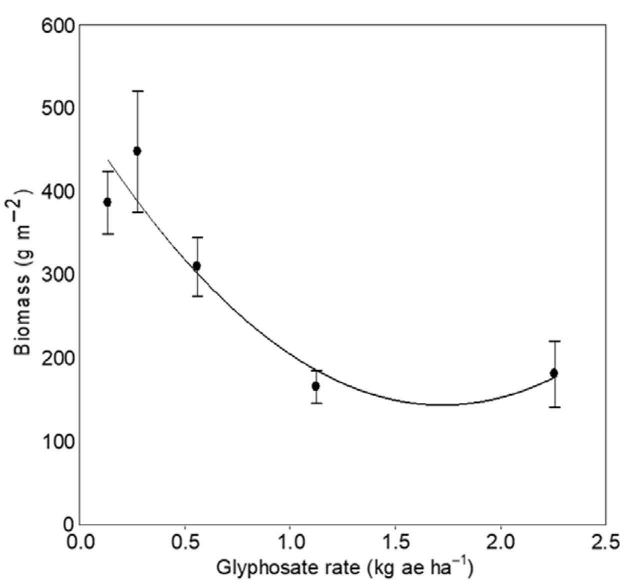

Figure 2. Rhizoma perennial peanut biomass as a function of glyphosate rate for data combined across 2015 and 2016 at the Zolfo Springs, FL, location at 60 DAT. Predicted line is plotted with mean and standard error. The predicted model is $y = 117.4x^2 - 402.3x + 489.6$ ($R^2 = 0.89$), where y = biomass (g m^{-2}) and x = glyphosate rate (kg ae ha^{-1}).

Florigraze and Ona 33 were less tolerant to glyphosate than UF-Tito or Ecoturf (Figure 5). Estimates of I_{20} values were 1.0, 1.17, 1.38, and 1.56 kg ae ha^{-1} for Florigraze, Ona 33, UF-Tito, and Ecoturf, respectively. When averaged over glyphosate rates, injury to Florigraze was at least 4% greater than that to UF-Tito or Ecoturf at 30 DAT (Table 1). Likewise, Ona 33 exhibited greater injury than Ecoturf. Biomass results corresponded with the injury data for Ecoturf and UF-Tito biomass being at least 2-fold greater than that of Florigraze. Weed biomass in Florigraze was at least 1.8-fold

https://doi.org/10.1017/wet.2020.126 Published online by Cambridge University Press

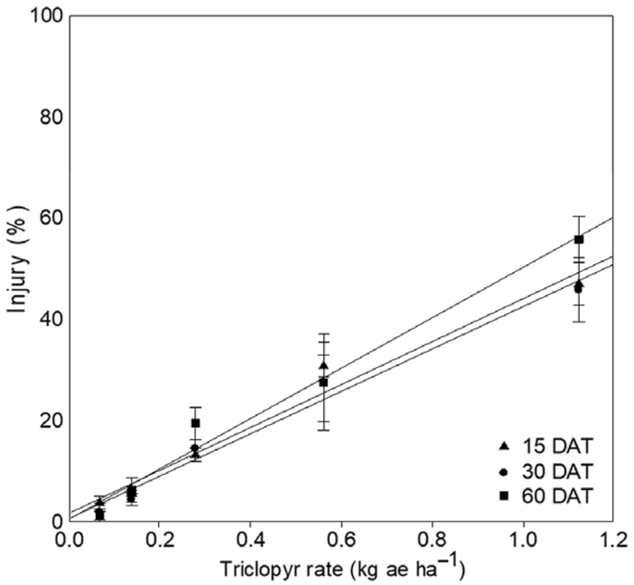

Figure 3. Rhizoma perennial peanut injury as a function of triclopyr rate for data combined across 2015 and 2016 at the Zolfo Springs, FL, location. Predicted line is plotted with mean and standard error. The predicted model for 15 DAT is y = 42.4x + 1.56 (R^2 = 0.97); 30 DAT is y = 41.9x + 0.55 (R^2 = 0.98); and 60 DAT is y = 49.8x + 0.37 (R^2 = 0.98), where y = injury (%) and x = triclopyr rate (kg ae ha^{-1}).

