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Efficacy of PRE and POST Herbicides for Control of Citron Melon (*Citrullus lanatus* var. *citroides*)

Analiza Henedina M. Ramirez, Amit J. Jhala, and Megh Singh*

Citron melon is a monoecious and hairy annual vine commonly found in citrus orchards and cotton and peanut fields. There is limited information available on citron melon control with PRE- and POST-applied herbicides in Florida citrus. Experiments were conducted to evaluate the response of citron melon to 11 PRE and 18 POST herbicides under greenhouse conditions. Indaziflam applied PRE at 0.095 kg ai ha^{-1} resulted in 13% citron melon emergence at 14 d after treatment (DAT). The majority of PRE herbicides did not affect emergence at 14 DAT. Efficacy of PRE herbicides at 21 DAT resulted in > 90% control of citron melon with bromacil, premix formulation of bromacil + diuron, flumioxazin, indaziflam at 0.073 and 0.095, norflurazon, and simazine. Citron melon control was < 30% 21 DAT following PRE-applied diuron, oryzalin, and flazasulfuron. Control of citron melon varied by POST herbicides and growth stage. Regardless of citron melon growth stage, glyphosate, glufosinate, saflufenacil, paraquat, and flumioxazin provided > 90% at 7 and 14 DAT. Carfentrazone, flazasulfuron, imazapic, pyrithiobac-Na, rimsulfuron, trifloxysulfuron, and premix of 2,4-D + glyphosate controlled citron melon at least 90% when applied to two- to four-leaf plants. Control was reduced when application was delayed to the six- to eight-leaf stage. Bentazon and halosulfuron controlled citron melon 11 to 31% regardless of growth stage. Biomass of citron melon at 14 DAT was reduced > 50% in all herbicide treatments except with bentazon and halosulfuron applied at both stages, and dicamba, mesotrione, imazapic, and rimsulfuron applied to six- to eight-leaf citron melon. The results of this study indicate that citron melon can be adequately controlled with several PRE- or POST-applied herbicides; however, research is required to evaluate PRE followed by POST programs or their tank mixtures for season-long control of citron melon under field conditions.
Nomenclature: Citron melon, *Citrullus lanatus* (Thunb.) Mats and Nakai var. *citroides* (L. H. Bailey) Mansf. CILAC; citrus, *Citrus* spp.; cotton, *Gossypium hirsutum* L.; peanut, *Arachis hypogaea* L.
Keywords: Biomass, citrus, emergence, herbicide efficacy.

Citrullus lanatus var. *citroides* es una enredadera pilosa anual monoica que se encuentra en plantaciones de cítricos y campos de algodón y maní. Hay poca información disponible sobre el control de *C. lanatus* con herbicidas aplicados PRE y POST en plantaciones de cítricos en Florida. Se realizaron experimentos bajo condiciones de invernadero para evaluar la respuesta de esta maleza a 11 herbicidas PRE y 18 POST. Indaziflam aplicado PRE a 0.095 kg ai ha^{-1} resultó en 13% de emergencia de *C. lanatus* 14 días después del tratamiento (DAT). La mayoría de herbicidas PRE no afectaron la emergencia14 DAT. La eficacia de los herbicidas PRE 21 DAT resultó en >90% de control de *C. lanatus* con bromacil, una formulación pre-mezclada de bromacil + diuron, flumioxazin, indaziflam a 0.073 y 0.095, norflurazon, y simazine. El control de *C. lanatus* fue <30% 21 DAT después de aplicaciones PRE de diuron, oryzalin y flazasulfuron. El control de esta maleza varió dependiendo de los herbicidas POST y del estado de crecimiento. Independientemente del estado de crecimiento de *C. lanatus*, glyphosate, glufosinate, saflufenacil, paraquat y flumioxazin brindaron >90% a 7 y 14 DAT. Carfentrazone, flazasulfuron, imazapic, pyrithiobac-Na, rimsulfuron, trifloxysulfuron, y una pre-mezcla de 2,4-D + glyphosate controlaron *C. lanatus* al menos 90% cuando se aplicaron a plantas con dos a cuatro hojas. El control se redujo cuando la aplicación se atrasó hasta el estado de seis a ocho hojas. Bentazon y halosulfuron controlaron *C. lanatus* 11 a 31% sin importar el estado de crecimiento. La biomasa de *C. lanatus* a 14 DAT se redujo >50% en todos los tratamientos de herbicidas excepto con bentazon y halosulfuron aplicados en ambos estados, y dicamba, mezotrione, imazapic y rimsulfuron aplicados en el estado de seis a ocho hojas. Los resultados de este estudio indican que *C. lanatus* se puede controlar adecuadamente con varios herbicidas aplicados PRE y POST. Sin embargo, se necesita investigación para evaluar el control de *C. lanatus* a lo largo del ciclo de producción en condiciones de campo usando programas de aplicaciones PRE seguidas por aplicaciones POST o usando mezclas en tanque.

