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Evaluation of Herbicides for Management of Weeds in Sweet Basil (*Ocimum basilicum*)

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Sweet basil (*Ocimum basilicum* L.) is one of the world's most popular herbs, with much of the U.S. fresh market basil being produced in Florida. Basil herbicide trials were initiated to select potential candidates for chemical weed control of pigweed, purslane, lambsquarters, and goosegrass in commercial production. On sandy soils, pre-emergence application of linuron at 0.1 lb/acre and napropamide at 3.93 lb/acre resulted in the highest basil yield (8,302 lb/acre and 5,229 lb/acre, respectively) and satisfactory weed control (75.3% and 79.3%, respectively). In the combinations of pre-/post-emergence herbicide treatments, linuron at 0.15 lb per acre/linuron at 0.05 lb per acre scored the highest yield (13,280 lb/acre) and satisfactory weed control (73.5% and 96.8%, respectively). On muck soils, pre-emergence application of linuron at 0.125, 0.25, and 0.375 lb/acre resulted in significant weed control and acceptable crop vigor. Of the post-emergence treatments, only linuron at 0.1 lb/acre provided significant weed control with minimal reductions in crop vigor. Prometryn resulted in crop death and imazethapyr significantly reduced crop vigor at the rates tested. Of the combination of pre-/post-emergence herbicide treatment, only linuron at 0.125 lb per acre/linuron at 0.10 lb per acre resulted in reasonable crop vigor (63%) and good weed control (91%).

Sweet basil (*Ocimum basilicum* L.) is commercially the most important annual culinary herb cultivated in the United States. For culinary purposes, the herb is used both fresh and dry. Basil is also a source of essential oil and oleoresin for manufacturing perfumes, food flavors, and aromatherapy products (Simon, 1995). Florida ranks fourth nationally in acreage of fresh market herb production with 1,279 acres in the U.S., a total of 3,200 acres (2007 USDA Census). While combined statistics make it difficult to ascertain the precise economic value of a particular crop, growers and shippers indicate sweet basil is the lead market driver of all their culinary herbs.

Weeds have been a continual problem in basil field production especially with repeated plantings (Shuler, 2008). The major weed species were pigweed (smooth pigweed, *Amaranthus hybridus* L. at the Boynton Beach site, and spiny amaranth, *Amaranthus spinosus* L. at the Belle Glade site), common lambsquarters (*Chenopodium album* L.), and purslane (*Portulaca oleracea* L.) in that order at both sites, and goosegrass at the Boynton Beach site. In southern Florida, basil growers battle weeds by fumigation, such as metam sodium ($300/acre). Weeds after basil germination would be dealt with row-middle cultivation ($30/acre). If weeds were still a problem inside the row, hand weeding sometimes has to be the only and most expensive option ($1,200/acre). While mechanical cultivation and hand-hoeing have been used as alternatives to fumigation, these are frequently too costly or ineffective. Thus, basil growers have sought for effective herbicides for use in basil production. Currently very few herbicides are labeled for weed management in herb production. The primary objective of this research was to identify potential candidates for chemical weed control in basil and to use the field data for IR-4 labeling application.

Materials and Methods

Herbicide experiments on sweet basil were conducted on two application methods (pre-emergence vs. post-emergence) and two distinctive soil types. One was on mineral soil (Myakka sand) with a pH of 6.6 and organic matter content of 1.5% at a commercial field site located in Boynton Beach, FL in the spring of 2009 and again in the winter of 2010 to spring 2011, and the other on organic soil (Pahokee muck) with a pH of 6.7 and organic matter content of 80% at the Everglades Research and Education Center, Belle Glade, FL.