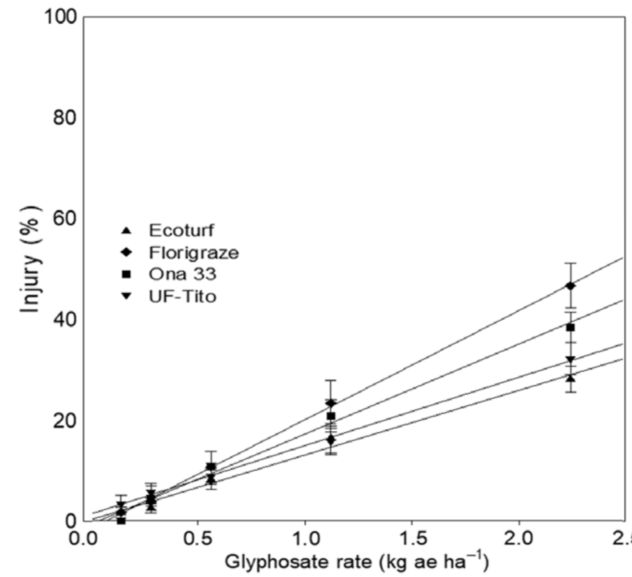

Figure 5. Rhizoma perennial peanut variety injury as a function of glyphosate rate at 30 DAT at the Ona, FL, location. Data are combined across two runs in 2016. Predicted line is plotted with mean and standard error. The predicted model for Ecoturf is y = 12.7x + 0.23 (R^2 = 0.99); Florigraze, y = 21.5x − 1.54 (R^2 = 0.99); Ona 33, y = 17.7x − 0.63 (R^2 = 0.99); and UF-Tito, y = 13.5x + 1.36 (R^2 = 0.99), where y = injury (%) and x = glyphosate rate (kg ae ha^{-1}).

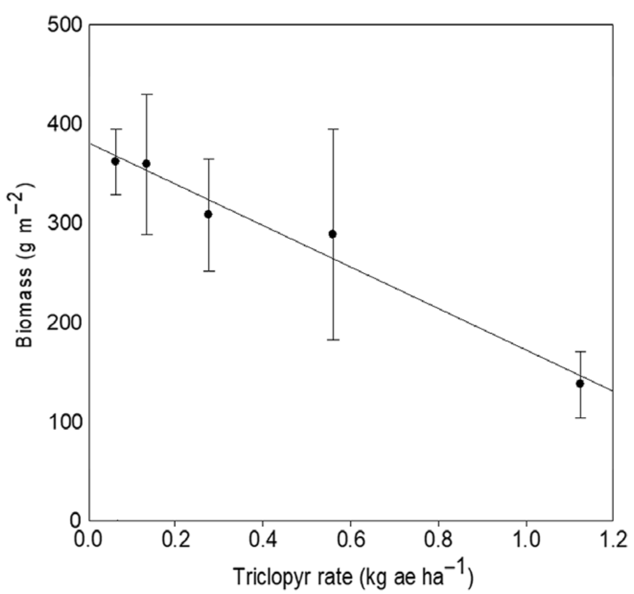

Figure 4. Rhizoma perennial peanut biomass as a function of triclopyr rate for data combined across 2015 and 2016 at the Zolfo Springs, FL, location at 60 DAT. Predicted line is plotted with mean and standard error. The predicted model is y = −210.7x + 382.8 (R^2 = 0.97), where y = biomass (g m^{-2}) and x = triclopyr rate (kg ae ha^{-1}).

greater compared to other varieties. Overall, Ecoturf was found to be the most tolerant to glyphosate among the four RPP varieties evaluated in this study.

