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EVALUATION OF PEPPER TOLERANCE TO SELECTED PREPLANT HERBICIDES

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Abstract. **Two studies were carried out at Bradenton, FL and three studies were carried out at Gainesville, FL from 1994 through 1996 to evaluate the tolerance of bell pepper (*Capsicum annuum* L.) to several herbicides applied preplant under polyethylene mulch. Pebulate, napropamide, trifluralin, and lactofen applied preemergence (pre) and preplant incorporated (ppi) did not reduce pepper plant vigor nor shoot biomass in the spring of 1994. Pebulate applied at 2.0 lb/acre pre reduced vigor and yield as compared to pebulate 2.0 lb/acre ppi in the fall of 1994 at Bradenton. Pepper was tolerant to applications of napropamide (2.0 and 4.0) lb/acre, pebulate (2.0, 3.0, 4.0) lb/acre ppi, clomozone (1.0 lb/acre) ppi, metalachlor (1.5 lb/acre) ppi, pendimethalin and trifluralin at 0.75 lb/acre ppi, lactofen (0.5 lb/acre) pre, rimsulfuron, (0.016 and 0.024 lb/acre) and thiazopyr (0.125 and 0.25 lb/acre) pre at Gainesville. Vigor and yield were reduced with applications of EPTC at 3.0 lb/acre ppi and oxyfluorfen at 0.5 lb/acre pre.**

Methyl bromide plus chloropicrin are labeled for use as a preplant fumigant and have been highly effective in controlling nematodes, soilborne diseases, insects, and weeds in mulched pepper production in Florida for the past 20 years. Methyl bromide was listed as a Class I ozone depleting substance on 30 Nov. 1993, and a phase-out date of 1 Jan. 2001 was established under the U.S. Clean Air Act (Section 602). Currently available alternative fumigants to methyl bromide will not adequately control nutsedges nor several broadleaf and grass weeds under Florida cultural conditions. Herbicides will be needed to control these weeds in an alternative production management situation (Stall, 1994).

At the present time, only napropamide has a label for use under polyethylene mulch in pepper production. The label is for a surface application, but it is labeled for preplant incorporated (ppi) application in non-mulched situations. Trifluralin has a label for use in pepper, but has no mention of use with mulch. Clomozone also is labeled for ppi use. Clomozone is relatively volatile and its use under mulch is questionable.

A tolerance has been established for the use of metalachlor in pepper, but the third party label is for directed-shielded applications to pepper row middles. Also, a tolerance is being established for lactofen for row middle use only. EPTC has had a tolerance established on the fruiting vegetable subgroup (tomato, pepper, eggplant) but does not have a label for use, and pebulate is labeled for use on tomato, but does not have a tolerance established to be able to be labeled on pepper (USDA, 1982).

Several other herbicides may be effective under mulch for pepper production. Pendimethelin has been a candidate for IR-4 tolerance establishment in pepper. Oxyfluorfen volatilizes under mulch. Bellinder *et al.* (1993) found that if seven days elapsed between oxyfluorfen application and mulching, residues on the soil surface would be volatilized during that period. When oxyfluorfen was applied, mulch immediately applied, and two to three weeks elapsed before strawberry transplanting, no damage was observed (Stall *et al.*, 1995). This same phenomenon may also apply to clomozone application under mulch.

Rimsulfuron is labeled in a few midwestern states for weed control in potato. Trials in Florida have also shown good tomato tolerance to the herbicide (Bewick *et al.*, 1995). Thiazopyr is also being tested in many vegetable crop situations.

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Initial studies have found a high degree of tolerance to the herbicide in pepper (Stall, 1995).

The purpose of the study was to ascertain pepper tolerance to herbicide applications under mulch in a methyl bromide alternative situation.

