PROGRESS REPORT

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PROJECT TITLE: IMPROVING SOIL HEALTH FOR STRAWBERRY PRODUCTION IN THE SOUTHEAST: PROVIDING TOOLS FOR GROWERS

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PUBLIC ABSTRACT

In the Southeast United States (SEUSA), strawberries are grown as an annual crop. Several on-farm research studies have been conducted over the last 15 years to develop economically viable non-fumigant soil-borne disease management programs. Management systems that have been evaluated were to utilize compost, cover crops, crop rotations, organic amendments, and bio-fumigation of soil with a mustard meal, and the use of anaerobic soil disinfestation (ASD) methods. We also have advanced novel biological control agents (BCAs) as potential products for use in the strawberry production system and the long term, these will be integrated into biologically-based production systems. Our main objective of this project was to advance strawberry production systems and garner a greater capacity of farming system approach that contributes to soil health, disease suppression, and yield. We have established an experiment at Horticultural Crops Research Station, Castle Hayne, NC during the 2020-2021 strawberry growing season. We evaluated and compared the ASD using model sources of carbon (mustard meal, molasses), cover crops plus compost, and chemical soil fumigation performances in strawberry plasticulture production systems. The experiment was a randomized complete block design and replicated four times with 10 treatments. Four weeks after soil treatments were initiated, cv 'Camarosa' was planted and strawberry plant health, nematode counts, weed density, and plant biomass data were collected to assess treatment effects. Total yield was assessed bi-weekly and cumulative yields were calculated in lbs/A. All ASD treatments, fumigant PicClor-60, and non-amended controls using TIF (UTC-STD), significantly increased total yield compared to plots covered with clear plastic (amended or not-amended). Yields were similar for the fumigated, amended, and UTC-STD. In, contrast, the fumigated and three ASD treatments generated significantly higher yields than the UTC-STD in 2020, the previous year. Independence analysis showed the treatment ranking of total yield secured in 2020 and the yield secured in the 2021 was highly significant. The Spearman's correlation coefficient statistic was 0.98 (*P*-value >0.0001), indicating that the treatments that generated the highest yield in the 2020 also generated the highest yield in the 2021. The findings of this study indicated that the use of ASD treatments can provide comparable yields as fumigation.

INTRODUCTION

Soil-borne fungal pathogens, nematodes, and weeds are considered major biotic factors limiting strawberry productions in the SEUSA. Among them, black root rot (Coons, 1924) is a major disease complex of strawberry (*Fragaria* × *ananassa*), caused by pathogenic fungi (*Pythium irregulare,* and *Rhizoctonia fragariae*) and the plant-parasitic nematode (*Pratylenchus* spp.) in North Carolina and surrounding states (Abad et al., 1999; LaMondia, 2003). Black root rot complex causes the death of feeder roots and the degradation of structural roots resulting in an overall decrease in productivity (Maas, 1998) and can cause up to 40% yield losses (https://content.ces.ncsu.edu/black-root-rot-of-strawberry).

Methyl bromide (MeBr), a soil fumigant has been used in strawberry production that relied on the single application of a broad-spectrum biocide to disinfest soils before planting. Due to health and environmental concerns, this soil fumigant was phased out for commercial use. Major research has been focused on soil management practices to promote sustainable soil quality, productivity, and soil health (Pankhurst et al. 1997). These included management practices were cover crops, reduced tillage, composts, mulches, and organic amendments (Abawi and Widmer, 2000; Louws et al. 2000). Cover crops (e. g., ryegrass, pearl millet, oat, white clover, hairy vetch) have been incorporated as green manure before planting cash crops. The use of cover crops not only enhances soil health and crop yield but also, can prevent erosion, reduce soil-borne pathogen and plant-parasitic nematode populations, and add organic matter or nitrogen (e. g., legumes) to the subsequent cash crop (Fageria et al. 2005). Likewise, the application of organic amendments (e. g., mustard meals, molasses, rice barn) and composts increased organic matters and microbial populations, suppressed the soil-borne pathogens, and led to improving the soil quality (Pera et al. 1983). Several non-chemical cultural practices such as soil amendments, composts or crop residues, cover crops other than host resistance, have been utilized and significantly enhanced C: N ratios and favorable soil chemical properties to improve soil health indicators, increase yield, and reduce soil-borne pathogens in vegetables and strawberry (Bernard et al. 2012; Cohen and Mazzola, 2006; Fang et al., 2012; Larkin et al. 2011; Litterick et al. 2004; Watanabe et al. 2011). To that end we have invested extensive efforts in tactic diversification, not sole reliance on fumigants (intensive characterization of strawberry crop phenology and pathogen diversity and dynamics to implement IPM protocols) and documented the main root problem we need to manage is Black Root Rot (BRR). In parallel and complementary work, we also invested the development and evaluation of farming-systems approaches to help our stakeholders. In the long term, we believe the only long-term effective way to advance strawberry production systems and to manage these BRR pathogens is through a farming systems approach that preserves soil quality and health. A farming systems approach is rooted in the core premise that biologically-based solutions and different types of farming system approaches can be developed and economically implemented. Management systems that we have evaluated and continue to develop include the utility of compost, cover crops, crop rotations, amendments with beneficial microbes, biofumigation/amendment of soils with mustard meal, and the use of anaerobic soil disinfestation (ASD) methods.

