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Evaluation of Residual Chlorothalonil Levels on Processing Tomato Foliage Using the TOM-CAST Spray Program

Jane M. Patterson
The Ohio State University

Sue E. Nokes
University of Kentucky, sue.nokes@uky.edu

Mark A. Bennett
The Ohio State University

Richard E. Riedel
The Ohio State University

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J. M. Patterson, S. E. Nokes, M. A. Bennett, R. E. Riedel

Abstract. *Field tomatoes were sprayed with chlorothalonil on a fixed–interval spray program and a TOM–CAST spray program with disease severity value threshold of 18. Foliage samples from upper and lower canopy layers were collected prior to spray re–applications. Chlorothalonil residue data were compared to the chlorothalonil efficacy threshold (1.2 $\mu g/cm^2$). Using a seven–day interval program, eight of the nine and seven of the nine spray intervals had chlorothalonil residues above the critical level for the upper and lower canopy layers, respectively. Using the TOM–CAST program, four of the five spray intervals had chlorothalonil residues above the critical level for both upper and lower canopy layers when the DSV threshold of 18 was reached. Persistence of chlorothalonil residues at effective concentrations could lengthen the spray interval beyond the DSV–based spray recommendation.*

Keywords. *Processing tomatoes, Chlorothalonil, TOM–CAST, Persistence.*

The desire to optimize fungicide use has led processing tomato growers in the Midwest away from fixed–interval spray methods to more informed spray scheduling with TOM–CAST (Pitblado, 1988; 1992), a disease forecasting program for processing tomatoes. The conventional spray timing method recommends chlorothalonil be re–applied every 7 to 10 days until two weeks prior to harvest. While effective, this practice may use more fungicide than needed, resulting in added expense to the grower and potential environmental concerns. TOM–CAST, an adaptation of the FAST program (Madden et al., 1978), is available and currently being used by producers in the Midwestern United States and Ontario, Canada (Gleason et al., 1995). Weather sensors monitor the tomato microclimate, and data are evaluated using TOM–CAST. In the TOM–CAST algorithm, the number of hours of leaf wetness per day and mean air temperature during the wet periods is used to determine a daily disease severity value (DSV), ranging between zero and four. The longer the wet periods and the higher the temperatures the larger the DSV. Daily DSVs are summed until the cumulative DSV reaches a predetermined action threshold (typically between 15 and 20) and the grower is advised to re–apply fungicide. Compared to a fixed–interval spray schedule, fewer fungicide applications have been reported in the Midwest and Ontario using the TOM–CAST system (Gleason et al., 1995).

TOM–CAST recommends spray intervals based solely on climatic variables and does not directly take into account the residual fungicide that may be present on the plant from previous sprays. Knowledge of persistence is important for determining the minimum number of chemical applications that will control a disease. Chlorothalonil persistence studies have been performed on a variety of crops, including tomatoes (Lukens and Ou, 1976; Bruhn and Fry, 1982; Elliot and Spurr, 1993). Lukens and Ou (1976) studied chlorothalonil residues on field tomatoes and determined the log concentration of foliar residue was linear with time, and the loss of residue was most rapid for the top leaves and slowest for the bottom leaves. No prior published studies have been performed evaluating the actual chlorothalonil residues on tomato foliage using a TOM–CAST spray schedule. The study conducted here was exploratory in nature, with its intent to examine field data to see if there is a need for a more detailed analysis. The objective of this study was to compare actual chlorothalonil residues on tomato foliage with a critical efficacy threshold prior to fungicide re–application for both a fixed–interval spray schedule and a TOM–CAST spray schedule.

Methods and Materials

Site Description and Cultural Practices.

