# Effects of Different Winter Cover Crops on Conservation Tillage Tomato Quality and Yield

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## Abstract

The increased use of conservation tillage in vegetable production requires more information be developed on the role of cover crops in weed control, tomato (*Lycopersicon esculentum* L ) quality and yield. Three conservation-tillage systems utilizing crimson clover (*Trifolium incarnatum* L.), turnip (*Brassica rapa* L.) and cereal rye (*Secale cereale* L.) as winter cover crops were compared to a conventional black polythene mulch system, with and without herbicide, for weed control and tomato yield. Herbicide treatments included a preemergence (PRE) application of metalochlor (1.87 kg a.i. $ha^{-1}$) either alone or followed by an early postemergence (POST) metribuzin (0.56 kg a.i. $ha^{-1}$) application followed by a late POST application of clethodim (0.28 kg a.i. $ha^{-1}$). All covers were flattened with a mechanical roller/crimper prior to chemical termination. Without herbicide, weed control provided by cover crop residues ranged from 0 to 91% 4 WAT, depending on cover and weed species. Clover controlled yellow nutsedge (*Cyperus esculentus* L.) and smallflower morningglory (*Jacquemontia tamnifolia* L.) 48 and 50%, respectively, while providing only 1 to 2% control of smooth pigweed (*Amaranthus hybridus* L.), tall morningglory, wild radish and leafy spurge (*Euphorbia esula* L.). Turnip residue provided ≤ 34% control of all the weeds. Rye provided 81 to 91% control of Virginia buttonweed (*Diodia virginiana* L.) and smallflower morningglory Griseb.) respectively, whereas large crabgrass (*Digitaria sanguinalis* (L.) Scop.) control was only 11%. Neither cover crop nor the polythene mulch system provided adequate large crabgrass or wild radish (*Raphanus raphanistrum* L.) control without herbicide. Tomato stand establishment was not affected by any cover crop residue treatment compared to plastic mulch. Tomato yield was least in non treated control and was maximized with inclusion of the POST application. Pooled over herbicide treatments yield was less following either crimson clover or turnip cover crops compared to rye or the polythene mulch system. Averaged across cover crops, both herbicide programs resulted in better yields compared to the non-treated check.

## Introduction

Tomato production systems typically utilize conventional tillage, a bedded plastic mulch culture, and multiple herbicide applications to keep fields weed free. Intensive use of synthetic chemical in their production has raised consumer and ecological concerns. Use of plastic mulches in sustainable or organic production systems is also not universally perceived as sustainable. Therefore, alternative production practices that decrease tomato production inputs while maintaining yields and quality are desired. Use of high residue cover crops combined with reduced tillage systems may produce such results.

Southeastern US receives adequate rainfall in the winter months, thus timely planted winter cover crops can attain relatively high biomass before termination. Cover crops can enhance overall productivity and soil quality by increasing organic matter and nitrogen content (Sainju et al., 2002), as well aid in water conservation by increasing soil water infiltration rates (Arriaga and Balkcom, 2005). Additionally, previous research has shown that weed control can be provided by high residue cover crops in both field and vegetable crops (Teasdale and Abdul-Baki 1998; Creamer et al., 1997; Price et al., 2006). Winter cover crop biomass can affect subsequent early season weed suppression (Saini et al., 2006; Teasdale and Mohler, 2000).

Adoption of cover crops in tomato production has been limited as transplanters have problems penetrating heavy residue and there are valid concerns for excessive residue interfering with soil reception of soil-active herbicides. Studies have reported favorable results with use of cover crops in tomato production management systems. Abdul-Baki and Teasdale (1993) obtained higher yields with hairy vetch in no tillage systems compared to plastic and paper mulches under conventional tillage systems. Akemo et al. (2000) studied the effect of spring sown cover crops on tomato production in Ohio and concluded that tomatoes grown following cover crop systems produced better yields. Teasdale and Abdul-Baki (1998) concluded that weed control achieved by cover crop mixtures was better compared to legume monocultures, but herbicides were always required to attain effective weed control and maintain tomato yields. Massiunas et al. (1995) also concluded that when tomatoes were grown following a rye cover crop additional control measures were required to achieve season long weed control. Teasdale and Abdul-Baki (1998) concluded that new equipment and management strategies are required to avoid yield losses and to fully utilize the potential of cover crops and their mixtures.