Data averaged across RPP varieties illustrated that injury followed a linear response to increasing glyphosate rate at 15, 30, and 60 DAT (Figure 6). It is also important to note that there was no RPP injury between rating timing at the lower rates of glyphosate; however, injury was greater at 15 and 30 DAT compared to 60 DAT with glyphosate at rates ≥1.12 kg ae ha^{-1} (data not shown). Estimated I_{20} values were 1.28, 1.23, and 1.60 kg ae ha^{-1} at 15, 30, and 60 DAT, respectively. RPP and weed biomass followed a quadratic response to increasing glyphosate rate (Figure 7). In general, RPP biomass after glyphosate application was similar to that of the untreated control except for the highest rate of glyphosate used in the study. Glyphosate applied at 2.17 kg ae ha^{-1} was estimated to reduce RPP biomass by 20%. Conversely, weed biomass was affected with glyphosate at rates ≥0.56 kg ae ha^{-1}. Ratio analysis estimated that glyphosate at 1.21 kg ae ha^{-1} resulted in optimum RPP biomass production and weed biomass reduction (Figure 8). At this rate, RPP biomass is estimated at 199 g m^{-2} (Figure 7), which is similar to the biomass from untreated plots.

Previous research indicated that RPP is tolerant to glyphosate at 1.21 kg ae ha^{-1}, and RPP recovered at this rate (Valencia et al. 1999). Similarly, Dwyer et al. (1989) observed perennial peanut (*A. pintoi* Krapov & W.C. Greg.) tolerance to glyphosate. Research by Quesenberry et al. (2010) reported that RPP yields were similar among varieties under various environmental and management condition, and the same was found for Ona 33 in relation to other varieties (Mislevy et al. 2007). However, the biomass of Florigraze was less than that of other varieties in this study. This could be attributed to potential susceptibility of Florigraze to weed competition compared to that of other varieties. Similar results were reported in previous research illustrating that UF-Tito was more competitive with common bermudagrass (*Cynodon dactylon* L.) than Florigraze (Quesenberry et al. 2010).

Triclopyr Study

There was no interaction of RPP variety and triclopyr rate, except for injury at 30 DAT, on RPP injury and biomass (data not shown). The main effect of variety or triclopyr rate was significant at 15, 30, and 60 DAT for RPP injury, and for RPP and weed biomass. The RPP injury trend among varieties at 30 DAT indicated that

https://doi.org/10.1017/wet.2020.126 Published online by Cambridge University Press

Table 1. Rhizoma perennial peanut variety injury, biomass, and broadleaf weed biomass averaged over glyphosate rate at the Ona, FL, location.[a,b]

	Injury			Biomass	
Variety	15 DAT	30 DAT	60 DAT	Peanut	Weed
	%			$g\ m^{-2}$	
Ecoturf	13 a	11 c	13 a	221 a	80 b
Florigraze	13 a	17 a	13 a	93 b	147 a
Ona 33	16 a	15 ab	14 a	208 a	43 b
UF-Tito	12 a	13 bc	11 a	235 a	46 b

[a]Data are combined across two runs in 2016. Glyphosate was applied at 0.14, 0.28, 0.56, 1.12, and 2.24 kg ae ha^{-1}.
[b]Means within a column followed by the same letter are not different based on Fisher's protected LSD at $P \leq 0.05$.

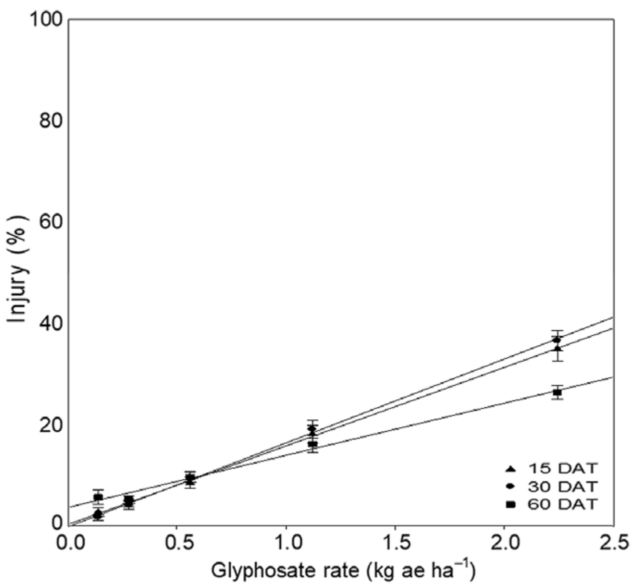

Figure 6. Rhizoma perennial peanut injury as a function of glyphosate rate for data pulled across four varieties at the Ona, FL location. Data are combined across two runs in 2016. Predicted line is plotted with mean and standard error. The predicted model for 15 DAT is $y = 15.4x + 0.25$ ($R^2 = 0.99$); 30 DAT, $y = 16.4x - 0.20$ ($R^2 = 0.99$); and 60 DAT, $y = 10.2x + 3.61$ ($R^2 = 0.99$), where y = injury (%) and x = glyphosate rate (kg ae ha^{-1}).

