Impact of Reduced Fungicide and Tillage on Foliar Blight, Fruit Rot, and Yield of Processing Tomatoes

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ABSTRACT

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The effect of reduced tillage, soil-surface crop residue maintenance, and reduced fungicide input on processing tomato yield and disease incidence was studied in 1990 to 1992. Fall-seeded rye was desiccated in strips in early spring; the remainder, after 1.2 m of growth. Strips were zone tilled (ZT) 35 cm deep with no soil inversion. The ZT system permitted desiccated inter-row rye residue to persist throughout the summer, providing approximately 90% cover of the soil surface. Tomatoes were transplanted into the prepared strips. The ZT system did not affect marketable yield or percent fruit with mold (1991 to 1992); but it decreased (1990), increased (1991), and did not affect (1992) defoliation caused by early blight (EB) compared to a conventional tillage production system using a moldboard plow, disk, or both. The fungicide, Bravo 720 (chlorothalonil), was applied as follows: none, weekly, or a full or reduced rate at intervals according to the disease forecasting model, TOM-CAST. Fungicide treatment did not enhance marketable yield compared to that of the unsprayed treatment. TOM-CAST–based treatments did not consistently provide control of defoliation compared to that in plots sprayed weekly. However, compared to weekly sprays, select forecast-generated spray schedules required 45 to 80% fewer applications to limit fruit mold incidence caused by *Alternaria solani* (EB), *Colletotrichum coccodes* (anthracnose), and *Rhizoctonia solani* (soil rot). Conservation tillage practices, soil-surface residue maintenance, and reduced fungicide input were integrated without compromising yield and management of disease, affording advantages of sustained farmland productivity.

Additional keywords: cover crop, disease forecaster, integrated pest management, sustainable agriculture, zone tillage

Over 25,000 ha of tomatoes are grown in Michigan, Ohio, Indiana, and Ontario (the north central production region), with an estimated annual farm gate value of $145 million dollars (16,28). Current processing tomato (PRT) yields approach 70 $t \cdot ha^{-1}$ compared to 5 to 8 $t \cdot ha^{-1}$ recorded by Brown in 1929 (3). Such advances have been augmented by superior cultivars, specialization, mechanization, intensive soil tillage with high fertilizer inputs, and significant chemical control of weeds, insects, and disease. However, such "conventional" high-input production systems raise production costs and are counterproductive to a sustainable agricultural system (8). Research to decrease agricultural inputs without compromising crop yield and quality is needed. Alternative production systems emphasize the reduction of pesticide input and topsoil loss (29) through weather-based fungicide applications and reduced tillage practices, respectively (8,23,25,29).

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Reduced fungicide use on PRT has been implemented using disease forecasting programs without increasing disease-related losses in the north central region (2,10). A forecast system for early blight (EB) caused by *Alternaria solani* on tomato (FAST) was developed by Madden et al. (13), identifies favorable EB periods, and suggests fungicide spray timing, resulting in fewer sprays (13,17). Pitblado (18) simplified FAST into TOM-CAST, effective against several tomato foliar and fruit diseases, including EB, anthracnose, and Septoria leaf spot.

In contrast, reduced tillage practices have not been sufficiently developed or implemented in the north central region. Moldboard plowing and intensive tillage are considered crucial for breaking the life cycle of pests (22,27), and excess surface-crop residue in no-till fields has been associated with reduced tomato yields (21). However, surface residue is a key factor in limiting topsoil losses. To decrease adverse effects on yield, McKeown et al. (14) tilled cover crops in strips before field-setting tomato transplants, and they obtained identical yields for 2 years but reduced them a third year. Therefore, reduced-tillage systems that do not reduce tomato yield but provide adequate coverage of bare soil need to be designed.

Designing reduced tillage management practices has not always included a plant pathology component (27,29). Benefits of reduced tillage, reduced fungicide input, and their possible interactions on PRT productivity and disease incidence need evaluation. For example, thresholds for tomato fruit mold incidence that determine processing acceptability are low (10,20), and reduced-tillage practices that result in increased fruit mold incidence are unacceptable.

