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WATER RESOURCE MANAGEMENT IN FRUIT AND VEGETABLE PRODUCTION USING ALTERNATIVE MULCHES

Gary L. HAWKINS

University of Georgia, 1420 Experiment Station Road, Watkinsville, GA 30677, USA

Corresponding author email: ghawkins@uga.edu

Abstract

Water management and conservation tillage practices can be important when producing fruit and vegetable crops in areas of limited water resources. This study evaluated six alternative mulching materials - compost, biofilm plastic, newspaper, craft paper, compost with glycerin, and a no-mulch control - against standard low-density polyethylene (LDPE) plastic in a bedded watermelon production system. Three replications of each treatment (mulches) were randomly placed in sections of watermelon rows. Weed density, soil moisture, and temperature were monitored to assess the performance of each mulch. Results showed that all treatments, except for the control and compost, provided effective weed suppression comparable to LDPE. Soil temperature and moisture levels varied across treatments, with compost producing the highest and lowest recorded temperatures. These findings suggest that several alternative mulches, when used in combination with conservation tillage, offer viable, sustainable options for small-scale fruit and vegetable production.

Key words: *sustainability, alternative mulches, water, conservation practices.*

INTRODUCTION

Farmers produce a wide variety of crops that supply the food and fiber essential to our daily lives. In the cultivation of many of these crops - particularly fruits and vegetables - plastic mulches have been used since the 1950s to conserve soil moisture, suppress weeds, stabilize soil temperature, reduce insect pressure, and enhance crop yield (Goldberger et al., 2013; Ibarra-Jimenez et al., 2006; Anderson et al., 1995; Diaz-Perez, 2023; David & Kumar, 2023; Kasirajan & Ngouajio, 2012). These mulches are typically made from low-density polyethylene (LDPE) (Beriot et al., 2023; Kasirajan & Ngouajio, 2012) and are usually removed after one or more production cycles. However, during removal or repeated use, LDPE fragments often remain in the soil, where they do not degrade, or they may be carried to marine environments via runoff (Serrano-Ruiz et al., 2021). When left in the field over multiple seasons, these fragments can form concave pockets that trap water and nutrients, potentially limiting root penetration and affecting plant health (David & Kumar, 2023; Beriot et al., 2023).

A conceptual illustration of these issues is provided in Figure 1.

While recycling may appear to be a potential solution, the processes of removing, cleaning, and repurposing LDPE are complex and largely impractical for most producers (Kasirajan & Ngouajio, 2012). This raises an important question: what are the viable alternatives?

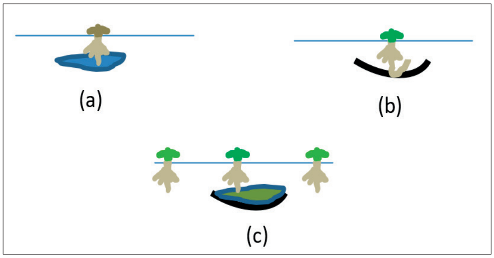


Figure 1. Conceptual illustration of the potential negative effects of residual plastic mulch in the soil: (a) Plastic traps water, leading to root rot and plant death; (b) Plastic impedes downward root growth; (c) Plastic creates isolated zones of water and nutrients, preventing their uptake by surrounding plants (Illustration by G. Hawkins)

Farmers are generally recognized as responsible stewards of the land they manage for food and fiber production (Carmichael et al., 2023; Sherval et al., 2018). While the use of plastic mulch is common and not inherently problematic, many producers seek alternative approaches that allow them to maintain soil moisture, suppress insect pressure, and, in some cases, protect crops from wind. These approaches often involve the use of alternative mulches in fruit and vegetable production systems (Anderson et al., 1995; David & Kumar, 2023; Kasirajan & Ngouajio, 2012). The farmer collaborating on this project employs conservation tillage practices, incorporating cover crops to enhance soil organic matter, reduce erosion, support soil biota, and provide wind protection for young watermelon plants. He currently uses LDPE plastic mulch to achieve many of these agronomic benefits. However, he has expressed concerns about the long-term accumulation of LDPE in the soil, particularly the potential for creating perched water tables or obstructing root penetration - issues illustrated in Figure 1b. As a result, the objective of this study was to evaluate practical alternatives to LDPE mulch, particularly those that may be better suited for adoption on small farms or in conservation-oriented production systems.