Citron melon is a monoecious and hairy annual vine. It is a native of Africa and its spread was attributed to its escape from cultivation of watermelon [*Citrullus lanatus* (Thunb.) Matsum. and Nakai] (Smith and Cooley 1973). It is widely distributed in the southern and eastern United States and is also found in southern California and Arizona (Bryson and DeFelice 2009). In Florida it is found in 23 of 67 counties (U.S. Department of Agriculture [USDA] 2012).

Young seedlings of citron melon are characterized by large, thick, ovate, and shiny green cotyledons with very distinct venation (Hall et al. 2010). Mature plants possess tendrils on the side of deeply divided leaves. Leaves are alternate rough and have three to four pairs of rounded lobes. Flowers are solitary, with broad yellow petals. The fruit is a hard berry with many seeds and is light green or variegated light and dark green in color. Seeds are ovoid and flattened, with various colors ranging from white to dark reddish brown, tan or

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blackish brown, to green (Bryson and DeFelice 2009; Hall et al. 2010).

Citron melon is a troublesome weed in many southern crops such as citrus, cotton, grain sorghum [*Sorghum bicolor* (L.) Moench], and peanut (Grichar et al. 2001, 2002; Smith and Cooley 1973; Webster 2001). In peanut, it is most troublesome during digging and inverting procedures (Young et al. 1982). Its viney growth may lengthen time required for field drying of peanut vines and pods, increasing the chance of exposing peanut pods to rainfall events, thereby causing harvest losses (Grichar et al. 2001). In cotton, yield was reduced by 20 to 35% due to citron melon interference (Smith and Cooley 1973). In citrus, vine weeds such as citron melon interfere with grove operations such as herbicide application and harvesting, and it also competes with younger citrus trees for nutrients and moisture (Futch 2006).

Traditionally, citron melon has been controlled through cultivation, crop rotation, deep plowing, and hand-hoeing in most annual cropping systems (Smith and Cooley 1973). In citrus, tillage as a means of weed control is seldom used since trees are commonly planted in raised beds. In addition, almost 90% of citrus growers rely on herbicides to manage weed problems due to their greater efficacy and cost efficiency. Control of citron melon with PRE herbicides has been evaluated in peanut. Grichar et al. (2002) reported that flumioxazin alone or tank-mixed with pendimethalin, and pendimethalin followed by lactofen provided 85% early-season control of citron melon in peanut. Furthermore, pendimethalin followed by lactofen resulted in 75% late-season control, while pendimethalin alone or in combination with imazethapyr, metolachlor, or oxyflourfen did not control citron melon.

Adequate control of citron melon with a limited number of POST herbicides has been reported in peanut and cotton (Grichar et al. 2001; Smith and Cooley 1973). In peanut, imazapic at 0.07 kg ai ha^{-1} applied early or late POST and 2,4-DB at 0.28 kg ae ha^{-1} applied late POST provided $>$ 80% control (Grichar et al. 2001). Diuron at 0.9 kg ai ha^{-1}, fluometuron at 0.9 kg ai ha^{-1}, prometryn at 0.9 kg ai ha^{-1}, and atrazine at 1.1 kg ai ha^{-1} provided 87 to 100% control of citron melon when applied to two- to four-leaf seedlings grown in sandy soil (Smith and Cooley 1973). Older seedlings (those with runners) were harder to control with a single herbicide application (Smith and Cooley 1973).

