Response of Several Transplanted Pepper Cultivars to Variable Rates and Methods of Application of Clomazone

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Abstract. Field studies were conducted to evaluate the tolerance of several pepper (*Capsicum annuum* L.) cultivars to the herbicide clomazone. Peppers tested included the bell cultivars Yolo Wonder and Jupiter; the banana cultivar Sweet Banana; and the pungent cultivars Jalapeno and Red Chili. Treatments were clomazone at 0.56 or 1.12 kg·ha⁻¹ a.i. applied either preplant incorporated (PPI), pretransplant (PRE-T), or posttransplant (POS-T) on the day of transplanting, plus a nontreated control. Clomazone at 1.12 kg·ha⁻¹ a.i. PPI and PRE-T significantly injured (bleaching or chlorosis of foliage) 'Sweet Banana' (40% and 20%, respectively) and 'Red Chili' (30% and 18%, respectively) in 1993 in early-season evaluations, but this injury was transient and did not significantly affect total fruit number or yield. Injury to any cultivar from POS-T clomazone at 0.56 and 1.12 kg·ha⁻¹ a.i. was nonsignificant. Overall, tolerance to clomazone was excellent for all treatments and across all cultivars. Yield was not reduced significantly by any treatment. Chemical names used: 2-[(2-chlorophenyl) methyl]-4, 4-dimethyl-3-isoxazolidinone (clomazone).

Peppers grow well in warm climates with a long growing season (Granberry and Colditz, 1990), which is also conducive to increased weed pressure. They are poor competitors with weeds and yields can be significantly reduced if weeds are not properly controlled (Frank et al., 1988, 1992; Eshel et al. 1973). Fumigation as a means of weed control is being limited by the restricted use and eventual elimination of methyl-bromide from the U.S. pesticide market (Csinos et al., 1997), and the cost of hand weeding is often prohibitive (Lanini and Strange, 1994). Georgia farmers grew >2000 ha of bell, hot, and banana peppers in 1998 (Mizelle, 1999), and North Carolina and South Carolina added significant hectareage in this regional production area (Hodges et al., 1995). The freshly harvested Georgia crop is distributed from June through August, mostly east of the Mississippi River to the cities of Atlanta, Chicago, Philadelphia, New York, Detroit, and Boston, with

some distribution into Canada (Mizelle, 1990). Sixty-eight percent of Georgia's crop is grown with polyethylene bed covers (Mizelle, 1999) to aid in the control of pests and diseases. No ground cover is used on the remaining area. Few herbicides are available for weed control in either of these systems.

Weed control in Georgia commercial pepper production relies primarily on five herbicides: clomazone, bensulide [*O,O*-bis (1-methylethyl) S-[2-(phenylsulfonyl) amino]ethyl phosphorodithioate], trifluralin [2,6-dinitro-4-(trifluoromethyl)benzenamine]; and napropamide [*N,N*-diethyl-2-(1-naphthalenyloxy)propanamide] for residual weed control; and sethoxydim {2-[1-(ethoxymino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} for postemergence grass control (Ahrens, 1994).

Clomazone at 0.56 or 1.12 kg·ha⁻¹ a.i. offers application versatility and control of field sandbur (*Cenchrus incertus* M.A. Curtis), barnyardgrass (*Echinochloa crus-galli* L.), large and smooth crabgrass [*Digitaria sanguinalis* (L.) Scopoli and *D. ischaemum* (Schreber) Schreber ex Muhl., respectively], several foxtail (*Setaria*) species, prickly sida (*Sida spinosa* L.), jimsonweed (*Datura stramonium* L.), Florida beggarweed [*Desmodium tortuosum* (Sw.) DC.], small flower morning-glory (*Jacquemontia tamnifolia* L.), velvetleaf (*Abutilon theophrasti* Medik.), and spurred anoda [*Anoda cristata* (L.) Schlecht] (Ahrens, 1994), all of which can be troublesome weeds in vegetable production in the southeastern U.S. (Grey et al., 2000). However, clomazone does not control sicklepod (*Senna obtusifolia* L.) or pigweed (*Amaranthus* sp.).

Clomazone is currently registered for use in the solanaceous crop tobacco (*Nicotianum*

tabacum L.) and for various pepper types, including bell, hot, sweet, and pimento (Barth, et al., 1995). Persistence of this herbicide, when applied at rates ≤1.4 kg·ha⁻¹ a.i. in the southern region of the United States, requires a 9-month rotational restriction for peanut (*Arachis hypogaea* L.), corn (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench.], potato (*Solanum tuberosum* L.), and sugar beet (*Beta vulgaris* L.) (FMC 1998).