MATERIALS AND METHODS

The project was conducted in the watermelon-growing region near Cordele, Georgia, USA. The collaborating farmer employs conservation tillage practices and plants a cover crops each fall following the harvest of his commercial crop. He also practices crop rotation. In late winter or early spring, he terminates strips of the cover crop in preparation for bedding and planting watermelon. Once the cover crop has fully died back, he prepares the watermelon beds by tilling, forming raised beds, and laying plastic mulch over the planting rows (Figure 2). The plastic is applied using a custom-built plastic layer designed to form beds with a width of 0.45 meters (18 inches), as shown in Figure 2b.

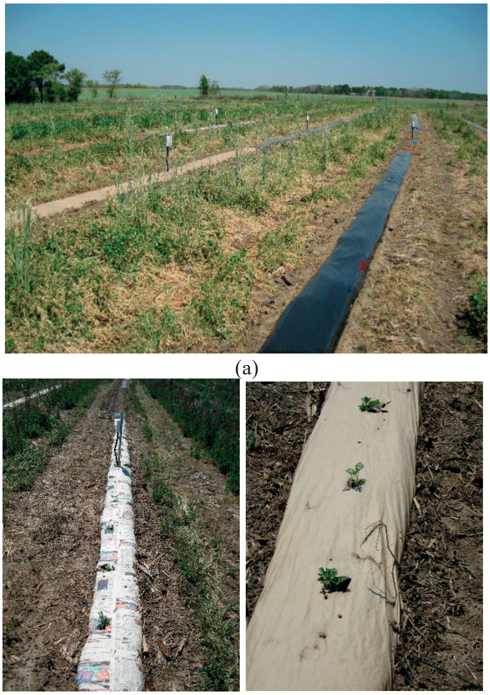
After the plastic mulch was laid, the author cut 8.8-meter (29-foot) sections to install three randomized, replicated treatments: (1) control (no alternative cover), and contractor-grade or brown craft paper. Due to limited availability, treatments using compost and compost mixed with glycerin (a byproduct of biodiesel production) were restricted to shorter sections measuring 2.7 meters (9 feet) in length. A portion of the installed treatments is shown in Figure 3, along with the dataloggers used to monitor soil temperature and moisture.

As shown in Figure 3a and 3b, various sensors were installed during the treatment setup to monitor environmental conditions. Soil moisture sensors (Decagon Devices 10HS Capacitance Sensors; see NOTE), temperature sensors (Decagon Devices), a rain gauge (Decagon Devices ECRN-50), and a datalogger (Decagon Devices EM-50) were used to collect data on soil moisture and temperature at 15-minute intervals. Soil moisture sensors were installed vertically to monitor the top 15 cm (6 inches) of the soil profile, while temperature sensors were placed directly on the soil surface beneath each mulch treatment.

(a)

(b)

Figure 2. (a) Bed preparation by tilling a narrow 0.6 m (24-inch) strip through the cover crop and installing biodegradable plastic or four layers of newspaper;
(b) Formation of a 0.5 m (20-inch) finished bed with plastic mulch laid over the tilled area between standing cover crop rows
(Images by G. Hawkins)



(a)

(b) (c)

Figure 3. Alternative mulch treatments installed in a watermelon field, along with dataloggers used to monitor soil temperature and moisture. (a) Multiple treatment rows with various mulch types; (b) Newspaper mulch with planted watermelon seedlings; (c) Craft paper mulch with planted watermelon seedlings (Images by G. Hawkins)

Throughout the growing season, weed density was also monitored. Weeds were counted, averaged by treatment, and normalized to a per-acre basis to enable comparison.
All collected data were stored, analyzed, and graphed using Microsoft Excel.
After sensor installation and treatment setup, the farmer mechanically planted the watermelon crop

RESULTS AND DISCUSSIONS

The findings from this study are presented in the following figures and categorized by key parameters: weed count, temperature, and soil moisture.