Several PRE- and POST-applied herbicides are registered for weed control in citrus (Futch and Singh 2011); however, none of them list citron melon on their labels. No information is available on the response of citron melon to PRE and POST herbicides registered or under investigation for weed control in Florida citrus. Several new herbicides such as indaziflam, carfentrazone, and saflufenacil have recently been registered for weed control in Florida citrus, while others like flazasulfuron and glufosinate are being evaluated and may be registered in the near future. The objective of this research was to determine the efficacy of several PRE and POST herbicides registered or under investigation for weed control in Florida citrus on citron melon. In addition, several herbicides being used for control of citron melon in cotton and peanut were included to confirm their efficacy to control this problem weed.

Materials and Methods

Greenhouse studies were conducted at the Citrus Research and Education Center, University of Florida in Lake Alfred, FL. Fruits of citron melon were collected from citrus groves near Lake Alfred and Winter Garden, FL, in 2010. Seeds were extracted, cleaned, air-dried, and stored at 5 C until the initiation of the studies. A preliminary study was conducted to determine the germination and viability of citron melon seeds. The results suggested that germination was 98%, indicating that citron melon seeds were viable and nondormant. The soil used in the PRE herbicide study was collected from a citrus grove near Davenport, FL. This site had been a citrus grove and was free from any agricultural operation or herbicide for at least 15 yr. The soil was a Candler sand (hyperthermic, uncoated Typic Quartzipsamment; $>$ 89% sand, $<$ 7% silt, $<$ 5% clay, and $<$ 0.5% organic matter).

PRE Herbicide Study. Fifteen seeds of citron melon were seeded at a 2- to 3-cm depth in Styrofoam cups (12-cm diameter and 5-cm height) filled with Candler sand. The bottoms of the Styrofoam cups were perforated for drainage. Treatments consisted of indaziflam at three rates (0.045, 0.073, and 0.095 kg ai ha^{-1}) and field use rates as recommended for citrus by the respective manufacturers of diuron, bromacil, commercial premix of bromacil + diuron, flumioxazin, norflurazon, pendimethalin, simazine, oryzalin, diclosulam, and flazasulfuron. Details of the PRE herbicide treatments are given in Table 1. The herbicides were applied on the soil surface using a chamber track bench sprayer fitted with Teejet 8002 nozzle (Teejet Technologies, Wheaton, IL) and calibrated to deliver 187 L ha^{-1} at 279 kPa. Treated pots were watered 4 h after treatment. The plants were kept in the greenhouse and watered daily until the project was terminated at 21 DAT. The greenhouse was maintained at day/night temperature of 25/16 C ($\pm$0.5 C), 70% ($\pm$5%) relative humidity, and a normal photoperiod.

Visible control was assessed at 7, 14, and 21 DAT using a 0 to 100% scale on which 0% means no control and 100% means no emergence or complete death of plants. All emerging seedlings were counted at 7 and 14 DAT. Data were compiled as cumulative emergence and expressed as percentage of seeds sown.

POST Herbicide Study. Five seeds of citron melon were sown at a depth of 2 to 3 cm in plastic pots, 12- cm diameter by 12-cm height, filled with commercial potting mix (Sun Gro Metro-mix, Sun Gro Horticulture Distribution Inc., Bellevue, WA). Plants were thinned to three plants per pot at 7 days after emergence (DAE) and were kept in a greenhouse. Plants were watered daily and foliar fertilizer solution (Tractite 20-20-20, Helena Chemical Company, Collierville, TN) was applied weekly starting at 3 DAE until plants were treated with herbicides. Plants were grown to the two- to four-leaf or six- to eight-leaf stage when plants were 10 to 14 cm and 28 to 33 cm tall, respectively. Treatment consisted of 18 POST herbicides applied to two- to four-leaf or six- to eight-leaf citron melon (Table 2). Herbicide rates used were based on the recommended field use rate for either citrus (if herbicide was registered for citrus), cotton, or peanut. Appropriate adjuvants such as nonionic (Induce, Helena

Table 1. Details of herbicide treatments used in the PRE herbicide study.

