



Effectiveness of Flumioxazin Alone and in Combination with Glufosinate-ammonium for Control of Parthenium (*Parthenium hysterophorus*) under Grove Conditions in Homestead, Florida

MARCEL BARBIER, JONATHAN CRANE, JOSE CASTILLO, AND YUNCONG LI*

University of Florida, IFAS, Tropical Research and Education Center, 18905 SW 280th Street, Homestead, FL 33031

ADDITIONAL INDEX WORDS. *Parthenium hysterophorus*, carrot weed, star weed, weed control

Parthenium hysterophorus L. is a member of the Asteraceae and is indigenous to Mexico, and Central and South America. It is a widely distributed invasive weed in India, Australia, Taiwan, Ethiopia, and in 23 states in the U.S. In Florida, parthenium is found in 24 of the state's 67 counties. Parthenium invades urban and disturbed areas as well as the vegetable fields and fruit groves throughout southern Miami-Dade County. Roundup PowerMax®, Rely® and Chateau® alone and Rely® plus Chateau® applied in several combinations were investigated in a field trial for their efficacy in controlling parthenium under south Florida grove conditions. Treatments were laid out in a completely randomized design with three replications of each treatment. Parthenium plant population was assessed by counting green live plants within a 361-inch² grid 1 day prior and 10 times at 15-day intervals after post herbicide application. Data were analyzed as repeated measures analysis using Student's *t*-test ($\alpha = 0.1$). Overall, parthenium control was significantly greater for Chateau® plus Rely® treatments compared to Chateau®, Rely® and Roundup PowerMax® alone. In general, Chateau® plus Rely® provided the best parthenium control; however, there was little difference among Chateau® rates. In general, Rely®, Chateau®, and Roundup PowerMax® alone treatments were similar to water control. The best parthenium control required the combination of Chateau® and Rely® at the rates investigated.

Parthenium (*Parthenium hysterophorus* L.), a member of the Asteraceae family, is also commonly called congress weed, carrot weed, ragweed parthenium, Santa Maria feverfew, whitetop weed, star weed, chatak chandani, ramphool, hierba amarga, falsa altamisa, camomille balais, and camomille z'oiseaux. Indigenous to the subtropics of Mexico and Central and South America (MacFadyen, 2004; Oudhia, 2001), parthenium is considered a very invasive and problematic weed species in Asia (India, Bangladesh, Japan, Nepal, Pakistan, Sri Lanka, and Taiwan); Africa (Ethiopia, Eritrea, Kenya, Madagascar, Mauritius, Mayotte, Mozambique, Reunion, Seychelles, Somalia, South Africa, Swaziland, Uganda, and Zimbabwe); North America [United States (Alabama, Arkansas, Connecticut, Delaware, District of Columbia, Hawaii, Illinois, Kansas, Louisiana, Maryland, Massachusetts, Michigan, Missouri, Mississippi, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, South Carolina, Texas, and Virginia), Bermuda, and Mexico; Central America and the Caribbean (Cuba, Dominican Republic, Guadeloupe, Guatemala, Honduras, Jamaica, Martinique, Netherlands Antilles, Puerto Rico, St. Barthelemy, and Trinidad and Tobago)]; South America (Argentina, Bolivia, Brazil, Ecuador, Peru, Paraguay, and Venezuela) and Oceania [Australia (Queensland, New South Wales, Northern Territory)], French Polynesia, New Caledonia, Papua New Guinea, and Vanuatu] (EPPO, 2011; MacFadyen, 2004; Oudhia, 2001). In the United States, parthenium is found in 23 states (USDA–NRCS, 2011). In Florida, parthenium is found in 24 of the state's 67 counties (Wunderlin and Hansen, 2008). Invasion pathways of parthenium in agroecosystems include contaminated

seed, animal transport, road vehicles and machinery, and wind and water currents (MacFayden, 2010).