Materials and Methods

Five trials were conducted at two locations. Trials were conducted at the Gulf Coast Research and Education Center, Bradenton, Florida in the spring and fall of 1994 on a Eau Gallie fine sand (sandy, siliceous, hyperthermic Alfic Haplaquod) and at the Horticultural Unit, Gainesville, Florida on a Pomona sand (sandy siliceous, hypothermic quartzipammentic Haplumbrept) in the spring of 1994 and 1995 and on a Kanapaha sand (loamy, siliceous, hyperthermic Grossarenic Paleaquults) in the spring of 1996. All trials were on single polyethylene mulch covered beds. 'Capistrano' pepper were transplanted 1 ft apart in row in all trials with a single row/bed at Bradenton and two rows/bed at Gainesville.

Herbicide treatments were applied with a CO_2 powered backpack sprayer at the rate of 26.5 gpa and a pressure of 26 psi at Bradenton in the spring of 1994 and with a tractor mounted CO_2 powered sprayer at a rate of 61.7 gpa and a pressure of 30 psi in the fall of 1994. In Gainesville, all herbicide treatments were applied with a CO_2 powered backpack sprayer at the rate of 30 gpa and a pressure of 30 psi.

In the spring of 1994 Bradenton trial, the herbicide treatments were: pebulate applied at 2.0 and 4.0 lb/acre both to the soil surface (pre) and preplant incorporated (ppi), trifluralin at 1.0 and 2.0 lb/acre ppi, napropamide (2.0 lb/acre) pre and ppi and lactofen (1.0 lb/acre) pre and ppi. The ppi treatments were incorporated 2 inches deep. The fall herbicide treatments at the Bradenton location were: napropamide applied at 1.0 and 2.0 lb/acre and incorporated 4 inches, pebulate applied at 2.0 and 4.0 lb/acre and incorporated 4 inches, pebulate (4.0 lb/acre) and incorporated 6 inches, pebulate (2.0 and 4.0 lb/acre) applied pre, and lactofen applied at 1.0 and 2.0 lb/acre and incorporated 4 inches. At the Bradenton location 1, 3-D plus chloropicrin (Telone C-17) was injected into the bed after herbicide applications at a rate of 21.4 gpa. A fumigated and a non-fumigated check were added to each trial.

The herbicide treatments at the Gainesville location were: napropamide at 2.0 and 4.0 lb/acre ppi, pebulate at 2.0 lb/acre ppi in 1994, 2.0 and 3.0 lb/acre ppi in 1995 and 2.0, 3.0 and 4.0 lb/acre ppi in 1996, clomozone at 1.0 lb/acre ppi, metolachlor at 1.5 lb/acre ppi, pendimethalin and trifluralin at 0.75 lb/acre ppi in 1995 and 1996, EPTC at 3.0 lb/acre ppi, lactofen at 0.5 lb/acre pre, oxyfluorfen at 0.5 lb/acre pre, rimsulfuron at 0.25 lb/acre pre in 1995 and 1996 and 0.38 lb/acre pre all three years, and thiazopyr at 0.125 and 0.25 lb/acre in 1995 and 1996. Ppi treatments were incorporated to a depth of 6 inches with a rototiller. 1, 3-D + chloropicrin (Telone C-17) was injected into the beds in 1994 and 1996 at a rate of 35 gpa and in 1995 1, 3-D alone (Telone II) was injected at the rate of 30 gpa.

Treatments were applied at Bradenton on 5 April 1994 and 23 Sept. 1994. Peppers were transplanted on 20, April and 18 Oct. 1994. In Gainesville, treatments were applied on 30 March 1994, 18 April 1995, and 3 March 1996. Pepper were transplanted on 20 April 1994, 10 May 1995, and 29 March 1996. Irrigation at the Bradenton location was by seep and by overhead at Gainesville.

During the season, pepper growth vigor was rated by a system where 0 equals no vigor (death) and 100 was no loss of vigor. Vigor ratings were taken at Bradenton on 10 May and 5 Dec. 1994. Ratings at the Gainesville location were taken on 9 May and 2 June, 1994, 25 May and 20 June, 1995, and 16 May and 4 June 1996.

Pepper fresh shoot weight was evaluated 9 June 1994 at Bradenton. Pepper fruit yields, were taken from two harvests for the fall 1994 trial at Bradenton and from one harvest per trial at Gainesville. Yield was converted to 28 pound bushels/acre. Data was analyzed by analysis of variance and mean separations was preformed by Duncans Multiple Range Test.