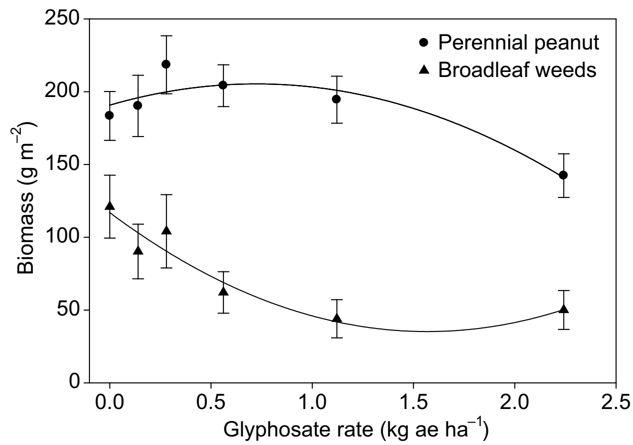

Figure 7. Rhizoma perennial peanut and broadleaf weed biomass as a function of glyphosate rate at 60 DAT for data pulled across four varieties at the Ona, FL, location. Data are combined across two runs in 2016. Predicted line is plotted with mean and standard error. The predicted model for rhizoma perennial peanut is $y = -27.9x^2 + 40.4x + 190.8$ ($R^2 = 0.86$); and broadleaf weeds, $y = 33.3x^2 - 104.3x + 117$ ($R^2 = 0.91$), where y = biomass (g m^{-2}) and x = glyphosate rate (kg ae ha^{-1}).

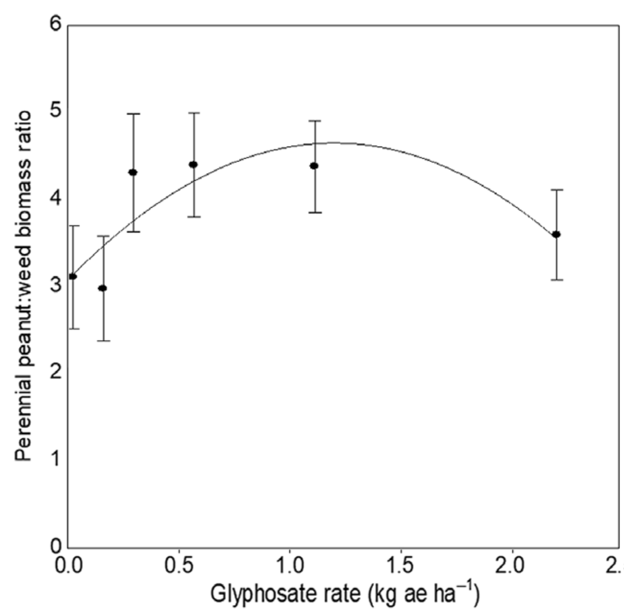

Figure 8. Rhizoma perennial peanut and broadleaf weed biomass ratio as a function of glyphosate rate at 60 DAT at the Ona, FL location. Data are combined across two runs in 2016. Predicted line is plotted with mean and standard error. The predicted model is $y = -1.0x^2 + 2.5x + 3.1$ ($R^2 = 0.7$), where y = rhizoma perennial peanut and broadleaf weed biomass ratio and x = glyphosate rate (kg ae ha^{-1}).

UF-Tito was the least tolerant variety and that Ona 33 and Ecoturf were the most tolerant varieties to triclopyr (Figure 9). Estimated I_{20} values were 0.55, 0.74, 0.97, and 1.12 kg ae ha^{-1} for UF-Tito, Florigraze, Ona 33, and Ecoturf, respectively. When averaged over triclopyr rates, injury to UF-Tito was at least 1.5-fold and 1.3-fold greater than injury to the other three varieties at 15 and 30 DAT, respectively, but UF-Tito and Florigraze injuries were similar by 60 DAT (Table 2). Likewise, Florigraze biomass was at least 2.1-fold lower than that of other varieties, and this result was similar to that with glyphosate. Weed biomass collected from Florigraze plots was at least 1.7-fold greater compared with that of other varieties. As mentioned previously, the difference in Florigraze biomass may be due to weed competition at this location because this variety is reported to be more susceptible to weed competition because of its prostrate growth habit (Mislevy et al. 2007).