Parthenium invades agricultural areas, disturbed areas, range and grasslands, and urban areas (MacDadyen, 2004). Infestations of parthenium can also degrade natural ecosystems, and compete with native species. Parthenium contains sesquiterpene and phenolic compounds that are toxic to cattle, and when consumed by cattle, the meat and milk produced can be tainted (Oudhia, 2001). Furthermore, continuous contact with the plant produces dermatitis, and its pollen can induce hay fever or asthma in humans and livestock, especially horses. Parthenium aggressively colonizes disturbed sites and causes major negative impacts on pastures and crops. In India and Ethiopia, parthenium has been reported to reduce agronomic crop yields 40% to 97% (EPPO, 2011). In Queensland (Australia), parthenium invaded 170,000 km² of high-quality grazing areas and losses to the cattle industry have been estimated at about \$21 million dollars per year (EPPO, 2011; MacFadyen, 2004; Oudhia, 2001).

Parthenium (Fig. 1) is an erect annual herb with vigorous growth and numerous small flowers (3/16th-inch diameter) (MacFayden, 2010). Leaves are finely lobed, 1–4 inches wide, light green, and held on branching stems. Plants grow up to 1 to 3 ft high and have a deep taproot. Young plants form a basal rosette of strongly dissected leaves that are up to 12 inches long (Fig. 1). Once stem elongation is initiated, smaller leaves are produced and the plant becomes multi-branched in its extremities. Flower heads are small (1/16th inch across) and numerous in open panicles. Achenes are very small (~1/10th inch long), black, obovate shaped, and lightweight (EPPO, 2011; MacFayden, 2004). Parthenium is capable of profuse flowering. Normally, only five seeds are borne

*Corresponding author; phone: (305) 246-7001 ext. 282; email: yunli@ufl.edu



Fig. 1. (A) Parthenium flower top view 100x; (B) parthenium flower bottom view 100x; (C) parthenium leaf 25x view; (D) parthenium young plant; (E) parthenium adult plant.

per head in spite of the large number of disk florets per single flower head; however, up to 11,300 flower heads per plant have been recorded (MacFayden, 2004). A single parthenium plant may produce up to about 56,500 seeds. However, because parthenium has an indeterminate flowering habit and an extended flowering period, a single plant during its entire lifetime may bear 750,000 seeds (MacFadyen, 2004). Parthenium has ability to flower and produce seeds as early as one month after sprouting and may have a flowering period of 14 months or more (Fatimah and Ahmad, 2009). Temperature for seed germination ranges from 46 to 86 °F with 72 to 77 °F as the optimum. Buried seeds (about 2.5 inches deep) are persistent and 70% or more may remain viable in the soil for up to 2 years; however, seeds on the surface remain viable for up to 6 months (Navie et al., 1998).

Lack of parthenium response to glyphosate has been observed in south Florida (Crane et al., 2006). Consequently, several herbicides have been tested for control of parthenium alone or in tank-mix combinations including Roundup UltraMax® (glyphosate; Monsanto Co., St. Louis, MO), Aim EC® (carfentrazone-ethyl; FMC Corp., Philadelphia, PA) plus crop oil, Finale® (glufosinate-ammonium; Bayer CropScience LP, Research Triangle Park, NC) plus the adjuvant Liberate™ (lecithin, methyl esters of fatty acids and alcohol ethoxylate; Loveland Products, Inc., Greeley, CO), and Finale® plus Roundup UltraMax® (Crane et al., 2006). Nearly all of the parthenium control was attributed to Finale® (glufosinate-ammonium). However, due to environmental concerns Finale® was not registered for use in commercial groves in south Florida.

The objective of this study was to compare post application of Chateau® alone at different rates in combination with Rely® and Roundup PowerMax® for the control of parthenium under grove conditions in south Florida.

Materials and Methods

A field trial to evaluate the efficacy of three post herbicides for parthenium control was conducted at the Tropical Research and Education Center in Homestead, FL in 2011. Soil type was a

Krome very gravelly sandy loam (Noble, 1996). The field was a 5-year-old 'Simmonds' avocado grove (*Persea americana* Miller). The experiment was arranged in a completely randomized design with three replications of treatments. Plots were 8 ft wide × 15 ft long. Treatments consisted of Roundup PowerMax® (glyphosate; Monsanto Co.) plus ammonium sulfate (17 lb/100 gal) plus Freeway® (dimethylpolysiloxane; Loveland Products Inc.); Rely® (glufosinate-ammonium; Bayer Environmental Science) alone and Chateau® (flumioxazin; Valent U.S.A. Corp., Walnut Creek, CA) alone and at three different rates (4, 6, and 12 oz per acre) tank mixed with Rely® (Table 1). An untreated control (water only) was included. Application rates were based on 36 gal of spray mix per acre. Weed species present in addition to parthenium included three-lobed false mallow [Malvaceae; *Malvastrum coromandelianum* (L.) Garcke], black medick (Fabaceae; *Medicago lupulina* L.), and Virginia pepperweed (Brassicaceae; *Lepidium virginicum* L.). In general, parthenium weeds were greater than 6 inches tall at the time of herbicide application (Fig. 1). Mention of trade names or commercial products in this publication is solely for

Table 1. Herbicide treatments for control of parthenium.