Tobacco can be safely treated with clomazone as a posttransplant (POS-T) treatment over the top of plants up to 7 d after transplanting, but before weed emergence, without significant crop injury or yield reduction (Bruff, et al., 1996). Although not registered, transplanted watermelon [*Citrullus lanatus* (Thunb.) Matsum and Nak.] has exhibited tolerance when treated with clomazone POS-T at 0.8 kg·ha⁻¹ a.i. on the day of transplanting (Grey et al., 2000). Clomazone is registered for soil application prior to transplanting bell, hot, sweet, and pimento peppers before weed emergence either as a preplant incorporated (PPI) or preemergence (PRE) treatment, but not as a posttransplant (POS-T) application. Weston and Barrett (1989) noted that bell peppers are 86 times more tolerant than is tomato (*Lycopersicon esculentum* L.) to root exposure to clomazone, with metabolism considered the mechanism of selectivity.

Banana peppers are sensitive to PPI and PRE treatments (FMC, 1998), possibly because of increased root contact with clomazone-treated soil during transplanting. Similar responses have been observed with ethalfluralin [N-ethyl-N-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine] (Kupatt et al. 1983; Precheur, 1983). When ethalfluralin was applied to the soil surface prior to transplanting squash (*Cucurbita pepo* L.), injury occurred because transplanting equipment moved treated soil into contact with the plants. No injury was observed when ethalfluralin was applied over the top of squash plants immediately after transplanting (Kupatt et al., 1983; Precheur, 1983). POS-T application of clomazone to sensitive pepper cultivars could limit root exposure, reducing injury to a level that would not significantly affect yield.

While clomazone is currently registered for use with some pepper cultivars, the development of alternative methods of clomazone application, such as POS-T, could offer growers more options, including use on sensitive cultivars, and improved weed control by delaying herbicide application until after transplanting. Because of the limited number of herbicide options and the lack of information available about cultivar response, a study was designed to determine: 1) tolerance of several pepper cultivars in field trials to clomazone; and 2) the effect of application timing on pepper tolerance and yield.

Materials and Methods

Experiments were conducted in 1993 at the Georgia Experiment Station near Griffin, and in 1994 and 1995 at the Bledsoe Research Farm near Williamson. Soil at both locations

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was Cecil sandy clay loam (clayey, kaolinitic, thermic, Typic Hapludult) 61% sand, 17% silt, 22% clay, 1% to 2% organic matter, and pH 6.1 to 6.5.

Commercial pepper cultivars commonly grown in the southeastern United States at the time these studies were initiated were selected, based on consultation with extension representatives. Four pepper cultivars were grown each year. In 1993, 1994, and 1995, the bell pepper cultivars Yolo Wonder and Jupiter and the banana cultivar Sweet Banana were planted. In 1993 the pungent cultivar Red Chili was used; however, seed were not available in 1994 or 1995, so the pungent cultivar Jalapeno was planted. Pepper transplants were grown in a greenhouse in 50-cm³ cells containing commercial potting media (Metro-Mix 3000, W.R. Grace and Co., Cambridge, Mass). They were watered daily and fertilized three times weekly with a water-soluble fertilizer (20N-8.8P-16.6K plus micronutrients at a concentration of 200 mg·L⁻¹ N; Peters Professional General Purpose Fertilizer, W.R. Grace and Co.). Minimum/maximum greenhouse temperatures were 20 and 30 °C, and only natural light was used during transplant production. Seedlings remained in the greenhouse for 6 weeks before being hand-transplanted in the field (7.5 cm into soil) on 17 May 1993, 28 June 1994, or 5 May 1995, following conventional tillage by moldboard plowing and smoothing using a rotary tiller. The experimental design was a factorial arrangement of treatments [three herbicide application methods (PPI, PRE-T, or POS-T) by two rates]. A randomized complete-block design was used with four replications/treatment. Each plot was a single row 3.6 m wide × 7.6 m long. The target stand was 0.95 plants/m² for the nontreated (100% stand establishment), and this standard served as the basis for stand reduction determinations.

Irrigation was applied as needed by overhead sprinklers, and fertilizer was applied based on the Univ. of Georgia soil test recommendations for pepper production (Granberry and Colditz, 1990). Insects were monitored and carbaryl insecticide [(1-naphthyl N-methylcarbamate) was applied when necessary (MacDonald, 1999). Plots were maintained weed-free by hand hoeing for the first month after transplanting.

Herbicide systems evaluated for all three years (all rates expressed as a.i.) included clomazone emulsifiable concentrate (0.5 kg·L⁻¹), applied as a single treatment either PPI, PRE-T, or POS-T, to peppers at 0.56 or 1.12 kg·ha⁻¹, along with a nontreated control for each cultivar. Clomazone was applied on the day of transplanting with a CO₂-pressurized backpack sprayer calibrated to deliver 187 L·ha⁻¹ at 210 kPa. The PPI treatments were incorporated to a depth of 2.5 cm with a power tiller, PRE-T treatments were made to the soil surface prior to transplanting, and POS-T treatments were made to the surface over the top of transplanted peppers.

