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Hairy Vetch Mulch Favorably Impacts Yield of Processing Tomatoes

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Abstract. **Ten cultivars of processing tomatoes (*Lycopersicon esculentum* Mill.) grown in bare soil or on black polyethylene and hairy vetch (*Vicia villosa* Roth.) mulches were evaluated for yield, fruit processing quality, and leaf necrosis. Yields were higher, fruit was heavier, and leaf necrosis less in hairy vetch than in bare soil or black polyethylene mulch. With the exception of pH, yield and fruit quality component responses to mulch treatments were not cultivar-dependent. Fruit pH, soluble solids concentration, and color equaled values obtained using bare soil production practices. Percent solids was highest with black polyethylene and lowest in hairy vetch. The hairy vetch mulch delayed fruit maturity compared to the bare soil and black polyethylene. The hairy vetch cultural system has the potential to increase yield of processing tomatoes.**

Tomatoes grown for processing represent the largest segment of the processed vegetable industry in North America. The United States produces ≈48% of the world's supply of tomatoes grown for processing (Sullivan and Ravara, 1990). The crop occupies ≈142,000 ha with a total yield of more than 10 million t and an annual farm gate value of $700 million [U.S. Dept. of Agriculture (USDA, 1991)]. More than 90% of total production in the United States is grown in California (Bennett, 1988).

In the mid-Atlantic United States, processing tomatoes are viewed as a low investment crop. Because of occasional dry spells and irregular rainfall during the growth period, most processing tomato fields receive three to five irrigations (Garrison and Mangano, 1993; Garrison and Russell, 1991; Orzolek and Kaplan, 1984). The crops often encounter environmental stress, including high temperature (Garrison and Russell, 1991), drought (Orzolek and Kaplan, 1994), and long periods of rain and high humidity (Garrison and Mangano, 1993), which increase damage by pathogens, interfere with optimum harvest, and reduce yield and quality. As a result, major fluctuations in yield from year to year make production of processing tomatoes in the eastern states more risky and less competitive with favorable locations, such as California. Average yields in the mid-Atlantic states are ≈47 $t \cdot ha^{-1}$ (USDA, 1991) as compared to >84 $t \cdot ha^{-1}$ in California (Johannessen, 1990).

The greatest limitation to yield has been attributed to an unbalanced shoot/root system in which root growth and development are limited by soil compaction (Johannessen, 1990). Compacted soils restrict water movement and availability and reduce drainage and aeration. Frequent use of heavy machinery, such as those used in plowing and cultivation, contributes significantly to soil compaction. Alternative production systems that combine reduced tillage with cover crops effectively reduce soil compaction and improve water penetration, drainage, soil aeration, and yield (Abdul-Baki and Teasdale, 1993a).

Various winter annual cover crops have been evaluated for vegetable crop production singly (Abdul-Baki and Teasdale, 1993b; Stivers and Shennan, 1991) or in mixtures (Creamer, 1994). The impact of these alternative cultural practices on tomato production has been favorable (Creamer, 1994). Yields were higher and fruit quality was better in these than in the conventional systems, resulting in greater profit (Kelley et al., 1995). Our preliminary results on four processing tomato cultivars demonstrated a positive effect of hairy vetch mulch on yield and average fruit weight when compared to conventional production systems (Abdul-Baki et al., 1993b). Our objective in this research was to determine the effects of hairy vetch and black polyethylene mulch on yield, fruit weight, product quality, and foliage necrosis of 10 processing tomato cultivars.

Materials and Methods

The experiments were conducted in Summer 1994 at the farm of the Beltsville Agricultural Research Center, Beltsville, Md. The soil is a Keyport fine loam (clayey, mixed, mesic Acquic Hapludult) with 2% slope. Two mulch treatments (black polyethylene and hairy vetch) were compared to bare soil, the conventional method for growing processing tomatoes commercially. Plots were organized in a split-plot design with mulch as whole plots and cultivars as subplots, each subplot consisting of 12 plants spaced 37 cm within the single row. Treatments were replicated four times with 14 plants per replicate. Ten commonly planted cultivars of processing tomatoes, representing early, midseason, and late maturity, were selected (Table 1). Except for 'Red Rock', which was developed by the USDA as an extra-firm cultivar for fresh market and processing, seeds for all cultivars were obtained from commercial sources.