Our objectives were to evaluate the effects of ZT and TOM-CAST on yield and disease incidence, and to determine if TOM-CAST recommendations would need to be modulated with reduced-tillage practices.

MATERIALS AND METHODS

Location and design of field experiments. Field experiments were conducted in 1990 to 1992 on a Spinks sandy loam (87.4% sand, 6.0% silt, and 6.6% clay) at the Southwest Michigan Research and Extension Center, Benton Harbor. Seedlings of Ohio 7870 (1990) or Heinz 8704 (1991-92) PRT were grown in a commercial greenhouse in 288-cell flats for 4 to 5 weeks. Seedlings were transplanted in late May or early June each year using a single-row transplanter with double-disk openers and a wide rubber drive wheel. Transplants were spaced 0.3 m on 1.5-m centers.

A split-split plot design was used with four replicates in randomized complete blocks. Each replicate was two 12 × 84 m main plots (eight in total) separated by approximately 9 m of sod. Main-plot treatments included continuous tomato (1990 to 1992) or tomato rotated with the pickling cucumber cv. Flurry, which was direct-seeded in early June 1991. Immediately after cucumbers were harvested, plots were disked and seeded to a mustard green manure crop that grew until disk-incorporated late October. (The mustard crop was chosen for its potential to reduce inoculum of plant pathogens [15], to grow rapidly as a source of organic matter, to protect sandy soils from erosion, and to retain nutrients that otherwise might leach from the soil [23]. The mustard crop was included as part of the production system, and the experiment was not designed to determine its potential benefits.) Continuous tomato production was used to provide high disease pressure. Standard commercial cultural practices were used for fertilization, irrigation, and weed and insect control.

Tillage. Each main plot was subdivided into two 12 × 42 m subplots. Conventional tillage consisted of spring moldboard plowing 20 to 23 cm deep when the fall-seeded rye was 15 to 20 cm tall. The field was disked, dragged, or both, once or twice more before planting. For ZT, paraquat (Gramoxone 1.1 kg a.i.·ha^{-1}) was applied in late March or early April in strips 0.46 m wide on 1.5-m (row) centers to minimize rye biomass for tomato or cucumber plantings. The Tye paratill (Tye Company, Lockney, Texas) fractured the soil to approximately 35 cm deep with minor surface disturbance and no soil inversion. The interrow rye was desiccated with paraquat when it reached a height of 1 to 1.2 m. Tillage was not necessary to drill rye into the ZT plots following the 1990 tomato harvest. However, the next spring, soil compaction warranted ZT on row centers that had tomato plants.

Fungicide treatment. Each subplot was divided into seven 12 × 6 m sub-subplots (for a 2 × 2 × 7 factorial design [n = 112]), which consisted of one row for data collection (inner 6-m section) and three treated (border) rows. Fungicide sprays were as follows: none, weekly, or sprayed at intervals according to TOM-CAST (18) (Table 1). Seven treatments, one duplicated, were applied in 1990 to 1991, and seven in 1992 (Table 1). Hourly mean temperature and leaf wetness were recorded using Omnidata model DP223 (Omnidata International, Inc., Logan, Utah). Three disease severity values (DSV) (15, 20, and 25 DSV) were adopted as bench marks for spraying chlorothalonil (Bravo 720) at the recommended rate (4.2 liters·ha^{-1}; F) or at a reduced rate (2.8 liters·ha^{-1}; R). The initial spray depended on planting date or cumulative DSVs according to TOM-CAST (Table 1) (10).

Fungicides were applied with a hand-held boom connected to an FMC tractor-drawn sprayer. The boom width was adjusted with plant growth to 1.2 m, and there were four swivel T-Jet nozzles, two on the boom (45°) and two on 35-cm drop nozzles (90°). The pressure was 667 kPa at the sprayer pump, and 836 liters·ha^{-1} was applied.

