Weed Technology

www.cambridge.org/wet

Research Article

**Cite this article:** Buzanini AC and Boyd NS (2023) Tomato and bell pepper tolerance to preemergence herbicides applied posttransplant in plasticulture production. Weed Technol. **37**: 67–70. doi: 10.1017/wet.2022.98

Received: 18 July 2022
Revised: 14 November 2022
Accepted: 16 December 2022
First published online: 23 December 2022

**Associate Editor:**
Darren Robinson, University of Guelph

**Nomenclature:**
Fomesafen; halosufuron; metribuzin; pendimethalin; *S*-metolachlor; bell pepper, *Capsicum annuum*; tomato, *Solanum lycopersicum* L.

**Keywords:**
Herbicide; planting holes; vegetables

**Author for correspondence:**
Nathan S. Boyd, Professor, University of Florida, Gulf Coast Research and Education Center, 14625 CR 672, Wimauma, FL, 33598
Email: nsboyd@ufl.edu



# Tomato and bell pepper tolerance to preemergence herbicides applied posttransplant in plasticulture production

Ana C. Buzanini[1] and Nathan S. Boyd[2]

[1]Postdoctoral Research Associate University of Florida, Gulf Coast Research and Education Center, Wimauma, FL, USA and [2]Professor, University of Florida, Gulf Coast Research and Education Center, Wimauma, FL, USA

## Abstract

Preemergence (PRE) herbicides are often banded over the entire top of raised beds for broadleaf and grass control in plasticulture vegetable production systems. However, broadleaf and grass weeds may emerge from the planting holes and tears in the plastic mulch. Banded application results in herbicides applied where no holes occur, and therefore, where they are not needed. Our objective is to identify herbicides that do not harm transplanted crops when directed at transplant holes after transplant (POST) with the aim to reduce off-target applications. Therefore, we evaluated tomato and pepper tolerance to PRE herbicides applied to transplant holes 2 wk after transplant and the subsequent effects on crop tolerance and weed density. Halosulfuron, *S*-metolachlor, metribuzin, and pendimethalin did not injure tomato transplants, reduce height, or reduce yield. Fomesafen caused some tomato injury (7%) but had no effect on other measured parameters in Trial I. All PRE herbicides injured peppers by ≥19%, although no effect on yield was observed. Overall, halosulfuron, *S*-metolachlor, metribuzin, and pendimethalin can be safely applied to tomato transplant holes 2 wk after transplant with no significant crop injury nor effects on final yield, but none of the evaluated herbicides are safe for use on pepper crops.

## Introduction

In 2019, Florida produced 60% and 45% of the total U.S. value for fresh market tomatoes and bell peppers, respectively (USDA-NASS 2020). Most of these crops were grown using a plasticulture production system (Boyd and Schumann 2018). Plastic mulch has many benefits including effective weed suppression in the crop row (Lamont 2017; Tarrant et al. 2020). However, broadleaf and grass weeds still germinate and emerge in the transplant holes (Garvey et al. 2013). This proximity of the weeds to the crop maximizes the weed-crop competition, and in turn, crop growth and development can also be influenced (Monks and Oliver 1988; Pike et al. 1990).

Herbicides applied preemergence (PRE) and a limited number of postemergent (POST) herbicides are registered for use on vegetable crops and are used for weed management. PRE herbicides are typically broadcast applied over the bed top prior to laying the plastic mulch, which results in the application of herbicides where there are no transplant holes, and subsequently, where weeds cannot emerge. The application of herbicides only where the plastic is punctured would be a preferred approach because it would reduce overall herbicide use. Boyd and Schumann (2018) developed a hole-punch applicator that takes this approach and applies herbicides only where the plastic is punctured during the hole-punch operation. Their approach reduced PRE herbicide use by 88% to 92% compared to conventional banded applications. However, with both methods the soil is disturbed during the transplant operation, and as a result, weed control is likely to be reduced.