Objectives of this study were to evaluate: 1) tomato stand establishment utilizing a prototype high residue transplanter, 2) weed control and tomato performance in three different high residue conservation tillage systems.

## Material and Methods

The experiment was conducted in the fall of 2004 and 2005 at the North Alabama Horticulture Experiment Station, Cullman, AL and in fall 2005 at Tuskegee University's George Washington Carver Agriculture Experiment Station, Tuskegee, AL. The soils were Hartsell fine sandy loam at Cullman and Marvyn fine sandy loam at Tuskegee. The experimental design was a randomized complete block with four treatment replicates. The plot size at both locations was 2.5 by 6 m containing a single row of tomatoes with 0.46 m spacing between the plants.

The three winter cover crops consisting of cereal rye (*Secale cereale* L.), crimson clover (*Trifolium incarnatum* L.) and turnip (*Brassica rapa* L) were compared to black polythene mulch for their weed suppressive potential and effect on yield and grade of fresh market tomatoes. Winter cover crops were planted with a no till drill each fall. Rye was seeded at a rate of 100 kg $ha^{-1}$, whereas clover and turnip were seeded at 28 kg $ha^{-1}$. Nitrogen was applied at a rate of 67.25 kg $ha^{-1}$ on rye and turnip plots in early spring of each year. To determine the winter cover crop biomass production, plants were clipped at the ground level from one randomly selected 0.25 $m^2$ area per replicate immediately before termination. Plant samples were dried at 65 C for 72 hours and weighed. The winter cover crops were terminated each spring with a mechanical roller crimper prior to a chemical application of glyphosate at 1.12 a.e. kg $ha^{-1}$. The rolling process produced a uniform residue cover over the plots.

Four cover systems (three winter cover crops plus plastic) were evaluated with and without herbicide for weed control. Herbicide treatments included a preemergence (PRE) application of metalochlor (1.87 kg a.i. $ha^{-1}$) either alone or followed by an early postemergence (EPOST) metribuzin (0.56 kg a.i. $ha^{-1}$) application followed by a late POST (LPOST) application of clethodim (0.28 kg a.i. $ha^{-1}$). The PRE application was applied one day before transplanting, the EPOST application was applied 14 days after transplanting, and the LPOST application was delayed until tomatoes were near mid-bloom. Tomato cv. 'Florida 47' seedlings were transplanted on $4^{th}$ April in 2005 and on April $9^{th}$ in 2006 at Cullman and April $19^{th}$ at Tuskegee.

Seedlings were planted with a modified RJ No-till transplanter (RJ Equipment, Blenhiem, Ontario) (Figures 1 and 2), which had a subsoiler shank installed to penetrate the heavy residue and disrupt a naturally occurring compacted soil layer found at both experimental sites at a depth of 30-40 cm. Additionally, two driving wheels were utilized (one wheel on each side of the tomato row) instead of the original single wheel at the center of the row, to improve stability. This modification also helps to minimize re-compaction of the soil opening created by the shank. The plastic-mulch plots were conventionally tilled utilizing a tractor mounted rototiller prior to bedding and plastic installation; tomatoes were hand transplanted in the plastic mulch each year. Water was applied to all the plots immediately after transplanting. Thereafter, the plots were irrigated every other day using a surface drip tape as needed. General production practices included staking and fertilization (preplant application of 13-13-13 achieving 88.5 kg of N $ha^{-1}$) and then 7.8 kg of calcium nitrate per hectare was applied once every week with the irrigation system.