Seeds were sown in a greenhouse on 13 Apr. in 128-cell flats (cell size $3 \times 3 \times 7$ cm) filled with Jiffy Mix (50% peat : 50% horticultural grade vermiculite). Flats were fertilized with a solution containing Peters 20N–8.8P–16.6K (Grace Sierra Horticultural Products, Milpitas, Calif.) at 37 $g \cdot liter^{-1}$ water. The seedlings were maintained for 4 weeks in the greenhouse and 1 week in a cold frame and transplanted on 17 May.

Beds, 1.5 m center to center and 15 cm high, were prepared and the drip irrigation lines were laid as described by Abdul-Baki and Teasdale (1993b). Beds for the hairy vetch mulch treatment were prepared in mid-Sept. 1993. The hairy vetch seed was sown on 24 Sept. at 45 $kg \cdot ha^{-1}$ using a Brillion seeder (Brillion Iron Work, Brillion, Wis.). The hairy vetch received no water, herbicide, fertilizer, or any other treatment until it was mowed on 16 May 1994 with a high-speed flail mower (Hesston Corp., Oregon, Ill.). It cut the plants ≈3 to 5 cm above the bed surface.

Beds for the black polyethylene and bare soil treatments were prepared on 13 May 1994 as described earlier (Abdul-Baki and Teasdale, 1993a). The tomato seedlings were planted using a minimum tillage planter developed by Morse (Morse et al., 1993). Peters starter fertilizer (9N–19.6P–12.5K) was applied at 37 $g \cdot liter^{-1}$ water as part of the planting process. The drip lines in the bare soil and polyethylene treatments were buried 5 cm deep in the soil and 8 to 10 cm away from the plants. In the hairy vetch treatment, drip lines were laid on the vetch mulch 8 to 10 cm away from the plants and held in position with U-shaped wire at 5-m intervals.

Plots were irrigated every other day to avoid water stress. Colorado potato beetles were controlled using Bt-based insecticides.

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Fungicides tetrachloroisophthalonitrile (chlorothalonil) and copper hydroxide were applied as needed using manufacturers' suggested rates, and 4-amino-1,1-dimethlylethyl-3-(methylthio)-1,2,4-triazin-5(4*H*)-one (metribuzin at 0.56 kg•ha^{-1}) was applied as a postemergence herbicide 3 weeks subsequent to planting. Fertilizer application was limited to soluble N applied through the drip system in equal portions weekly over 13 weeks as $Ca(NO_3)_2$, using a total of 56 kg•ha^{-1} for the hairy vetch plots and double that rate for the bare soil and polyethylene mulch.

Multiple nondestructive hand harvests were made to investigate treatment effect on speed of maturation. One sample (20 fruit) was taken from each replication for quality determination using pH, soluble solids concentration (SSC), percent solids, and fruit color as quality indices (National Food Processors Assn., 1992). Another sample (≈200 fruit) was taken to determine average fruit weight. Yield was evaluated according to Garrison and Rossell (1991). Total yield was the sum of the red fruit picked at all harvests plus those mature green, which were picked only at the last harvest. Plant necrosis as affected by mulch type was evaluated on 19 Aug. and 2 Sept. by four independent evaluators scoring percent necrotic leaf area that exhibited necrosis. As results were similar at each date, data were combined for analysis. Analysis of variance was performed using SAS version 6.08 General Linear Models procedure.

Results

Processing tomato yields for bare soil and black polyethylene and hairy vetch mulches differed significantly between mulches and among cultivars (Table 1). Lack of a significant mulch × cultivar interaction indicated that cultivars responded similarly to mulch treatments (Table 2). Average yields of the 10 cultivars in bare soil were not significantly different from those in black polyethylene and averaged 82 t•ha^{-1} (Table 1). Average yield of the 10 cultivars in the hairy vetch mulch was 26.3 t•ha^{-1} higher than that in bare soil. The greatest yield response due to hairy vetch was in 'Ohio 8245' (43%), followed by 'Nema 1200' (42%), and the least was in 'Red Rock' (15%). Our yields were higher than those reported in California (USDA, 1991), partly because we had multiple nondestructive instead of one destructive harvest. The highest yields were with 'Hypeel 696'.

Yields harvested at various time intervals indicate that crop maturity was similar in bare soil and black polyethylene (Table 3). Most of the yield in these treatments matured during the second and third harvest intervals. Harvest in hairy vetch was delayed and most of the crop matured during the fourth harvest interval.

