Evaluation of Preemergence Herbicides in Vegetable Crops

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SUMMARY. In an effort to identify new herbicides for vegetables crops, broccoli (*Brassica oleracea*) cantaloupe (*Cucumis melo*), carrot (*Daucus carota*), head lettuce (*Lactuca sativa*), bulb onion (*Allium cepa*), spinach (*Spinacia oleracea*) and processing tomato (*Lycopersicon esculentum*) were evaluated in the field for tolerance to eight herbicides. The following herbicides and rates, expressed in a.i. lb/acre, were applied preemergence: carfentrazone, 0.05, 0.1, 0.15 and 0.2; flufenacet, 0.525; flumioxazin, 0.063, 0.125 and 0.25; halosulfuron, 0.032 and 0.047; isoxaben, 0.25 and 0.50; rimsulfuron, 0.016 and 0.031; SAN 582, 0.94 and 1.20 and sulfentrazone, 0.15 and 0.25 (1.000 lb/acre = 1.1208 kg·ha^{-1}). Tolerance was evaluated by measuring crop stand, injury and biomass. Several leads for new vegetable herbicides were identified. Lettuce demonstrated tolerance to carfentrazone at 0.05 and 0.10 lb/acre. Cantaloupe and processing tomato were tolerant of halosulfuron at 0.032 and 0.047 lb/acre. Broccoli, cantaloupe and processing tomato were tolerant of SAN 582 at 0.94 lb/acre. Broccoli and carrot were tolerant of sulfentrazone at 0.15 lb/acre.

Vegetable crops are an important part of U.S. agriculture. The combined value of the broccoli, cantaloupe, carrot, lettuce, bulb onion, spinach, and processing tomato crops totaled $4.4 billion in 1999, from a harvested area of 920,000 acres (372,600 ha) (U.S. Dept. of Agriculture, 2000). The quantity and quality of the vegetable harvest depend on good weed management. Several studies have demonstrated the competitive effects of weeds on vegetable crops. Broccoli yield was reduced by competition with italian ryegrass (*Lolium perenne*) (Bell, 1995). Purple nutsedge (*Cyperus rotundus*) competition reduced carrot yield by 39% and 50% (William and Warren, 1975). Weed cover of 25% decreased lettuce yield by 20% to 40%, and more than 25% cover resulted in complete yield loss (Lanini and LeStrange, 1991). Weed competition has reduced the quantity of onion (Amrutkar et al., 1998; Verma and Singh, 1997; Wicks et al., 1973) and spinach yield (Fennimore et al., 2001). Barnyard-grass (*Echinochloa crus galli*) competition reduced tomato yield by 26% to 84% (Bhowmik and Reddy 1988) and nightshade (*Solanum* sp.) competition has reduced the yield of both seeded and transplanted tomatoes (Weaver et al., 1987). Weed contamination reduces the quality of leafy vegetable crops such as spinach (Fennimore et al., 2001) and weeds can serve as alternate hosts for diseases and insect pests.

Although important to the vegetable industry, only a few preemergence herbicides are registered and literature regarding the tolerance of vegetable crops to preemergence herbicides is limited. Without herbicides yield can be reduced (Bell, 2000) or handweeding expenses may increase (Prather, 1996). The number of herbicides available to vegetable growers may be further reduced in the near future (Bell et al., 2000). The Food Quality Protection Act of 1996 requires the Environmental Protection Agency (EPA) to review tolerances for all pesticides registered before 3 Aug. 1996. Pesticides believed to pose the greatest risk are to be reviewed first. Preemergence vegetable herbicides in the first round of review include: bensulide, cycloate, pebulate, pendimethalin, and trifluralin. The likely result of EPA's review is the loss of some herbicide uses on vegetable crops. Voluntary manufacturer withdrawal has also reduced the number of herbicides available to vegetable growers. The fresh market spinach herbicide, diethatyl, was voluntarily withdrawn from the market in 1992. From 1996 to 2001, an important broccoli and onion herbicide, DCPA, was withdrawn from the market (C. Duerkson, personal communication). As current herbicide registrations are lost, few new herbicides are registered for vegetables. The vegetable crop market is not large enough to encourage the herbicide industry to develop new products and the potential liability for damage to high value vegetable crops discourages manufacturers from seeking registration. Many new low-rate herbicides have been developed for major agronomic crops; some of these herbicides may also have selectivity in vegetables. The goal of this study was to evaluate several vegetables crops for tolerance to many of the new herbicides developed for other markets. Because these chemicals are already proven herbicides, evaluation of weed control was not a part of this study.