Previous research has shown that PRE herbicides when applied on the bed top prior to the plastic mulch being applied usually provide effective suppression of weeds during the early season, but do not provide season-long control (Yu et al. 2019). Herbicide application following transplant establishment should improve weed control in the planting holes. Yu et al. (2021) reported tomato tolerance from fomesafen, *S*-metolachlor, metribuzin, and oxyfluorfen on different carrier volumes when applied in narrow bands over the planting holes 2 wk after transplant with no significant tomato injury stunting or yield reduction. Ackley et al. (1997) also observed that metribuzin and rimsulfuron applied 10 wk after transplant did not affect the final tomato yield and still observed reasonable weed control.

We conclude that posttransplant PRE herbicide applications may be safe for use with pepper and tomato crops and provide desirable weed control while at the same time substantially reducing herbicide inputs. We also believe that smart spray technology developed at the University of Florida (Boyd and Schumann, 2018) could be used to accomplish this goal. The first step is to identify safe herbicide options for both crops. Consequently, the objectives of this research were

**Table 1.** Herbicide product, application rate, and manufacturer information.

| Common name | Trade name | Rate | Manufacturer, city, state |
|---|---|---|---|
| | | g ai ha$^{-1}$ | |
| Halosulfuron | Sandea® Herbicide | 52 | Canyon Group LLC., c/o Gowan Company, P.O. Box 5569, Yuma, AZ |
| *S*-metolachlor | Dual II Magnum® | 1,070 | Syngenta Crop Protection, LLC, P.O. Box 18300, Greensboro, NC |
| Metribuzin | Tricor® 4F | 540 | United Phosphorus, Inc., 630 Freedom Business Center, Suite 402, King of Prussia, PA |
| Fomesafen | Reflex® | 280 | Syngenta Crop Protection, LLC, P.O. Box 18300, Greensboro, NC |
| Pendimethalin | Prowl® $H_20$ | 532 | BASF Corporation, 26 Davis Drive, Research Triangle Park, NC |

to 1) evaluate tomato and bell pepper tolerance to PRE herbicides applied 2 wk posttransplant, and 2) evaluate weed control with the posttransplant herbicides.

## Material and methods

### Experimental Site

Four field research trials were conducted at the Gulf Coast Research and Education Center (GCREC) in Balm, FL (27.76°N, 82.22°W). The soil at the research site is a Myakka fine sand (sandy, siliceous hyperthermic Oxyaqui Alorthod), pH 6.5, and with 1.2% organic matter. Raised beds were shaped and formed with bed pressing equipment (Kennco Manufacturing, Ruskin, FL). The dimension of the raised beds was 30.5 cm tall and 66 cm wide on the top with 1.5 m between beds. The beds were formed and fumigated with 225 kg ha$^{-1}$ of 1,3 dichloropropene+chloropicrin (Pic-Clor 60; Soil Chemicals Corporation D/B/A Cardinal Professional Products, Hollister, CA). Immediately following fumigation the beds were covered with virtually impermeable film (thickness = 1.25 mm; Berry Plastics Corp., Evansville, IN) with double-drip-tape buried at 2.5 cm beneath the soil surface in the middle of each bed.

The experimental design was a randomized complete block design with four replications. The herbicides evaluated for both crops were halosulfuron, S-metolachlor, metribuzin, fomesafen, and pendimethalin, with a nontreated control (Table 1). These herbicides were chosen for use on both tomato and pepper with all products registered as PRE herbicides for tomato. Even though the PRE herbicides metribuzin and fomesafen are not registered for use on pepper crops, we opted to evaluate them for potential use.