At the Boynton Beach location, 'Nu-far' sweet basil was direct-seeded on 22 Jan. 2009, 15 Nov. 2010, and 10 Feb. 2011 (a repeat of the 15 Nov. 2010 trial), in four rows atop 8-inch raised beds that were 48 inches wide on 6-ft centers. Between-row spacing was 10 inches and in-row spacing by approximately 1 inch. Experimental units consisted of 20-ft sections of a single bed and these were replicated four times in a randomized complete-block

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design. Herbicides were applied with a CO_2-powered backpack sprayer operated at 30 psi and calibrated to deliver 30 gpa with a hand-held boom equipped with two 110-04 flat-fan nozzles spaced at 20 inches. Pre-emergence herbicides were applied immediately following planting and were followed by approximately 0.25 inches of overhead irrigation to water-in the herbicide after application. Pre-emergence treatment data were collected 18 days after planting (DAP). Post herbicide treatments were applied 10 d after planting (DAP) when basil and broadleaf weeds had emerged with the first true leaves of basil just beginning to show. Post-emergence data were collected 7 DAP. Crop vigor and weed control ratings were determined by visual ratings on a scale of 0 to 100 where 0 equaled no crop vigor (dead) and 100 equaled no loss of vigor due to phytotoxicity of the herbicide, and 0 equaled no weed control and 100 equaled complete weed control. Weed densities were determined by recording the number of individual weeds within a randomly selected 2-ft^2 area in each experimental unit. Sweet basil yield was estimated by harvesting 5 ft of two center rows.

At the Belle Glade location, 'Italian Large Leaf' sweet basil was direct-seeded on 24 Nov. 2009 in two rows atop 6-inch raised beds that were 16 inches wide on 3-ft centers. Row and plant spacing were identical to that used at Boynton site. Herbicide application was done using a single-nozzle hand-held boom equipped with a 110-04 flat-fan nozzle centered over the bed. Surfactants were not used in this trial to minimize crop injury. Experimental units were a single bed width by 12 ft long and were replicated four times in a 4 × 3 × 4 factorial experiment arranged in a split-plot design with post herbicide rates as subplot treatments. The procedures in pre-emergence and post-emergence treatment and data collection were the same with the Boynton Beach site.

Results and Discussion

In the first trial, which was planted on 22 Jan. 2009 at the Boynton Beach site, all five pre herbicides provided significant weed control; however, basil crop vigor was reduced by napropamide and halosulfuron at the rates tested (Table 1). In most severe cases the new germination was killed by linuron at both rates (0.5 and 0.25 lb/acre), S-metalochlor at both rates (0.95 and 0.64 lb/acre), and dimethenamid at the lone rate tested (0.25 lb/acre). In post-emergence herbicide treatments, linuron (0.5 lb/acre) and halosulfuron (0.023 lb/acre) provided significantly better weed control (82% and 70%, respectively) than that of clopyralid (23%). The crop visually looked the best with linuron (0.5 lb/acre) at harvest age, presumably due to the compensation by better weed control than the two latter chemicals and the untreated control (Table 1).

The second and third trials on the sandy soil were adjusted to lower rates than those used in the first trial; thus less phytotoxicity was observed. In the pre-emergence treatments alone, linuron at 0.1 lb/acre provided excellent crop vigor (100%), good weed control (75.3%), and highest yield (8,302 lb/acre) (Table 2); followed by napropamide at 3.93 lb/acre with excellent crop vigor (100%), best weed control (79.3%), and good yield (5,229 lb/acre). Imazethapyr had poor weed control and lowest yield at the rates tested although crop vigor was somewhat acceptable. In the combinations of pre-/post-emergence herbicide treatments, linuron at 0.05 lb per acre/linuron at 0.05 lb per acre (Table 2) resulted in excellent crop vigor (100%), good weed control (81%, 13%, 100%, and100% for smooth pigweed, purslane, lambsquarters, and goosegrass, respectively) and highest yield (13,280 lb/acre). Similarly, the combinations of linuron at 0.15 lb per acre/linuron at 0.05 lb per acre provided good crop vigor (94%), excellent weed control (100%, 94%, 100%, and 93% for smooth pigweed, purslane, lambsquarters, and goosegrass, respectively) and highest yield (13,280 lb/acre). Considering the rotation value of pre- and post-emergence herbicides, the combination of napropamide at 2.94 lb per acre/linuron at 0.05 lb per acre was also a good option, which resulted in excellent crop vigor (100%), good weed control (97%, 88%, 100%, and 85% for smooth pigweed, purslane, lambsquarters, and goosegrass, respectively) and good yield (12,173 lbs/acre). Imazethapyr and linuron combinations generally had lower crop vigor and poorer weed control, thus lower yield. This may have been caused by the higher phytotoxicity by imazethapyr, similar to that observed in the stand-alone pre-emergence treatments (Table 2).