The tomatoes were grown on raised beds at The Ohio State University Horticulture Farm in Columbus, Ohio, in a

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The authors are **Jane M. Patterson**, ***ASAE Member Engineer***, Graduate Research Fellow, Department of Food, Agricultural, and Biological Engineering, The Ohio State University, Wooster, Ohio, **Sue E. Nokes**, ***ASAE Member Engineer***, Associate Professor, Department of Biosystems and Agricultural Engineering, University of Kentucky, Lexington, Kentucky, **Mark A. Bennett**, Professor, Department of Horticulture and Crop Science, and **Richard E. Riedel**, Professor, Department of Plant Pathology, The Ohio State University, Columbus, Ohio. **Corresponding author:** J. M. Patterson, 1680 Madison Avenue, Department of Food, Agricultural, and Biological Engineering, The Ohio State University, Wooster, Ohio 44691; phone: 330–263–3700 ext. 2876; fax: 330–263–3670; e–mail: patterson.125@osu.edu.

Kokomo silty loam soil. Standard cultural practices were followed with the exception of chlorothalonil application.

Tomato plants (cv. Peto 696) were transplanted 5 June 1998 (156 Julian day) at a planting density of approximately 30,000 plants per ha, into single row plots (1.52 × 9.14 m). Chlorothalonil (Bravo Ultrex, ISK Biosciences Corporation, Mentor, Ohio) was applied according to either a seven–day interval or TOM–CAST with DSV of 18 at a rate of 3.08 kg a.i. per ha with a single row CO_2–powered (414 kPa) tractor–mounted boom with five Delevan (Delevan Inc., West Des Moines, Iowa) hollow cone number 12 nozzles.

Total daily rainfall was recorded at the weather station located at The Ohio State University Horticulture Farm in Columbus, Ohio. A CR–10 data acquisition unit (Campbell Scientific, Logan, Utah) with an air temperature probe (Campbell Scientific, Model 108) and a coated leaf wetness sensing grid (Campbell Scientific, 237) was used to record and store hourly temperatures and leaf wetness presence within the tomato canopy.

Sample Collection.

Foliage samples from the upper and lower canopy layers were collected prior to fungicide re–application for all field trials. The upper canopy layer was designated as the top half of the plant directly exposed to weathering, and the lower canopy was the bottom half of the plant not directly exposed to weathering. Individual samples consisted of 50– to 100–g fresh weight of leaves. New latex gloves were worn to take each sample. Samples were sealed into individual plastic bags, placed on frozen freezer packs in a cooler, and immediately brought to an ultra–low freezer for storage. Three replications were used to determine the mean and standard error of the mean using SAS (1987) for all data samples.

Residue Analysis

The frozen leaf samples were packed in dry ice and taken to the Biosystems and Agricultural Engineering Department at the University of Kentucky (Lexington, Ky.) where chlorothalonil residue concentrations were determined by the magnetic particle–based enzyme immunoassay method (Lawruk et al., 1995). The immunoassay method was chosen because it was of similar accuracy, 1/20th the cost, and simpler to perform than using a multi–residue procedure. The chlorothalonil magnetic particle–based enzyme immunoassay procedure has not been previously reported for use on processing tomato foliage, but has been on other agricultural products (Lawruk et al., 1995). An extraction procedure based on extraction methods for similar vegetation was used (Strategic Diagnostics Inc., 1998). Extraction was performed by adding 20 mL of pesticide grade methanol to each leaf sample, consisting of 10 leaf disks (1.7 cm diameter). Dilution was performed by taking 25 μL of the methanol extract and adding 1.98 mL of sample diluent (buffer solution) (SDI, Newark, Del.). The dilution was performed a second time. The RaPID Assay System (SDI, Newark, Del.) was used to perform chlorothalonil quantification on the diluted sample solution. Results in ppb were converted to $\mu g/cm^2$ using a conversion factor of $5.67\ \mu g\ cm^{-2}\ ppb^{-1}$.

Determining Chlorothalonil Efficacy Threshold

Initial tests were performed to determine sensitivity of *C. coccodes* to chlorothalonil on filter paper. Filter paper was used rather than an actual leaf disk because the leaf surface was too corrugated to get meaningful spore counts and filter paper provided a completely flat surface. A dose–response curve was generated and the concentration of chlorothalonil necessary to reduce spore germination in half (ED_{50}) was approximately 1.1 to 1.2 $\mu g/cm^2$. A critical efficacy threshold of 1.2 $\mu g/cm^2$ for residual chlorothalonil to maintain protection against *A. solani*, *C. coccodes*, and *S. lycopersici* was used in the evaluation.