Data averaged across varieties illustrated that RPP injury followed a linear response to increased triclopyr rates at 15, 30, and 60 DAT. Estimated I_{20} values were 0.74, 0.79, and 0.95 kg ae ha^{-1}, respectively (Figure 10). In general, more injury was observed at 15 and 30 DAT than at 60 DAT. RPP and weed biomass followed a quadratic response to increasing triclopyr rates (Figure 11). RPP biomass was similar to that of the untreated control except when triclopyr was used at 1.12 kg ae ha^{-1}; however, the weed biomass was reduced at rates greater than 0.56 kg ae ha^{-1}. Based on regression estimates, triclopyr at 0.99 kg ae ha^{-1} was required for 20% RPP biomass reduction. This result contrasts with that of previous research that evaluated the effect of triclopyr on RPP, in which 0.56 kg ae ha^{-1} resulted in 30% to 50% biomass reduction at 60 DAT (Valencia et al. 1999). Furthermore, those authors reported that RPP regrowth occurred 2 mo after triclopyr application. The ratio analysis estimated that triclopyr rate above

https://doi.org/10.1017/wet.2020.126 Published online by Cambridge University Press

Table 2. Rhizoma perennial peanut variety injury, biomass, and broadleaf weed biomass averaged over triclopyr rate at the Ona, FL, location.[a,b]

	Injury			Biomass	
Variety	15 DAT	30 DAT	60 DAT	Peanut	Weed
	%			g m^{-2}	
Ecoturf	8 b	8 c	11 bc	207 ab	93 b
Florigraze	11 b	12 b	15 a	95 c	155 a
Ona 33	11 b	9 bc	8 c	234 a	21 c
UF-Tito	17 a	16 a	13 ab	199 b	48 c

[a]Data are combined across two runs in 2016. Triclopyr was applied at 0.07, 0.14, 0.28, 0.56, and 1.12 kg ae ha^{-1}.
[b]Means within a column followed by the same letter are not different based on Fisher's protected LSD at P ≤ 0.05.

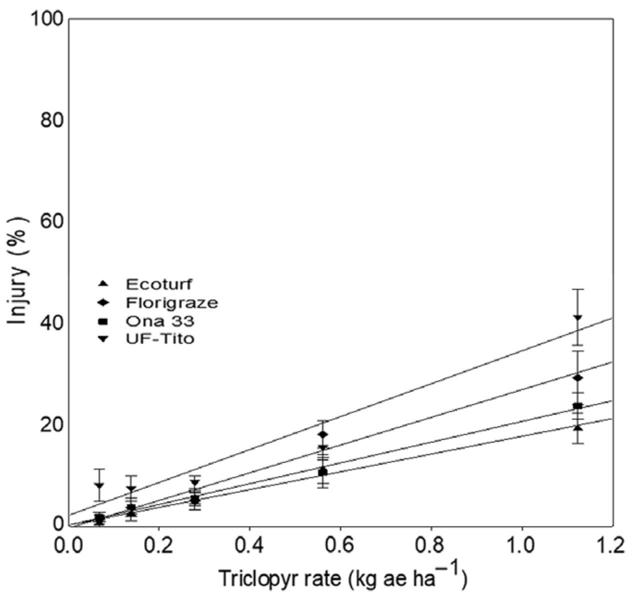

Figure 9. Rhizoma perennial peanut variety injury as a function of triclopyr rate at 30 DAT at the Ona, FL, location. Data are combined across two runs in 2016. Predicted line is plotted with mean and standard error. The predicted model for Ecoturf is y = 17.6x + 0.23 (R^2 = 0.99); Florigraze, y = 27.4x − 0.37 R^2 = 0.97); Ona 33, y = 20.5x + 0.21 (R^2 = 0.99); and UF-Tito, y = 32.5x + 2.11 (R^2 = 0.94), where y = injury (%) and x = triclopyr rate (kg ae ha^{-1}).