Assessment of surface rye residue. Percentage of rye residue coverage of the soil surface was estimated at monthly intervals in 1991 to 1992 (26). A string with 50 knots spaced 6 inches apart was laid across each plot. The number of knots that touched surface residue was counted and expressed as a percentage of total knots. This percentage correlates with percent cover of soil surface (26).

Assessment of foliar disease. Percentage of defoliation caused by EB was visually assessed weekly in the 6-m row section until 2 weeks before harvest.

Tomato harvest and assessment of fruit mold incidence. Plants were treated with ethephon (Ethrel) at 2.8 liters·ha^{-1} (1990) or 4.2 liters·ha^{-1} (1991 to 1992) 2 weeks before harvest. Harvest dates were 18 September 1990, 29 August 1991, and 29 September 1992. Fruit from 6 m of row were harvested and weighed for total yield. Subsequently, 20-liter subsamples were rated according to market standards for ripe fruit and incidence of EB, anthracnose (ANTH; *Colletotrichum coccodes*), and soil rot (SR; *Rhizoctonia solani*) without regard for disease severity. Categorized data were expressed as a percentage of the total weight of fruit evaluated.

Data analysis. The experiment determined the effect of fungicide treatment, tillage, a 1-year rotation, and their interactions. All data displayed homogenous variance (unless noted otherwise) as determined by Bartlett's test and analysis of variance (ANOVA) (7,12). A two-way factorial analysis was performed (12) with fungicide treatment as a split plot of tillage. There were eight replicates for 1990 foliar disease incidence and fruit yield (n = 112) and four for fruit mold incidence (n = 56); four for 1991 foliar disease incidence (n = 56) and fruit yield (n = 56). Certain plots were above a field tile that malfunctioned; no fruit harvest values were obvious outliers in 1990, but AUDPC values in four of 112 plots were outliers, and new values were substituted using the MISVALEST subroutine of MSTAT-C (Michigan State University), and degrees of freedom were corrected accordingly in the total error mean square. No outliers were noted in 1991. In 1992, the problem persisted and affected two replicates of a complete treatment (i.e., many sub-subplots in CT subplots in rotation main plots). Because of unreliable data for two replicates, means were calculated based on observations collected from the two remaining replicates (four 12 × 84 m main plots). Rotation did not show significant effects for all parameters in a three-way

Table 1. Date of fungicide treatment, number of fungicide applications, and date of initial fungicide application (1990, 1991, and 1992)

	Number of fungicide applications (date of first application)[v]		
Fungicide treatment	**1990**	**1991**	**1992**
Weekly	15 (15 June)	11 (16 June)	13 (25 June)
DSV[w] 15R[x]	NA[y]	6 (26 June)	5 (16 July)
DSV 15F	NA	6 (26 June)	4[z]
DSV 20R	4 (11 July)	4 (26 June)	4 (16 July)
DSV 20F	4 (11 July)	4 (26 June)	3[z]
DSV 25R	3 (11 July)	NA	NA
DSV 25F	3 (11 July)	NA	3 (16 July)
No spray	0	0	0

[v] Date of initial application for weekly or TOM-CAST–based spray programs.
[w] Fungicide applied after the accumulation of every 15, 20, or 25 disease severity values (DSV).
[x] R = reduced rate of chlorothalonil (Bravo 720, 2.8 liters·ha^{-1}); F = full rate of chlorothalonil (4.2 liters·ha^{-1}).
[y] Treatment not applied during this year.
[z] Initial recommended spray inadvertently omitted.

Table 2. Back-transformed values for the area under the disease progress curve for early blight on processing tomato. Analysis of variance and mean separation were based on log-transformed data

Fungicide treatment[x]	1990[y]	1991	1992
Weekly	69 d	154 c	290 c
DSV 15R	...	252 b	511 b
DSV 15F	...	216 b	457 b
DSV 20R	91 bc	226 b	504 b
DSV 20F	83 cd	205 b	436 b
DSV 25R	100 bc	...	...
DSV 25F	107 b	...	422 b
No spray	156 a	447 a	989 a
Tillage treatment			
CT	108**[z]	212**	506
ZT	85	308	462

[x] Chlorothalonil was applied as follows: none, weekly, or as TOM-CAST–based full (F) and reduced (R) rates after the accumulation of every 15, 20, or 25 disease severity values (DSV).
[y] Values are means of eight, four, and four replicates for 1990, 1991, and 1992, respectively. Means within each column are separated by the least significant difference (LSD) test (12, $P = 0.05$).
[z] ** = F test significant at $P = 0.01$.

factorial analysis, and therefore two main plots under continuous tomato and two subject to a 1-year rotation were analyzed as four replicates using a two-way factorial model (n = 56 rather than 112) to test the effect of fungicide and tillage.