At 2 wk after transplant (WATP), herbicides were applied to planting holes with a $CO_2$-pressurized backpack sprayer to simulate the hole punch applicator previous reported by Boyd and Schumann (2018). The average hole size was 0.79 cm by 0.79 cm. The hole-punch applicator was not used because the current version is designed for use pretransplant. The sprayer was calibrated to deliver a carrier volume of 187 L ha$^{-1}$ at 241 kPa with a boom equipped with a single 8002EVS flat-fan nozzle (Teejet Spraying Systems Co., Roswell, GA). The spray was directed at the base of the transplant and positioned to ensure the spray covered the transplant hole and provided a consistent application rate.

### Tomato and Pepper Tolerance of PRE Herbicides Applied on the Planting Holes

Tomato (cv 'Winter Haven') experiments were conducted in 2018 with Trial I conducted in spring, and Trial II in the fall. The raised beds were formed and fumigated on January 29, 2018, and July 13, 2018, in Trial I and II, respectively, as previously described. The plot was a single 22.8-m raised bed. Tomato plants were spaced 60 cm between plants, and were transplanted on March 7, 2018, and August 15, 2018, in a single row per bed in Trials I and II, respectively.

For Pepper (cv 'Aristotle') two experiments were also conducted, where Trial I was conducted in fall 2018 and Trial II in spring 2019. The raised beds were formed and fumigated with previously described fumigants on July 11, 2018, and January 25, 2019, in Trial I and Trial II, respectively. The plot was a single 22.8-m raised bed. Pepper plants were spaced 38 cm apart and were transplanted in a double row per bed on August 15, 2018 (Trial I), and March 12, 2019 (Trial II).

The weather conditions, including average, minimum, and maximum air temperature in the spring and fall were similar throughout the experimental period for both crops, though monthly averages increased from the beginning to the end of the experiment in the spring but declined over time in the fall (Table 2). During the fall, the rainfall was substantially greater, especially during the first month of the experiment when the herbicides were applied, when 201 mm fell in the fall, and 29 and 26 mm fell in spring 2018 and spring 2019, respectively.

Data collection included tomato and pepper crop injury, height, and yield for both crops, and weed count in all trials. Crop injury was evaluated on a percent scale, where 0% represented no visual injury and 100% represented complete plant desiccation. In the tomato trial I, the visual injury was evaluated at 4 and 6 WATP (April 6 and April 19, 2018, respectively). The height of 20 plants per plot was measured with a meter stick (cm), for tomato trial I at 5, 7, and 10 WATP (April 9, April 23, and May 18, 2018, respectively). Total weeds in the planting hole were counted in in each plot at 10 WATP (May 18, 2018), and at 11, 13 and 15 WATP (May 22, June 4, and June 19, 2018). Sites were selected with limited weed pressure because the focus was crop tolerance. Accordingly, few weeds emerged, and we did not attempt to distinguish weed species. The number of living crop plants were counted in each plot, harvest at season end, and the fruits weighed. On tomato Trial II, visual injury and height were evaluated at 2 and 5 WATP (September 11 and October 5, 2018, respectively), weeds were counted at 2 and 4 WATP (September 11 and September 25, 2018, respectively), and harvest occurred at 8 WATP (October 25, 2018).

During Trial I, pepper height was evaluated at 6 WATP (September 25, 2018), weeds counted at 11 WATP (October 29, 2018), and harvested at 13 WATP (November 15). For Trial II, visual injury was evaluated at 3 and 5 WATP (April 4 and April 16, 2018, respectively), height and weed density were evaluated at 5 WATP (April 17, 2019), and harvest occurred at 10 a 12 WATP (May 23 and June 6, 2019, respectively).

### Statistical Analysis

Data were subject to ANOVA using the MIXED procedure in SAS software (version 9.4; SAS Institute, Cary, NC). Data were subjected to one-way ANOVA, and herbicides are considered as the fixed factor, while the block was considered as the random factor.