Results and Discussion

Mean residual chlorothalonil concentrations observed in the upper and lower canopy layers prior to spray re–application and corresponding weather data for the 1998 seven–day interval field trial and the 1998 TOM–CAST field trial are presented in figures 1 and 2, respectively. For the seven–day interval program, eight of the nine spray intervals had mean residual chlorothalonil levels on upper canopy foliage statistically higher ($P < 0.1$) than the protective threshold (1.2 $\mu g/cm^2$) (fig. 1). On the lower canopy foliage, seven of the nine spray intervals had mean chlorothalonil residue levels statistically higher ($P < 0.1$) than the protective threshold (fig.1). These results are not surprising since the seven–day calendar method is the most conservative protection strategy. Regular chlorothalonil re–application causes residues to build up under certain climatic conditions (i.e., low rainfall and mild temperatures), as was seen in both the upper and lower canopy during the midseason. Field data collected from a 10–day spray interval during the 1993 and 1995 seasons exhibited similar trends (data not shown). The low chlorothalonil residue measurements in both the upper and lower canopy at the end of the season may be attributed to the rainfall event that occurred one day prior to these measurements.

For the TOM–CAST DSV–based spray program, four of the five spray intervals had mean chlorothalonil residue levels statistically higher ($P < 0.1$) than the protective threshold on both the upper and lower canopy foliage (fig. 2). For the first spray interval, the majority of rainfall occurred during this period and the mean chlorothalonil residues at the end of the interval were below the critical level. For the remaining spray intervals, mean chlorothalonil residues were above the critical level. Comparing chlorothalonil residue levels of TOM–CAST and the seven–day interval program, TOM–CAST reduced the number of spray applications for the season by four while maintaining chlorothalonil residue levels well above the critical level. This result is in agreement with other studies (Gleason et al., 1995).

A minimum concentration of chlorothalonil on the plant surface is necessary to control fungal disease development and subsequent infection. Lukens and Ou (1976) determined that the concentration of chlorothalonil necessary to reduce appressorium formation of *A. solani* in half (ED_{50}) on tomato foliage was 1.2 $\mu g/cm^2$. From extrapolation of data, Brenneman et al. (1990) indicated that approximately 1 to 2 $\mu g/cm^2$ of chlorothalonil is required to ensure protection of peanut foliage. Taking other estimates (Brenneman et al., 1990; Lukens and Ou, 1976) into account, Elliot and Spurr