Mean areas under the disease progress curve (AUDPC) expressed as percent–days were calculated (24) as

$$AUDPC = \sum_{i=1}^{n-1}\left[\frac{(Y_{i+1} + Y_i)}{2}\right]\left[(t_{i+1} - t_i)\right]$$

where Y_i = disease severity at the ith observation, t_i = time (days) after the initial rating at the ith observation, and n = total number of observations. Variance of AUDPC values was not homogeneous each year. Therefore, AUDPC was transformed to $\log_{10}$ before ANOVA and separation of means. All AUDPC values reported are back-transformed (antilog) data.

Correlation or regression analyses among data sets were performed using Pearson's correlation coefficient or a model that provided good fit, respectively.

RESULTS

Persistence of rye surface residue. Allowing the rye between the row centers in ZT plots to grow to 1.2 m prior to desiccation facilitated persistence of a soil cover throughout the growing season each year. For example, in 1992, surface residue covered 3.3% or less of the soil surface in CT plots compared to >90% in ZT plots. Data from 1991 were similar.

Impact of rotation, tillage, and fungicide on disease incidence and fruit yield. In 1992, rotation did not cause significant effects for all measured parameters in a three-way factorial analysis. Therefore, the data were analyzed for tillage and fungicide effects only, as described above. Analysis of variance demonstrated that no interactions between tillage and fungicide occurred over the 3-year study. Therefore, we report the main effects of tillage and the main effects of fungicide for each parameter measured.

Tillage effects on foliar disease caused by EB. There was no consistent effect of tillage on defoliation caused by EB. In 1990, ZT decreased severity of defoliation caused by EB compared to CT (Table 2, Fig. 1A). In 1991, planting tomatoes in the same plots used in 1990 resulted in higher levels of defoliation in ZT plots (Table 2, Fig. 1B). Overwintered tomato residue was abundant in these ZT plots prior to transplanting the new crop. Finally, tillage did not affect defoliation in 1992 (Table 2, Fig. 1C).

Fungicide effects on foliar disease caused by EB. Fungicide treatments reduced defoliation compared to that in the unsprayed plot each year (Table 2). In 1990, full-rate fungicide applied every 20 DSVs provided foliar disease control comparable to that with weekly fungicide applications (Table 2). The DSV 25F and reduced fungicide-rate treatments resulted in less control than that in plots sprayed weekly (Table 2). In 1991 and 1992, weekly fungicide applications more effectively limited foliar disease than did fungicide sprays applied according to TOM-CAST (Table 2).