Pepper injury, based on bleaching and chlorosis, was visually estimated on a scale of 0 (no injury) to 100% (death) on 14 June 1993. Plant

height was recorded 16 July 1993. Because of maturity differences among cultivars, peppers were harvested by hand from the entire length of row when the first fruit of each cultivar matured. Total pepper numbers and weight were recorded for each plot at each harvest. 'Yolo Wonder' and 'Jupiter' bell peppers (>8 cm diameter) were harvested on a weekly basis beginning on 7 July 1993 and biweekly beginning on 23 June 1995, for a total of three harvests each year. 'Sweet Banana' (>10 cm length) was harvested four times on a weekly basis beginning on 2 July 1993 and three times on a biweekly basis beginning on 23 June 1995. 'Red Chili' (>8 cm length) was harvested three times on a biweekly basis beginning on 23 July 1993. 'Jalapeno' was harvested biweekly beginning on 23 June 1995 for a total of three harvests both years. No peppers were harvested in 1994 because of a weather catastrophe discussed later.

Pepper injury, height, fruit number/ha, and kg·ha⁻¹, both on an individual harvest basis, and as the total for the season, were subjected to analysis of variance to determine treatment effects, and year-by-treatment interactions. Treatment means were separated with the appropriate Fisher's protected least significant difference test (LSD) at $P \leq 0.05$.

Results and Discussion

Analysis of the data revealed treatment by year interactions for injury and yield data (fruit number/ha and kg·ha⁻¹), preventing the pooling of data across years. Therefore, all data are presented on an individual year basis. Individual harvest timings were not equivalent across years, thus only total harvest data for the 1993 and 1995 seasons are presented. Relative treatment effects on pepper yield were consistent for 1993 and 1995. Some effects are nonsignificant despite large numerical differences due to variation among replication. Nearly 50 cm of rain fell during a 72-h period beginning 4 July 1994, 6 d after the trial was initiated and no data were collected for that year.

Foliar response. 'Yolo Wonder', 'Jupiter', and 'Jalapeno' peppers were not significantly injured by either rate or method of herbicide application. All of these cultivars exhibited excellent tolerance (4% injury or less) in 1993 and 1995 (Table 1). Weston and Jones (1990) noted similar affects with

clomazone at 0.8 and 1.7 kg·ha⁻¹ a.i. POS-T on 'Yolo Wonder'.

'Sweet Banana' was significantly injured in 1993 by the 1.12 kg·ha⁻¹ application of clomazone PPI and PRE-T, and exhibited foliar bleaching. However, this same rate of clomazone applied POS-T did not injure 'Sweet Banana' significantly and was comparable to application of 0.56 kg·ha⁻¹ PPI and PRE-T. Foliar bleaching did not occur in 1995 for 'Sweet Banana'. In 'Red Chili', bleaching was significant with clomazone 1.12 kg·ha⁻¹ applied PPI (30%) and PRE-T (40%), but not when applied POS-T (18%). This may be partially attributable to the effect of continued exposure of the developing root system to clomazone. Clomazone PPI or mechanical disturbance of soil after PRE-T application increased root exposure, enhanced transplant herbicide uptake, and increased bleaching. This response has been previously reported in soybean [*Glycine max* (L.) Merr] (Langton et al., 1997). Injury has also been observed in muskmelon (*Cucumis melo* L.) and watermelon when clomazone was applied at 1.7 kg·ha⁻¹ PRE-T and followed immediately by irrigation (Boyhan, et al., 1995). These results indicate that clomazone at 1.12 kg·ha⁻¹ can be applied more safely as a PRE than as a PPI herbicide in 'Sweet Banana' and 'Red Chili' peppers. For our test, pepper tolerance to clomazone was high for all treatments and foliar injury was transient.

Stand and height response to clomazone.

There were no significant differences for stand or height response for any pepper cultivar in 1993 (data not presented). While early season foliar injury was observed, it proved to be transient and resulted in no significant stand or height reductions two months later for clomazone PPI, PRE, or POS-T. Similarly, there were no reported reductions in tobacco stand with clomazone POS-T at 0.84 kg·ha⁻¹ (Walker et al., 1998) or 0.56 and 1.12 kg·ha⁻¹ (Yelverton et al., 1994).