Materials and methods

Field studies were conducted at three California sites in 1999. Sites included the University of California, Davis, the Coachella Valley Agricultural Research Station at Indio, and the U.S. Dept. of Agriculture (USDA) Research Station in Salinas. The location of these sites allowed herbicides to be characterized in three major California vegetable production areas, central valley, desert southern California and central coast, respectively. Production areas differ in climate and soil characteristics. The climate at Davis is characterized by hot subhumid summers. Indio has a hot and arid climate with high sunlight and heat advection. A marine influence moderates temperatures and creates frequent summer fog at Salinas. Mean high and low temperatures for the period between planting and harvest were 82.8 and 50.1 °F (28.2 and 10.1 °C) at Davis, 80.6 and 53.4 °F (27.0 and 11.9

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Table 1. The effect of preemergence herbicides on broccoli stand, crop injury, and biomass. Data are from three sites: Davis (D), Indio (I), and Salinas (S) Calif.

Herbicide	Rate (a.i. lb/acre)[z]	Stand count[y] (plant/m)			Crop injury[x] (1–10)			Biomass[w] (% HWC)	
		D	I	S	D	I	S	D	I/S[v]
Carfentrazone	0.05	4.9	25.7	14.5	0.3	1.2	1.5	115.5	41.9
Carfentrazone	0.10	3.6	19.7	6.3	0.4	5.0	2.0	115.3	27.8
Carfentrazone	0.15	3.7	22.0	4.3	0.6	4.8	5.0	119.0	17.2
Carfentrazone	0.20	6.6	6.0	0.5	2.0	7.2	9.5	70.1	3.2
Flufenacet	0.525	3.3	59.7	6.5	3.8	2.2	3.5	58.3	60.8
Halosulfuron	0.032	3.1	25.0	15.5	7.8	5.3	4.5	14.8	9.4
Halosulfuron	0.047	3.5	20.0	16.0	8.8	4.7	4.8	8.5	1.1
Isoxaben	0.25	0.0	47.0	0.0	10.0	1.0	10.0	0.0	24.1
Isoxaben	0.50	0.0	34.7	0.0	10.0	2.0	10.0	0.0	28.0
Rimsulfuron	0.016	4.9	55.7	16.0	3.5	3.3	4.5	98.3	21.4
Rimsulfuron	0.031	2.8	26.0	15.8	7.4	5.3	4.3	15.5	2.3
SAN 582	0.94	3.7	26.0	15.0	1.6	1.0	1.0	115.4	84.2
SAN 582	1.20	4.0	52.0	13.0	2.3	1.2	1.0	108.2	52.3
Sulfentrazone	0.15	4.4	61.7	15.5	0.3	0.5	0.0	129.4	67.3
Sulfentrazone	0.25	2.7	30.0	9.3	4.6	3.8	5.5	42.6	34.1
Handweeded	0.00	3.1	51.0	16.0	0.0	0.0	0.0	100.0	100.0
$LSD_{(0.05)}$		3.7	21.2	4.1	1.4	2.6	2.1	50.6	34.1

[z]1.000 lb/acre=1.1208 kg·ha^{-1}.
[y]Number of plants per meter of row (1.0 plant/m = 3.28 plants/ft).
[x]Visually assessed crop injury at scale of 0 to 10; 0=no injury and 10=plant death.
[w]Above ground biomass from 1 m (3.28 ft) of row, expressed as a percentage of the handweeded check (HWC).
[v]Data were pooled for two sites.

