

# Tolerance of Cucurbits to the Herbicides Clomazone, Ethalfluralin, and Pendimethalin. I. Summer Squash

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**Abstract.** Field studies were conducted in 1993, 1994, and 1996 to determine the tolerance of several cultivars of zucchini and yellow crookneck squash (*Cucurbita pepo* L.) to various rates and methods of application of clomazone, ethalfluralin, and pendimethalin. Applying herbicides preplant soil incorporated (PPI), preemergence (PRE), at seedling emergence (SE), or early postemergence (EPOT) resulted in plant injury that varied from 0% to 98%. Ethalfluralin and pendimethalin (PPI) at 1.12 kg·ha<sup>-1</sup> a.i. resulted in the greatest stand and yield reductions across all cultivars. Fruit number and weight declined for all cultivars in 1993 and 1994 as the amount of pendimethalin applied PRE was increased. Zucchini ('Senator') fruit size was significantly reduced for the first three harvests in 1993 by PRE application of pendimethalin or PPI application of ethalfluralin, at all rates. Yellow squash ('Dixie') fruit size was unaffected by herbicide treatment for any harvests during 1993 or 1996. Yellow and zucchini squash yield, fruit number, and average fruit weight were equal to, or greater than, those of the untreated control for PRE clomazone using either the emulsifiable concentrate formulation (EC) during 1993, 1994, and 1996 or the microencapsulated formulation (ME) during 1996. Foliar bleaching and stunting by clomazone was evident in early-season visual observations and ratings, but the effect was transient. Foliar bleaching by clomazone PPI (1.12 kg·ha<sup>-1</sup> a.i.) was more evident in 'Senator' zucchini, and yield was significantly reduced in 1993. These effects of clomazone PPI were not evident in 1994 for either 'Elite' or 'Senator' zucchini squash. Chemical names used: 2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolidinone (clomazone); N-ethyl-N-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine (ethalfluralin); N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine (pendimethalin).

Georgia consistently ranks among the top five states in squash production (yellow and zucchini), with more than 4440 ha harvested in 1998 (Mizelle, 1999). Twenty-one percent of the State's squash hectareage is grown with polyethylene bed covers (Mizelle, 1999) to help control pest and diseases, the remainder on bare ground. A limited number of herbicides are available for weed control in either of these systems.

Weed control in squash is heavily reliant on three herbicides: bensulide {O,O-bis(1-methylethyl) S-[2-[(phenylsulfonyl)amino] ethyl] phosphorodithioate} and ethalfluralin for residual weed control; and sethoxydim {2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} for postemergence grass control (Ahrens, 1994). Bensulide must be applied preplant soil incorporated (PPI), and is primarily effective against annual grasses but not dicot species (Ahrens, 1994). Bensulide also has a long residual period, which can cause injury when small grains are grown in rapid rotation (Frost et al., 1983; Monaco and Skroch, 1980).

Ethalfluralin, the dinitroaniline herbicide most commonly used on squash in Georgia, can injure or kill emerging seedlings and reduce yield (Kupatt et al., 1983; Monaco and Skroch, 1980). Darmstadt (1979) reported 12% root injury to squash when ethalfluralin was applied at 1.4 kg·ha<sup>-1</sup> a.i. preemergence (PRE) followed by 1.9 cm of irrigation. When ethalfluralin was applied to the soil surface prior to transplanting squash, injury occurred because transplanting equipment moved treated soil into contact with plants. No injury was observed when ethalfluralin was applied over the tops of plants immediately after transplanting (Kupatt et al., 1983; Precheur 1983).

Of the cucurbits examined by Monaco and Skroch (1980), squash was least tolerant to ethalfluralin. The number of herbicides available for cucurbit production is limited (Kupatt et al., 1983), and this restricts the use of conservation tillage practices (NeSmith et al., 1994).