**Table 2.** Monthly weather data in 2018/2019.[a]

| | Spring 2018 | | | | Fall 2018 | | | | Spring 2019 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | March | April | May | June | August | September | October | November | March | April | May | June |
| Average air temperature (C) | 17.1 | 21.6 | 23.4 | 26.1 | 26.2 | 26.6 | 24.3 | 19.9 | 19.2 | 22.5 | 26.1 | 27.3 |
| Minimum air temperature (C) | 0.1 | 8.2 | 13.0 | 19.0 | 20.1 | 21.2 | 8.5 | 1.5 | 4.4 | 10.3 | 16.9 | 20.7 |
| Maximum air temperature (C) | 30.0 | 31.8 | 32.8 | 34.9 | 34.5 | 34.8 | 33.4 | 32.1 | 31.1 | 33.0 | 36.7 | 38.3 |
| Rainfall (mm) | 29.2 | 85.3 | 328.7 | 175.0 | 201.4 | 116.3 | 14.0 | 55.4 | 25.9 | 40.1 | 66.5 | 208.3 |

[a]Weather data were obtained from the weather station located at the Gulf Coast Research and Education Center in Balm, FL, as obtained from the Florida Automated Weather Network.

**Table 3.** Effects of herbicide when applied with a precision applicator that targets plant holes in plastic mulch on tomato height, total marketable yield, and weed density.[a,e]

| | Tomato injury[b] | | Tomato height[c] | | Tomato yield | | Weed density[d] | |
|---|---|---|---|---|---|---|---|---|
| Treatment | Trial I | Trial II | Trial I | Trial II | Trial I | Trial II | Trial I | Trial II |
| | % | | cm | | kg ha$^{-1}$ | | No. per 100 m | |
| Nontreated control | 0 | 0 | 52 | 72 | 960 | 610 | 4 | 62 |
| Halosulfuron | 0 b | 2 | 54 | 78 | 990 | 610 | 8 | 11 |
| S-metolachlor | 0 b | 5 | 55 | 62 | 860 | 460 | 0 | 7 |
| Metribuzin | 3 b | 3 | 54 | 73 | 1,000 | 620 | 4 | 3 |
| Fomesafen | 7 a | 2 | 54 | 68 | 720 | 450 | 19 | 17 |
| Pendimethalin | 0 b | 2 | 55 | 76 | 950 | 680 | 10 | 29 |
| p-value | 0.03656 | 0.57989 | 0.56253 | 0.52698 | 0.7413 | 0.86630 | 0.12692 | 0.148203 |

[a]Abbreviation: WATP, weeks after transplant.
[b]Injury ratings are the average of measurements taken 4 and 5 WATP for the Trial I and 2 and 5 WATP for the Trial II. For injury, all ratings were compared with the nontreated control, but assigned nontreated control ratings of 0 were removed prior to analysis.
[c]Tomato heights were measured at 5, 7 and 8 WATP in Trial I and 2 and 5 WATP Trial II, respectively
[d]Weed density was measured at 10 WATP in Trial I and 2 and 4 WATP in Trial II.
[e]Treatments mean with the same column followed by the same letter is statistically equivalent according to Scott-Knott adjusted means comparisons at the 0.05 significance level.

Constant variance and normality were examined. Treatments means were separated using Scott-Knott multiple comparisons at $P \leq 0.05$. Data collected on multiple dates, such as visual injury and height, were analyzed using the repeated measure analysis.

## Results and Discussion

The herbicides applied in this study did not significantly affect tomato injury in Trial II ($P = 0.57989$), heights ($P = 0.56253$ and $P = 0.52698$ in trials I and II, respectively), yield ($P = 0.7413$, and $P = 0.86630$ in Trial I and II, respectively), and weed density in the planting holes ($P = 0.12692$ and $P = 0.148203$ in Trial I and II, respectively; Table 3). Fomesafen injury on tomato was observed in Trial I with an average of 7% injury. Injury following application of all other evaluated herbicides was less than 5%, and although fomesafen caused significantly more injury compared to other herbicides in Trial I, it did not significantly reduce tomato height or yield in either season. We conclude that all herbicides, with the exception of fomesafen can be safely applied after transplant.