Like yield responses, average fruit weights in the bare soil and black polyethylene treatments were similar and averaged 73 g/fruit. Average fruit weight in the hairy vetch (87 g) was significantly higher than that for the others. Preliminary data obtained in 1993 are consistent with the present results demonstrating an increase in yield and average fruit weight in tomatoes grown on hairy vetch mulch (Abdul-Baki and Teasdale, 1993b).

The percentage of foliar necrosis was similar in bare soil and black polyethylene and higher than that noted in hairy vetch (Table 4). Likewise, significant differences in the percentage of necrosis were noted among cultivars. 'Heinz 1439', 'Hypeel 696', 'Ohio 8245', 'Red Rock', and 'Hybrid 882' exhibited the least necrosis, whereas 'Nema 1200' and 'FM6203' exhibited the most, but these did not differ significantly from 'Spectrum 579'. Hairy vetch reduced average necrosis by ≈50% over bare soil and black polyethylene. Similar to yield observations, no mulch × cultivar interaction was evident (Table 2).

Mulches had a significant effect on fruit pH and solids (Table 5). Lack of significant cultivar × mulch interaction indicates that SSC, solids, and color responses to mulch treatments were not cultivar-dependent. Fruit pH for plants grown with hairy vetch and bare soil treatments were similar, but it was significantly higher with hairy vetch than black polyethylene (Table 5). Percent solids was highest with black polyethylene and lowest with hairy

Table 1. Yields of processing tomato cultivars grown in bare soil, black polyethylene film, and hairy vetch mulches.

	Yield (t•ha^{-1})			
Cultivar	Bare soil	Black polyethylene	Hairy vetch	Mean[z]
Brigade	92.5	82.9	119.8	98.4 b
FM 6203	73.7	67.2	91.2	77.4 cd
Heinz 1439	79.3	90.5	108.7	92.8 b
Hybrid 882	79.2	85.9	106.6	90.6 bc
Hypeel 696	96.8	116.3	134.3	115.8 a
Nema 1200	64.7	62.8	92.1	73.2 d
Nema 1400	79.7[y]	84.7	95.2	86.2 b–d
Ohio 8245	85.9	84.5	122.8	97.7 b
Red Rock	86.3	78.5	99.2	88.0 bc
Spectrum 579	80.2	72.2	111.3	87.9 bc
Mean[z]	81.8 b	82.5 b	108.1 a	

[z]Letters denote mean separations based on protected least significant difference test ($P \leq 0.05$).

Table 2. Analyses of variance for yield, necrosis, and fruit quality components of processing tomato cultivars as a function of cultivar and mulch.

Source	df	F value	Probability
Variable: Yield			
Block	3	12.12	0.0001
Mulch	2	10.72[z]	0.0104[z]
Block × mulch	6	2.77	0.0168
Cultivar	9	5.57	0.001
Mulch × cultivar	18	0.57	0.9113
Variable: Necrosis (%)			
Block	3	33.53	0.0001
Mulch	2	7.38	0.0241[z]
Block × mulch	6	10.16	0.0001
Cultivar	9	5.88	0.0001
Mulch × cultivar	18	0.90	0.5819
Variable: pH			
Mulch	2	16.79	0.0314
Cultivar	9	14.05	0.0001
Mulch × cultivar	18	2.79	0.0008
Variable: SSC[y]			
Mulch	2	1.96	0.3383
Cultivar	9	19.80	0.0000
Mulch × cultivar	18	1.16	0.3160
Variable: Solids (%)			
Mulch	2	11.6	0.0001
Cultivar	9	16.6	0.0001
Mulch × cultivar	18	1.07	0.3965
Variable: Fruit color			
Mulch	2	1.90	0.2925
Cultivar	9	33.45	0.0001
Mulch × cultivar	18	1.18	0.2290

[z]F values of probability using block × mulch as error term.
[y]SSC = soluble solids concentration.

Table 3. Percentage of total yield harvested at each of four harvest intervals as influenced by mulch.

	Percentage of total yield by harvest interval[z]			
Mulch	1	2	3	4
Bare soil	16 a[y]	32 b	39 a	13 b
Black polyethylene	19 a	42 a	24 b	15 b
Hairy vetch	0 b	12 c	25 b	63 a

[z]Interval 1 = 1–3 Aug.; Interval 2 = 8–11 Aug.; Interval 3 = 15–22 Aug.; Interval 4 = 30 Aug.–27 Sept.
[y]Mean separation, within harvest intervals, according to an LSD test ($P \leq 0.05$)

Table 4. Percent necrosis in foliage of processing tomato cultivars grown with bare soil or mulches.