Pendimethalin, another dinitroaniline herbicide, is registered for use in several crops to control grasses and small-seeded dicots (Ahrens, 1994). It can be applied PRE and does not require incorporation. Therefore, pendimethalin could be useful for weed control in squash. However, tolerance of squash to pendimethalin has not been evaluated in the southeastern United States.

Clomazone can be PRE applied without incorporation. It is currently registered for use in soybean [*Glycine max* (L.) Merrill], bell pepper (*Capsicum annuum* L.), tobacco (*Nicotianum tabacum* L.), canning pumpkin (*Cucurbita pepo* L.), and, in some states, processing squash (Barth et al., 1995). While field studies have indicated that clomazone may provide full-season PRE weed control in selected cucurbits, differential phytotoxicity and sensitivity among cucurbits may be cultivar-specific (Barth et al., 1995). Clomazone inhibits photosynthesis and carotenoid biosynthesis in higher plants, and application to sensitive species results in bleaching or whitening of photosynthetic tissues, chlorosis, and death (Duke et al., 1985).

Having a limited number of herbicide options can lead to inadequate weed control in summer squash, which in turn can complicate harvest and reduce yield and quality. Registration of additional herbicides or the development of alternative methods of herbicide application could improve profitability. Because of the limited number of herbicides available to growers and amount of information available about cultivar response, a study was designed to determine: 1) the tolerance of several squash cultivars in field trials to clomazone, ethalfluralin and pendimethalin; and 2) the effect of time of application on squash tolerance and yield.

## Materials and Methods

Field experiments were conducted at the Southwest Georgia Branch Experiment Station near Plains, Ga., in 1993 and 1994 on a Faceville sandy loam (clayey, kaolinitic, thermic, Typic Kandiodults) with 71% sand, 13% silt, 16% clay, and 1% organic matter, at pH 6.0. Experiments were also conducted during 1996 at Griffin, Ga., on a Cecil sandy clay loam (clayey, kaolinitic, thermic Typic Hapludult) with 61% sand, 17% silt, 22% clay, and pH 6.6. Summer squash seed were planted ≈1.5 cm deep in the spring of each year into a prepared seedbed using a precision vacuum planter. Planting dates were 7 May 1993, 21 Apr. 1994, and 11 June 1996, following conventional tillage by moldboard plowing, then smoothing with a rotary tiller. The experimental design was a randomized complete-block with four replications (blocks). Plots consisted of either two or four rows (76 cm wide × 6.1 m

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long) within a plot, depending on the number of cultivars used in the experiment. 'Dixie', a yellow crookneck cultivar, and 'Senator', a zucchini cultivar, were planted in all 3 years. In addition, 'Elite' zucchini and 'Lemondrop' yellow straight-neck squash were added in 1994 experiments.

All plots were irrigated (2.5 cm) immediately after planting and PRE application of herbicide to ensure crop stand and incorporation of the herbicide. Additional irrigation was applied as needed and fertilizer was applied based on soil test recommendations for squash vegetable production. Insects were monitored and sprayed with carbaryl (1-naphthyl *N*-methylcarbamate) insecticide when necessary at recommended rates (Adams and Riley, 1999). All tests were maintained weed-free throughout the growing season.

All herbicide rates are expressed in kg·ha<sup>-1</sup> a.i. unless otherwise stated. Herbicide treatments evaluated during 1993 and 1994 were: 1) clomazone emulsifiable concentrate (EC) (0.48 kg·ha<sup>-1</sup>) at three rates PPI and PRE; 2) ethalfluralin EC (0.36 kg·ha<sup>-1</sup>) at two rates applied as PPI, PRE, at seedling emergence (SE), and early postemergence (EPOT); 3) pendimethalin EC (0.48 kg·ha<sup>-1</sup>) at three rates PRE; and 4) a nontreated control (Table 1). Herbicide treatments evaluated during 1996 were: 1) clomazone EC applied at 0.84 and 1.12 kg·ha<sup>-1</sup> PRE; 2) clomazone microencapsulated formulation (ME) (0.36 kg·ha<sup>-1</sup>) applied at 0.56, 0.84, and 1.26 kg·ha<sup>-1</sup> PRE; 3) ethalfluralin EC at 0.67 kg·ha<sup>-1</sup> PRE; and 4) a nontreated control. Herbicides were applied with a backpack sprayer calibrated to deliver 187 L·ha<sup>-1</sup> at 210 kPa. While all PPI treatments were incorporated with a power tiller, PRE treatments were made to the surface immediately after seeding. All SE herbicide treatments were made as the emerging hypocotyl began to lift the crusted surface of the soil, but before any plant tissue was visible. The EPOT herbicide treatments were applied 27 and 18 d