Treatment	Trade name	Formulation	Rate	Manufacturer
			kg ai ha^{-1}	
Indaziflam 1	Alion	200 g L^{-1}	0.044	Bayer CropScience, Research Triangle Park, NC
Indaziflam 2	Alion	200 g L^{-1}	0.073	Bayer CropScience, Research Triangle Park, NC
Indaziflam 3	Alion	200 g L^{-1}	0.095	Bayer CropScience, Research Triangle Park, NC
Bromacil	Hyvar X	800 g kg^{-1}	1.800	DuPont Corp., Wilmington, DE
Bromacil + diuron	Krovar 1	400 g kg^{-1} bromacil + 400 g kg^{-1} diuron	1.35 + 1.35	Du Pont Corp, Wilmington, DE
Diclosulam	Strongarm	840 g L^{-1}	0.026	Dow Agrosciences LLC, Indianapolis, IN
Diuron	Direx	409 g L^{-1}	2.240	Du Pont Corp, Wilmington, DE
Flazasulfuron	Katana	250 g/	0.037	ISK BioSciences Corp, Concord, OH
Flumioxazin	Chateau	510 g kg^{-1}	0.107	Valent U.S.A. Corp, Walnut, CA
Norflurazon	Solicam	800 g kg^{-1}	2.643	Syngenta Crop Protection, Inc Greensboro, NC
Oryzalin	Oryzalin	410 g kg^{-1}	4.400	Makhteshim Agan of North America Inc, Raleigh, NC
Pendimethalin	Prowl H_20	387 g L^{-1}	3.194	BASF Corp Research Triangle Park, NC
Simazine	Princep	480 g L^{-1}	2.693	Syngenta Crop Protection Inc, Greensboro, NC

Chemical Company, Collierville, TN), crop oil concentrate (Agri-dex, Helena Chemical Company), or methylated seed oil (Aero Dyne-Amic, Helena Chemical Company) and ammonium sulfate (DSM Chemicals North America Inc., Augusta, GA) were added to the herbicide solutions based on label recommendations. Treatments were applied using the same chamber track bench sprayer used in the PRE herbicide study. Visible control was assessed at 7 and 14 DAT using the same scale previously described. The aboveground biomass was harvested and dried in an oven at 70 C for 7 d, and weights were recorded. Plant dry weights were converted to a percentage of the nontreated control.

Experimental Design and Statistical Analysis. The treatments in the PRE herbicide study were arranged in a randomized complete block (RCB) while treatments in the POST herbicide study were arranged as a factorial in RCB. Treatments in both studies were replicated three times, and both studies were repeated. Data on percent control were arcsine square root transformed to correct for variance homogeneity prior to analysis; however, transformation did not improve variance homogeneity so analyses were performed on untransformed data. All data were subjected to analysis of variance using the MIXED procedure of SAS (SAS version 9.3, SAS Institute Inc., Cary, NC) with experimental repeats as random effects and herbicides and stage of growth as fixed effects. Treatment means were separated using LSMEANS at $P \leq 0.05$. For the POST herbicide study, data were analyzed as a factorial in RCB with herbicides and growth stages as fixed effects and experimental repeats as random effects.

Results and Discussion

PRE Herbicides Study. Citron melon emergence was affected by herbicides applied PRE at 7 DAT, but most

Table 2. Details of herbicide treatments used in the POST herbicide study.