Weed control was determined by visual ratings (0% = no control, 100% = complete control) 28 days after the EPOST herbicide treatment (DAT). All weed species present were evaluated for control (as a reduction in total above ground biomass resulting from both reduced emergence and growth) and the combined average for each rating and treatment was calculated. Ripe tomatoes were hand harvested weekly over the entire plot area and fruits separated according to size into small, medium, large, and extra large categories.

Non-normality and heterogeneous variances are usually encountered with percent control data that span a large range. Data were arcsine transformed to achieve normality of residuals and among treatment homogeneity of variances. The data were subjected to analysis of variance as implemented in SAS PROC MIXED. Difference between treatments means were determined by single degree of freedom contrasts.

## Results and Discussion

Twelve weed species were evaluated in this experiment (Table 1). Only three weeds were present in more than one field location. A cover by location and treatment by location interactions were significant for both large crabgrass [*Digitaria sanguinalis* (L.) Scop.] and yellow nutsedge (*Cyperus esculentus* L.). Herbicide treatment effects were significant for most weeds except ivyleaf morningglory (*Ipomoea hederacea* Jacq.), Virginia buttonweed (*Diodia virginiana* L.), and smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb.]. The cover by treatment interaction was significant only for tall morningglory [*Ipomoea purpurea* (L.) Roth] and leafy spurge (*Euphorbia esula* L.). Lack of cover by herbicide treatment interaction for most weeds indicates the absence of weed control synergism. The three way interaction was not significant for any of the weed species present in multiple locations. Only significant main and interaction effects will be discussed in the remainder of the paper.

There were no differences in weed control provided by clover and turnip residue at 4 WAT as is evident from the contrasts (Table 2). Pooled over all the herbicide treatments, clover residue provided 48% control of yellow nutsedge and 50% control of smallflower morningglory. All other weed species were controlled ≤ 30%. Turnip residue did not provide adequate control of any of the weeds providing 34% control of goosegrass [*Eleusine indica* (L.) Gaertn.] and 32% control of both smallflower morningglory and broadleaf signalgrass [*Urochloa platyphylla* (Nash) RD Webster ]. Neither clover nor turnip residues adequately controlled other weed species evaluated in the experiment. Rye residue was the most effective at suppressing weeds. Rye provided good control of Virginia buttonweed (81%), smallflower morningglory (91%) and yellow nutsedge (76%), but provided ≤ 31% control of large crabgrass, wild radish (*Raphanus raphanistrum* L.) and smooth pigweed (*Amaranthus hybridus* L.). When compared to clover and turnip, rye provided significantly higher control of most weeds. Smooth pigweed, pokeweed (*Phytolacca americana* L.), wild radish and large crabgrass were not controlled adequately (≤ 50%) by any winter cover residue. Weed control achieved with rye cover crop was comparable to plastic mulch. Plastic could not control Virginia buttonweed, smallflower morningglory and wild radish (≤ 9%). The control of only large crabgrass was significantly higher compared to rye.