after squash planting in 1993 and 1994, respectively.

Squash injury ratings for stunting and bleaching were visually estimated using a scale of 0% (no injury) to 100% (death) in 1993 and 1996. Stunting was rated in 1994. Stand counts were made in 1993 and 1994 and calculated as percentage of stand reduction based on the number of seeds planted per row; these counts were compared with stand counts in the nontreated controls made immediately after squash emergence. Bleaching, stunting, and stand reduction counts were taken 27 May 1993, 26 May 1994, and 24 June 1996.

Marketable squash were those having a transverse diameter of at least 4 cm (NeSmith, 1993). Yield was determined by hand harvesting marketable squash from the entire length of row, and recording their number and weight. No counts were made in 1994. Squash were harvested four times each year (14, 17, 21, and 29 June 1993; 31 May, 3, 9, and 14 June 1994; 22 and 30 July; and 2 and 9 Aug. 1996). Cumulative number and yield per ha are reported from the four harvest dates each year. Weight per fruit was determined by dividing the total fruit yield (kg·ha<sup>-1</sup>) by total fruit count.

Data for stand reduction, injury, bleaching, and yield were subjected to analysis of variance and means were separated with appropriate Fisher's protected least significant difference test (LSD) at  $P \leq 0.05$ . Where no significant cultivar  $\times$  treatment interactions were detected ( $P \leq 0.01$ ), the data were pooled for presentation.

## Results and Discussion

Treatment  $\times$  year interactions (1993 and 1994) and variation in response to treatment across years (1996 vs. 1993/1994) prevented the pooling of data across years; thus data are presented for each year. Nevertheless, cultivar-specific data were similar (i.e., crookneck

cultivars Dixie and Lemondrop and zucchini cultivars Elite and Senator) in the 1994 trial ( $P \leq 0.01$ ), allowing for individual and cumulative 1994 harvest data to be combined within a cultivar type.

## Effects on stand

Plots were seeded equally and reduction in stand in the nontreated control was a reflection of nonemergence of seedlings. Percentage of reduction of stands was not normalized to fit the nontreated controls to zero (Table 1).

**Clomazone.** The effects of time of treatment and rate of application of clomazone EC on stand reduction varied among cultivars and years, but were not significant in 1993 or 1994 (Table 1). Although stand was not significantly reduced, overall stand losses were generally higher in 1994 than in 1993, and were typically greater for 'Lemondrop' and 'Elite' than for 'Dixie' or 'Senator'.

**Ethalfluralin.** The EPOT applications of ethalfluralin did not reduce stand. However, PPI applications at 0.67 or 1.26 kg·ha<sup>-1</sup> reduced the stand of all squash cultivars in 1993 and 1994 (Table 1). Reductions were 34% to 86% and 62% to 98% at 0.67, and 1.26 kg·ha<sup>-1</sup> PPI, respectively. Therefore, the reduced seedling establishment observed was probably due to root injury. Root injury to cucurbits increases when dinitroaniline herbicides are incorporated (Darmstadt, 1979). When applied PPI, root and shoot exposure is increased because of dispersion of ethalfluralin in the seedbed. These negative effects of ethalfluralin on squash stand and vigor have been previously reported (Kupatt et al., 1983).