Fruit number and yield. Overall, fruit number and yield were not significantly affected by clomazone treatments in any pepper cultivars in any year (Table 2). There were no significant differences in 1993 for 'Jupiter', 'Yolo Wonder', 'Sweet Banana', or 'Red Chili' or in 1995 for 'Jalapeno'. Yield varied among years for individual cultivars, with the highest yields occurring with a POS-T application of clomazone at 0.56 or

Table 1. Percentage of early-season injury to pepper cultivars as influenced by clomazone application method.

Time of treatment ^a	Rate of application (kg·ha ⁻¹ a.i.)	Cultivar							
		Yolo Wonder		Jupiter		Sweet Banana		Red Chili	Jalapeno
		1993	1995	1993	1995	1993	1995	1993	1995
PPI	0.56	0	0	2	2	12	1	7	1
	1.12	0	1	2	2	40	2	30	0
PRE-T	0.56	0	3	0	0	10	0	10	0
	1.12	2	1	2	1	20	0	18	0
POS-T	0.56	2	3	0	0	7	1	2	1
	1.12	1	3	0	4	12	0	0	0
Nontreated		0	0	0	0	0	0	0	0
LSD _(0.05)		NS	NS	NS	NS	17	NS	10	NS

^aAbbreviations: PPI = preplant incorporated; PRE-T = pretransplant; POS-T = posttransplant.

^{ns}Nonsignificant.

Table 2. Effects of clomazone treatment on fruit yield of five pepper cultivars.

Time of treatment ²	Rate of application (kg·ha ⁻¹ a.i.)	Cultivar							
		Yolo Wonder		Jupiter		Sweet Banana		Red Chili	Jalapeno
		1993	1995	1993	1995	1993	1995	1993	1995
No. fruit/ha (1000s)									
PPI	0.56	5.7	13.9	8.1	13.9	132.6	74.9	139.9	92.5
	1.12	3.3	38.3	4.9	21.2	34.2	82.9	56.1	153.9
PRE-T	0.56	6.1	44.2	8.5	22.9	135.0	49.5	60.9	156.4
	1.12	6.5	51.2	7.7	37.1	68.7	94.4	116.3	138.6
POS-T	0.56	9.8	43.7	7.9	22.9	121.2	73.7	202.1	175.6
	1.12	6.9	41.2	7.3	37.8	144.3	97.8	151.3	138.8
Nontreated		6.5	12.2	7.3	9.0	177.7	35.9	182.6	87.8
LSD _(0.05)		NS	22.5	NS	NS	NS	36.9	10	NS
kg·ha ⁻¹									
PPI	0.56	610	880	960	1100	2010	1560	580	920
	1.12	280	2780	520	1630	1390	1850	240	1830
PRE-T	0.56	570	3070	1210	2330	1270	1310	250	1720
	1.12	590	4450	990	2950	980	2060	550	1590
POS-T	0.56	870	2870	620	1840	1750	1560	990	1940
	1.12	670	3220	930	3270	2330	2050	640	1490
Nontreated		560	760	900	580	2470	610	1030	810
LSD _(0.05)		NS	1800	NS	1400	NS	811	NS	NS

²Abbreviations: PPI = preplant incorporated; PRE-T = pretransplant; POS-T = posttransplant.

^{ns}Nonsignificant.

1.12 kg·ha⁻¹ a.i. for 'Yolo Wonder' (1993 and 1995), 'Jupiter' (1995), 'Sweet Banana' (1993 and 1995), 'Red Chili', and 'Jalapeno'. Cavero et al. (1996) noted no significant reductions in yield of seeded paprika peppers following postemergence application of clomazone (1.0 and 2.0 kg·ha⁻¹) to 6- to 8-leaf stage plants. Weston and Jones (1990) reported no significant differences in yield of 'Yolo Wonder' with clomazone at 0.8 or 1.7 kg·ha⁻¹ a.i. POS-T. Gilreath (1989) reported chlorosis and reduced vigor of tomato after applying clomazone at 1.12 kg·ha⁻¹ prebloom or postbloom, but plants quickly recovered and yield was not reduced. In our test, yields of nontreated plants varied with cultivar and year because of a late season increase in weed pressure.

Conclusions

Clomazone can be used either alone, or, when the weed spectrum dictates, in combination with other herbicides to control many common and troublesome weeds. Transplanted 'Sweet Banana', 'Red Chili', and 'Jalapeno' peppers exhibited good tolerance, stand establishment, and yield following application of clomazone at 0.56 and 1.12 kg·ha⁻¹ a.i. POS-T. Producers of these cultivars could add an additional herbicide to their weed control program if clomazone were registered for use as a POS-T treatment. 'Yolo Wonder' and 'Jupiter' were tolerant to PPI, PRE-T and POS-T treatments of clomazone at 0.56 and 1.12 kg·ha⁻¹ a.i. Clomazone is

currently registered for use as a POS-T treatment in tobacco and this same application method should be considered for the pepper cultivars evaluated in this study.

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