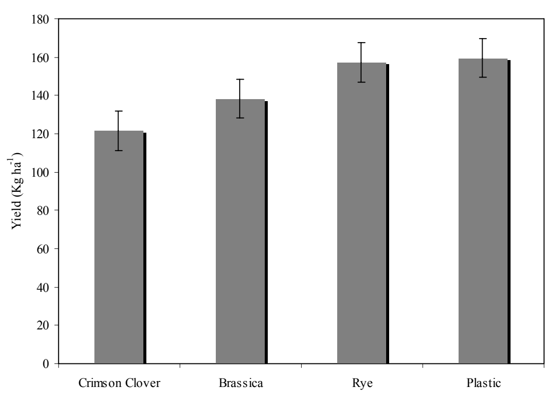


Fig 1. Effect of winter cover crops on tomato yield

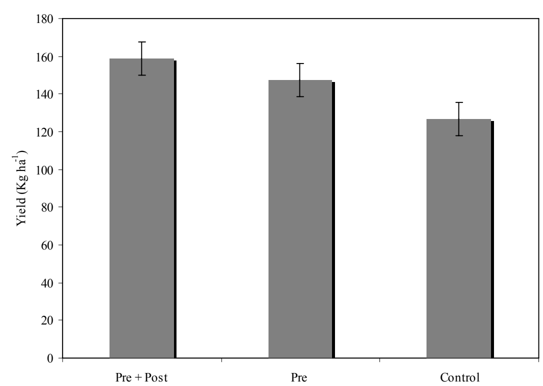


Fig 2. Effect of herbicide treatments on tomato yield

The effect of herbicide treatments on weed control was predictably more pronounced than the effect of cover crops. None of the weed species present were controlled adequately season-long without herbicides (Table 3). Weed control improved with application of the PRE herbicide with the exceptions of Virginia buttonweed and smallflower morningglory. Control of these weeds did not increase and was marginal even following the POST application. Control of broadleaf signalgrass, goosegrass, and yellow nutsedge improved significantly and was excellent (≥ 90%) with the inclusion of the POST herbicide application, whereas in other weed species the post application did not improve weed control. Reflecting the lack of season long weed control, weed control was minimal in treatments without herbicides.

Tomatoes were harvested only at the Cullman location in 2004 and 2005. Tomato plants were lost at Tuskegee due to an irrigation system failure immediately prior to fruit maturation. There was no interaction of year with winter cover crop and herbicide treatments nor was there a winter cover crop by herbicide interaction. Thus, the model reduces to a main effects model for winter cover crop and herbicide treatment effects. Pooled over herbicide treatments, the tomato yield was similar following rye cover and plastic mulch systems and the lowest fruit yield was observed in systems with a crimson clover winter cover crop (Figure 1). Averaged across winter cover crops, both herbicide programs resulted in better yields compared to the non treated check (Figure 2). Highest yield was obtained with the system containing both PRE and POST herbicides (Figure 2). This indicates that late season competition from weeds is as important as early season weed interference in maintaining yields.

Our study indicates that winter cover crop residue can provide early season weed control with supplemental use of EPOST herbicides. However, total reliance on winter cover crop for weed control was not sufficient and in all cases herbicides were required to provide season-long weed control and to maintain tomato yields.

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**Table 1: Analysis of variance for weed control[a]**

| Effect/Source | CYPES | AMAPA | DIGSA | BRAPP | ELEIN | PHTAM | PHBPU | EPHES | IPOHE | DIQVI | IAQTA | RAPRA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Environment (E) | 0.401 | **0.044** | **<0.001** | | | | | | | | | |
| Cover [C] | 0.186 | 0.104 | 0.388 | **0.003** | **0.006** | **0.001** | **<0.001** | **<0.001** | 0.074 | **<0.001** | **<0.001** | **0.015** |
| C x E | **0.090** | 0.173 | **0.021** | | | | | | | | | |
| Treatment (T) | **0.021** | **0.006** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | 0.496 | 0.157 | 0.058 | <0.001 |
| T x E | **0.001** | 0.376 | **<0.001** | | | | | | | | | |
| C x T | 0.268 | 0.981 | 0.143 | 0.307 | 0.254 | 0.762 | **0.009** | **0.004** | 0.968 | 0.788 | 0.891 | 0.763 |
| C x T x E | 0.762 | 0.447 | 0.410 | | | | | | | | | |
| **Weeds were present in:** | | | | | | | | | | | | |
| Year | | | | | | Location | | | | | | |
| 2005 | Cullman | Cullman | | Cullman | Cullman | Cullman | Cullman | Cullman | | | | |
| 2006 | Cullman | Cullman | Cullman | | | | | | Cullman | | | |
| 2006 | Tuskegee | Tuskegee | Tuskegee | | | | | | | Tuskegee | Tuskegee | Tuskegee |