Weed Count

As shown in Figure 4, the standard LDPE plastic mulch resulted in minimal weed emergence, with yellow nutsedge being the only species able to penetrate the mulch, averaging fewer than 444 plants per acre across five weekly sampling events (Webster, 2005). Similarly, biodegradable plastic, newspaper, craft paper, and compost with glycerin treatments also exhibited low weed pressure, with the newspaper treatment recording the highest among them - averaging 900 plants per acre.
Microbial activity trends corresponding to these treatments are summarized in Table 1, which presents colony counts over a five-week period. Compost treatment showed a steady increase in microbial populations, peaking at 47,329 CFU by May 17. In contrast, the control treatment had the highest microbial counts overall, while treatments like biofilm, newspaper, and craft paper exhibited moderate microbial activity. Compost with glycerin showed minimal microbial growth until the final sampling date, when a notable increase was observed.
In contrast, significantly higher weed densities were observed in the compost and no-mulch (control) treatments. The compost treatment averaged over 20,000 weeds per acre, while the control plot had the highest count, averaging over 48,000 plants per acre across the sampling period.

Tabel 1. Temporal dynamics of microbial populations under different organic amendments and controls

Sampling Date	Control	Biofilm	Newspaper	Craft Paper	Compost Gly	Compost
4/19/2010	18000	0	0	0	0	4303
4/26/2010	32333	0	0	333	0	6454
05/03/2010	48000	1000	667	333	0	15059
05/10/2010	63333	1500	1333	1000	0	31194
5/17/2010	78667	500	2667	0	2151	47329

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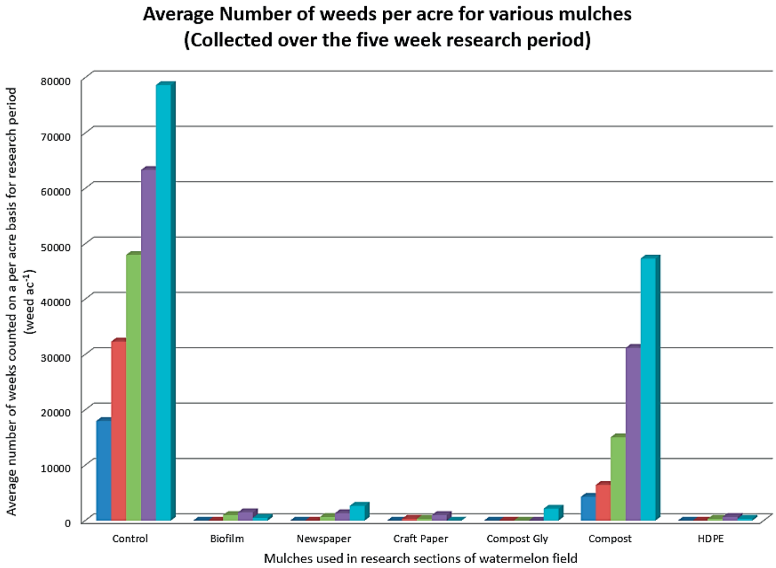

Figure 4. Graph and associated table showing the number of weeds collected from each mulch type during the five-week research period as indicated standardized to a per acre basis

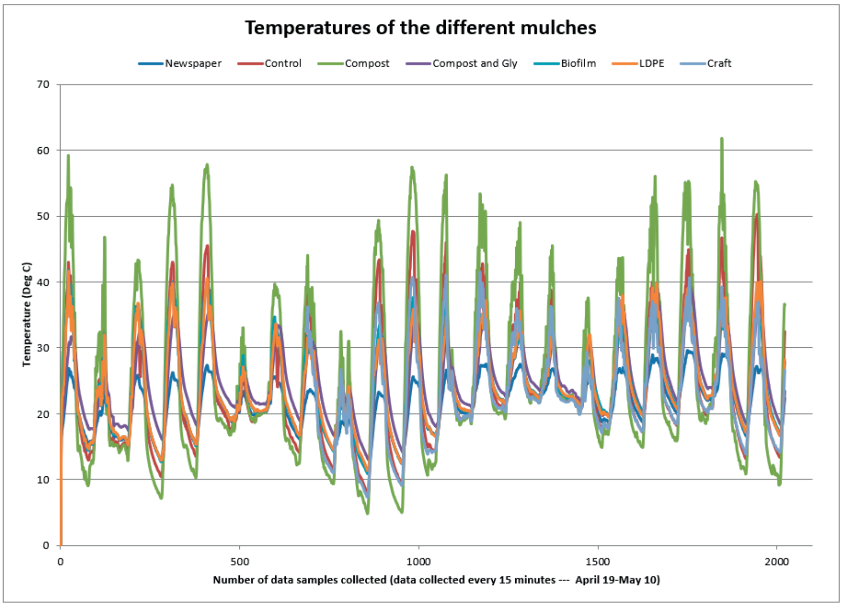

Figure 5. Temperatures as measured for the different treatments

Soil Moisture

Figure 6 illustrates the soil moisture dynamics under each mulch treatment throughout the study period. Soil moisture was measured to evaluate how different mulches influenced water retention in response to precipitation, which in this case included both natural rainfall and supplemental irrigation via a center pivot system.