Treatment	Trade name	Formulation	Rate	Manufacturer
			kg ae or ai ha^{-1}	
Bentazon[a]	Basagran	440 g L^{-1}	0.84	BASF Corp., Research Triangle Park, NC
Bromoxynil	Buctril	480 g L^{-1}	0.03	Bayer CropScience, Research Triangle Park, NC
Carfentrazone[b,d]	Aim	240 g L^{-1}	0.014	FMC Corp., Newark, NJ
Dicamba[b,d]	Clarity	480 g L^{-1}	0.28	BASF Corp., Research Triangle Park, NC
Flazasulfuron[b]	Katana	250 g kg^{-1}	0.04	PBI/Gordon Corp., Kansas City, MO
Flumioxazin[b,d]	Chateau	510 g kg^{-1}	0.82	Valent USA Corp., Walnut Creek, CA
Glufosinate[d]	Rely 280	245 g L^{-1}	0.98	Bayer CropScience, Research Triangle Park, NC
Glyphosate[b,d]	Roundup WeatherMax	660 g L^{-1}	1.25	Monsanto Co., St. Louis, MO
Halosulfuron[b]	Sempra	750 g kg^{-1}	0.04	Monsanto Co., St. Louis, MO
Imazapic[b,d]	Cadre	240 g L^{-1}	0.07	BASF Corp., Research Triangle Park, NC
Mesotrione[a,d]	Callisto	480 g L^{-1}	0.11	Syngenta Corp., Greensboro, NC
Paraquat[a]	Gramoxone Inteon	240 g L^{-1}	0.57	Syngenta Corp., Greensboro, NC
Pyrithiobac-Na[b]	Staple	850 g kg^{-1}	1.72	Du Pont, Wilmington, DE
Rimsulfuron[b,d]	Matrix	250 g L^{-1}	0.03	Du Pont, Wilmington, DE
Saflufenacil[c,d]	Treevix	700 g kg^{-1}	0.04	BASF Corp., Research Triangle Park, NC
Trifloxysulfuron	Envoke	700 g kg^{-1}	0.006	Syngenta Corp., Greensboro, NC
2,4-D	2,4-D amine	452 g L^{-1}	0.56	Helena Chemical Company, Collier, TN
2,4-D + glyphosate	Landmaster II	120 g L^{-1} + 144 g L^{-1}	0.39 + 0.28	Monsanto Co., St. Louis, MO

[a] Crop oil concentrate at 0.25% v/v was added to the herbicide solution

[b] Nonionic surfactant at 0.25% v/v was added to the herbicide solution

[c] Methylated seed oil at 1% v/v was added to the herbicide solution

[d] Ammonium sulfate at 18 g L^{-1} was added to the herbicide solution

Table 3. Effect of PRE herbicides on emergence (%) of citron melon at 7 and 14 d after treatment (DAT).

Treatment	Rate	Cumulative emergence[a,b]	
		7 DAT	14 DAT
	kg ai ha^{-1}	%	
Bromacil	1.800	77 abcd	85 ab
Bromacil + diuron	1.35	82 abc	98 a
Diclosulam	0.026	43 def	52 cd
Diuron	2.240	98 a	98 a
Flazasulfuron	0.037	42 ef	88 a
Flumioxazin	0.107	42 def	52 cd
Indaziflam 1	0.044	47 cdef	67 bc
Indaziflam 2	0.073	30 ef	33 de
Indaziflam 3	0.095	13 f	13 f
Norflurazon	2.643	90 ab	98 a
Oryzalin	4.400	75 abcd	97 a
Pendimethalin	3.194	90 ab	97 a
Simazine	2.693	62 bcde	97 a
Nontreated	—	98 a	98 a

[a] Means within a column followed by the same letter are not significantly different at $P \geq 0.05$.

[b] Data were compiled as cumulative emergence and expressed as percentage of seeds sown.

Table 4. Control of citron melon at 7, 14 and 21 days after treatment (DAT) with various PRE-emergence herbicides under greenhouse conditions.

Treatments	Rate	7 DAT[a]	14 DAT	21 DAT
	kg ai ha^{-1}	%		
Bromacil	1.8	22 ef	47 d	98 a
Bromacil + diuron	1.35 + 1.35	16 fg	30 de	94 a
Diclosulam	0.026	70 bc	68 c	57 c
Diuron	2.24	22 ef	30 de	34 d
Flazasulfuron	0.037	25 ef	30 de	30 d
Flumioxazin	0.107	62 bc	83 abc	91 a
Indaziflam 1	0.044	47 cd	73 bc	76 b
Indaziflam 2	0.073	57 bc	87 ab	90 ab
Indaziflam 3	0.095	83 a	96 a	98 a
Norflurazon	2.643	55 bc	82 abc	91 a
Oryzalin	4.4	0 g	15 e	13 e
Pendimethalin	3.194	50 cd	35 d	61 c
Simazine	2.693	33 de	32 de	96 a

[a] Means within a column followed by the same letter are not significantly different at $P \geq 0.05$.