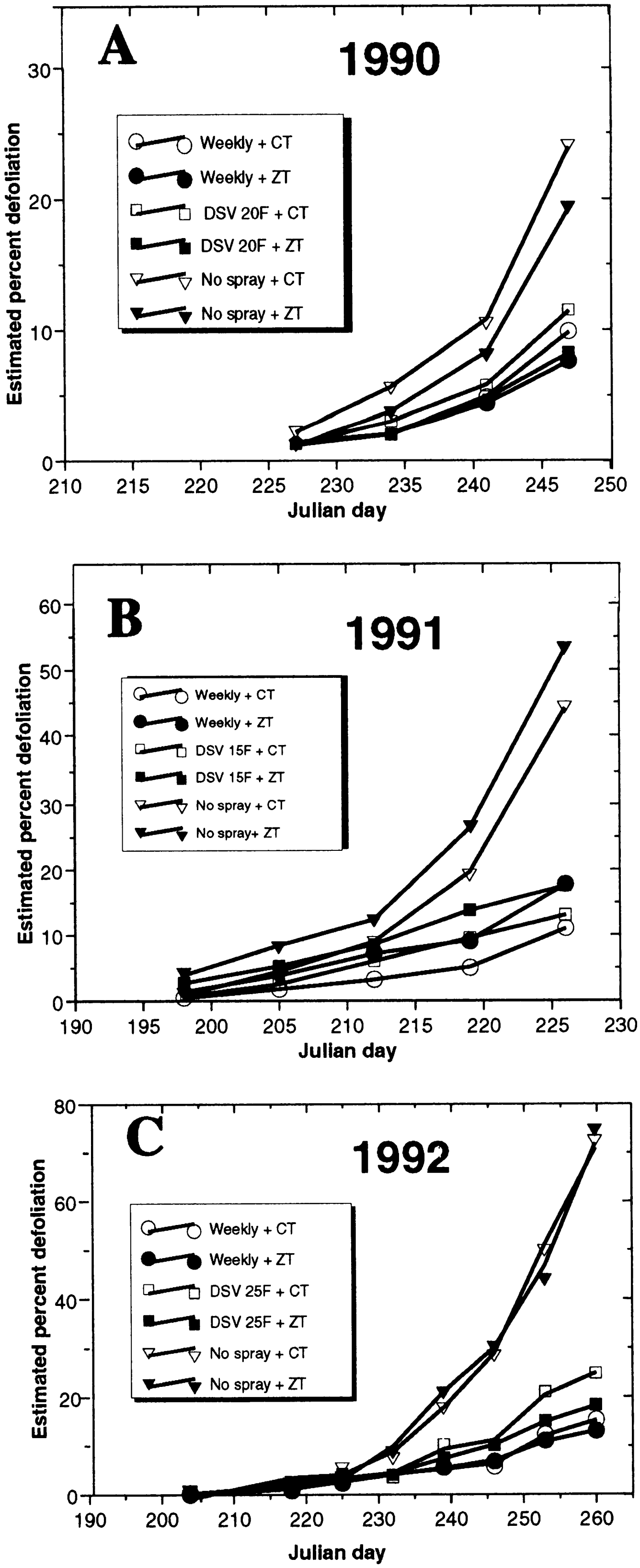

Fig 1. Effect of none, weekly, or TOM-CAST–based full-rate (F) chlorothalonil applications made after the accumulation of every 15, 20, or 25 disease severity values (DSV) and conventional tillage (CT) or zone tillage (ZT) on the estimated percentage of defoliation caused by early blight in **(A)** 1990, **(B)** 1991, **(C)** and 1992.

Tillage effects on fruit mold incidence. Tillage had no effect on fruit mold incidence (Fig. 2A to C).

Fungicide effects on fruit mold incidence. Fungicide treatments reduced fruit mold incidence compared to that in the unsprayed plot each year (Fig. 2A to C). In 1990, the DSV 20F and DSV 25F treatments provided control comparable to that of weekly sprays, resulting in 73 and 80% fewer fungicide applications, respectively (Table 1). Reduced fungicide rates (DSV 20R, DSV 25R) compromised control compared to that of weekly sprays (Fig. 2A). In 1991, all TOM-CAST–based treatments provided control comparable to that of the weekly treatment (Fig. 2B) yet required 45 to 64% fewer fungicide applications (Table 1). In 1992, the DSV 25F treatment provided control comparable to that of the weekly treatment (Fig. 2C) but required 77% fewer fungicide applications (Table 1). Reduced-rate treatments and the full-rate DSV 15 and 20 treatment that missed the first recommended spray (Table 1) did not provide control comparable to that in plots sprayed weekly (Fig. 2C).

Tillage effects on fruit yield and quality. Tillage had no effect on weight of harvested ripe fruit, total yield, or percentage of ripe fruit in any year, with one exception (Table 3): in 1990, ZT decreased the percent red fruit (Table 3).