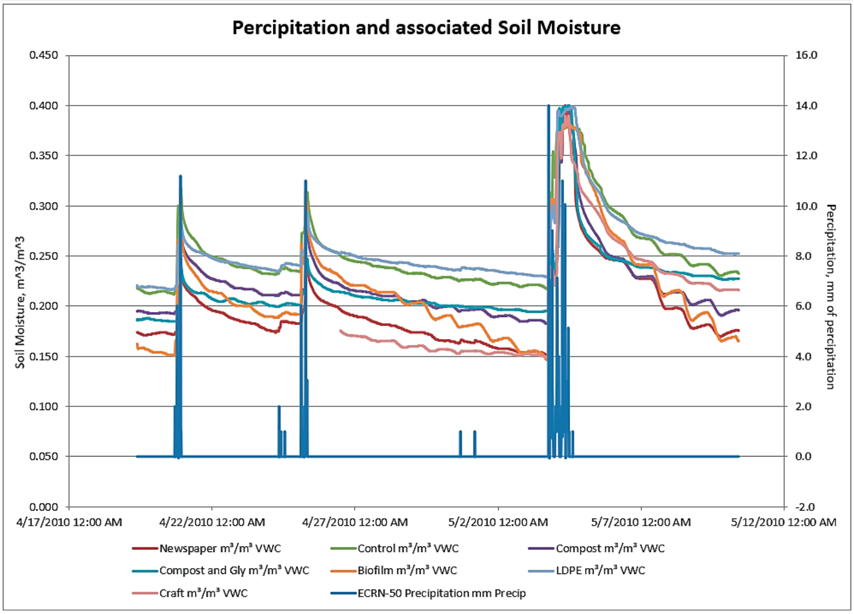

Figure 6. Precipitation and associated soil moisture under each mulch as measured in the top vertical 15 cm (6 inches) of soil

Soil moisture levels under the LDPE and control treatments were generally the highest, ranging from 0.22 to 0.40 $m^3\ m^{-3}$. In contrast, the craft paper and newspaper treatments exhibited lower soil moisture levels, ranging from 0.15 to 0.40 $m^3\ m^{-3}$. These differences suggest that denser or less permeable mulches like LDPE are more effective at conserving soil moisture.

Moisture loss patterns also varied based on precipitation intensity. Following small rainfall events (e.g., 10 mm), water infiltration and retention were relatively steady across treatments. However, during larger precipitation events (e.g., around May 4, which included multiple days with up to 14 mm of rainfall), the rate of moisture loss increased -likely due to higher soil saturation and increased evapotranspiration from expanding watermelon vines.

Overall, the soil moisture under all treatments was reasonably well maintained, aided by the irrigation system. For smaller-scale farms, drip or solid-set irrigation systems could offer similar benefits. Despite differences in volumetric water content across treatments, the rate of soil moisture decline remained consistent, highlighting the importance of mulch type in managing soil water retention.

CONCLUSIONS

This project demonstrated that several alternative mulches can be viable options for fruit and vegetable production, particularly for farmers seeking more sustainable practices. All tested mulches, except for compost, were effective in suppressing weeds and maintaining soil moisture levels comparable to those under standard LDPE plastic.

However, soil temperature responses varied among treatments, and some materials - such as compost - produced extreme temperature fluctuations that could pose risks depending on the crop. Additionally, practical considerations such as ease of deployment remain important. While all alternative mulches in this study were hand-laid, scaling their use for larger operations may present logistical challenges without specialized equipment.

Overall, with appropriate selection based on crop needs and farm scale, alternative mulches offer promising potential to support sustainable and conservation-oriented production systems.

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NOTE

Mention of specific company names does not imply recommendation by the author, or the University of Georgia, USA and other products may provide the same data. Decagon Devices were used in this study, but the company has been purchased by METER Group since the date of this research, but the current sensors are the same capacitance sensors as used in the research.

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