Although not significantly different from the nontreated control, some reduction in stand was evident with PRE application of ethalfluralin at both rates for all cultivars in 1994. Kupatt et al. (1983) observed a greater reduction in stand and vigor of squash from

Table 1. Effects of herbicide treatment on stand reduction in four squash cultivars in Georgia.

Treatment	Time of treatment <sup>a</sup>	Rate of application (kg·ha <sup>-1</sup> a.i.)	Stand reduction (%)					
			Dixie		Senator		Elite	Lemondrop
			1993	1994	1993	1994	1994	1994
Clomazone	PPI	0.56	0 c <sup>y</sup>	16 c-e	0 c	6 de	6 e	20 c-e
		0.84	0 c	5 e	0 c	9 de	14 de	15 c-e
		1.12	0 c	3 e	0 c	9 de	13 de	19 c-e
	PRE	0.56	0 c	4 e	0 c	11 c-e	10 de	18 c-e
		0.84	0 c	9 e	0 c	5 de	16 c-e	19 c-e
		1.12	0 c	9 e	0 c	11 c-e	4 e	19 c-e
Ethalfluralin	PPI	0.67	86 a	65 b	34 a	53 b	54 b	83 b
		1.26	67 a	96 a	62 a	81 a	94 a	98 a
	PRE	0.67	0 c	9 b	0 c	3 e	14 de	10 de
		1.26	0 c	18 c-e	0 c	11 b	11 de	21 cd
	SE	0.67	29 b	14 de	25 bc	1 e	16 c-e	14 c-e
		1.26	4 c	34 c	5 c	10 c-e	21 c	20 c-e
	EPOT	0.67	0 c	14 de	0 c	13 cd	15 c-e	10 de
		1.26	0 c	10 e	0 c	10 c-e	13 de	19 c-e
Pendimethalin	PRE	0.56	4 c	8 e	3 c	4 de	20 cd	16 c-e
		0.84	21 b	15 c-e	5 c	9 c-e	8 e	20 c-e
		1.12	18 b	33 c	14 bc	16 c	18 b	25 c
Nontreated control			0 c	8 e	0 c	11 c-e	10 de	9 e

<sup>a</sup>Preplant incorporated (PPI), preemergence (PRE), at seedling emergence (SE), or early postemergence (EPOT).

<sup>y</sup>Means separation within columns by Fisher's protected LSD test,  $P \leq 0.05$ .

PRE application of ethalfuralin than from PPI application, but our data indicate that ethalfuralin treatment (0.67 and 1.26 kg-ha<sup>-1</sup> at SE) reduced the stand of 'Dixie' significantly in 1993 and 1994 regardless of time of application.

**Pendimethalin.** Pendimethalin significantly reduced the stand of 'Dixie' and 'Lemondrop' in 1994 when applied at 1.12 kg-ha<sup>-1</sup> PRE (Table 1), but had no significant effect on any cultivar in 1993, or on 'Senator' or 'Elite' in 1994, regardless of rate of application. However, tolerance to pendimethalin tended to decrease with increasing application rate (i.e., stand reduction in 'Senator' in 1994 was 4%, 9%, and 16% for 0.56, 0.84, and 1.12 kg-ha<sup>-1</sup>, respectively). Like ethalfuralin, pendimethalin is a dinitroaniline herbicide and thus can affect the developing root and shoot during the seedling establishment phase when PPI or PRE are applied (Kupatt et al., 1993).

### Effects on stunting and injury

**Clomazone.** Clomazone EC had no significant effect on stunting of any cultivar in 1993, 1994 (Table 2), or 1996 (data not presented), regardless of time of treatment or rate of application; the same was true for clomazone ME in 1996 (data not presented).