Fungicide effects on fruit yield and quality. Fungicide treatment had no effect on weight of harvested ripe fruit, total yield, or percentage of ripe fruit in any year, with one exception (Table 3): in 1991, weekly sprays resulted in reduced total yield compared to the DSV 15F treatment.

Relationship between EB-caused defoliation and incidence of fruit mold. The incidence of fruit mold caused by EB was associated with defoliation based on AUDPC values (nontransformed values), and the extent of association varied each year. Incidence of EB fruit mold increased 1.4 to 2.3% for each 100 percent–day's increase in AUDPC. Regression values for 1990, 1991, and 1992 were: $Y = 1.38 + 0.014$ (EMS = 3.53; $R^2 = 0.127$); $Y = 0.27 + 0.014$ (EMS = 10.46; $R^2 = 0.34$); $Y = -1.35 + 0.023$ (EMS = 39.0; $R^2 = 0.559$), respectively. There was no relationship between AUDPC and ANTH or SR fruit mold incidence (data not shown). Likewise, there was no relationship between AUDPC values and total or marketable yield (data not shown).

Incidence of fruit mold due to EB and ANTH was correlated in 1990 to 1991, but not in 1992, as determined by Pearson's correlation coefficient (r). The coefficient, intercept, slope (±SE), and P value for the slope were 0.463, 0.12, 1.155 ± 0.3, and 0.001, respectively, for 1990, and 0.402, 1.61, 0.543 ± 0.17, and 0.003, respectively, for 1991.