Treatment	Rate (fluid oz/acre) ^z
Chateau®	4
Rely®	96
Chateau®	6
Rely®	96
Chateau®	12
Rely®	96
Rely®	96
Roundup PowerMax® ^y	128
Freeway®	12
Chateau®	12
Water (untreated control)	

^zAll treatments applied at 36 gal per acre.

^yTreatment included ammonium sulfate at 17 lb/100 gal (2% w/v).



Fig. 2. Herbicide boom with Quick Turbo FloodJet® nozzles spaced 20 inches apart and one flat-fan nozzle at the end of the boom.

the purpose of providing specific information and does not imply recommendation or endorsement by the University of Florida. Plots were sprayed using a herbicide sprayer outfitted with two Quick Turbo FloodJet® nozzles spaced 20 inches apart and one flat-fan nozzle at the end of the boom (Fig. 2). The herbicide tank was loaded with 10 gal of herbicide solution for each treatment. The sprayer was attached to a John Deere 5303 tractor (Fig. 3). The spraying pressure was set at 30 psi.

Parthenium plant density was determined by using a 19 inch × 19 inch square (361 inch²) quadrant (Fig. 4), which was used to randomly select a section of each treated plot. The number of living parthenium plants was counted prior (23 Sept. 2011) to treatment application. Herbicide treatments were applied on 24 Sept. 2011. The number of live parthenium plants was assessed by counting in the same manner every 15 d for up to 150 d after treatment application. Assessments were done on 5, 18, and 31 Oct., 18 Nov., and 12 and 23 Dec. 2011; and on 7 and 22 Jan. and 6 and 21 Feb. 2012. Data were analyzed using SAS (proc mixed) and repeated measures analysis. Treatments were compared using a *t*-test adjusted for multiple comparisons. The treatment × assessment date interaction was measured by using the trapezoidal method, used to discretize the time variable (days) and calculate



Fig. 3. Tractor with herbicide application boom.



Fig. 4. Parthenium count area per plot (19 × 19 inch square).

the average parthenium population between each pair of adjacent time points (Yeh, 2002).

Results and Discussion

There was a significant interaction between herbicide treatments and assessment dates (Table 2). Overall, all Chateau® plus Rely® treatments resulted in fewer parthenium plants over a 150-d period compared to Roundup PowerMax® treatments and the water control. Prior to herbicide treatments application, there were significantly more parthenium plants in the 4 fluid oz Chateau® plus Rely® plots compared with the other treatment plots (Table 3). Parthenium density in other plots was not statistically different.

Fifteen days after application, Chateau® and all Chateau® plus Rely® treatments had significantly fewer parthenium plants compared to water control (Table 3). Chateau® plus Rely® at the 4 oz and 8 oz rates had significantly fewer parthenium plants than all other treatments. At 30 and 45 d after treatment, Chateau® plus

Table 2. Herbicide effects on the average number of live parthenium plants over a 150-d period.

Treatment	Rate ^z (fluid oz/acre)	Mean interaction of treatments × assessment dates ^y
Chateau®	4	414.8 bc
Rely®	96	
Chateau®	6	381.8 bc
Rely®	96	
Chateau®	12	301.3 c
Rely®	96	
Rely®	96	803.5 ab
Roundup PowerMax® ^x	128	1001.5 a
Freeway®	12	
Chateau®	12	668.0 abc
Water (untreated control)		1037.2 a

^zAll treatments applied at 36 gal per acre (or whatever the spray volume was).

^yMeans with the same letter are not significantly different at *P*=0.05 level.

^xTreatment included ammonium sulfate at 17 lb/100 gal (2% w/v).

Table 3. Herbicide effects on the number of live parthenium plants prior and 15, 30, 45, and 60 d after treatment.