**Ethalfuralin.** Ethalfuralin at 0.67 or 1.26 kg-ha<sup>-1</sup> PPI significantly stunted all cultivars, ranging from 30% to 46%, and 49% to 98% in 1993 and 1994, respectively (Table 2). Significant stunting occurred with ethalfuralin at 1.26 kg-ha<sup>-1</sup> SE for 'Dixie' in 1993 and 1994 and 'Elite' and 'Lemondrop' in 1994. Although ethalfuralin at 1.26 kg-ha<sup>-1</sup> EPOT stunted 'Senator' 24% in 1994, no stunting was observed in 1993.

Applications in 1994 may have been applied before the plants were well established. The EPOT treatments were applied 18 d after planting in 1994, and 27 d after planting in

1993. These results indicate that squash seedlings should be completely emerged and established before postemergence applications (SE and EPOT) of ethalfuralin are made.

**Pendimethalin.** Pendimethalin at 1.12 kg-ha<sup>-1</sup> PRE significantly stunted all cultivars (25% to 88%, Table 2). Kupatt et al. (1983) reported severe stunting as a result of PRE applications of pendimethalin. We observed severe stunting of 'Dixie' and 'Senator' when pendimethalin was applied at 0.56 and 0.84 kg-ha<sup>-1</sup> PRE in 1993, but such injury was not observed in 1994. Variability in stunting injury across years and rates is related to duration of exposure. Kupatt et al. (1983) also reported that vigor (increased injury) of squash seedlings decreased as duration of exposure to PRE-applied pendimethalin increased. Seedlings must emerge through a concentrated pendimethalin layer following PRE application that they do not encounter with PPI applications; thus stunting can be higher with the PRE treatments. The potential for unpredictable and severe injury seriously limits the use of pendimethalin for weed control in squash.

### Chlorosis

**Clomazone.** Clomazone inhibits carotenoid biosynthesis (Ahrens 1994), hence chlorosis or "bleaching" of sensitive plants, such as squash, might be predicted. Bleaching of 'Dixie' and 'Senator' squash increased with increasing rate of application in 1993 when clomazone EC was applied either PPI or PRE (Table 2). Bleaching of 'Senator' was greatest (28%) when 1.12 kg-ha<sup>-1</sup> PPI clomazone EC was applied. Incorporation of clomazone into the root zone enhanced seedling herbicide uptake and increased bleaching. This response has also been observed in soybean (Langton et al., 1997). Bleaching was transient in tolerant plants; it was not evident either in the foliage or fruit by the first harvest (45 d after planting). Bleaching was not observed with 'Dixie' or

'Senator' in 1996 with either the EC or ME formulations of clomazone (data not presented). Barth et al. (1995) assayed carotenoid concentration to measure the bleaching of squash fruit after clomazone application. They determined that increasing the rate of application reduced carotenoid levels at harvest. The "bleaching" affect is transient and does not affect yield of crops for which clomazone is registered, including canning pumpkins (Barth et al., 1995), peas (*Pisum sativum* L.) (Boydston and Kraft, 1991), and peppers (Weston and Jones, 1990).

### Fruit size

Average fruit size (kg-fruit<sup>-1</sup>) was not significantly affected by any clomazone treatment in 1993 (data not presented). Season-long crop injury with 'Senator' was indicated by a reduction in fruit size with ethalfuralin (1.26 kg-ha<sup>-1</sup> PPI) and pendimethalin (1.12 kg-ha<sup>-1</sup> PRE); average fruit size for these treatments was 80 and 90 g/fruit, respectively, vs. 290 g for the nontreated control. 'Dixie' was tolerant to ethalfuralin and pendimethalin at all times of treatment and rates of application, and fruit size of this cultivar was not significantly reduced in 1993. No effects of clomazone or ethalfuralin on fruit size were detected in 1996.

### Yield

**Clomazone.** Squash number and weight per ha were closely associated in 1993 (Table 3) and 1996 (data not presented). Generally, fruit number and weight of 'Dixie' and 'Senator', for single or cumulative harvest, were unaffected by clomazone EC treatment, regardless of rate or application method. An exception to this trend was detected at the third harvest of 'Senator' in 1993, when fruit number and weight were significantly reduced at 1.12 kg-ha<sup>-1</sup> PPI. This may be partially attrib-

Table 2. Effects of herbicide treatment on early season stunting and bleaching in four cultivars of squash in Georgia.