Soil disinfestation methods using anaerobic decomposition of organic matter were developed in the Netherlands (Blok *et al.*, 2000) and Japan (Shinmura, 2000) as an ecological alternative to MeBr. It is also called “biological soil disinfestation”, “soil reductive sterilization” and “reductive soil disinfestation”. These methods are characterized by the incorporation of easily-decomposable soil amendments (e.g. wheat or rice bran, fresh crop residues, molasses), irrigation to increase soil moisture content, and tarping with polyethylene mulch for a period as short as two weeks to as long as fifteen weeks. The incorporation of a readily-available carbon source combined with irrigation stimulates rapid growth of aerobic microorganisms (microorganisms that need oxygen to survive). This depletes available soil oxygen and induces the soil microbial community to shift to facultative and obligate anaerobes (microorganisms that do not need oxygen to survive). Oxygen is partially limited by the polyethylene mulch as well as the soil water content. As anaerobic conditions form in the soil, soil-borne plant pathogens, plant-parasitic nematodes and certain weed species are controlled by mechanisms that are not entirely clear, but most likely relate to the toxic by-products of anaerobic decomposition (e.g. acetic, butyric, propionic acids), volatile compounds, biocontrol by anaerobic soil microorganisms, or oxygen deficiency (Butler *et al*., 2012; Shennan et al. 2009; Di Gioia et al. 2016; Shennan et al, 2016).

The main objective of this work is to evaluate the performances of ASD (molasses as a model carbon source), mustard meal, cover crops + compost, compared with soil fumigant (PicClor60), and untreated control (UTC) treatments, as biologically sustainable disease control options in strawberry production systems. Future work will include carbon sources originating from “waste-streams” in NC.

MATERIALS AND METHODS

During the 2020-2021 growing season, we established a randomized compete block design, replicated (four times), with 10 treatments experiment in an open field at the Horticultural Crops Research Station, Castle Hayne, NC. Each plot consisted of 3 beds 30 feet long planted to strawberries in twin rows and offset in the twin rows. In 2020, legume/grass (Cowpea: Pearl Millet, 100:10 lb/A) was field sown in late June. The summer cover was managed for optimum growth and then flail mowed to allow cut residue distribution evenly on the cover crop plots. Compost (12 Tons/A), produced using the Controlled Microbial Compost (CMC) system, was amended to these plots just before seeding. The cover crop and compost were soil incorporated 8 to12 inches deep using a PTO-driven rototiller. Beds were pulled and covered with totally impermeable film (TIF) with two drip tapes buried 2 to 4 in deep and spatially distributed in the bed. Cover crop residues were left under these conditions until strawberry plants were transplanted (3 weeks later). The cover crop was highly labile upon incorporation and plastic beds pulled well. In this study, the cover crop + compost plots were also flooded with water. ASD beds were established, and drip irrigation was applied (via the two buried lines) within 16-24 hours to saturate the beds and induce anaerobic conditions in the topsoil. To collect temperature and redox potential data, sensors were programmed to collect data during the treatment period. Redox electrodes hooked up to Campbell Scientific dataloggers to calculate real-time changes in the redox potential (anaerobic state) of the soil. Carbon treatments included molasses (5000 lbs/A; full rate) or half rate (2500 lbs/A) and Mustard Meal (Biofence) applied in 2000 lbs/A (full rate) or half rate (1000 lbs/A). An additional treatment consisted of half rate of each. In addition, molasses at the full rate was covered with clear plastic. The most common commercial fumigant, Pic-Clor60 was used as a control and injected into the beds during the bed formation process at 300lbs/treated A (positive control). Untreated controls included beds overlain with TIF or clear plastic but without a fumigant or amendments. Strawberry cv 'Camarosa' was planted in Oct; managed over the winter and harvested from mid-April to Mid-June 2021 at bi-weekly intervals. Whole plant samples were collected at peak harvest to assess plant dry weights of the crowns and leaves. Field soil samples were collected as a baseline at cover crop seeding (from each rep), at planting from each plot, and again at peak harvest and 12 months later. Soils were analyzed for nutrient, pH, carbon, microbial activity, and soil health parameters. Nematode counts were done at NCDA, Nematology Lab, Raleigh, NC. All experimental data were collected from the 40 plants of the harvesting area in the inner bed to limit inter-plot interference. Yield data were analyzed using a two-way repeated-measures analysis. Spearman's correlation coefficient between the 2020 and 2021 yield data.

