Concerns of Transplanting Tomatoes into DNA-Treated Soil in Buried Drip Fields

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For decades, dinitroaniline (DNA) herbicides have been used in California in tomatoes and crops rotated with tomatoes with few negative issues reported, but reports of damage to tomatoes caused by DNA herbicides have greatly increased in Fresno County. We conducted a small-plot field trial in 2012 to look at possible cause(s) of why we were seeing this tomato injury where labeled rates of DNA herbicides were used.

Over the last two decades, processing tomato production in Fresno County has shifted from using sprinkler and furrow irrigation with annual deep tillage to buried drip irrigation with shallow tillage. Today, 100,000 acres of processing tomatoes in the county are transplanted and over 95% is farmed using buried drip irrigation and shallow tillage. High costs of surface water ($100-$300/ac ft) and expense of moving sprinkler pipe ($100/acre) have been the driving forces in this shift toward using buried drip in processing tomatoes. Growers save water, costs, and achieve yields of 60 tons per acre or more when buried drip irrigation is used. An added benefit of using buried drip is that the bed surface remains fairly dry during the growing season, so weed emergence is generally reduced, saving in hand-weeding costs.

To help reduce the cost of having to replace drip tape every time a new crop is planted and save in land preparation operations, the tape is buried about 10" deep and left in-place in "semi-permanent" beds for the life of the tape, which is usually three to five years. Once tomatoes are harvested, the beds are tilled shallow to destroy crop residues and prepare beds for the next crop planting. Under this type of production system, rotational crop options are limited, including tomatoes, cotton, dry beans, and melons, all of which DNA herbicides are routinely used in to help control weeds.

In 2009, we began observing commercial processing tomato fields in western Fresno County that showed stunted tomato plants with substantial root reduction. Field patterns of crop damage and plant symptoms expressed was consistent with injury caused by DNA herbicides. We determined that there were four factors common to nearly all of the fields we visited where crop injury occurred: 1) pendimethalin was used in the tomato crop and/or the previous crop(s), 2) tomatoes were produced using semi-permanent beds with buried drip irrigation and shallow cultivation, 3) deep tillage was not performed for bed preparation before tomato planting, and 4) tomato root plugs were planted shallow (<3" deep), although some fields showed damage even when tomatoes were planted at a depth of four to five inches. Furthermore, the number of fields showing tomato damage was greater during years when the region received below-normal winter rainfall amounts, particularly in 2009/10 and 2011/12.

We conducted a field trial in 2012 to determine whether or not planting tomatoes too shallow was the likely cause of crop injury observed in commercial fields treated with labeled preplant DNA herbicides. The trial was conducted at the UC West Side Research and Extension Center in Five Points, California in a clay loam soil. The trial was set up as a split-plot experimental design with four replications. Six preplant herbicides (trifluralin, pendimethalin, s-metolachlor, pendimethalin + s-metolachlor, sulfentrazone, and no herbicide) used at labeled rates were the main plot treatments and two planting depths (<2" and 4-5") were the sub-plot treatments.

Sixty-inch tomato beds were prepared in May and drip tape was placed 10" deep in the center of the beds with one drip line per bed. Herbicides were applied with a pressurized CO_2 backpack sprayer, and then incorporated 3" deep with a three-row bed shaper. Tomato transplants were planted with a hand trowel into treated beds in a single line, with plant root plugs placed either directly into the herbicide-treated zone (<2" deep) or below the herbicide zone (4-5" deep). Sprinkler irrigation was used to apply 1.5" of water immediately after planting, and then all plots were irrigated with buried drip the rest of the season. Effects on tomato growth were measured by visually rating above-ground growth and determining shoot and root dry weights (DW) at 7, 14, 21, and 35 days after treatment (DAT). To determine shoot and root DW, two plants per plot were removed with a shovel, the soil washed from the roots with water, and plants clipped at the top of each root plug. Shoot and root portions were oven-dried at 110 °F for seven days then weighed. Plots were not taken to yield.

Results from the study showed that plots not treated with a preplant herbicide had the best overall above-ground plant growth and produced the highest shoot and root DW (table 1). Although plots treated with DNA herbicides (trifluralin and pendimethalin) alone had significantly lower root DW than no herbicide plots at 35 DAT, top shoot DW were not different than the no herbicide plots. All other herbicide treatments produced significantly lower shoot and root DW and above-ground growth.

Planting depth had a significant impact on tomato growth and shoot and root DW at 35 DAT (table 2). Planting shallow resulted in a 12%, 37%, and 24% reduction in visual plant growth, shoot DW, and root DW, respectively. Results were similar when comparisons were made without including the no herbicide treatment in the evaluation (data not shown).

When we took into consideration both herbicide and planting depth effects, data at 35 DAT showed that all of the herbicides used resulted in a reduction in root DW, regardless of planting depth (table 3). However, shoot DW of trifluralin- and pendimethalin-treated plots were similar to that of no herbicide plots, except where tomatoes were planted shallow in pendimethalin-treated plots, in which case shoot DW was reduced. Similarly, plots treated with s-metolachlor, pendimethalin + s-metolachlor, and sulfentrazone had a lower shoot DW when tomatoes were planted shallow.