Treatment	Time of treatment <sup>z</sup>	Rate of application (kg·ha <sup>-1</sup> a.i.)	Stunting (%)						Bleaching (%)	
			Dixie		Senator		Elite	Lemondrop	1993	
			1993	1994	1993	1994	1994	1994	Dixie	Senator
Clomazone	PPI	0.56	1 e <sup>y</sup>	5 c	0 e	1 d	1 d	5 e	0 b	6 b
		0.84	0 e	4 c	5 e	1 d	4 d	10 de	0 b	15 cb
		1.12	0 e	1 c	9 e	1 d	1 d	10 de	5 a	28 a
	PRE	0.56	0 e	3 c	0 e	5 d	5 d	5 e	0 b	0 b
		0.84	0 e	0 c	0 e	0 d	5 d	14 cd	1 b	10 b–d
		1.12	0 e	0 c	0 e	0 d	0 d	0 e	8 a	20 ab
Ethalfuralin	PPI	0.67	45 c	85 a	46 c	49 b	49 b	85 a	0 b	0d
		1.26	30 d	95 a	30 d	83 a	98 a	90 a	0 b	0 d
	PRE	0.67	5 e	3 c	4 e	0 d	3 d	3 e	0 b	0 d
		1.26	0 e	4 c	0 e	4 d	0 d	9 de	0 b	0 d
	SE	0.67	8 e	0 c	10 e	5 d	11 d	3 e	0 b	0 d
		1.26	14 e	24 b	8 e	5 d	26 c	24 bc	0 b	0 d
	EPOT	0.67	0 e	5 c	0 e	0 d	0 d	0 e	0 b	0 d
		1.26	0 e	5 c	0 e	24 c	5 d	11 c–e	0 b	0 d
Pendimethalin	PRE	0.56	46 c	0 c	31 d	0 d	3 d	0 e	0 b	0 d
		0.84	68 b	0 c	63 b	3 d	0 d	15 cd	0 b	0 d
		1.12	88 a	31 b	78 a	29 c	25 c	31 b	0 b	0 d
Nontreated control			0 e	0 c	0 e	0 d	0 d	3 e	0 b	0 d

<sup>a</sup>Preplant incorporated (PPI), preemergence (PRE), at seedling emergence (SE), or early postemergence (EPOT).

<sup>b</sup>Means separation within columns by Fisher's protected LSD test,  $P \leq 0.05$ .

utable to effects on plant bleaching (28%) during continued exposure of the developing root system to clomazone. Bleaching has also been observed in muskmelon (*Cucumis melo* L.) and watermelon (*Citrullus lanatus* Thunb.) when clomazone was applied at 1.7 kg·ha<sup>-1</sup> PRE and followed immediately by irrigation (Boyhan, et al., 1995). These results indicate that clomazone is applied more safely as a PRE than as a PPI herbicide. This trend was not evident for the combined zucchini cultivars in 1994 (Table 4), where individual harvest and total yields (number and weight) were similar to those of the control. Total fruit number and weight were unaffected by PRE treatments of either clomazone EC or ME during 1996 (data not presented).

**Ethalfuralin.** Ethalfuralin significantly reduced fruit number and weight of all culti-

vars except 'Senator' (first harvest 1994) when applied at 0.67 or 1.26 kg·ha<sup>-1</sup> PPI in 1993 and 1994 (Tables 3 and 4). PPI treatments of ethalfuralin reduced seedling establishment, which reduced stand and cumulative weight. Total fruit number and weight were unaffected by ethalfuralin at 0.67 kg·ha<sup>-1</sup> PRE during 1996. Although PRE and SE applications of ethalfuralin caused early-season injury to seedlings, this did not affect fruit number or weight. Application of ethalfuralin EPOT did not affect yield for individual or total harvest. Based on these data, EPOT may be a better method of application of ethalfuralin than PPI and SE treatments.