Days after treatment	Treatment	Mean no. of plants ^z
Prior	Water	22.5 b
	4 oz Chateau® plus 96 oz Rely®	40.5 a
	6 oz Chateau® plus 96 oz Rely®	29.3 ab
	8 oz Chateau® plus 96 oz Rely®	22.8 b
	Rely®	23.2 b
	Roundup PowerMax® ^y	20.3 b
	12 oz Chateau®	27.3 ab
15	Water	21.5 a
	4 oz Chateau® plus 96 oz Rely®	1.3 d
	6 oz Chateau® plus 96 oz Rely®	4.2 bcd
	8 oz Chateau® plus 96 oz Rely®	2.2 cd
	Rely®	13.8 abc
	Roundup PowerMax® ^y	14.8 ab
	12 oz Chateau®	8.0 bcd
30	Water	13.0 a
	4 oz Chateau® plus 96 oz Rely®	0.5 b
	6 oz Chateau® plus 96 oz Rely®	1.3 b
	8 oz Chateau® plus 96 oz Rely®	0.0 b
	Rely®	7.8 ab
	Roundup PowerMax® ^y	13.2 a
	12 oz Chateau®	5.7 ab
45	Water	8.5 a
	4 oz Chateau® plus 96 oz Rely®	0.5 b
	6 oz Chateau® plus 96 oz Rely®	0.8 b
	8 oz Chateau® plus 96 oz Rely®	0.0 b
	Rely®	5.8 ab
	Roundup PowerMax® ^y	9.0 a
	12 oz Chateau®	5.7 ab
60	Water	3.7 ab
	4 oz Chateau® plus 96 oz Rely®	1.0 b
	6 oz Chateau® plus 96 oz Rely®	1.0 b
	8 oz Chateau® plus 96 oz Rely®	1.0 b
	Rely®	3.5 ab
	Roundup PowerMax® ^y	4.8 a
	12 oz Chateau®	2.7 ab
75	Water	4.0 ab
	4 oz Chateau® plus 96 oz Rely®	1.2 b
	6 oz Chateau® plus 96 oz Rely®	1.0 b
	8 oz Chateau® plus 96 oz Rely®	2.0 ab

^zMeans with the same letter are not significantly different at $P=0.05$ level.
^yTreatment included ammonium sulfate at 17 lb/100 gal (2% w/v) plus 20 oz Freeway®.

Rely® treatments had significantly fewer parthenium plants than Roundup PowerMax® and water control; however, they were not statistically different than Chateau® applied alone. Chateau® plus Rely® treatments were not statistically different from Chateau® or Rely® applied alone. At 60 and 75 d after treatment, Roundup PowerMax® had significantly more parthenium than all Chateau® plus Rely® treatments. All other treatments had similar control.

In general, from 90 to 135 d after treatment all Chateau® plus Rely® treated plots had significantly fewer parthenium plants compared to Roundup PowerMax treated plots (Table 4). However, there was no significant difference among all other

Table 4. Herbicide effects on the number of live parthenium plants 90, 105, 120, 135, and 150 d after application.

Days after treatment	Treatment	Mean no. of plants ^z
90	Water	2.7 ab
	4 oz Chateau® plus 96 oz Rely®	0.7 b
	6 oz Chateau® plus 96 oz Rely®	0.7 b
	8 oz Chateau® plus 96 oz Rely®	1.5 b
	Rely®	2.8 ab
	Roundup PowerMax® ^y	4.0 a
	12 oz Chateau®	2.3 ab
105	Water	1.8 ab
	4 oz Chateau® plus 96 oz Rely®	0.3 c
	6 oz Chateau® plus 96 oz Rely®	0.3 c
	8 oz Chateau® plus 96 oz Rely®	0.7 bc
	Rely®	1.7 abc
	Roundup PowerMax® ^y	2.5 a
	12 oz Chateau®	1.2 abc
120	Water	0.8 ab
	4 oz Chateau® plus 96 oz Rely®	0.3 b
	6 oz Chateau® plus 96 oz Rely®	0.3 b
	8 oz Chateau® plus 96 oz Rely®	0.3 b
	Rely®	0.7 ab
	Roundup PowerMax® ^y	1.2 a
	12 oz Chateau®	0.7 ab
135	Water	0.3 ab
	4 oz Chateau® plus 96 oz Rely®	0.0 b
	6 oz Chateau® plus 96 oz Rely®	0.0 b
	8 oz Chateau® plus 96 oz Rely®	0.2 ab
	Rely®	0.5 a
	Roundup PowerMax® ^y	0.3 ab
	12 oz Chateau®	0.3 ab
150	Water	0.2 a
	4 oz Chateau® plus 96 oz Rely®	0.0 a
	6 oz Chateau® plus 96 oz Rely®	0.0 a
	8 oz Chateau® plus 96 oz Rely®	0.0 a
	Rely®	0.2 a
	Roundup PowerMax® ^y	0.2 a
	12 oz Chateau®	0.0 a