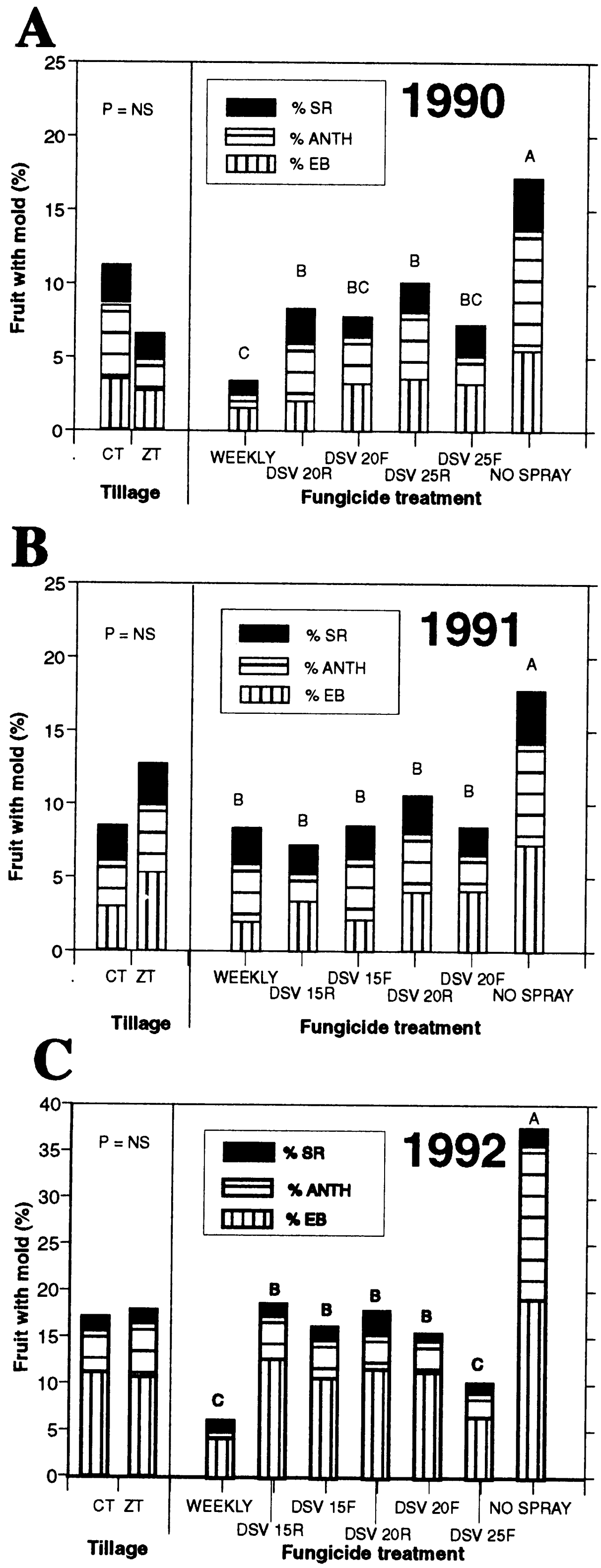

Fig. 2. Effect of none, weekly, or TOM-CAST–based full-rate (F) and reduced-rate (R) chlorothalonil applications made after the accumulation of every 15, 20, or 25 disease severity values (DSV) and conventional tillage (CT) or zone tillage (ZT) on the percentage of incidence of fruit with mold due to early blight (EB), anthracnose (ANTH), and soil rot (SR) in (**A**) 1990, (**B**) 1991, and (**C**) 1992. Histogram bars with the same letter are not significantly different (LSD, $P = 0.05$). Tillage effects are not significantly different (NS).

DISCUSSION

We designed and evaluated a tomato production system that included reduced tillage and fungicide inputs. The ZT system eliminated four CT operations over the 3-year study, limiting exposure of the soil to the elements. Early spring desiccation of strips in overwintered rye and growth of interrow rye to 1.2 m prior to desiccation, followed by ZT, ensured 90% coverage of the soil surface for the entire cropping season. Therefore, benefits of reduced tillage systems as documented by others, such as reduced water and wind erosion of soil, reduced wind-whipping of plants, and enhanced water-use efficiency (1,5,9) should apply to this production system. This study complements such research and evaluated the effect of reduced tillage on PRT productivity, disease incidence, and fruit quality. The ZT system had no consistent effect on defoliation caused by EB. ZT decreased (1990), increased (1991), or did not affect (1992) AUDPC values; but more importantly, ZT had no effect on the percentage of fruit with mold or weight of total yield and marketable yield in any year. These results are in contrast to studies that relied on complete no-tillage (21) or modified reduced tillage (14). In this study, ZT reduced the percentage of ripe fruit in 1990, possibly because of delayed foliage senescence (Fig. 1A), known to delay fruit maturation (11).

In this study, fall-seeded rye was included as an overwinter soil cover for its allelopathic effects on early weed seed germination (22) and as an interrow surface residue during the cropping season. Because reduced tomato yield is associated with rye residue (6,21), possibly because of allelopathic effects (22) or pathogenic microbes that persist on organic debris (4), we prepared strips of killed rye in early spring to limit biomass accumulation where tomatoes were to be planted. The ZT was included to limit soil compaction effects. Complete tillage (disking) was performed after the cucumber harvest and mustard crop to bury crop debris and disrupt the life cycle of weeds, pests, and pathogens. The mustard crop was chosen for its agronomic benefits and potential antipathogen activity. The continuous tomato treatment (no rotation) was included to enhance natural levels of inoculum to evaluate critically the utility of TOM-CAST under high disease pressure.

Inclusion of TOM-CAST enabled evaluation of reduced fungicide input influenced by tillage. Analysis of variance revealed no fungicide tillage interactions (1990 to 1992). This simplified data analysis suggests that less complex experimental designs can explain fungicide and tillage effects, and should facilitate production recommendations. For example, TOM-CAST recommendations do not need to be modified for growers who adopt reduced tillage practices conducted in this study.

Our observations of TOM-CAST effects on disease and crop productivity complement results from the north central region (2,10,19). In this study, we chose DSV thresholds of 20 and 25 in 1990, 15 and 20 in 1991, and 15, 20, and 25 in 1992 based on expected inoculum levels. In each year, the most liberal full-rate application schedule required 45 to 80% fewer applications but did not affect fruit mold incidence, total yield, or marketable fruit compared to weekly sprays. Growers who implement TOM-CAST could therefore benefit directly through reduced production costs. Based on this study and an estimated cost of \$45.70 per hectare per application of chlorothalonil (10), reduced number of sprays resulted in a savings of \$548.40, \$319.90, and \$450.70 per hectare in 1990, 1991, and 1992, respectively. In contrast to no yield effects, TOM-CAST–based treatments resulted in inferior control of defoliation caused by EB as compared to that in plots sprayed weekly. However, for the PRT system in this study, there was no relationship between defoliation and marketable yield.