PRE treatments did not influence emergence at 14 DAT (Table 3). There was lower emergence (13 to 47%) in pots treated with diclosulam, flumioxazin, flazasulfuron, and indaziflam at all rates compared with the other PRE herbicides and the untreated control at 7 DAT (Table 3). At 14 DAT, diclosulam, flumioxazin, and indaziflam at all rates had lower emergence than the untreated and the other PRE herbicide treatments. The lowest emergence (13%) was observed following indaziflam at the 0.095 kg ha^{-1} compared to all other treatments at 14 DAT (Table 3).

Control of citron melon at 7 DAT was < 65% except for indaziflam at 0.095 kg ha^{-1} and diclosulam, which provided 83 and 70% control, respectively (Table 4). However, control following diclosulam was similar to other PRE herbicides such as flumioxazin, indaziflam at 0.044 and 0.073 kg ha^{-1}, norflurazon, and pendimethalin. Control of citron melon at 14 DAT increased to > 80% with indaziflam at 0.073 and 0.095 kg ha^{-1}, flumioxazin, and norflurazon, while 68 to 73% control was observed following application of indaziflam at 0.044 kg ha^{-1} and diclosulam. Control following oryzalin, bromacil, premix of bromacil + diuron, diuron, flazasulfuron, pendimethalin, and simazine was < 50% at 14 DAT (Table 4).

Control of citron melon increased at 21 DAT, except with diclosulam, flazasulfuron, and oryzalin (Table 4). Indaziflam at 0.073 and 0.095 kg ha^{-1}, bromacil, bromacil + diuron, flumioxazin, norflurazon, and simazine provided > 90% control at 21 DAT. Citron melon control was < 40% with diuron, flazasulfuron, and oryzalin at 21 DAT. Field experiments conducted in California orchards and vineyards reported that indaziflam provided excellent residual control (> 80%) of several grasses and broadleaf weeds at 90 DAT (Jhala and Hanson 2011). A previous study reported that several morningglory species, including ivyleaf (*Ipomoea hederacea* Jacq.), pitted (*I. lacunosa* L.), tall [*I. purpurea* (L.) Roth.], cypressvine (*I. quamoclit* L.), and willowleaf (*I. wrightii* Gray) were also not controlled with preplant application of diuron at 0.6 and 2.1 kg ha^{-1} (Crowley et al. 1979). Similarly,bigroot morningglory [*I. pandurata* (L.) G.F.W. Mey] was not controlled by preplant application of oryzalin either alone or with subsequent applications of 2,4-D or linuron (Prochaska and Fretz 1976).

Earlier studies on wild watermelon, believed to be the predecessor of citron melon, showed that diuron at rates lower than those used in this study provided 63% control during the first year, but control was reduced in the second year of study (Smith and Cooley 1973). This study also reported that fluometuron provided more consistent control by reducing the stand, growth, and reproduction of wild watermelon. Propazine provided 90% control and inhibited the growth and reproduction of surviving wild watermelon plants (Smith and Cooley 1973). Diclosulam and flumioxazin were effective in controlling citron melon in peanut while fluometuron and pyrithiobac-Na were effective in controlling citron melon in cotton (Hall et al. 2010).

The results of this study suggest that citron melon can be adequately controlled by a number of PRE-applied herbicides that were evaluated and are currently used in citrus. Indaziflam, a new herbicide for citrus was effective in controlling citron melon by reducing emergence and injuring emerged seedlings. It provided comparable control with the traditionally used PRE herbicides in citrus such as bromacil, premix of bromacil + diuron, norflurazon, and simazine. Indaziflam is also effective on other vine weeds, such as pitted morningglory, and partially controls ivyleaf morningglory (Anonymous 2012). It also provided excellent residual control of many grass, broadleaf, and sedge weeds in Florida citrus even at 90 DAT (Singh et al. 2011b). Among the traditionally used PRE herbicides in citrus, bromacil, the commercial premix of bromacil + diuron, norflurazon, and simazine provided similar control of citron melon as indaziflam 21 DAT; however, diclosulam, diuron, flazasulfuron, oryzalin, and pendimethlain were not effective.