^zMeans with the same letter are not significantly different at $P=0.05$ level.
^yTreatment included ammonium sulfate at 17 lb/100 gal (2% w/v) plus 20 oz Freeway®.

treatments except 105 d after treatment with 4 oz Chateau® and 6 oz Chateau® plus Rely® treatments having significantly fewer parthenium plants than water control and Roundup PowerMax® treatments. At 150 d after application there were no significant differences among all treatments.

In general, Chateau® plus Rely® provided the best parthenium control; however, there was little difference among Chateau® rates (Tables 3–4). Rely®, Chateau®, and Roundup PowerMax® alone were similar to water control. The best parthenium control required the combination of Chateau® at 4 to 8 fluid oz per acre plus Rely® at 96 fluid oz per acre rates. A combination of flumioxazin plus glufosinate-ammonium provided the best control of parthenium under south Florida conditions. Either compound alone was not efficacious.

Literature Cited

- Crane, J.H., R. Stubblefield, and C.W. Meister. 2006. Herbicide efficacy to control parthenium (*Parthenium hysterophorus*) under grove conditions in Homestead, Florida. *Proc. Fla. State Hort. Soc.* 119:9–12.
- European and Mediterranean Plant Protection Organization (EPPO) [web page from EPPO – Database]; http://www.eppo.org/QUARANTINE/Alert_List/invasive_plants/Parthenium_hysterophorus.htm [Accessed 8 Oct. 2011]
- MacFadyen, R. 2004. *Parthenium hysterophorus* (herb) [web page from Global Invasive Species Database]; <http://www.issg.org/database/species/ecology.asp?si=153&fr=1&sts=> [Accessed by Jonathan Crane on 23 Dec. 2004].
- MacFadyen, R. 2010. *Parthenium hysterophorus* (herb) [web page from Global Invasive Species Database]; <http://issg.org/database/species/ecology.asp?si=153&fr=1&sts=&lang=EN> [Accessed 8 Oct. 2011].
- Navie, S.C., F.D. Panetta, R.E. McFadyen, and S.W. Adkins. 1998. Behaviour of buried and surface-sown seeds of *Parthenium hysterophorus*. *Weed Res.* 38:335–341.
- Noble, C.V., R.W. Drew, and J.D. Slabaugh. 1996. Soil survey of Dade County area, Florida. USDA–NRCS, Washington, DC. p. 13–18, 58, 61.
- Oudhia, P. 2001. *Parthenium hysterophorus*: Traditional medicinal uses [web page from NewCROP™ the New Crop Resource Online Program]; <http://www.hort.purdue.edu/newcrop/cropfactsheets/parthenium.html> [Accessed 8 Oct. 2011]
- USDA–NRCS. 2011. Plants profile, *Parthenium hysterophorus* L. *Parthenium hysterophorus* L. [web page from the USDA-NRCS Plants Profile]; <http://plants.usda.gov/java/profile?symbol=PAHY> [Accessed 8 Oct. 2011]
- Wunderlin, R.P. and B.F. Hansen. 2008. *Parthenium hysterophorus* [web page from Institute for Systematic Botany, University of South Florida, Tampa. Atlas of Florida Vascular Plants]; <http://www.florida.plantatlas.usf.edu/Plant.aspx?id=1526> [Accessed 8 Oct. 2011]
- Yeh, Shi-Tao. 2002. Using trapezoidal rule for the area under a curve calculation. [web page from SAS Institute Inc.] <http://www2.sas.com/proceedings/sugi27/p229-27.pdf> [Accessed 21 Feb. 2012]