°C) at Indio and 67.2 and 52.0 °F (19.6 and 11.1 °C) at Salinas. Soil at the Davis location was a fine silty loam (37% sand, 41% silt, 22% clay, 0.8% organic matter and pH 7.2); at Indio, a sandy loam (76% sand, 20% silt, 4% clay and 0.5% organic matter and pH 7.2) and at Salinas, loam (49% sand, 34% silt, 17% clay, 2.5% organic matter and pH 8.0).

Cultural practices and crop varieties used in these studies were typical for each region. Planting dates varied according to location. At Davis, all crops except spinach were planted on 27 and 28 Apr. Spinach was planted on 17 Aug. To avoid the heat, spinach is planted in late summer in the central valley. Crops were planted 24 Feb. at Indio and 25 May in Salinas. Plot size varied by site and ranged from 130 to 540 ft^2 (12.1 to 50.2 m^2). One row of each vegetable was planted per plot. Crops were irrigated as needed by overhead sprinkler. Varieties screened at Davis were: broccoli' Sprinter', cantaloupe 'Topnet', carrot 'PakMorF1' head lettuce 'Salinas', onion 'White Ivory', spinach 'Diamond' and processing tomato 'Heinz 9492'. Crop varieties screened at Indio were: broccoli 'Marathon', cantaloupe 'Topmark', carrot 'Goldmine', head lettuce 'Salinas', onion 'Southport White Gold', and spinach 'Bassanova'. Varieties evaluated at Salinas were: broccoli 'Marathon', cantaloupe 'Topnet', carrot 'Neptune', head lettuce 'Pacific Pride', onion 'Staccato', spinach 'Nordic' and processing tomato 'Halley 3155'.

Herbicides and rates were selected after consultation with manufacturers. The following herbicides and rates, in a.i. lb/acre, were applied: carfentrazone at 0.50, 0.10, 0.15, and 0.20; flufenacet at 0.525; flumioxazin at 0.063, 0.125, and 0.25; halosulfuron at 0.03 and 0.047; isoxaben at 0.25 and 0.50; rimsulfuron at 0.016 and 0.031; SAN 582 at 0.94 and 1.20; and sulfentrazone at 0.15 and 0.25. A hand-weeded check (HWC) and an untreated check were included among the treatments. The HWC was weeded at least once every 2 weeks. Herbicides were applied postplant preemergence at 20 to 30 gal/acre (186.9 to 280.3 L·ha^{-1}) with CO_2 pressurized backpack sprayers using 8002VS flat fan nozzles. Overhead sprinkler irrigation was used to incorporate herbicides within 24 h after application. About 0.75 inches (19 mm) of water was applied.

Stand counts, crop injury and crop biomass measurements were collected. Visual crop injury estimates were made at 14, 28, and 56 d after treatment (DAT). Each crop was compared to the same crop in the HWC and visual injury estimates were made on a scale of 0 to 10; 0 represented no damage and 10, plant death. The stand of each crop in 1 m (3.28 ft) of row was assessed at 14 and 28 DAT. At Davis, a visual estimate of stand relative to an untreated control was made instead of a count for carrot and onion. The crop biomass sample was taken at 46 to 57 DAT from a 1-m (3.3-ft) long section of row at the plot center. Crop shoots were cut at the soil surface and biomass measured as fresh or dry weight. All crops, except spinach, were at an immature vegetative stage when harvested. Crop biomass was used as a quantitative measure representative of crop vigor. Fresh weight was measured immediately after harvest and dry weight after 7 d at 122 °F (50 °C). Only the injury ratings and stand counts taken at 14 DAT are presented. Ratings taken 14 DAT were the most sensitive because injury symptoms decreased over time. Stand counts changed very little so only the data collected 14 DAT is presented. Three ratings were used to describe the degree of tolerance to an herbicide: acceptable, moderately acceptable, and unacceptable. Crop tolerance was rated acceptable if stand count, injury and biomass measurements did not signifi-

Table 2. The effect of preemergence herbicides on cantaloupe stand, crop injury, and biomass. Data are from three sites: Davis (D), Indio (I), and Salinas (S) Calif.