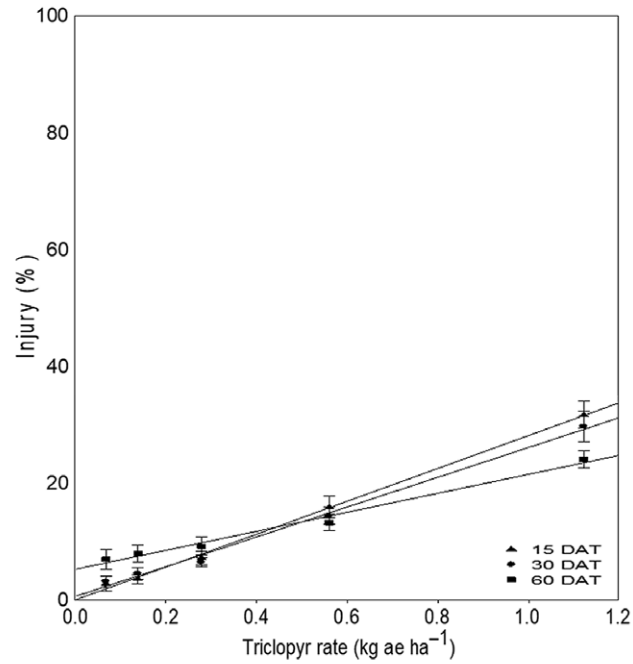

Figure 10. Rhizoma perennial peanut injury as a function of triclopyr rate for data pulled across four varieties at the Ona, FL, location. Data are combined across two runs in 2016. Predicted line is plotted with mean and standard error. The predicted model for 15 DAT is y = 27.3x − 0.07 (R^2 = 0.99); 30 DAT, y = 24.7x + 0.51 (R^2 = 0.99); and 60 DAT, y = 15.7x + 5.02 (R^2 = 0.99), where y = injury (%) and x = triclopyr rate (kg ae ha^{-1}).

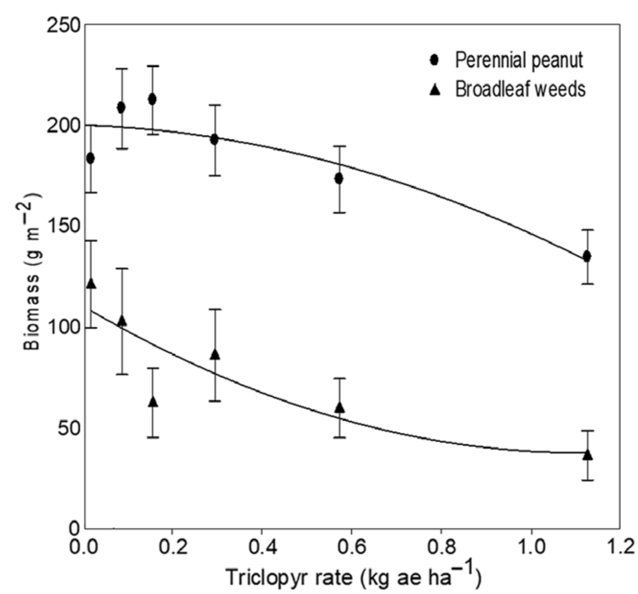

Figure 11. Rhizoma perennial peanut and broadleaf weed biomass as a function of triclopyr rate at 60 DAT for data pulled across four varieties at the Ona, FL, location. Data are combined across two runs in 2016. Predicted line is plotted with mean and standard error. The predicted model for rhizoma perennial peanut is y = −45.7x^2 − 8.8x + 200.2 (R^2 = 0.84); and broadleaf weeds, y = 58.0x^2 − 127.9 + 108 (R^2 = 0.77), where y = biomass (g m^{-2}) and x = triclopyr rate (kg ae ha^{-1}).

0.07 kg ae ha^{-1} would result in optimum RPP biomass production and weed biomass reduction (Figure 12). Valencia et al. (1999) reported that triclopyr was very effective at reducing broadleaf weeds in RPP swards.