POST Herbicide Study. Control of citron melon varied by growth stage and POST herbicide treatments (Table 5). Several POST herbicides controlled two- to four-leaf better

Table 5. Control of citron melon at 7 and 14 d after treatment (DAT) with POST herbicides applied at two growth stages under greenhouse conditions.

		7 DAT		14 DAT	
Treatments	Rate	2- to 4-leaf	6- to 8-leaf	2- to 4-leaf	6- to 8-leaf
	kg ae or ai ha^{-1}	%			
Bentazon	0.84	11 j	9 l	13 k	16 k
Bromoxynil	0.03	69 d	38 h	65 efg	52 hi
Carfentrazone	0.014	89 bc	66 de	93 abc	72 e
Dicamba	0.28	50 fg	36 h	61 fgh	52 hi
Flazasulfuron	0.04	93 abc	36 h	100 a	73 de
Flumioxazin	0.82	100 a	92 abc	100 a	94 ab
Glufosinate	0.98	100 a	100 a	100 a	100 a
Glyphosate	1.25	99 a	100 a	100 a	100 a
Halosulfuron	0.04	24 i	11 kl	31 j	11 k
Imazapic	0.07	91 abc	50 fg	99 a	69 ef
Mesotrione	0.11	44 gh	18 ij	59 gh	42 i
Paraquat	0.57	100 a	100 a	100 a	100 a
Pyrithiobac	1.72	92 ab	58 ef	100 a	83 cd
Rimsulfuron	0.03	89 bc	46 gh	90 abc	60 fgh
Saflufenacil	0.04	100 a	100 a	100 a	100 a
Trifloxysulfuron	0.006	94 abc	72 efg	100 a	88 bc
2,4-D amine	0.56	50 fg	36 h	63 efg	58 gh
2,4-D + glyphosate	0.39 + 0.28	84 c	63 de	100 a	94 a

[a] Means within a column followed by the same letter(s) are not significantly different at P ≥ 0.05.

than the six- to eight-leaf citron melon 7 DAT; however, some herbicides, including flumioxazin, glyphosate, glufosinate, paraquat, and saflufenacil, provided similar control regardless of growth stage. Carfentrazone, imazapic, pyrithiobac, flazasulfuron, rimsulfuron, trifloxysulfuron, and the premix of 2,4-D + glyphosate provided 84 to 94% control of two- to four-leaf citron melon 7 DAT (Table 5). There was < 70% control of both two- to four-leaf and six- to eight-leaf citron melon with 2,4-D, bentazon, bromoxynil, dicamba, mesotrione, and halosulfuron at 7 DAT (Table 5).

Control of citron melon increased at 14 DAT (Table 5). Citron melon was controlled with flumioxazin, glyphosate, glufosinate, paraquat, saflufenacil, and 2,4 D + glyphosate applied to two- to four-leaf and six- to eight-leaf citron melon. Similar levels of control were observed for carfentrazone, flazasulfuron, imazapic, pyrithiobac, rimsulfuron, and trifloxysulfuron applied to smaller citron melon plants. Control was 52 to 73% for 2,4-D, bromoxynil, and dicamba regardless of citron melon stage. Similar control was obtained with mesotrione applied to two- to four-leaf citron melon plants and with imazapic, flazasulfuron, and rimsulfuron applied to six- to eight-leaf citron plants. Control was < 50% with bentazon and halosulfuron applied to two- to four-leaf and six- to eight-leaf citron melon and mesotrione applied to older citron melon plants.

Grichar et al. (2002) reported excellent season-long control of citron melon in peanut with imazapic at 0.04 kg ha^{-1} applied early-POST followed by late-POST (≥ 94%) and 2,4-DB applied late-POST (> 80%). Other herbicides such as aciflourfen at 0.45 kg ha^{-1} applied late-POST, imazetapyr at 0.07 kg ha^{-1} early-POST, lactofen at 0.28 kg ha^{-1} at all application timings provided > 80% control but control declined later in the season. Imazapic was also tested in this study at a higher rate (0.07 kg ha^{-1}) but only controlled young citron melon plants. This suggests that under field conditions a sequential application could be beneficial.