Herbicide	Rate (a.i. lb/acre)[z]	Stand count[y] (plant/m)		Crop injury[x] (1–10)			Biomass[w] (% HWC)	
		D	I/S[v]	D	I	S	D	I/S[v]
Carfentrazone	0.05	12.2	16.7	3.5	2.3	0.8	27.9	43.6
Carfentrazone	0.10	6.2	7.4	3.4	4.3	1.8	29.5	74.3
Carfentrazone	0.15	7.1	9.0	4.8	2.5	2.5	22.1	61.4
Carfentrazone	0.20	4.9	5.4	4.8	5.2	2.3	20.4	25.7
Flufenacet	0.525	7.3	9.6	2.1	4.7	2.5	68.1	66.4
Halosulfuron	0.032	12.2	16.3	1.0	0.3	0.3	95.9	152.1
Halosulfuron	0.047	8.9	11.4	0.8	1.0	3.0	88.6	60.7
Isoxaben	0.25	7.4	11.1	2.5	0.8	7.0	7.0	85.7
Isoxaben	0.50	4.8	7.1	6.0	1.0	10.0	0.0	48.6
Rimsulfuron	0.016	8.9	13.4	3.0	1.0	2.8	12.1	17.9
Rimsulfuron	0.031	8.9	13.7	6.0	1.0	4.5	1.8	30.0
SAN 582	0.94	7.7	10.3	1.0	1.5	6.4	89.3	45.7
SAN 582	1.20	6.6	9.1	1.0	2.7	6.3	68.9	26.4
Sulfentrazone	0.15	10.2	14.7	6.0	1.2	2.8	13.9	98.6
Sulfentrazone	0.25	8.6	12.6	9.0	1.7	4.5	12.1	62.1
Handweeded	0.00	11.1	15.4	0.0	0.0	0.0	100.0	100.0
$LSD_{(0.05)}$		5.0	8.1	1.9	2.9	3.8	14.3	67.9

[z]1.000 lb/acre = 1.1208 $kg \cdot ha^{-1}$.
[y]Number of plants per meter of row (1.0 plant/m = 3.28 plants/ft).
[x]Visually assessed crop injury at scale of 0 to 10; 0 = no injury and 10 = plant death.
[w]Above ground biomass from 1 m (3.28 ft) of row, expressed as a percentage of the handweeded check (HWC).
[v]Data were pooled for two sites.

cantly differ from the HWC at any site. If a crop injury rating or a stand count differed from the HWC at only one site, and all other measurements were acceptable then crop tolerance was designated moderate. All other tolerances were regarded as unacceptable.

Treatments were arranged in a randomized complete block design replicated three times at Indio and four at Davis and Salinas. To allow comparison of data among sites biomass measurements were converted to a percentage of the HWC before analysis. For the same reason stand count data for carrot from Salinas and Indio were converted to a percentage of the untreated check. Data for each crop were subjected to analysis of variance using SAS Proc GLM (SAS Institute; 1998). When significant site by treatment interaction occurred, data are presented by site. Fisher's protected LSD ($P \leq 0.05$) was used to detect differences between treatment means.

