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Single season effects of mixed-species cover crops on tomato health (cultivar Celebrity) in multi-state field trials

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ABSTRACT

Cover crop use can help mitigate the deleterious effects of common cropping practices (e.g., tillage) and is, therefore, an important component of soil health maintenance. While known to be beneficial in the long-term, the short-term effects of cover crops, specifically mixed-species cover crops in organic systems are less clear. Cover crop effects on tomato productivity and disease severity were recorded over three field seasons (2010, 2011 and 2012) at sixteen field sites in three states, Maryland, New York and Ohio (MD, NY and OH), each with distinct soilborne disease pressure. Plots of five state-specific cover crop treatments were established the season prior to tomato production; the resulting plant residue was incorporated the following spring approximately four weeks before tomato planting. Total fruit yields along with early-season shoot height and fresh weight were used to compare treatment effects on productivity. Treatment disease severity ratings relied on natural inoculum. Interestingly, the effect of a single season of cover cropping on total yield was significant in no more than 25% of all site years. Similarly, cover crop effects on tomato disease levels were significant in 0–44% of the sixteen field sites. However, significant field-specific patterns were observed in every state across multiple years for some treatments. For example, in New York in 2010, tomato yields following all mixed cover crops were greater than the single rye cover crop in one field, but this pattern was reversed in the adjacent field. Thus, no general recommendation of a specific cover crop mixture can be made for near-term enhancement of tomato productivity or for reduction of disease. Therefore, growers should focus on location and operation-specific variables when choosing cover crops.

1. Introduction

Organic agriculture relies on ecologically based methods of crop production, employing a variety of techniques for integrated pest management and retention of soil fertility. Planting cover crops is one strategy, used for centuries, that has been shown to increase organic matter, reduce erosion, improve physical characteristics of the soil, prevent leaching of soil nitrogen, suppress weeds and reduce disease incidence (Snapp et al., 2005; Thurston, 1990). Recommendations for specific cover crops have been provided based on the unique advantages each is supposed to confer. For example, Graminaceous species of cover crop (e.g., annual rye (*Lolium multiflorum* Lam.) and winter rye (*Secale cereale* M. Bieb)) improve soil physical structure, produce ample biomass adding to organic matter and sequester excess nitrogen in the soil, which prevents leaching (Snapp et al., 2005; Treadwell et al., 2010). Leguminous species (e.g., hairy vetch (*Vicia villosa* Roth), crimson clover (*Trifolium incarnatum* L.) and alfalfa (*Medicago sativa* L.)) can provide additional nitrogen through symbioses with nitrogen-fixing rhizobacteria (Snapp et al., 2005). Some members of the family Brassicaceae (e.g., forage radish (*Raphanus sativus* var.

Abbreviations: GLM, general linear model; CCT, cover crop treatment; AUDPC, area under disease progress curve; ANOVA, analysis of variance; HSD, Honestly Significant Differences; PPN/PAN, plant-pathogenic nematodes/plant-associated nematodes; RKN, root-knot nematodes.

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longipinnatus L.) and forage turnip (*Brassica rapa* var. *rapa* L.)) have a long taproot, which facilitates water infiltration and breaks up compaction (Chen and Weil, 2009). This family also produces glucosinolates that hydrolyze to release various volatile compounds, the most biologically active of which is isothiocyanate. These compounds have been found to serve as effective biofumigants in some systems, acting similarly to the synthetic pesticide metam sodium, which generates methyl isothiocyanate when in contact with damp soil (Matthiessen and Kirkegaard, 2006). Mixing species of cover crops in one planting is a strategy to take advantage of the benefits promoted by each. For example, the carbon to nitrogen ratio can be balanced, facilitating a slower release of nitrogen, which can be better utilized by crops during the growing season. By mixing species with complementary growth patterns, a grower can also maximize weed control, nitrogen sequestration, biomass production and diversity of beneficial insect populations (Treadwell et al., 2010). For example, by pairing rye and vetch, the quick-growing rye will prevent weed establishment and utilize nitrogen added by the vetch, which grows more slowly (Snapp et al., 2005).

Numerous experiments have shown that cover crops can increase yield and protect crop plants from soilborne disease (Abawi and Widmer, 2000; Abdul-Baki et al., 1996; Bulluck and Ristaino, 2002; Larkin and Griffin, 2007; Mazzola and Mullinix, 2005; Zhou and Everts, 2004). However, not all studies have observed a benefit from specific cover crops or green manures on yield, disease severity or suppression of plant-pathogenic nematode (PPN) populations (Chellemi, 2006; Hartz et al., 2005). The complex interaction of various factors such as cover crop species or cultivar, soil characteristics, crop-pathogen system and environment determines the extent to which cover crops can beneficially impact vegetable crop health. Interpreting the impacts on crop health can be complicated. For instance, one study found that cover crops improved crop health, thereby leading to decreased seedling mortality despite increased disease severity caused by *Fusarium* spp. and *Pythium* spp. (Medvecky et al., 2007).