At the organic soil site in Belle Glade, weed control and crop vigor assessments were made 23 d after seeding. Linuron pre-emergence herbicide treatments resulted in significant weed control, ranging from 65% at the 0.125 lb/acre rate, to 83% at the 0.375 lb/acre rate in the absence of a post-emergence treatment (Table 3). Crop vigor where linuron was applied only as a pre-emergence treatment was excellent, ranging from 90% to 98%, for the 0.25 lb and 0.125 lb rates, respectively. Of the post-emergence herbicides and rates examined, linuron at the 0.1 lb/acre rate provided for crop vigor ratings that were considered acceptable (>50%), while providing significant weed control, in the absence or presence of a linuron pre treatment. Basil receiving linuron at 0.1 lb displayed limited stunting but no necrosis. In contrast, post treatment with imazethapyr or prometryn produced unacceptable

Table 1. Pre- and post-emergence herbicide effect on sweet basil and weeds, Boynton Beach, FL, Spring 2009.

Herbicide	Rate (lb/acre)	Crop vigor (%)[z]	Weed control (%)[y]	Phytotoxicity rating[x]
Pre-emergence				
Untreated	0.00	100 a	0 b	0.0 b
Linuron	0.25	0 c	88 a	5.0 a
Linuron	0.50	0 c	93 a	5.0 a
S-metalochlor	0.64	0 c	90 a	5.0 a
S-metalochlor	0.95	0 c	93 a	5.0 a
Dimethenamid	0.25	0 c	90 a	5.0 a
Napropamide	2.00	88 b	88 a	0.0 b
Halosulfuron	0.023	84 b	83 a	0.0 b
LSD (0.05)[w]		6	12	4
Post-emergence				
Untreated	0.00	100 a	0 b	0.0 c
Linuron[v]	0.50	30 c	82 a	3.7 a
Halosulfuron[v]	0.023	57 b	70 a	2.7 ab
Clopyralid	0.094	73 b	23 b	2.0 b
LSD (0.05)[w]		22	32	1.5

[z]Ratings were 0 = no vigor (dead) to 100 where there was no loss of vigor.
[y]Ratings were 0 = no weed control to 100 where there was total weed control.
[x]Ratings were 0 = no crop plant injury to 5 where crop was dead.
[w]Mean separation in columns by Duncan's multiple range test, 5% level.
[v]Nonionic surfactant at 0.25% volume to volume.

Table 2. Herbicide effect of pre-emergence and pre-/post-emergence combination on sweet basil and weeds, Boynton Beach, FL, Winter 2010–Spring 2011.