Results and discussion

Broccoli was tolerant to sulfentrazone at 0.15 lb/acre (Table 1). Crop injury was 0.5 or less among the sites, and stand count and biomass measurements did not differ from the HWC at any site. At 0.25 lb/acre, sulfentrazone injured broccoli and reduced biomass. The difference in response for a small change in the rate of sulfentrazone indicates a narrow window of selectivity. Broccoli showed moderate tolerance of SAN 582 at 0.94 lb/acre. The amount of biomass and level of injury were acceptable at all sites, but stand count was lower than acceptable at Indio. Cantaloupe was tolerant to halosulfuron. Stand count, injury and biomass measurements did not differ from the HWC at any site (Table 2). Cantaloupe also showed moderate tolerance to SAN 582 at 0.94 lb/acre. At Davis and Indio ratings were acceptable, but at Salinas cantaloupe was injured by treatment with 0.94 lb/acre SAN 582. Carrot demonstrated moderate tolerance to sulfentrazone at 0.15 lb/acre (Table 3). Carrot stand count and biomass were acceptable at all sites, only crop injury was higher than acceptable at Salinas. Lettuce was moderately tolerant to carfentrazone at 0.05 and 0.10 lb/acre (Table 4). Biomass and stand counts were acceptable for this treatment at all sites, but carfentrazone injured lettuce at Indio. Processing tomato was tolerant to halosulfuron at 0.032 and 0.047 lb/acre (Table 5). Stand, injury and biomass values were within the acceptable range at all sites for both rates of halosulfuron. Tomato was also tolerant to SAN 582 at 0.94 lb/acre. Stand and biomass were acceptable at all sites, but injury was rated at 3.7 at Indio. Processing tomato was tolerant to rimsulfuron, but because rimsulfuron is already registered for use in tomato, it is not considered a lead. Onion and spinach did not demonstrate tolerance to any of the herbicide treatments (data not shown). None of the crops were tolerant to any of the three rates of flumioxazin that were tested (data not shown).

For some treatments differences in results among sites were large. Isoxaben, for example, caused less injury to crops, other than lettuce, at Indio compared to the other two sites. The many treatments with various chemistries and modes of action in addition to the several varieties of crops used in this study make it difficult to isolate the reasons for differences in results among sites. Temperature and soil characteristics are known to affect herbicide activity and crop sensitivity, and these qualities differed among the sites. The temperature was warmer at Davis and Indio compared to Salinas. The average daily high temperatures for Davis and Indio were 82.8 and 80.6 °F, respectively; while at Salinas the average daily high was 67.2 °F. The crops also differ in their response to temperature. Lettuce and spinach grow better in cooler conditions while tomatoes prefer warmer a tem-

Table 3. The effect of preemergence herbicides on carrot stand, crop injury, and biomass. Data are from three sites: Davis (D), Indio (I), and Salinas (S) Calif.

Herbicide	Rate (a.i. lb/acre)[z]	Stand count[y] (% untreated) D/I[v]	S	Crop injury[x] (1–10) D	I	S	Biomass[w] (% HWC) D	I/S[v]
Carfentrazone	0.05	75.0	70.2	0.0	1.0	0.3	90.9	56.6
Carfentrazone	0.10	67.1	50.0	0.1	2.3	4.5	117.8	57.3
Carfentrazone	0.15	56.4	23.0	0.3	2.0	7.0	90.5	39.7
Carfentrazone	0.20	60.7	4.0	0.1	1.2	8.8	118.9	25.8
Flufenacet	0.525	74.1	69.4	2.4	1.2	1.5	90.4	67.4
Halosulfuron	0.032	45.7	87.0	7.1	1.2	7.0	3.3	28.0
Halosulfuron	0.047	30.7	82.5	8.8	2.0	7.3	0.0	11.7
Isoxaben	0.25	47.1	34.6	5.5	1.3	2.0	43.0	58.7
Isoxaben	0.50	34.3	15.4	8.3	1.2	2.3	102.3	46.0
Rimsulfuron	0.016	60.6	69.9	3.9	0.7	6.8	54.8	43.1
Rimsulfuron	0.031	60.0	68.4	6.8	0.8	8.0	12.7	33.5
SAN 582	0.94	42.1	30.0	8.6	3.0	5.3	57.8	39.9
SAN 582	1.20	40.0	18.0	8.8	3.7	5.8	71.9	16.6
Sulfentrazone	0.15	78.3	65.7	0.9	0.5	4.3	89.6	96.8
Sulfentrazone	0.25	76.4	32.8	1.1	0.5	7.5	103.9	44.8
Handweeded	0.00	77.3	74.3	0.0	0.0	0.3	100.0	100.0
$LSD_{(0.05)}$		25.5	23.0	2.2	2.9	2.7	35.4	31.4