**Pendimethalin.** 'Dixie' and 'Senator' fruit number and weight for the first and total harvest in 1993 were significantly reduced by pendimethalin applied at 0.84 and 1.12

kg·ha<sup>-1</sup> PRE (Table 3). Application at 0.56 kg·ha<sup>-1</sup> PRE significantly reduced fruit number and weight of 'Dixie', but not of 'Senator'. Yield of yellow squash was significantly reduced by pendimethalin applied at 0.84 and 1.12 kg·ha<sup>-1</sup> PRE in 1994 and by all rates of pendimethalin applied in 1994 (Table 4). Total yield of zucchini was significantly reduced only by the highest rate of pendimethalin, but yield in the first harvest was not. The tolerance to pendimethalin at 0.56 kg·ha<sup>-1</sup> PRE was higher for zucchini as than for yellow squash, and this was reflected in total harvest weight.

In summary, these data indicate that clomazone, either the EC or ME formulation, can be used safely as a PRE herbicide in summer yellow or zucchini squash at rates ranging from 0.56 to 1.12 kg·ha<sup>-1</sup>. Minimal or no effects on stand, early-season growth,

Table 3. Effects of herbicide treatment on fresh fruit number and yield in two squash cultivars in Georgia in 1993.

			No. fruit/ha (in 1000s)				Yield (t·ha <sup>-1</sup> )			
			Dixie		Senator		Dixie		Senator	
Treatment	Time of treatment <sup>z</sup>	Rate of application (kg·ha <sup>-1</sup> a.i.)	First harvest	Total harvest	First harvest	Total harvest	First harvest	Total harvest	First harvest	Total harvest
Clomazone	PPI	0.56	16.8 ab <sup>y</sup>	40.1 a-c	7.3 bc	27.8 ab	4.2 a-d	10.6 a-c	3.1 a-d	15.1 ab
		0.84	14.6 b-d	38.1 a-d	2.2 d	22.7 b	3.1 c-e	8.6 c-e	1.1 e-f	13.7 ab
		1.12	18.3 ab	44.6 ab	7.4 bc	26.4 ab	5.2 ab	12.4 ab	3.4 a-d	11.8 ab
	PRE	0.56	19.0 ab	43.9 ab	9.5 ab	30.7 ab	4.2 a-c	11.0 a-c	4.2 ab	18.4 ab
		0.84	18.3 ab	40.3 a-c	8.6 a-c	27.8 ab	4.5 a-c	10.5 a-c	3.1 a-d	18.7 ab
		1.12	20.5 a	47.6 a	8.6 a-c	22.7 b	5.5 a	13.7 a	2.6 b-e	14.8 ab
Ethalfuralin	PPI	0.67	1.5 f	7.3 h	2.2 d	8.8 c	0.5 f	2.1 h	1.1 edf	5.5 c
		1.26	6.6 ef	19.8 f-h	2.2 d	8.0 c	1.9 ef	5.3 e-g	1.3 c-f	5.6 c
	PRE	0.67	16.1 ab	39.5 a-c	7.3 bc	30.7 ab	4.1 a-d	10.2 a-c	2.7 b-d	16.6 ab
		1.26	13.9 b-d	33.7 b-e	7.3 bc	27.1 ab	2.9 c-e	7.6 c-e	3.7 a-c	17.8 ab
	SE	0.67	8.8 de	24.9 e-f	5.9 c	22.7 b	2.4 de	6.5 d-f	2.3 b-e	12.7 b
		1.26	10.2 c-e	30.7 c-f	9.5 ab	33.7 a	2.9 c-e	8.7 c-e	3.2 a-d	18.7 ab
	EPOT	0.67	14.6 a-c	37.3 a-d	12.4 a	33.7 a	3.6 b-d	8.4 c-e	5.3 a	19.8 a
		1.26	14.6 b-d	32.9 b-e	8.8 ab	28.5 ab	3.6 b-d	8.7 c-e	4.0 ab	17.1 ab
Pendimethalin	PRE	0.56	5.1 ef	21.2 e-g	5.9 c	28.5 ab	1.5 ef	5.5 e-g	2.1 b-e	15.5 ab
		0.84	0.7 f	11.0 gh	0.7 d	8.8 c	0.2 f	2.9 f-h	0.3 f	4.5 c
		1.12	1.5 f	9.5 h	0.0 d	2.2 c	0.3 f	2.4 gh	0.2 f	1.3 c
Nontreated control			16.1 ab	37.3 a-d	5.9 c	29.3 ab	3.9 a-d	9.4 b-d	2.3 b-e	18.2 ab