RESULTS

Total yields were suppressed in plots where clear plastic was used (Figure 1). The remaining plots did not vary significantly in total yield (Figure 1) nor marketable yields (data not shown). The ranking of the treatments were highly similar to the treatment yield effects of the 2020 harvest (Figure 2). In 2020, the Pic-Clor60 and all ASD treatments were similar (Figure 2). In 2020, the Pic-Clor60, Molasses + Mustard combination (½ rate each), Molasses full rate, and Mustard ½ rate generated higher yields than the non-amended plots (UTC-STD) covered with TIF ($P=0.05$). Independence analysis showed the treatment ranking of total yield secured in 2020, and the yield secured in 2021, was highly significant. The Spearman's correlation coefficient statistic was 0.98 (P-value >0.0001) (Figure 3), indicating that the treatments that generated the highest yield in the 2020 also generated the highest yield in the 2021.

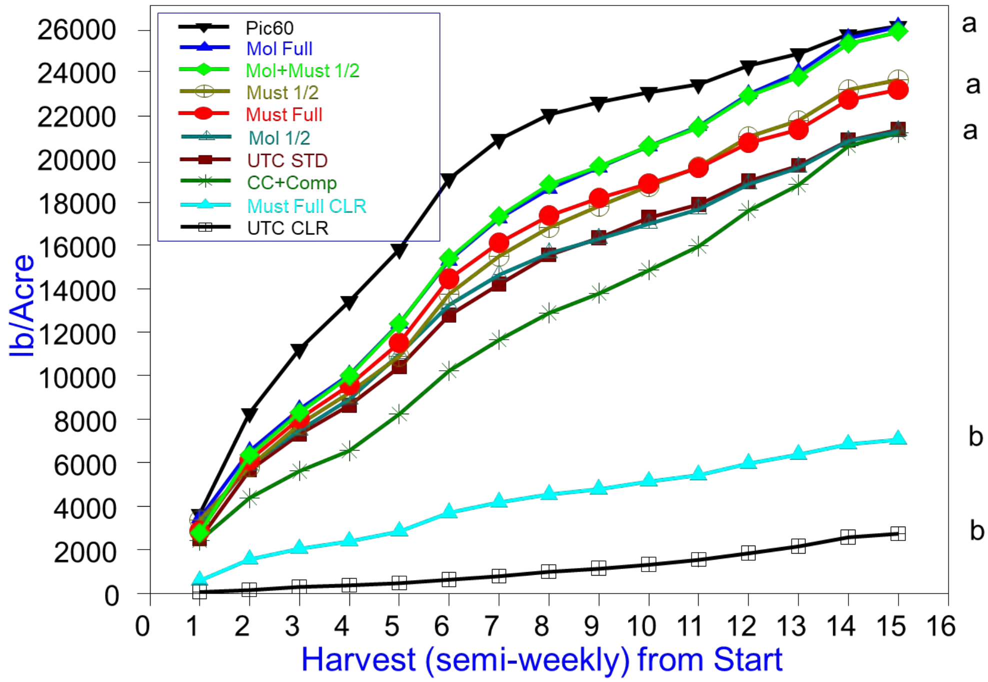

FIGURE 1. Cumulative marketable yield progress curves at semi-weekly harvests, spring 2021. Each curve followed by the same letter are not significantly different from each other based on repeated measures analysis and the Fisher Protected LSD (P = 0.05).