The results from this research illustrate differences in RPP response to glyphosate or triclopyr application between two study locations. The predicted I_{20} rate for glyphosate was 0.78 kg ae ha^{-1} at the Zolfo Springs location, whereas 1.6 kg ae ha^{-1} was estimated for the Ona location. This result corresponded with RPP biomass and illustrates that glyphosate needed for a 20% biomass reduction was 0.53 and 2.17 kg ae ha^{-1} at the Zolfo springs and Ona locations, respectively. The results further suggested that the I_{20} rate for glyphosate was higher than the rate for 20% biomass reduction at Zolfo Springs; however, this result was contrary for the Ona site. The reason for the differences between the two sites could be attributed to the difference in the age of RPP stand at Zolfo Springs versus that at Ona. Furthermore, the site at Zolfo Springs was disturbed 18 mo prior to study initiation, and this could have resulted on the differential response of glyphosate on RPP compared to that at the Ona location. The results also illustrate that despite injury, glyphosate applied at less than 1.12 kg ae ha^{-1} is

https://doi.org/10.1017/wet.2020.126 Published online by Cambridge University Press

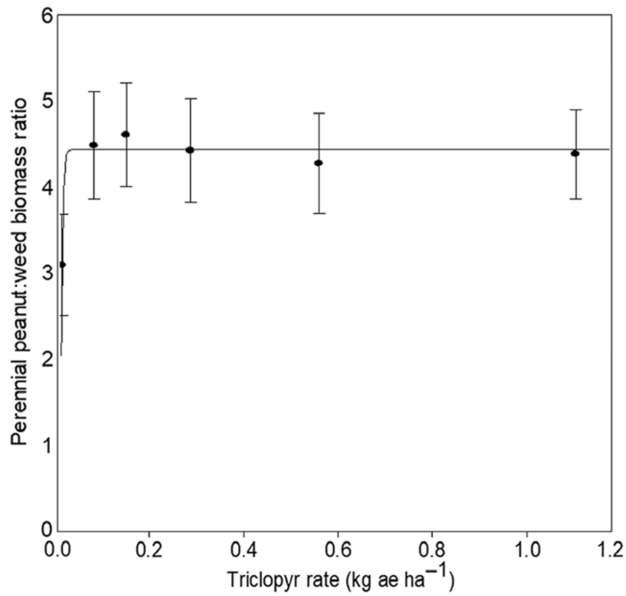

Figure 12. Rhizoma perennial peanut and broadleaf weed biomass ratio as a function of triclopyr rate at 60 DAT at the Ona, FL, location. Data are combined across two runs in 2016. Predicted line is plotted with mean and standard error. The predicted model is $y = -1.5*\exp\{-\exp[-(x+4.0)/-5.5]\}$ ($R^2 = 0.96$), where y = rhizoma perennial peanut and broadleaf weed biomass ratio and x = triclopyr rate (kg ae ha^{-1}).

unlikely to reduce RPP biomass. This result agrees with the findings from previous research reporting that RPP recovery from injury and dry matter was unaffected with glyphosate applied at 1.12 kg ae ha^{-1} (Valencia et al. 1999).

Similar to experiments when glyphosate was used, there were differences in RPP response to triclopyr between the two locations. The estimated triclopyr I_{20} value (0.39 kg ae ha^{-1}) was similar to the predicted rate for 20% biomass reduction (0.45 kg ae ha^{-1}) at the Zolfo Springs location. However, the I_{20} value (0.95 kg ae ha^{-1}) estimate and triclopyr rate (0.99 kg ae ha^{-1}) predicted to result 20% biomass reduction at the Ona location were higher than those at Zolfo Springs. Valencia et al. (1999) also reported that there was no difference on RPP dry matter without or with triclopyr at $<$1.12 kg ae ha^{-1} at 2 mo after application.

Overall, the results from this research illustrate that that RPP is relatively tolerant to glyphosate and triclopyr, and that sward age could have a potential influence on RPP tolerance to these herbicides. Furthermore, some level of injury should be expected from these herbicides and increased injury should be expected as higher application rates are used for optimum weed control in RPP swards. Future research should evaluate the effects of glyphosate or triclopyr applied sequentially or mixed with other labeled herbicides, and on various ages of RPP sward.