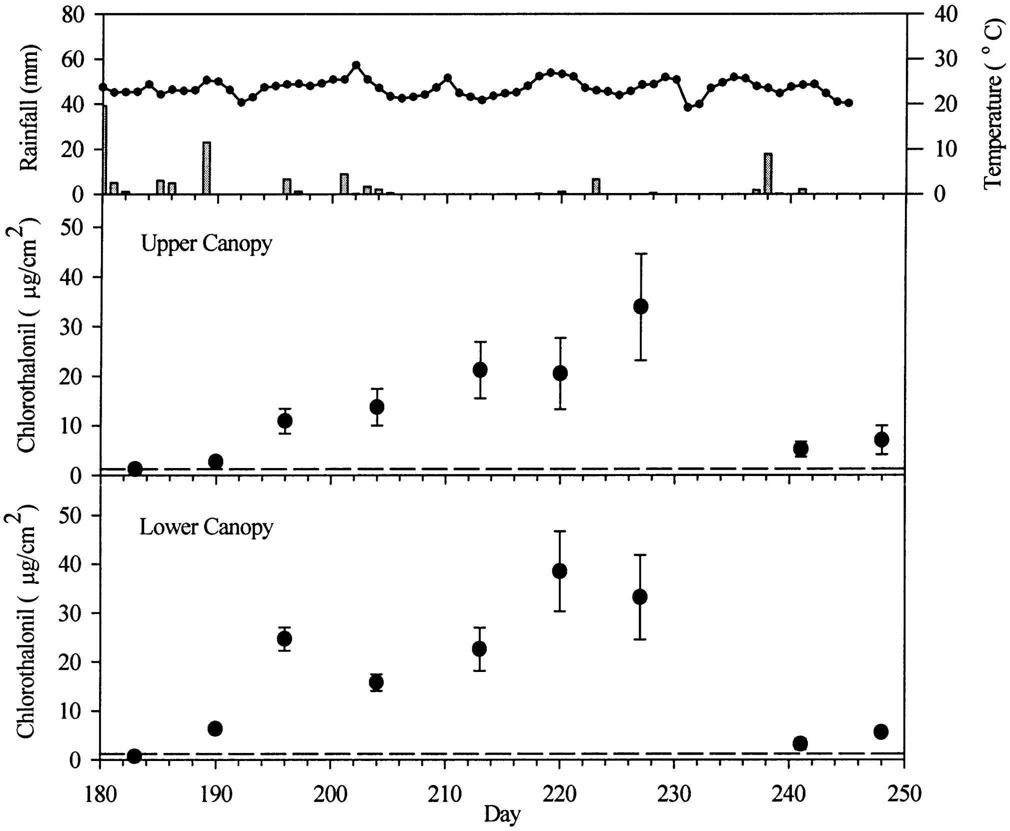

Figure 1. Mean observed residual chlorothalonil concentrations (µg/cm²) on upper and lower canopy processing tomato foliage prior to chlorothalonil re–application on a seven–day interval spray program and corresponding daily total rainfall and mean daily temperature during the 1998 season in Columbus, Ohio. Error bars represent standard error of the mean; • mean foliage chlorothalonil residue, - - - chlorothalonil efficacy threshold (1.2 µg/cm²), (bar) rainfall, ——•—— temperature.

(1993) determined that 1.5 µg/cm² would be a good but conservative estimate of a chlorothalonil efficacy threshold on peanut foliage. Results from the current study for chlorothalonil efficacy against *C. coccodes* on filter paper were similar. Based on this initial test and the accumulated information, the critical efficacy threshold for residual chlorothalonil to maintain protection against *A. solani*, *C. coccodes*, and *S. lycopersici* that was selected (1.2 µg/cm²) was reasonable.

Few spray application decision aids consider more than the impact of microclimate on disease (e.g. TOM–CAST). From field data, evaluation of mean residual chlorothalonil concentrations on tomato foliage indicates that for some conditions spray intervals could be lengthened without reducing the fungicide's effectiveness. Results from the 1998 field trial using the TOM–CAST program (fig. 2) showed chlorothalonil residues to persist consistently at effective concentrations at the time of the DSV–based spray recommendation. If chlorothalonil persists on the foliage and continues to provide effective fungal control, then the intervals between fungicide applications could be lengthened.

TOM–CAST provides a tool for predicting when disease development is favorable and fungicide is necessary, but cannot predict whether enough fungicide is present on the foliage for effective fungal control. TOM–CAST does not discriminate between sources of wetness (i.e. dew and rain) when making decisions. Rainfall is the major weather factor influencing dissipation of chlorothalonil from foliage (Bruhn and Fry, 1982). Temperature also impacts the loss of chlorothalonil (Bruhn and Fry, 1982). This study, exploratory in nature, shows that chlorothalonil residue levels are an important factor to consider before making an application decision.

Quantifying the behavior of chlorothalonil persistence on tomato foliage could assist in developing improved simulation models and in evaluating fungicide management strategies. Further research is underway to determine the effect of rainfall and temperature on chlorothalonil dissipation on tomato foliage. The TOM–CAST disease forecasting program and a weather–driven chlorothalonil persistence and efficacy prediction model will be linked into an integrated decision aid. Reduced fungicide use while maintaining fungal control would result in lower cost to producers and reduced potential for fungicide accumulation on the produce.

Conclusions

Chlorothalonil residue data on processing tomato foliage were found to be significantly higher than a critical chlorothalonil efficacy threshold (1.2 µg/cm²) for four out of five spray intervals evaluated using a TOM–CAST spray program with DSV of 18. Knowledge of chlorothalonil residues could lengthen the spray interval beyond the DSV–based spray recommendation. The study shows that chlorothalonil residue levels are an important factor to consider before making a fungicide re–application decision.