Pre-emergence herbicide rate (lb/acre)	Post-emergence linuron rate (lb/acre)	Crop vigor (%)[z]	Weed control (%)[y] Smooth pigweed	Purslane	Lambsquarters	Goosegrass	Yield (lb/acre)[x]
Napropamide 3.93	0.0	100 a	62 b	92 a	---	84 a	5,229 c
Napropamide 2.94	0.0	100 a	16 d	59 c	---	33 d	2,988 d
Napropamide 1.96	0.0	96 a	25 d	52 d	---	56 c	4,868 c
Linuron 0.05	0.0	99 a	6 e	64 c	---	50 c	913 e
Linuron 0.10	0.0	100 a	83 a	86 a	---	57 c	8,302 a
Linuron 0.15	0.0	0	---[w]	---	---	---	---
Imazethapyr 0.05	0.0	98 a	33 c	59 c	---	32 d	2,768 d
Imazethapyr 0.10	0.0	99 a	36 c	50 d	---	50 c	2,988 d
Imazethapyr 0.15	0.0	98 a	34 c	53 c	---	75 b	1,992 e
Untreated	0.0	100 a	0 e	0 e	---	0 e	996 e
LSD (0.05)[x]		14	17	13	---	19	2,000 e
Napropamide 3.93	0.05	99 a	100 a	67 b	100 a	96	10,181
	0.10	84 c	100 a	100 a	100 a	100 a	8,853 d
Napropamide 2.94	0.05	100 a	97 a	88 a	100 a	85 b	12,173 a
	0.10	96 a	100 a	88 a	100 a	99 a	11,122 b
Napropamide 1.96	0.05	89 b	100 a	88 a	100 a	85 b	11,952 a
	0.10	87 b	100 a	96 a	100 a	100 a	7,636 d
Linuron 0.05	0.05	100 a	81 b	13 e	100 a	100 a	13,280 a
	0.10	92 b	100 a	75 b	100 a	82 c	7,857 d
Linuron 0.10	0.05	97 a	94 a	96 a	100 a	89 b	10,181 c
	0.10	93 b	100 a	96 a	100 a	89 b	10,735 b
Linuron 0.15	0.05	94 a	100 a	94 a	100 a	93 a	13,280 a
	0.10	97 a	100 a	100 a	100 a	78 c	10,735 b
Imazethapyr 0.05	0.05	99 a	94 a	67 b	100 a	78 c	8,189 d
	0.10	75 e	63 d	100 a	100 a	69 d	10,292 c
Imazethapyr 0.10	0.05	98 a	100 a	71 b	100 a	85 b	9,739 c
	0.10	80 c	100 a	92 a	100 a	70 d	8,079 d
Imazethapyr 0.15	0.05	97 a	97 a	67 b	96 c	78 c	9,960 c
	0.10	72 e	100 a	94 a	100 a	93 a	8,632 d
Untreated 0.0	0.0	100 a	0 e	0 e	0 e	0 e	2,000 e
LSD (0.05)[x]		7	10	22	2	8	1,412

[z]Ratings were 0 = no vigor (dead) to 100 where there was no loss of vigor.
[y]Ratings were 0 = no weed control to 100 where there was total weed control.
[x]Mean separation in columns by Duncan's multiple range test, 5% level.
[w]Missing data due to crop death at linuron at 0.15 lb/acre rate, and no lambsquarters data collected in pre-emergence treatment.

crop vigor ratings (<50%) at all rates tested, although many of these treatments provided excellent weed control.

Comparing two different soil types in crop response to herbicide treatment, sweet basil performed well at a lower rate of herbicide application in sandy soil than that in muck soil. This may be explained by the considerable difference in organic matter content (80% vs. 1.5%). Muck soils have been demonstrated to chemically bind with many pre-emergence herbicides and are therefore somewhat more forgiving (Stevenson, 1972; Upchurch and Mason, 1962) in terms of phytotoxicity. Of the herbicides tested, napropamide has recently added basil to its label for use in New Jersey under the auspices of a 24(c) registration (United Phophorus, Inc., 2009), but linuron is not labeled. With the need for additional herbicides registered for use on basil being dire (Mossler, 2008), more of these effective chemicals should be submitted through the IR-4 process to give growers more needed tools. Additional research with this herbicide, investigating various rates, application methods, and herbicide combinations is recommended.

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Table 3. Pre- and post-emergence herbicide effect on sweet basil and weeds, Belle Glade, FL, Winter 2009.