Results and Discussion

There were no differences in vigor or mean fresh weight of pepper plants due to treatment in the spring 1994 trial at Bradenton (data not shown). There were differences in season-long purple nutsedge control (*Cyperus rotundus* L.). The highest control was seen in the pebulate at 2.0 and 4.0 lb/acre ppi and napropapnide at 2.0 lb/acre ppi treatments. Populations of purple nutsedge were highly variable in the fall 1994 trial at Bradenton, masking any treatment effects. There were no differences among the herbicide treatments and the nontreated control at any time during the experiment; however the 1,3-D alone appeared to stimulate sprouting and emergence of nutsedge tubers. More tubers per square foot emerged in this treatment than any of the herbicide combinations or the nontreated control (data not shown). The pepper plants in the two check treatments, the pebulate 2.0 pre, and the lactofen 2.0 ppi treatments showed the lowest vigor, (Table 1). The treatments of napropamide 2.0 lb/acre ppi and pebulate at 4.0 lb/acre 6 inch incorporated ppi had significantly greater vigor than these. The pebulate 2.0 lb/acre ppi treatment produced pepper with greater vigor than the fumigated check and pebulate 2.0 lb/acre applied pre. The vigor of pepper in the remaining plots were not significantly different. Highest yields were obtained from pepper treated with 2.0 lb/acre pebulate incorporated 4 inches. These yields were significantly greater than the 2.0 lb/acre pebulate applied pre to the soil surface. The pepper from both napropamide treatments, the 2.0 lb/acre ppi, the 4.0 lb/acre 6 inch ppi, and the 4.0 lb/acre pre pebulate treatments and the 2.0 lb/acre lactofen treatment had significantly higher yields than the fumigated check. The low yield in the fumigated

Table 1. Pepper vigor and yield as affected by herbicide application and rate Bradenton, FL fall 1996.

Herbicide	Rate (lb/acre)	Application method	Vigor[z]	Yield (bu/acre)[y]
Untreated	—	—	76 bcd[x]	327 abc
C-17 alone	—	—	68 d	177 c
Napropamide	1.0	4" ppi	83 abc	436 ab
Napropamide	2.0	4" ppi	91 a	436 ab
Pebulate	2.0	4" ppi	88 ab	546 a
Pebulate	4.0	4" ppi	86 abc	396 abc
Pebulate	4.0	6" ppi	90 a	450 ab
Pebulate	2.0	pre	75 cd	273 bc
Pebulate	4.0	pre	82 abc	430 ab
Lactofen	1.0	4" ppi	80 abc	389 abc
Lactofen	2.0	4" ppi	77 bcd	430 ab

[z]Vigor ratings are 0 = no vigor or death and 100 = no loss of vigor.
[y]Converted to 28 lb bushel.
[x]Mean separation by Duncan's Multiple Range Test (P = 0.05).

Table 2. Pepper plant vigor as affected by herbicides, Gainesville, FL.

Herbicides	Rate lb/acre	Application	Early vigor[z]			Late vigor		
			1994	1995	1996	1994	1995	1996
Untreated			93 a[y]	95 ab	93 a-d	83 ab	98 a	88 abc
Napropamide	2.0	ppi	88 ab	93 ab	85 a-d	88 ab	93 a	95 ab
Napropamide	4.0	ppi	85 ab	100 a	98 ab	85 ab	100 a	90 abc
Pebulate	2.0	ppi	88 ab	88 abc	98 ab	75 ab	90 ab	95 ab
Pebulate	3.0	ppi	—	90 ab	95 abc	—	85 abc	90 abc
Pebulate	4.0	ppi	—	—	88 a-d	—	—	85 bc
Clomozone	1.0	ppi	88 ab	78 abc	100 a	85 ab	80 abc	92 abc
Metolachlor	1.5	ppi	98 a	90 ab	88 a-d	98 a	88 ab	83 c
Pendimethalin	0.75	ppi	—	83 abc	78 cd	—	88 ab	88 abc
Trifluralin	0.75	ppi	—	88 abc	95 abc	—	90 ab	98 a
EPTC	3.0	ppi	63b	75 bc	75 d	63 b	68 c	83 c
Lactofen	0.5	pre	98 a	95 a	98 ab	93 a	98 a	88 abc
Oxyfluorfen	0.5	pre	75 ab	68 c	93 a-d	78 ab	73 bc	98 a
Rimsulfuron	0.016	pre	—	95 ab	98 ab	—	100 a	90 abc
Rimsulfuron	0.024	pre	83 ab	90 ab	80 bcd	85 ab	95 a	90 abc
Thiazopyr	0.125	pre	—	80 abc	95 abc	—	85 abc	95 ab
Thiazopyr	0.25	pre	—	100 a	98 ab	—	95 a	95 ab