	Necrosis (%)			
Cultivar	Bare soil	Black polyethylene	Hairy vetch	Mean
Brigade	26[z]	37	13	25 c[y]
FM 6203	39	45	19	34 a
Heinz 1439	21	30	13	21 c
Hybrid 882	25	27	15	22 c
Hypeel 696	26	32	15	24 c
Nema 1200	46	44	24	38 a
Nema 1400	29	40	13	27 bc
Ohio 8245	25	40	13	26 c
Red Rock	31	31	10	24 c
Spectrum 579	40	42	17	33 ab
Mean[y]	31 a	37 a	15 b	

[z]Means of four independent raters over two dates.
[y]Letters denote mean separations based on least significant difference, $P \leq 0.05$.

Table 5. Fruit quality components of processing tomato cultivars as affected by mulch type.

	Mulch type		
Quality component	Bare soil	Black polyethylene	Hairy vetch
pH	4.45 ab[z]	4.40 b	4.50 a
SSC[y]	4.2 a	4.2 a	4.1 a
Solids (%)	5.0 b	5.1 a	4.8 c
Color	43 a	41 a	45 a

[z]Letters denote mean separations based on least significant difference ($P \leq 0.05$) for individual quality components compared across treatments.
[y]SSC = soluble solids concentration.

vetch. SSC and color values of fruit were similar for all mulch treatments.

Discussion

The shift in processing tomato production from the mid-Atlantic and midwestern United States to California was the result of market pressure for low production cost. The fact that processing tomatoes are not among the high-value cash crops leaves the producers with a narrow margin of profits. Favorable climate, sophisticated mechanization, and large-scale farming in California increased yield by ≈35 t·ha^{-1} compared to the mid-Atlantic states and reduced production costs, making production in the mid-Atlantic states less attractive (Sullivan, 1992). If yields could be improved at no additional production cost, processing tomato production in the mid-Atlantic states has the potential to increase.

Our results suggest that growing processing tomatoes in a hairy vetch mulch can significantly increase yields and may make production in the mid-Atlantic states more profitable. The production cost in the hairy vetch system would exceed production cost in the bare soil system because of the additional cost of vetch seed ($84/ha) and mowing ($15/ha). However, the profit from increased yield and reduced N input in the hairy vetch production may offset these production costs. Increasing N application in the bare soil system could potentially provide equivalent yield at an about equivalent cost, which could require N rates exceeding recommended levels and increase the potential for environmental contamination. In addition, research with corn (*Zea mays* L.) has shown that the increases in yield and economic return by hairy vetch are not only due to N but also to additional factors relating to improved soil structure and water use efficiency (Decker et al., 1994). Similar results were observed with fresh-market tomatoes (Kelly et al., 1995).

Yields of all cultivars in our test responded favorably to the hairy vetch mulch treatment, suggesting that the observed yield response is not cultivar-dependent. Similar favorable yield responses were noted in cultivars of fresh-market tomatoes grown in hairy vetch mulch as compared to polyethylene mulch (Abdul-Baki and Teasdale, 1993a). Lower levels of leaf necrosis in the hairy vetch mulch late in the season presumably permitted plants to increase leaf area duration and produce photosynthate for an extended period of time, thus increasing production potential. Further studies are needed to address potential causes of foliar necrosis.

Although yields in the hairy vetch mulch averaged 32% more than for bare soil, percent solids were lower in fruit from the hairy vetch plots compared to black polyethylene or bare soil. The increase in yield, however, more than compensates for this slight reduction in fruit solids. Since no significant differences were evident for fruit pH, color, or SSC between hairy vetch and current production practices, which employ bare soil culture, hairy vetch culture lends itself quite well to present industry expectations of fruit quality.

In summary, hairy vetch mulch increased tomato yield and fruit weight and decreased foliar necrosis in processing tomatoes. With the exception of fruit solids, quality components measured on fruit from hairy vetch treatments equaled those obtained using present bare soil production practices. The slight decline in solids is more than offset, however, by the potential increase in yield using hairy vetch mulch. Adoption of cultural systems employing hairy vetch mulch in applicable production regions has the potential to increase yield for processing tomatoes.

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