Similar results were observed by Yu et al. (2021), when the use of a banded application of *S*-metolachlor and metribuzin on the tomato planting holes presented slight crop injury, and fomesafen caused an average of 7% injury, but no reduction in crop growth or yield were observed. The potential injury risk by fomesafen was previous reported by Mohseni-Moghadam and Doohan (2017a), when fomesafen was applied 1 d before transplant on processing tomato. Tomato injury ranged from 0% to 28%, with the crop completely recovered, and no effects on the final yield were reported, showing that even previously applied fomesafen can result in considerable potential injury to tomato plants.

The results for pepper (Table 4) also indicated that there was no significant effect of herbicide type on yield ($P = 0.50290$, and $P = 0.49633$ in Trial I and II, respectively). All the herbicides caused significant crop injury (≥19%). Fomesafen and metribuzin caused significant pepper injury, with an average of 59% injury for fomesafen and 80% for metribuzin. Both herbicides also stunted the pepper shoots in Trial II with an average reduction of 11 cm and 8 cm for metribuzin and fomesafen respectively, when compared with the heights of plants with other herbicide treatments. We conclude that the injury observed would not be acceptable to growers, and therefore, none of the options can be considered safe.

Grey et al. (2002) observed pepper foliage injuries when fomesafen was applied PRE or posttransplant on the day of transplanting with damage ranging from 0% to 14%. Grey et al. (2002) observed no effect on yield with transient damage that was visible only 7 to 10 d after application. Less than 9% injury was observed when *S*-metolachlor and halosulfuron were applied posttransplant, and as shown in this study the crops recovered (Bangarwa et al. 2009; Devkota et al. 2015).

In all Trials, the weed density in the planting holes was unaffected by the herbicide type ($P = 0.12692$, $P = 0.148203$, $P = 0.2444$, and $P = 0.22583$ in tomato Trial I, tomato Trial II, pepper Trial I, and pepper Trial II, respectively; Tables 3 and 4). The results of the current study agree with those of previous research in which no differences in weed control have been reported with herbicide treatments using the hole-punch smart sprayer (Boyd and Schumann 2018). This was expected because low weed density areas were selected, and because the focus was to confirm the tolerance of tomato and pepper plants when herbicides are applied in established transplanted plants with a precision herbicide applicator.

We conclude that halosulfuron, *S*-metolachlor, metribuzin and pendimethalin are safe to apply posttransplant in tomato 2 WATP. However, the use of fomesafen can cause significant injuries to tomato plants, although no decrease in yield was observed. None of the evaluated herbicides can be recommended as a safe

https://doi.org/10.1017/wet.2022.98 Published online by Cambridge University Press

**Table 4.** Effect of herbicide when applied with a precision applicator that targets plant holes in plastic mulch on bell pepper height, total marketable yield, and weed density.[a,e]

| Treatment | Pepper injury[b] | | Pepper height[c] | | Pepper yield | | Weed density[d] | |
|---|---|---|---|---|---|---|---|---|
| | Trial I | Trial II | Trial I | Trial II | Trial I | Trial II | Trial I | Trial II |
| | %— | | cm— | | kg $ha^{-1}$ | | No. per 100 m | |
| Nontreated control | — | 0.00 | 21 | 28 a | 920 | 2,450 | 537 | 148 |
| Halosulfuron | — | 19 c | 21 | 30 a | 1,220 | 2,550 | 369 | 29 |
| S-metolachlor | — | 26 c | 19 | 29 a | 860 | 1,810 | 349 | 115 |
| Metribuzin | — | 80 a | 18 | 19 b | 830 | 1,180 | 258 | 86 |
| Fomesafen | — | 59 b | 20 | 22 b | 780 | 1,570 | 226 | 33 |
| Pendimethalin | — | 19 c | 20 | 31 a | 890 | 1,780 | 205 | 127 |
| p-value | | 0.0000 | 0.75854 | 0.00055 | 0.50290 | 0.49633 | 0.2444 | 0.22583 |