[z]Ratings of 100 = no loss of vigor, and 0 = no vigor or death.
[y]Means separated by Duncan's Multiple Range Test (P = 0.05).

check treatment was due to purple nutsedge competition, while the reduced yield from 2.0 lb/acre pebulate applied pre was most likely due to crop phytotoxicity, even though lactofen applied at 4.0 lb/acre pre did not demonstrate the vigor or yield reduction seen from the 2.0 lb/acre rate.

The highest early and late pepper vigor ratings from the three experiments at the Gainesville location were in the lactofen applied at 0.5 lb/acre pre, the napropamide ppi treatments, and the rimsulfuron (0.016) pre treatment (Table 2). Vigor of pepper treated with metolachlor at 1.5 lb/acre pre was also good in 1994, but, in 1996 late vigor ratings was one of the lowest. Yield was not reduced significantly because of this loss in vigor (Table 3).

Purple nutsedge infestations were not uniform across plots nor replications in any other three experiments at Gainesville. Significant control was seen only in the EPTC treatment in 1994 (data not shown). In 1995, nutsedge emerged through the mulch less then 2 weeks after herbicide application and fumigation, but before transplanting pepper. A glyphosate application at 3.0 lb/acre over the top of the mulch controlled the nutsedge season long in all plots.

Pepper vigor was reduced by the EPTC treatment in all three years at Gainesville. With the exception of late rating in 1995 for oxyfluorfen, all the remaining treatments produced vigor ratings of pepper equal to or higher than the untreated check. With EPTC, yields were lowest two out of three years in Gainesville. There were no significant differences among treatments for yield in 1994 due to high variance among reps. Pepper with herbicide treatments produced yields greater than the untreated check. With no nutsedge pressure in 1995 and 1996, there were differences in yield between treatments.

The highest yields were from pepper with the rimsulfuron (0.016 lb/acre) treatment plots with the higher rate of napropamide and with lactofen. The highest yields in 1996 were from pepper in the thiozopyr (0.125 lb/acre) treated plots. These yields were significantly higher than with EPTC, but not significantly greater than with any other treatment.

From these trials, it is evident that there is a good degree of tolerance to most of the herbicides evaluated. The tolerance of EPTC at 3.0 lb/acre ppi seems to be marginal, but lower rates may provide acceptable tolerance. The use of oxyfluorfen also may be more acceptable at a lower rate. Pepper was tolerant to the newer herbicides such as lactofen, rimsulfuron, and thiazopyr. More work must be done to establish rates and application methods for the candidate herbicides. Also, applications of two or more herbicides to increase the control of weed spectrum found in specific areas must be developed. Napropamide plus pebulate at 2.0 lb/acre each seemed to increase the control of nutsedge over higher rates of either alone with no loss of vigor or yield (Stall, unpublished data). Also, establishment of tolerances for several of these candidate herbicides on pepper should begin or continue.

Table 3. Pepper yield as affected by herbicides, 1994, 1995, 1996, Gainesville, FL.