Fewer studies have investigated mixed-species green manures. A rye-vetch green manure reduced incidence of Southern blight on tomato and increased populations of beneficial Pseudomonads (Bulluck and Ristaino, 2002). A rye–legume mixture also increased yield of tomatoes and suppressed weeds more effectively than a rye monocrop (Teasdale and Abdul-Baki, 1998). A rye and a rye–field pea mixture of cover crops both had positive effects on tomato growth and yield as compared to bare ground (Akemo et al., 2000). Mixed species of hay used on land in transition to organic management reduced damping-off of tomato by *Pythium* spp. and *Rhizoctonia solani* by 3–30% (Baysal et al., 2008).

The goal of this study was to investigate the near-term effects of mixed-species green manures on subsequent plantings of tomato (*Solanum lycopersicum* L.) in organic production systems. The experiment was conducted in three states at multiple locations, each with different types of soilborne disease pressure, including Phytophthora blight caused by *Phytophthora capsici* Leonian (NY), Southern blight caused by *Sclerotium rofsii* Sacc. (MD), plant-pathogenic nematodes (MD) and Rhizoctonia root rot caused by *R. solani* J.G. Kühn (OH). Crop and soil variables were chosen to examine the effects of a single season application of cover crops on tomato productivity and disease severity. The hypothesis tested was that a one-season application of mixed-species cover crops would provide enhanced productivity and reduce disease severity regardless of location or year, as compared to single-species cover crop applications or a bare ground control. Statistical testing was performed for each field and year separately in order to detect site-specific effects.

Table 1
Seeding rates for CCTs in MD, NY and OH.

	Treatments and seeding rate (kg/ha)
MD	
1	Hairy vetch (79) + winter rye (79)
2	Hairy vetch (25)
3	Hairy vetch (42) + forage radish (42)
4	Mixed-species hay (125)[a]
5	No cover
NY	
1	Hairy vetch (34) + winter rye (79)
2	Crimson clover (10) + annual rye (18)
3	Forage turnip (15) + winter rye (45)
4	Winter rye (135)
5	No cover
OH	
1	Mixed-species hay (56/112)[a]
2	Winter rye (150)
3	Hairy vetch (50)
4	Hairy vetch (25) + winter rye (75)
5	Forage radish (10)

[a] Mixed-species hay included red fescue (*Festuca rubra* L.), orchard grass (*Dactylis glomerata* L.), timothy (*Phleum pratense* L.), red clover and alfalfa. Composition was determined by equal seed number in MD and OH. Seeding rates in OH were 56 kg/ha in 2010 and 112 kg/ha in 2011 and 2012.

2. Materials and methods

2.1. Experimental design and management

Research was conducted in 2010, 2011 and 2012 at the University of Maryland Lower Eastern Shore Research and Education Center, Salisbury, the New York State Agricultural Experimental Station, Phytophthora blight research farm in Geneva and the Ohio Agricultural Research and Development Center, Wooster. The three states and years included in the study sum to sixteen different field-site years and a total of 370 separate plots.

The experiment was conducted as a randomized complete-block design with four blocks (NY and OH) or six blocks (MD) and five treatments per block. Each year different fields were used in each location in order to test the single season impacts of the cover crop treatments.

In MD, the trial was conducted in one field per year (5 treatments × 6 blocks) for a total of 30 plots per year. Plots were 64 m × 122 m and had two rows of black plastic on 21 m centers. A single row of tomatoes were transplanted 0.6 m apart within each row. Soil at this location was Fort Mott loamy sand and Rosedale loamy sand.

In NY, the trial was conducted in two fields per year (5 treatments × 4 blocks) for a total of 40 plots per year. Plots were 24 m × 76 m with one row of plastic on 31 m centers. A single row of tomatoes were transplanted 0.6 m apart within the row. Soil at this location was Odessa silt loam.

In OH, the trial was conducted in three fields (5 treatments × 4 blocks) for a total of 60 plots in 2010 and 2011, but only one field (5 treatments × 8 replicates) for a total of 40 plots in 2012 Plots were 31 m × 61 m with four rows of black plastic on 153 m centers. A single row of tomatoes were transplanted 0.6 m apart within each row. In this location, the soil was a Wooster Riddles silt loam.

The five treatments of mixed-species green manure combinations were different in each state based on local growing conditions and practices. The treatments and seeding rates are listed in Table 1. Cover crop seed was sown in the fall and the cover crop was mowed and tilled in as a green manure the following spring three to five weeks before transplanting the tomatoes (Supplementary Table A). Before tilling in the cover crop biomass, the fresh above-ground plant residue was weighed from a 12 m × 12 m portion of each plot