Table 1. Tomato growth and dry weights sorted by herbicide treatment

Herbicide	Growth[1] 21 DAT	Growth[1] 35 DAT	Shoot DW[2] 21 DAT	Shoot DW[2] 35 DAT	Root DW[3] 21 DAT	Root DW[3] 35 DAT
trifluralin	8.8 ab	9.4 a	11.80 a	113.86 a	2.32 b	5.93 b
pendimethalin	8.3 b	8.6 b	10.60 a	92.06 ab	2.28 b	4.29 cd
s-metolachlor	6.8 c	8.0 bc	6.98 b	73.63 bc	1.20 c	5.17 bc
pendimethalin+ s-metolachlor	5.5 c	7.5 c	4.88 c	77.78 b	0.76 d	3.44 de
sulfentrazone	5.7 c	6.8 d	5.24 c	49.83 c	1.14 c	2.60 e
no herbicide	9.8 a	9.9 a	12.15 a	113.08 a	2.67 a	8.39 a
P=0.05 *CV (%)*	*7.13*	*9.47*	*16.07*	*24.26*	*17.77*	*17.42*
LSD	*1.35*	*0.68*	*1.70*	*24.74*	*0.34*	*1.82*

[1]Growth rating based on a visual rating of 0 to 10; 0 = plants dead and 10 = vigorous, healthy plants
[2]Shoot (gm); includes plant portion above root plug and [3]Root (gm); includes plant plug and roots

Table 2. Tomato growth and dry weights sorted by planting depth

Planting Depth	Growth[1] 21 DAT	Growth[1] 35 DAT	Shoot DW[2] 21 DAT	Shoot DW[2] 35 DAT	Root DW[3] 21 DAT	Root DW[3] 35 DAT
Normal (4 to 5” deep)	8.2 a	8.9 a	10.06 a	106.17 a	2.05 a	5.64 a
Shallow (<2” deep)	6.8 b	7.8 b	7.16 b	67.24 b	1.41 b	4.30 b
P=0.05 *CV (%)*	*7.13*	*9.47*	*16.07*	*24.26*	*17.77*	*17.42*

[1]Growth rating based on a visual rating of 0 to 10; 0 = plants dead and 10 = vigorous, healthy plants
[2]Shoot (gm); includes plant portion above root plug and [3]Root (gm); includes plant plug and roots

Table 3. Tomato growth and dry weights sorted by herbicide treatment and planting depth

Herbicide	Planting depth	Growth[1] 21 DAT	Growth[1] 35 DAT	Shoot DW[2] 21 DAT	Shoot DW[2] 35 DAT	Root DW[3] 21 DAT	Root DW[3] 35 DAT
trifluralin	4 to 5”	9.8 a	9.8 ab	14.02 a	134.97 a	2.59 ab	7.01 bc
trifluralin	<2”	7.7 b	8.9 abc	9.57 bc	92.75 a-d	2.05 bc	4.85 de
pendimethalin	4 to 5”	9.7 a	9.5 ab	11.83 ab	111.18 ab	2.83 a	4.92 de
pendimethalin	<2”	7.0 bc	7.7 cd	9.37 bcd	72.95 b-e	1.72 c	3.67 efg
s-metolachlor	4 to 5”	8.0 b	8.2 bcd	8.91 cde	94.48 a-d	1.43 cd	5.77 cd
s-metolachlor	<2”	5.7 de	7.8 cd	5.04 fg	52.78 de	0.97 de	4.58 def
pendimethalin + s-metolachlor	4 to 5”	5.7 de	8.3 bcd	6.57 def	101.13 a-c	1.00 de	4.40 def
pendimethalin + s-metolachlor	<2”	5.3 de	6.7 de	3.19 g	54.43 de	0.52 e	2.48 g
sulfentrazone	4 to 5”	6.3 cd	7.5 cde	6.20 ef	60.16 c-e	1.57 cd	2.91 fg
sulfentrazone	<2”	5.0 e	6.0 e	4.27 fg	39.50 e	0.70 e	2.29 g
no herbicide	4 to 5”	9.8 a	10.0 a	12.80 a	135.12 a	2.86 a	8.85 a
no herbicide	<2”	9.8 a	9.8 ab	11.50 abc	91.04 a-d	2.47 ab	7.98 ab
P=0.05	*CV (%)*	*7.13*	*9.47*	*16.07*	*24.26*	*17.77*	*17.42*
	LSD	*1.12*	*1.66*	*2.90*	*44.15*	*0.64*	*1.82*

[1]Growth rating based on a visual rating of 0 to 10; 0 = plants dead and 10 = vigorous, healthy plants
[2]Shoot (gm); includes plant portion above root plug and [3]Root (gm); includes plant plug and roots

Transplanting tomatoes shallow into soil previously treated with DNA herbicides can cause reduced shoot and root growth, although the amount of root growth reduction may not necessarily reflect an equal reduction in shoot growth. Not surprisingly, this confirms the fact that growers need to make sure tomato transplants are place below the herbicide-treated soil or shoot and root DW and above-ground growth will likely be reduced. This helps explain what we had observed in commercial tomato fields.

Surprisingly, it appears from this study that pendimethalin negatively affected shoot and root growth more so than trifluralin. Pendimethalin (Prowl H2O) was registered in California in 2008 as a preplant incorporated herbicide option for tomato growers. While DNA herbicides are not thought to be mobile in the soil, our data and observations suggest that downward movement of pendimethalin through the soil profile may have occurred, since water from the buried drip tape was not a limiting factor, and tomato roots in pendimethalin-treated plots was clearly reduced. A similar argument could be made where s-metolachlor and sulfentrazone were used. It's not clear if the initial sprinkler irrigation contributed to any downward movement of herbicides. Although the soil was not tested for the presence of DNA herbicides before or after treatment, no DNA herbicides were applied to this field location for at least 12 months before the project was started.

Additional work needs to be done where tomatoes are grown on semi-permanent beds with buried drip irrigation and shallow tillage to determine the extent to which this production technique (conditions of low soil surface moisture and reduced soil mixing) may have on DNA herbicide carryover and potential impacts on tomato growth and fruit yield.