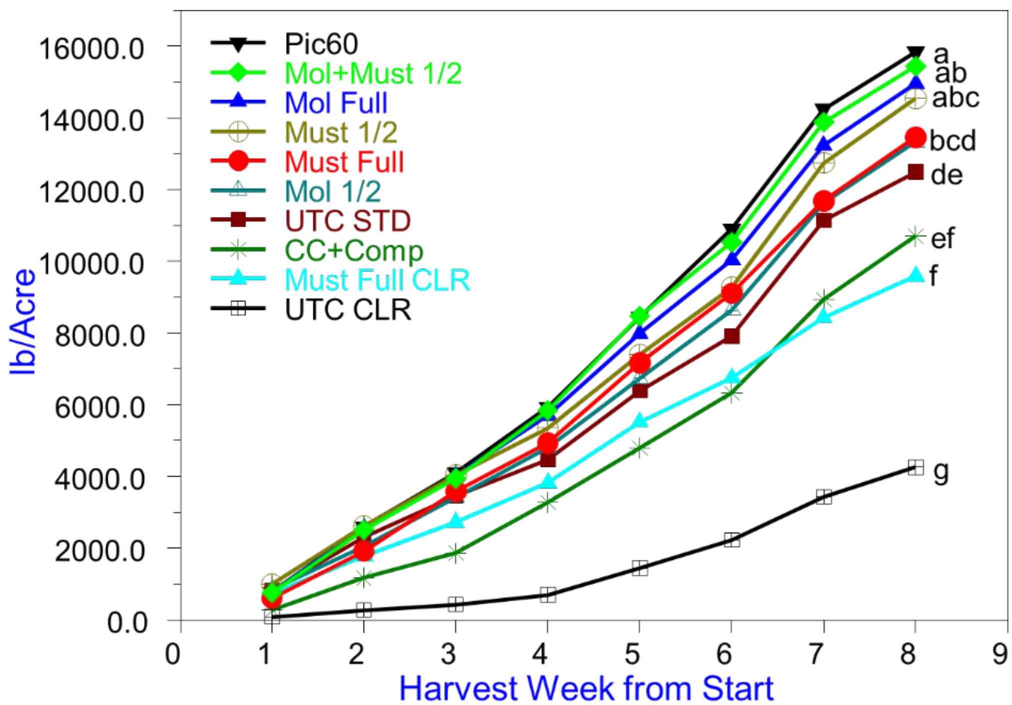

FIGURE 2. Cumulative marketable yield progress curves for 2020 at weekly harvests. Each curve followed by the same letter are not significantly different from each other based on repeated measures analysis and the Fisher Protected LSD (P = 0.05).