[a]Abbreviation: WATP, weeks after transplant.
[b]Injury ratings are the average of measurements at 3 and 5 WATP for Trial II. For injury, all ratings were compared with the nontreated control, but assigned nontreated control ratings of 0 were removed prior to analysis.
[c]Pepper heights were measured at 6 and 5 WATP in Trial I and Trial II, respectively
[d]Weed density was measured at 11 WATP in Trial I and 5 WATP in Trial II.
[e]Treatments mean with the same column followed by the same letter is statistically equivalent according to Scott-Knott adjusted means comparisons at the 0.05 significance level.

option for PRE weed control on posttransplant pepper. We conclude that we have identified multiple PRE herbicides that can be safely applied after transplant in tomato but were unable to identify a safe option for pepper.

**Acknowledgments.** We acknowledge the technical assistance of Mike Sweat, Laura Reuss, and the farm crew at the Gulf Coast Research and Education Center for assistance with crop management. This research was funded by a specialty crop block grant EAM190100XXXXG036. No conflicts of interest have been declared.

## References

Ackley JA, Wilson HP, Hines TE (1997) Rimsulfuron and metribuzin efficacy in transplanted tomato (*Lycopersicon esculentum*). Weed Technol 11:324–328

Bangarwa SK, Norsworthy JK, Gbur EE (2009) Cover crop and herbicide combinations for weed control in polyethylene-mulched bell pepper. HortTechnology 19:405–410

Boyd NS, Schumann AW (2018) Development and evaluation of a hole-punch applicator for precision application of preemergence herbicides in plasticulture production. Weed Technol 33:142–146

Devkota P, Norsworthy K, Rainey R (2015) Efficacy, and economics of herbicide programs compared to methyl bromide for weed control in polyethylene-mulched bell pepper. Weed Technol 29:284–297

Garvey PV Jr, Meyers SL, Monks DW (2013) Influence of palmer amaranth (*Amaranthus palmeri*) on the critical period for weed control in plasticulture-grown tomato. Weed Technol 27:165–170

Grey TL, Bridges DC, NeSmith DS (2002) Transplanted pepper (*Capsicum annuum*) tolerance to selected herbicides and method of application. J Veg Crop Prod 8:27–39

Lamont WJ (2017) Plastic mulches for the production of vegetable crops. Pages 45–60 *in* Orzolek ML. A Guide to the Manufacture, Performance, and Potential of Plastics in Agriculture. Amsterdam: Elsevier

Mohseni-Moghadam M, Doohan D (2017a) Fomesafen crop tolerance and weed control in processing tomato. Weed Technol 31:441–446

Monks DW, Oliver LR (1988) Interactions between soybean (*Glycine max*) cultivars and selected weeds. Weed Sci 36:770–774

Pike DR, Stoller EW, Wax LM (1990) Modeling soybean growth and canopy apportionment in weed-soybean (*Glycine max*) competition. Weed Sci 38:522–527

Tarrant AR, Brainard DC, Hayden ZD (2020) Cover crop performance between plastic-mulched beds: impacts on weeds and soil resources. HortScience 55:1069–1077

[USDA-NASS] U.S. Department of Agriculture–National Agriculture Statistics Service (2020) Florida Agricultural overview. Summary. https://www.nass.usda.gov/Statistics_by_State/Florida/Publications/Annual_Statistical_Bulletin/2020/A1thru10Over-2020.pdf Accessed: March 10, 2021

Yu J, Sharpe SM, Boyd NS (2019) Fumigants alone or in combination with herbicide for weed management in bell pepper (*Capsicum annum*). Crop Prot 118:31–35

Yu J, Boyd NS, Schumann AW, Sharpe SM (2021) Tomato tolerance to preemergence herbicides in plasticulture using narrow bands and precision technology. Crop Prot 146:1056