Data on biomass reduction was consistent with the weed control data (Table 6). Reduction in biomass was observed with the application of glyphosate, glufosinate, paraquat, saflufenacil, and the premix of 2,4-D + glyphosate regardless of citron melon growth stage. Similar reduction in biomass were also observed with carfentrazone, flazasulfuron, flumioxazin, imazapic, pyrithiobac-Na, rimsulfuron, and trifloxysulfuron applied to two- to four-leaf citron melon. These were the same treatments that provided > 90% control of citron melon 14 DAT. Biomass was reduced the least with bentazon and halosulfuron applied to two- to four-leaf and six- to eight-leaf plants, and bromoxynil, dicamba, imazapic, mesotrione,

Table 6. Effect of POST herbicides applied to two- to four- and six- to eight-leaf citron melon on biomass reduction (%) at 14 d after treatment in POST Herbicide Study.

		Biomass reduction[a]	
Treatments	Rate	2- to 4-leaf	6- to 8-leaf
	kg ae or ai ha^{-1}	%	
Bentazon	0.84	38 jkl	27 l
Bromoxynil	0.03	76 cde	52 ghij
Carfentrazone	0.014	91 abc	59 fgh
Dicamba	0.28	73 def	37 jkl
Flazasulfuron	0.04	100 a	54 ghi
Flumioxazin	0.82	98 a	81 bcd
Glufosinate	0.98	100 a	100 a
Glyphosate	1.25	100 a	100 a
Halosulfuron	0.04	46 hij	31 kl
Imazapic	0.07	95 ab	42 ghij
Mesotrione	0.11	76 cde	43 ijk
Paraquat	0.57	100 a	100 a
Pyrithiobac	1.72	97 a	55 ghij
Rimsulfuron	0.03	86 abc	49 ghij
Saflufenacil	0.04	100 a	100 a
Trifloxysulfuron	0.006	100 a	62 efg
2,4-D amine	0.56	73 def	52 ghij
2,4-D + glyphosate	0.39 + 0.28	100 a	92 ab

[a] Means followed by the same letter are not significantly different at P ≥ 0.05

pyrithiobac, rimsulfuron, and 2,4-D amine applied to six- to eight-leaf plants (Table 6).

The results of this study suggest that citron melon can be adequately controlled with a number of available POST herbicides in citrus. Furthermore, application of some herbicides such as carfentrazone, imazapic, pyrithiobac, flazasulfuron, and rimsulfuron is more useful for control of young citron melon plants. Saflufenacil and carfentrazone, two new POST herbicides registered in Florida citrus, provided different levels of control. Saflufenacil was more effective than carfentrazone in controlling and reducing biomass of larger citron melon. The traditionally used POST herbicides such as glyphosate and paraquat provided excellent control of citron melon at any growth stage in this study. In addition, glufosinate has provided similar control, but it is not yet registered for commercial use in Florida citrus.

This is the first report on the efficacy of several PRE and POST herbicides on citron melon. Warm weather and frequent rainfall in Florida makes weed management an ongoing process throughout the year in citrus groves (Futch and Singh 2007). The majority of citrus groves receive multiple application of herbicides (PRE herbicides in winter followed by POST herbicides in the fall) to control weeds. Therefore, research is required to evaluate the efficacy of PRE followed by POST herbicides on citron melon under field conditions and to determine the impact of various herbicide regimes on citron melon emergence periodicity and regrowth after herbicide treatments. Moreover, tank-mixing herbicides is a common practice by citrus growers in Florida (Singh et al. 2011a). A tank mix of indaziflam with glyphosate provided excellent weed control in orchards and vineyards (Jhala and Hanson 2011). Therefore, research is required to determine the efficacy of various PRE and POST herbicide combinations to control citron melon and other vine weeds in Florida citrus. Furthermore, the various PRE and POST herbicides that effectively control citron melon can be used in designing herbicide rotations to minimize or delay development of resistance in this weed species.

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