<sup>z</sup>Preplant incorporated (PPI), preemergence (PRE), at seedling emergence (SE), or early postemergence (EPOT).

<sup>y</sup>Means separation within columns by Fisher's protected LSD test,  $P \leq 0.05$ .

Table 4. Effects of herbicide treatment on yield of zucchini and yellow squash in Georgia in 1994.

			Yield (t·ha <sup>-1</sup> )				
Treatment	Time of treatment <sup>z</sup>	Rate of application (kg·ha <sup>-1</sup> a.i.)	Zucchini		Yellow squash		
			First harvest	Total harvest	First harvest	Total harvest	
Clomazone	PPI	0.56	0.8 a–c <sup>y</sup>	32.3 a–c	2.1 c–e	18.2 b–d	
		0.84	1.3 bab	30.0 a–c	2.1 c–e	17.2 b–d	
		1.12	1.1 a–c	33.0 ab	1.7 c–e	17.4 b–d	
	PRE	0.56	1.3 ab	35.3 a	2.4 bc	21.9 ab	
		0.84	1.3 ab	30.9 a–c	1.7 c–e	17.5 b–d	
		1.12	1.1 a–c	31.2 a–c	2.2 b–d	20.5 ab	
Ethalfuralin	PPI	0.67	0.1 de	16.2 d	0.1 f	3.1 e	
		1.26	0.0 c	1.5 e	0.0 f	0.5 e	
		0.67	0.8 a–c	33.8 ab	2.9 ab	21.4 ab	
	PRE	1.26	1.3 ab	31.8 a–c	2.3 bc	19.8 b–d	
		0.67	0.7 a–c	30.5 a–c	2.3 bc	21.0 ab	
	SE	1.26	0.5 a–c	26.5 bc	1.4 b–d	16.8 cd	
		EPOT	0.67	1.4 ab	30.7 a–c	2.4 b–d	17.8 b–d
			1.26	1.0 a–c	32.2 a–c	2.2 b–d	18.6 b–d
Pendimethalin	PRE	0.56	1.3 ab	33.1 ab	2.6 a–c	19.4 b–d	
		0.84	1.1 a–c	34.0 a	1.7 c–e	16.7 cd	
		1.12	0.7 a–c	25.0 c	1.8 c–e	15.8 d	
Nontreated control			1.5 a	34.2 a	3.4 a	23.9 a	

<sup>z</sup>Preplant incorporated (PPI), preemergence (PRE), at seedling emergence (SE), or early postemergence (EPOT).

<sup>y</sup>Means separation within columns by Fisher's protected LSD test,  $P \leq 0.05$ .

yield, or maturity can be expected under the conditions of these experiments. Although treating with clomazone at  $0.84 \text{ kg}\cdot\text{ha}^{-1}$  increased the chances of early-season crop injury, increased injury did not always reduce yield. Ethalfluralin can be safely used in squash when applied at 0.67 and  $1.26 \text{ kg}\cdot\text{ha}^{-1}$  PRE or EPOT, but should not be applied PPI or SE; EPOT applications can be safely used in squash if delayed until seedlings are well-established. These data indicate that pendimethalin cannot be used on summer squash without risk of severe injury and yield reduction.

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