Acknowledgments. We thank Mr. Glen Emerson for use of his farm for a portion of this research. This project is a contribution of the Florida Agriculture Experiment Station and is based upon work that is supported by the U.S. Department of Agriculture–National Institute of Food and Agriculture, Hatch project under accession number 0231798, project number FL-ONA-005203. No conflict of interest has been declared.

References

Ball DM, Hoveland CS (2015) Southern forages, modern concepts for forage crop management, 5th ed. Corners, GA: International Plant Nutrition Institute

Cook B, Pengelly B, Brown S, Donnelly J, Eagles D, Franco A, Hanson J, Mullen B, Partridge I, Peters M, Schultze-Kraft R (2005). Tropical forages: An interactive selection tool. http://www.tropicalforages.info/key/Forages/Media/Html/About_us.htm. Accessed: July 20, 2020

Cruz-Hipolito H, Rojano-Delgado A, Dominguez-Valenzuela JA, Heredia A, Castro MD, Prado R (2011) Glyphosate tolerance by *Clitoria ternatea* and *Neonotonia wightii* plants involves differential adsorption and translocation of the herbicide. Plant Soil 347:221–230

Dwyer GT, O'Hare PJ, Cook BG (1989) Pinto's peanut: A ground cover for orchards. Queensland Agr J 6:153–154

Ferrell JA, Sellers BA, Mudge CR (2006) Evaluation of postemergent herbicides on rhizoma peanut injury and yield. Forage and Grazinglands 4:1–6

Foster J, Myer R, Adesogan AT, Carter J, Sollenberger L, Blount A (2017) Annual warm-season legumes for Florida and the United States Gulf Coast: Forage Yield, Nutritional Composition, and Feeding Value. EDIS Publication AN259. Gainesville: University of Florida Institute of Food and Agricultural Sciences. http://edis.ifas.ufl.edu/pdffiles/AN/AN25900.pdf. Accessed: July 15, 2020

Graham PH, Vance CP (2003) Legumes: importance and constraints to greater use. Plant Physiol 131:872–877

Mislevy P, Williams MJ, Blount AS, Quesenberry KH (2007) Influence of harvest management on rhizoma perennial peanut production, nutritive value and persistence on flatwood soils. Forage and Grazinglands 5:1–10

Quesenberry KH, Blount AR, Mislevy P, French EC, Williams MJ, Prine GM (2010) Registration of 'UF Tito' and 'UF Peace' rhizoma peanut cultivars with high dry matter yields, persistence, and disease tolerance. J Plant Regist 4:17–21

Sellers B, Ferrell J (2018) Weed control in perennial peanut. EDIS Publication SS-AGR-261. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/pdffiles/WG/WG21600.pdf. Accessed: July 19, 2020

Sellers BA, Devkota P (2020) Weed management in pastures and rangeland-2020. EDIS Publication SS-AGR-08. Gainesville: University of Florida Institute of Food and Agricultural Sciences. http://edis.ifas.ufl.edu/pdffiles/WG/WG00600.pdf. Accessed: July 18, 2020

Valencia E, Williams MJ, Sollenberger LE (1999) Yield and botanical composition of rhizoma peanut-grass swards treated with herbicides. Agron J 91:956–961

Vendramini J (2010) Forage evaluation and quality in Florida. Pages 92–105 *in* 21st Symposium on Florida Ruminant Nutrition. https://pdfs.semanticscholar.org/ccc6/d61412cbc215a8bbcdaf140961e93016ec30.pdf. Accessed: July 21, 2020

Villarreal M, Cochran RC, Villalobos L, Roja-Bourrillon A, Rodriguez R, Wickersham TA (2005) Dry-matter yields and crude protein and rumen-degradable protein concentrations of three *Arachis pintoi* ecotypes at different stages of regrowth in the humid tropics. Grass Forage Sci 60.3:237–243

Williams MJ, Chase Jr CC, Hammond AC (2004) Pasture management and forage utilization. Agron J 96:671–676

Williams MJ, Newman YC, Blount A (2017) Rhizoma perennial peanut. EDIS Publication SS-AGR-349. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/pdffiles/AG/AG35800.pdf. Accessed: July 12, 2020