Herbicide	Rate (lb/acre)	Application method	Yield (bu/acre)[y]		
			1994[z]	1995	1996
Untreated			231	486 a-e[x]	526 ab
Napropamide	2.0	ppi	786	632 a-d	589 ab
Napropamide	4.0	ppi	656	691 ab	546 ab
Pebulate	2.0	ppi	714	551 a-e	555 ab
Pebulate	3.0	ppi	—	388 cde	540 ab
Pebulate	4.0	ppi	—	—	548 ab
Clomozone	1.0	ppi	338	395 b-e	589 ab
Metolachlor	1.5	ppi	588	476 a-e	542 ab
Pendimethalin	0.75	ppi	—	499 a-e	456 ab
Trifluralin	0.75	ppi	—	478 a-e	548 ab
EPTC	3.0	ppi	481	299 e	387 b
Lactofen	0.5	pre	661	681 abc	578 ab
Oxyfluorfen	0.5	pre	669	361 de	604 ab
Rimsulfuron	0.25	pre	—	713 a	547 ab
Rimsulfuron	0.38	pre	368	576 a-e	510 ab
Thiazopyr	0.125	pre	—	560 a-e	622 a
Thiazopyr	0.25	pre	—	648 a-d	576 ab
			—		
			NS		

[z]Treatment differences were not significant (NS).
[y]28 lb bushel.
[x]Means separated by Duncan's Multiple Range Test (P = 0.05).

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EFFECT OF INCORPORATION METHOD ON PEBULATE EFFICACY UNDER POLYETHYLENE MULCH IN TOMATO[1]

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Abstract. **Pebulate incorporation methods were compared for purple nutsedge (*Cyperus rotundus* L.) control and tomato (*Lycopersicon esculentum* Mill.) response when applied with and without soil fumigation with a mixture of 1,3-dichloropropene and chloropicrin in the spring of 1996. Pebulate was incorporated into the soil with a rototiller, disk, or field cultivator (S-tine harrow with rolling crust breakers) prior to bed preparation and fumigation to determine if one method of incorporation was superior to the others in terms of nutsedge control. Initially, nutsedge control was improved by the addition of soil fumigant; however, by late season there was no difference in the nutsedge population in fumigated versus nonfumigated plots. Combination of pebulate with fumigant improved nutsedge control. There was no difference in nutsedge control with the three incorporation methods evaluated. Tomato plant vigor and fruit production were greater in plots receiving fumigant with no differences observed among incorporation methods in this study.**

Weed control, especially purple nutsedge control, has been demonstrated to be one of the most important limitations for any of the currently available fumigant alternatives to methyl bromide in polyethylene mulched tomato production (Gilreath et al., 1994). Therefore, for a fumigant alternative to be successful, it will require the addition of a herbicide for nutsedge control, which may, in turn, require additional equipment and time during the field and bed preparation stage. Pebulate provides good nutsedge control in both mulched and nonmulched tomatoes (Burgis, 1973; Brown, 1983; Gilreath et al., 1994). Early work with pebulate indicated that thorough soil incorporation improved efficacy and reduced phytotoxicity (Colbert, 1974) and the Tillam (pebulate) product label specifies this (Chemical & Pharmaceutical Press, 1995), due to the volatile nature of the compound (Weed Sci. Soc. of Amer., 1983). General recommendations for pebulate incorporation specify thorough incorporation immediately after application. Directions for preplant applications specify the use of power-driven cultivation equipment or a tandem disk, followed by a spike tooth harrow, with disking performed twice at right angles (cross disking). Rototiller incorporation of pebulate followed by soil injection of 1,3-dichloropropene + 17% chloropicrin (Telone C-17) has provided good nutsedge control in mulched tomato, usually as good as methyl bromide applied alone (Gilreath et al., 1994). Most tomato growers do not have rototillers with which they could incorporate pebulate. Although bed preparation equipment is available which includes a rototiller in the mouth of the bedder, the addition of the rototiller requires more horsepower, thus a larger tractor, than would be required for a typical bedder. Cultivation equipment which is readily available on farms typically consists of a disk and a field cultivator, also referred to as an S-tine harrow with small sweeps on it and crust and trash breaker rolling cages on the rear. Disking at right angles is virtually impossible due to the presence of field ditches for irrigation and drainage. Time constraints in land preparation, especially between the fall and spring seasons in west central Florida, dictate that operations proceed quickly and that a minimum amount of equipment be involved. Addition of an extra step or more equipment in the land and bed preparation phases

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