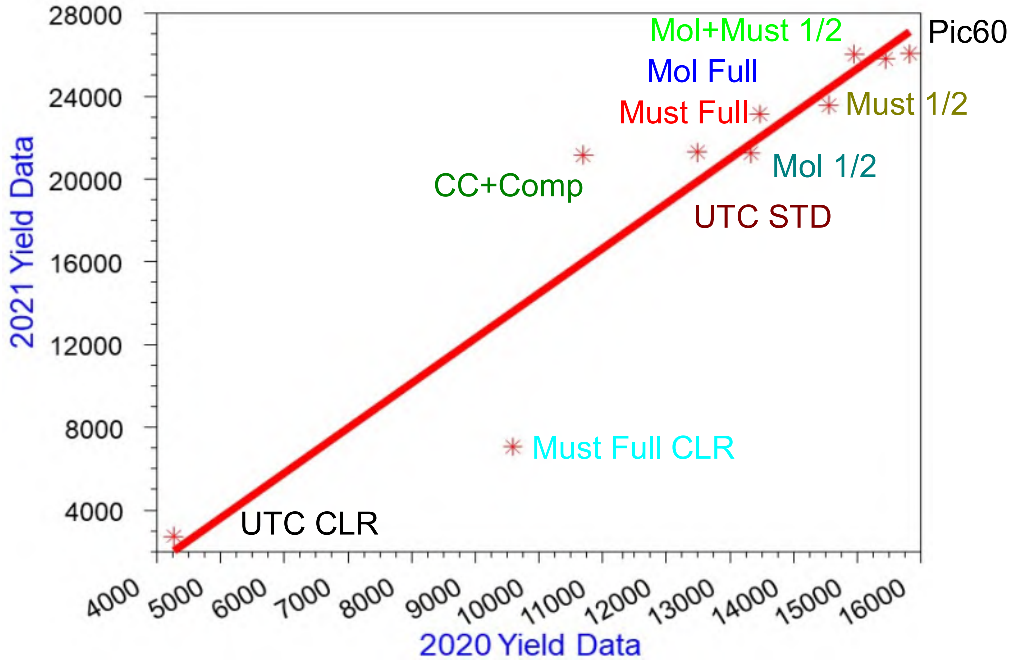

FIGURE 3. Spearman's correlation coefficient (0.98; *P*=0.01) between the 2020 and 2021 yield data.

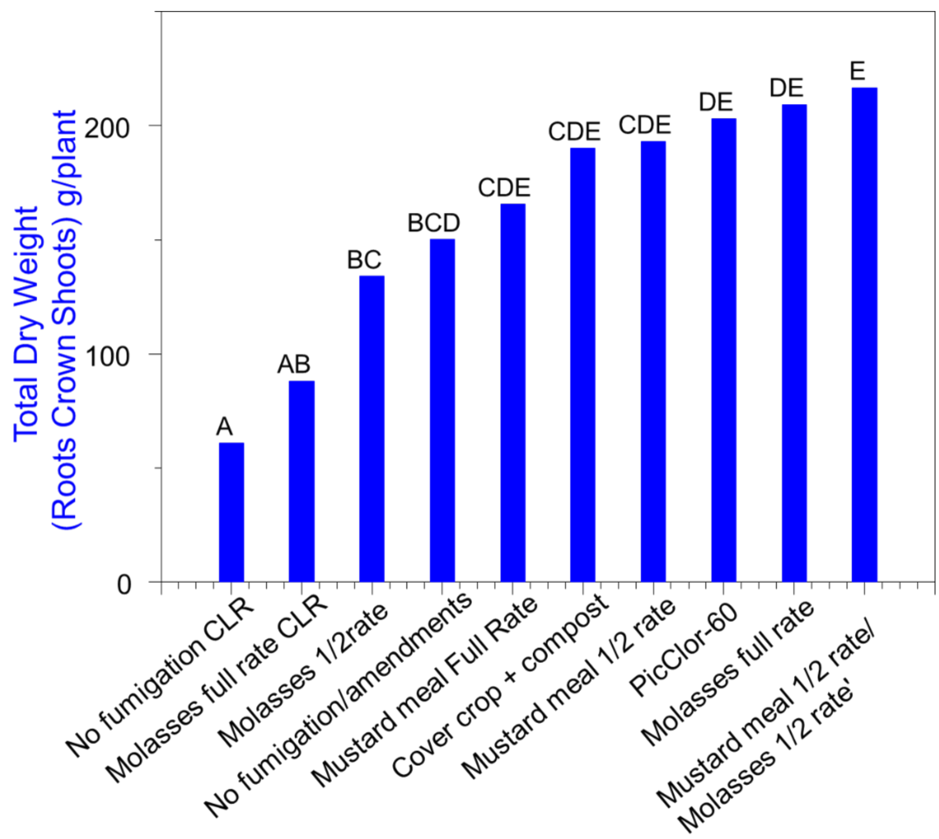

FIGURE 4. Total dry weight biomass (roots and crown shoots) sampled at peak harvest 2021.

In 2021, the ASD-treatment with molasses plus mustard meal at the ½ rate had significantly higher dry biomass of strawberry (Figure 4) compared to the untreated control covered with TIF. The plots covered with clear plastic, amended with molasses full rate (Mol Full CLR) or not amended (UTC CLR) had the lowest dry weight biomass.

OUTREACH AND SUMMARY

Findings of this study will be presented at the Agents Jan 5-6, 2022, Savanah, GA. Biologically based soil treatments were as effective as the standard fumigant in advancing plant growth and associated total yields. Effective treatments will be selected and repeated in the 2022 experiment.

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