**Table 2. The effect of cover crops on weed control. Data are combined over herbicide applications[a]**

| | Weeds Cullman 2005 | | | | | | | Weeds Tuskegee 2006 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cover | BRAPP | ELEIN | PHTAM | EPHES | AMACH | PHBPU | CYPES | DIQVI | DIGSA | IAQTA | RAPRA |
| ***Percent control*** | | | | | | | | | | | |
| Crimson clover | 30 | 25 | 14 | 2 | 1 | 1 | 48 | 29 | 15 | 50 | 1 |
| Raphanus sativus | 32 | 34 | 6 | 0 | 9 | 9 | 28 | 15 | 15 | 32 | 2 |
| Rye | 66 | 62 | 42 | 48 | 22 | 52 | 76 | 81 | 11 | 91 | 31 |
| Plastic | 70 | 64 | 74 | 64 | 53 | 66 | 72 | 0 | 52 | 1 | 9 |
| ***P-values from contrasts:*** | | | | | | | | | | | |
| Clover vs. Raphanus | 1.00 | 0.89 | 0.90 | 0.75 | 0.64 | 0.35 | 0.60 | 0.80 | 1.00 | 0.83 | 0.99 |
| Clover vs. Rye | 0.03 | 0.03 | 0.36 | **<0.001** | 0.11 | **<0.001** | 0.32 | 0.04 | 0.95 | 0.13 | 0.02 |
| Clover vs. Plastic | 0.01 | 0.02 | 0.01 | **<0.001** | **<0.001** | **<0.001** | 0.46 | 0.03 | 0.01 | 0.02 | 0.57 |
| Raphanus vs. Rye | 0.05 | 0.13 | 0.12 | **<0.001** | 0.65 | 0.01 | 0.03 | 0.00 | 0.96 | 0.02 | 0.03 |
| Raphanus vs. Plastic | 0.02 | 0.11 | **<0.001** | **<0.001** | 0.01 | **<0.001** | 0.05 | 0.19 | 0.01 | 0.14 | 0.76 |
| Rye vs. Plastic | 0.98 | 1.00 | 0.35 | 0.65 | 0.16 | 0.71 | 1.00 | **<0.001** | **<0.001** | **<0.001** | 0.26 |

**Table 3. Effect of herbicide treatments on weed control. Data are pooled over all covers[a]**

| | Cullman 2005 | | | | | Tuskegee 2006 | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | BRAPP | ELEIN | PHTAM | AMACH | CYPES | DIQVI | DIGSA | IAQTA | RAPRA |
| Percent control | | | | | | | | | |
| PRE + POST | 94 | 93 | 70 | 47 | 90 | 13 | 80 | 31 | 35 |
| PRE | 62 | 58 | 36 | 18 | 70 | 23 | 8 | 26 | 1 |
| Untreated control | 1 | 0 | 3 | 1 | 9 | 41 | 0 | 67 | 2 |
| ***P-values from contrasts:*** | | | | | | | | | |
| POST vs.control | **<0.001** | **<0.001** | 0.05 | 0.02 | 0.09 | 0.41 | **<0.001** | 0.74 | **<0.001** |
| PRE vs. control | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | 0.06 | **<0.001** | 0.06 | **<0.001** |
| POST vs.PRE | **<0.001** | **<0.001** | 0.01 | 0.01 | **<0.001** | 0.26 | 0.04 | 0.03 | 0.77 |

[a] Abbreviations: CYPES, Yellow nutsedge, AMAPA, Palmer amaranth, DIGSA, Large crabgrass, BRAPP, Broadleaf signalgrass, ELEIN, Goosegrass, PHTAM, Pokeweed, PHBPU, Tall morningglory, EPHES, Leafy spurge, IPOHE, Ivyleaf morningglory, DIQVI, Virginia buttonweed, IAQTA, Smallflower morningglory, RAPRA Wild radish.