[z]1.000 lb/acre = 1.1208 $kg\cdot ha^{-1}$.
[y]Number of plants per meter of row (1.0 plant/m = 3.28 plants/ft).
[x]Visually assessed crop injury at scale of 0 to 10; 0 = no injury and 10 = plant death.
[w]Above ground biomass from 1 m (3.28 ft) of row, expressed as a percentage of the handweeded check (HWC).
[v]Data were pooled for two sites.

perature. Differences in soil texture, organic matter content and pH can have a major impact on the efficacy of preemergence herbicides. Leaching of herbicides occurs easily on sandy soils such as those found at Indio, whereas herbicides bind to the clay and organic matter found in higher percentages at Davis and Salinas.

We have identified several promising new herbicides for vegetable crops. Carfentrazone at 0.05 and 0.10 lb/acre was acceptable for lettuce. Halosulfuron at 0.032 and 0.047 lb/acre was acceptable for cantaloupe and processing to-

Table 4. The effect of preemergence herbicides on lettuce stand, crop injury, and biomass. Data are from three sites: Davis (D), Indio (I), and Salinas (S) Calif.

Herbicide	Rate (a.i. lb/acre)[z]	Stand count[y] (plant/m) D	I	S	Crop injury[x] (1–10) D	I	S	Biomass[w] (% HWC) D	I/S[v]
Carfentrazone	0.05	5.1	5.0	14.8	0.3	6.3	0.0	68.3	116.1
Carfentrazone	0.10	5.6	5.0	11.3	0.4	3.0	2.3	85.3	49.3
Carfentrazone	0.15	6.1	3.3	13.5	0.6	4.3	3.8	97.8	55.0
Carfentrazone	0.20	3.3	3.0	14.8	2.0	6.3	4.8	34.2	83.4
Flufenacet	0.525	5.0	0.0	6.3	3.8	10.0	8.6	7.0	14.4
Halosulfuron	0.032	3.9	0.7	13.8	7.8	9.7	8.0	12.4	0.0
Halosulfuron	0.047	4.1	0.0	9.0	8.8	10.0	9.4	9.6	0.0
Isoxaben	0.25	0.0	4.0	0.5	10.0	8.0	7.5	0.0	11.3
Isoxaben	0.50	0.1	1.7	0.3	10.0	9.3	8.5	0.0	2.6
Rimsulfuron	0.016	3.9	2.0	18.0	3.5	7.3	7.8	11.8	2.3
Rimsulfuron	0.031	3.8	0.3	7.5	7.4	9.7	8.0	5.4	1.4
SAN 582	0.94	5.0	0.0	1.3	1.6	10.0	9.5	25.5	14.4
SAN 582	1.20	3.6	0.3	0.3	2.3	9.3	8.8	22.1	0.0
Sulfentrazone	0.15	6.7	6.7	10.5	0.3	3.5	7.0	66.2	28.5
Sulfentrazone	0.25	3.6	3.7	1.3	4.6	6.0	9.5	19.5	0.0
Handweeded	0.00	6.0	7.3	15.8	0.0	0.0	0.0	100.0	100.0
$LSD_{(0.05)}$		2.6	3.9	5.9	1.4	2.7	2.7	38.7	86.3

[z]1.000 lb/acre = 1.1208 $kg\cdot ha^{-1}$.
[y]Number of plants per meter of row (1.0 plant/m = 3.28 plants/ft).
[x]Visually assessed crop injury at scale of 0 to 10; 0 = no injury and 10 = plant death.
[w]Above ground biomass from 1 m (3.28 ft) of row, expressed as a percentage of the handweeded check (HWC).
[v]Data were pooled for two sites.