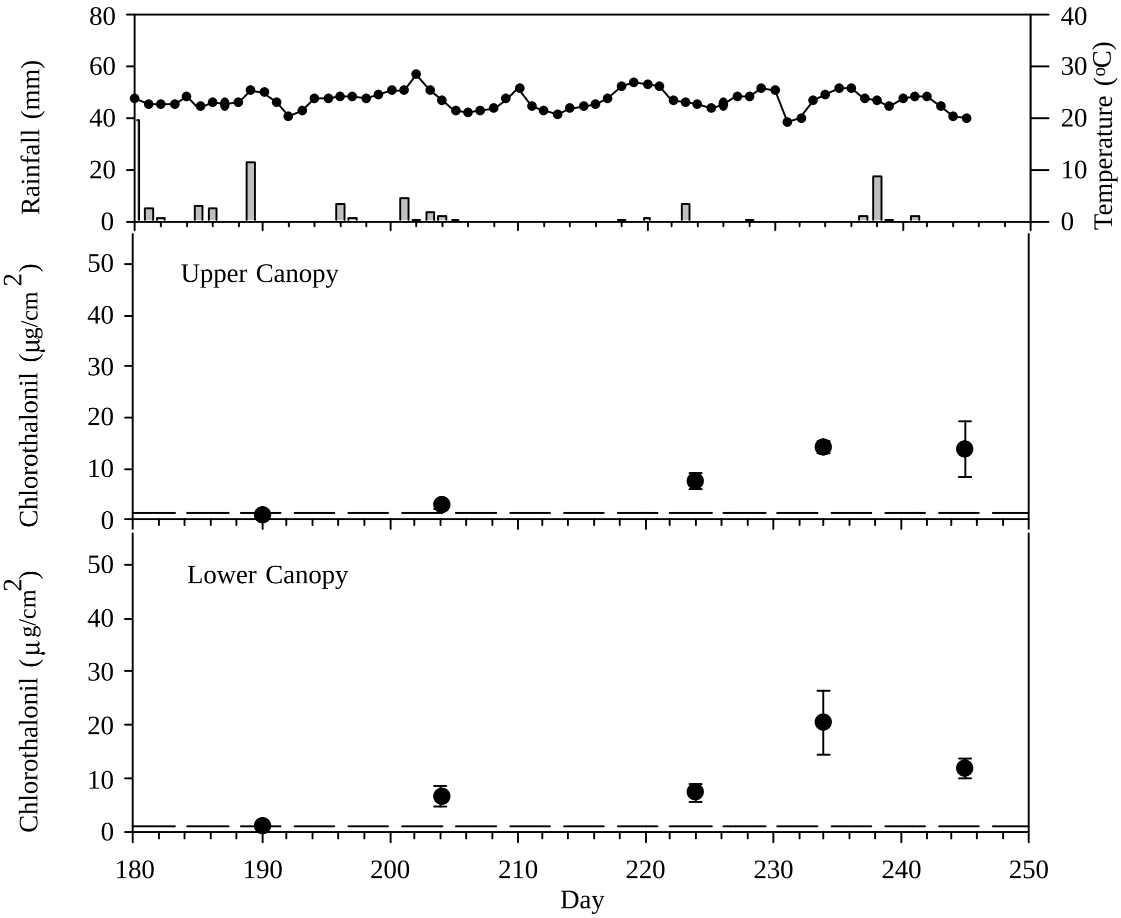

Figure 2. Mean observed residual chlorothalonil concentrations (µg/cm^2) on upper and lower canopy processing tomato foliage prior to chlorothalonil re–application on a TOM–CAST DSV 18–spray program and corresponding daily total rainfall and mean daily temperature during the 1998 season in Columbus, Ohio. Error bars represent standard error of the mean; • mean foliage chlorothalonil residue, - - - chlorothalonil efficiency threshold (1.2 µg/cm^2), (bar) rainfall, ——•—— temperature.

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