In 1990 and 1992, compared to weekly fungicide sprays, reduced rates (2.8 liters·ha^{-1}) applied according to TOM-CAST resulted in increased percentages of fruit with mold. These data suggest reduced fungicide input is best obtained by reducing the number of full-rate (4.2 liters·ha^{-1}) fungicide applications rather than the amount of fungicide per application. However, reduced fungicide rates did not affect total weight of harvested fruit or weight and percentage of ripe fruit. In fact, there was no statistical increase in total or marketable yield for plots with fungicide applications compared to unsprayed plots.

Lack of yield benefit due to fungicide in PRT systems also has been noted by Poysa et al. (19). Our correlation analysis, like theirs, highlighted that defoliation had very little impact on fruit mold incidence and no relationship to yield. Like Poysa et al. (19), we relied on natural levels of inoculum, and our study was initiated in fields with no recent history of tomato production. Disease levels, especially percentage of defoliation, increased during the 3-year study. Perhaps with short crop rotation or high initial inoculum, fungicides may have a more dramatic impact. In 1992, total yield in unsprayed plots was 25% less but not significant (P = 0.056). To a grower, however, this loss may represent an unacceptable risk.

The ZT system integrated with a reduced fungicide program required a higher level of management than a CT system and standard fungicide program. Management decisions included time of seeding for green manure and cover crops, timing of herbicide applications for preparation of strips and final desiccation of rye, timing of zone tillage, precision timing of postemergent herbicides, and forecast-based timing of fungicide applications. Such a production system requires more of a process-oriented and problem-solving approach to farming (8) than do product- or input-oriented systems. However, reduced tillage and season-long maintenance of soil surface residues, use of rye cover crops and green manure crops, and reduced pesticide inputs are valuable contributions to enhanced sustainability of specialized vegetable production systems.

Table 3. Effect of fungicide treatment and tillage on marketable yield (metric tonnes/ha) of processing tomato

Fungicide[u] treatment	1990			1991			1992[y]		
	Ripe[v]	Total wt[w]	% red[x]	Ripe	Total wt	% red	Ripe	Total wt	% red
Weekly	68.2[z]	81.2	84.1	38.7	59.8 a	63.8	9.4	48.9	19.7
DSV 15R	…	…	…	47.9	74.1 ab	64.7	8.6	41.0	23.1
DSV 15F	…	…	…	48.8	76.1 b	65.2	10.1	47.6	22.2
DSV 20R	68.6	80.9	85.1	41.6	69.8 ab	59.2	11.7	44.6	26.7
DSV 20F	63.8	78.5	81.1	46.9	72.2 ab	63.2	12.6	51.2	25.6
DSV 25R	62.7	79.5	80.3	…	…	…	…	…	…
DSV 25F	67.8	76.1	85.0	…	…	…	9.9	48.2	21.6
No spray	64.3	73.9	87.9	40.3	64.8 ab	61.0	11.2	35.1	32.5
Tillage treatment									
CT	63.3	73.6	86.0[z]	46.9	74.5	62.4	8.2	37.4	22.8
ZT	68.0	83.1	81.5	37.8	58.9	62.5	12.8	53.0	26.1

[u] Chlorothalonil was applied as follows: none, weekly, or as TOM-CAST–based full (F) and reduced (R) rates after the accumulation of every 15, 20, or 25 disease severity values (DSV).
[v] Fully ripe marketable fruit.
[w] All fruit including green fruit and culls caused by abiotic and biotic causes.
[x] Percentage of red fruit excludes culls.
[y] Means are the values of two main plots under continuous tomato and two subject to a 1-year rotation.
[z] Means with no letter or the same letter are not significantly different.

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