Table 5. The effect of preemergence herbicides on tomato stand, crop injury, and biomass. Data are from three sites: Davis (D), Riverside (R), and Salinas (S) Calif.

	Rate	Stand count[y] (plant/m)			Crop injury[x] (1–10)			Biomass[w] (% HWC)	
Herbicide	**(a.i. lb/acre)[z]**	**D**	**I**	**S**	**D**	**I**	**S**	**D**	**I/S[v]**
Carfentrazone	0.05	4.8	48.3	16.8	0.0	0.7	0.0	28.6	40.1
Carfentrazone	0.10	5.0	16.7	7.5	5.5	5.8	4.8	41.7	93.9
Carfentrazone	0.15	4.5	21.7	17.8	6.0	3.2	1.0	12.1	73.7
Carfentrazone	0.20	4.2	21.0	4.5	6.0	3.2	6.3	13.2	14.3
Flufenacet	0.525	3.5	5.0	11.0	2.5	8.0	5.5	5.1	8.4
Halosulfuron	0.032	5.5	52.3	11.8	1.0	1.2	0.3	84.4	100.0
Halosulfuron	0.047	5.0	55.0	20.3	1.5	0.5	1.3	103.2	87.7
Isoxaben	0.25	1.2	36.7	1.3	3.5	1.2	5.0	1.3	21.4
Isoxaben	0.50	0.5	35.0	1.0	7.5	1.0	10.0	0.1	25.3
Rimsulfuron	0.016	6.4	46.7	15.5	1.6	2.3	0.5	91.2	144.6
Rimsulfuron	0.031	5.0	60.7	18.0	2.0	0.5	1.3	101.4	123.7
SAN 582	0.94	5.7	38.0	16.3	1.5	3.7	0.8	89.5	89.9
SAN 582	1.20	5.8	19.7	17.8	1.5	4.7	0.8	85.4	42.6
Sulfentrazone	0.15	4.5	30.7	19.0	6.0	2.0	3.3	38.8	88.9
Sulfentrazone	0.25	3.5	28.3	12.5	8.0	2.2	7.0	28.8	42.1
Handweeded	0.00	4.9	52.0	16.5	0.0	0.0	0.5	100.0	100.0
$LSD_{(0.05)}$		0.5	23.9	5.8	1.9	3.1	2.9	15.5	53.4

[z] 1.000 lb/acre = 1.1208 $kg \cdot ha^{-1}$.
[y] Number of plants per meter of row (1.0 plant/m = 3.28 plants/ft).
[x] Visually assessed crop injury at scale of 0 to 10; 0 = no injury and 10 = plant death.
[w] Above ground biomass from 1 m (3.28 ft) of row, expressed as a percentage of the handweeded check (HWC).
[v] Data were pooled for two sites.

mato. SAN 582 at 0.94 lb/acre was acceptable for broccoli, cantaloupe and processing tomato. Sulfentrazone at 0.15 lb/acre was acceptable for broccoli and carrot. The preemergence herbicides identified in this study may provide vegetable growers with greater options for weed management. More herbicide options will increase the weed spectrum controlled with herbicides and avoid the development of resistant weeds that dependence on a single or very few herbicides can create. These studies were conducted to gather preliminary information on herbicide selectivity and no attempt was made to fully characterize the use of these herbicides in these crops. The successful crop and herbicide combinations demonstrated will be further characterized in full-season evaluations and will be recommended to the USDA's Interregional Project no. 4 (IR-4) program for further full season evaluation in other states. The low number of crop tolerance leads found suggests that replacement of existing herbicides will take a great deal of time. The consistency or inconsistency of herbicide activity in different locations is also an important factor for a manufacturer or IR-4 to consider. If current trends in government regulation and the herbicide industry continue much effort will need to be expended to prevent vegetable growers from being left with even fewer herbicide options than they currently have.

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