Pre-emergence Linuron Rate (lb/acre)	Post-emergence Herbicide	Post-emergence Rate (lb/acre)	Crop vigor rating[z]	Weed control (%)[y]	Spiny amaranth (no./ft²)[x]	Common lambsquarter (no./ft²)[x]	Common purslane (no./ft²)[x]	Total weed density (no./ft²)[x]
0.0	Linuron	0.0	100 a	0 d	21.5	0.75	1.75	24.00 a
		0.1	63 b	61 c	10.5	0.75	1.5	12.75 b
		0.15	40 c	74 b	0.5	0.25	0.25	1.00 c
		0.2	33 d	88 a	1.0	0.0	0.25	1.25 c
	Imazethapyr	0.0	100 a	0 d	12.75	1.0	2.25	16.00 a
		0.063	48 b	64 c	0.75	0.25	2.50	3.50 b
		0.094	40 c	71 b	0.25	1.0	3.50	4.75 b
		0.125	30 d	84 a	0.25	0.75	3.50	4.50 b
	Prometryn	0.0	100 a	0 d	12.25	1.0	3.0	16.25 a
		0.125	18 b	58 c	7.0	0.0	1.0	8.00 b
		0.25	8 c	76 b	3.75	0.0	1.0	4.75 c
		0.375	3 c	88 a	2.25	0.0	0.0	2.25 c
0.125	Linuron	0.0	93 a	67 b	19.25	1.75	0.75	21.75 a
		0.1	63 b	91 a	5.0	0.0	0.0	5.00 b
		0.15	48 b	96 a	1.0	0.0	0.0	1.00 b
		0.2	28 d	98 a	0.5	0.0	0.0	0.50 b
	Imazethapyr	0.0	98 a	68 b	10.0	1.0	0.75	11.75 a
		0.063	48 b	91 a	0.25	0.0	2.5	0.50 b
		0.094	35 c	93 a	0.0	0.5	1.0	1.50 b
		0.125	33 c	96 a	0.25	0.25	1.0	1.50 b
	Prometryn	0.0	90 a	60 c	9.25	0.25	1.5	11.00 a
		0.125	15 b	90 b	7.25	0.0	0.25	7.50 b
		0.25	5 c	96 ab	3.0	0.0	0.25	3.25 c
		0.375	3 c	98 a	0.25	0.0	0.0	0.25 c
0.25	Linuron	0.0	90 a	73 b	9.75	2.0	1.75	13.50 a
		0.1	58 b	95 a	1.75	0.0	0.75	2.50 b
		0.15	43 c	98 a	0.5	0.0	0.25	0.75 c
		0.2	25 d	99 a	0.0	0.0	0.0	0.00 c
	Imazethapyr	0.0	90 a	79 c	7.00	0.25	2.50	9.75 a
		0.063	45 b	91 b	0.75	0.0	3.25	4.00 b
		0.094	35 c	96 a	0.0	0.75	1.25	2.00 b
		0.125	33 c	97 a	0.0	1.00	2.5	3.50 b
	Prometryn	0.0	90 a	71 b	5.0	0.0	2.25	7.25 a
		0.125	18 b	91 a	7.5	0.0	2.25	9.75 a
		0.25	10 c	96 a	0.5	0.0	0.0	0.5 b
		0.375	3 d	98 a	0.0	0.0	0.5	0.5 b
0.375	Linuron	0.0	90 a	86 a	7.75	1.25	4.5	13.50 a
		0.1	58 b	97 b	2.25	0.0	1.5	3.75 b
		0.15	33 c	100 a	0.25	0.0	0.5	0.75 b
		0.2	23 d	100 a	0.0	0.0	0.0	0.00 b
	Imazethapyr	0.0	90 a	80 c	6.25	0.25	3.75	10.25 a
		0.063	45 b	92 b	0.0	0.25	1.75	2.00 b
		0.094	40 c	97 a	0.0	0.25	1.75	2.00 b
		0.125	30 d	97 a	0.0	0.0	2.0	2.00 b
	Prometryn	0.0	90 a	84 b	5.50	1.00	1.5	8.00 a
		0.125	13 b	97 a	0.50	0.0	1.25	1.75 b
		0.25	5 c	98 a	0.75	0.0	1.25	2.00 b
		0.375	3 c	97 a	0.0	0.0	0.25	0.25 b

[z]Ratings were 0 = no vigor (dead) to 100 where there was no loss of vigor.
[y]Ratings were 0 = no weed control to 100 where there was total weed control
[x]Mean weed density per square ft of bed.
[w]Mean separation in columns by Duncan's multiple range test, 5% level. Interactivity of linuron pre treatments and post herbicides disabled. Statistical comparisons were among rates of post herbicides individually.