RODALE INSTITUTE

BEYOND BLACK PLASTIC

Cover crops and organic no-till for vegetable production

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LETTER FROM THE EXECUTIVE DIRECTOR

Rodale Institute has been dedicated to making the world a better place through agriculture since J.I. Rodale first chalked our motto on a blackboard in 1947. Healthy Soil = Healthy Food = Healthy People drives all of our projects. It is the touchstone against which we test all of our efforts. Even then, J.I. understood that healthy soil is the foundation for growing healthy food. We are as committed today as ever to J.I. Rodale's conviction and the work Robert Rodale continued when he planted our roots on a 333-acre farm outside of Kutztown, Pennsylvania.

The research and outreach conducted at Rodale Institute is aimed at creating an agricultural system based on healthy soil. For more than sixty years, we've been researching organic agriculture, sharing our findings with farmers and scientists throughout the world, and advocating for policies that support growers.

One of the most rewarding developments in the last few decades has been that as we test and develop best practices for organic farmers, we find techniques and methods that can be adopted by all farmers.

This particular project found us addressing the soil health issues related to the use of tillage and black plastic in organic systems as well as the use of herbicides in no-till conventional systems. The goal was to determine whether or not we could make the benefits of no-till accessible to organic farmers as an alternative to tillage and black plastic, and provide all farmers with tools other than black plastic and herbicides to manage weeds and get a good cover crop kill.

As all farmers seek new ways to protect and conserve their soil and save time and money, there is a need for more collaborative research that creatively explores the possibilities within our established systems. Fostering more knowledge sharing between the conventional and organic farming communities and researching the results will be essential to creating a stronger, more resilient agriculture that goes beyond what is expected.

Through first-rate scientific research and education we hope to support all farmers in their journey towards a more sustainable food system.

Coach Mark Smallwood

FOREWORD

Since 1988, Northeast SARE has been making grants aimed at education and applied research to advance sustainable approaches to farming. Those 25 years have brought much learning and many successes as well as challenges. Innovation isn't always easy, in part because change can be risky—while familiar practices, warts and all, often have widespread support. Pushing the envelope too fast or too far can alienate the very constituents our grantees want to engage.

As a result, Northeast SARE has required its grantees to partner with, and seek input from, the farmers they seek to benefit. From the planning of proposals to their implementation to the sharing of results, it's supposed to be a collaborative effort. This process strengthens the relationships between grantees and their stakeholders and builds learning communities where ideas flow in all directions, not just from scientists to producers but in the other direction as well.

It took a certain kind of institution to embrace this model of inquiry in the early years of SARE—a few land grant universities were on board, and these were complemented by a handful of other forward-thinking institutions like the Rodale Institute. Many of these early partners, including Rodale, have had a continuing relationship with SARE, getting grants to explore a series of innovative ideas over the years and building strong networks of cooperating farmers.

In 1988, the first year of active SARE operations, the Rodale Institute came up with an idea to use videos to literally help farmers "see" how to adopt sustainable agriculture practices. Since then, Rodale has received grants to explore cover crops and no-till, organic grain production, and the use of compost or compost tea to improve crop yield and manage disease. Most recently, Rodale has been funded to study the effectiveness of a rye-vetch cover intercrop at suppressing weeds and increasing soil nitrogen in vegetable production, while still maintaining yield.

This project exemplifies a characteristic that resonates with our grant reviewers: going beyond incremental change that tweaks a single practice and instead testing a significant re-design of a cropping system. In this case, the overall goal is not only to eliminate the use of plastic mulch but also to provide legume nitrogen and improve physical aspects of soil health at the same time. As with any good SARE project, farmers are engaged throughout the multiyear research effort.

Rodale's success in getting Northeast SARE grants has rested in part on the ability to conduct research into sustainable agriculture using a systems approach to farming. It's easier and more predictable to focus on researching a single crop, a single pest, or a single barrier to production; it's much harder to investigate and understand whole-farm interactions that vary over space and time. We celebrate this intellectual ambition, especially when it's sufficiently grounded in reality to allow new ideas a reasonable chance of adoption. Northeast SARE's success rests with our grantees—our partners—who use the funding we provide to facilitate innovation, but always in cooperation with the farming community we both seek to serve.

Vern Grubinger, Northeast SARE regional coordinator

EXECUTIVE SUMMARY

While the use of black plastic is allowed within organic agriculture, it is inherently unsustainable as it is a petroleum-based product and difficult to recycle. Every acre of land farmed using a black plastic system produces 100-120 lb of waste that typically goes to landfills. What's more, when black plastic is used, 50-70% of a field is transformed into an impervious surface, increasing the volume of runoff by 40% and erosion by 80%. And when herbicides and pesticides are used on fields covered in black plastic, the concentration of these chemicals in the fields' runoff increases, making environmental and human health impacts even more of a concern. Finally, the increase in soil temperatures during hot summer days under black plastic mulch has been found to shift the soil organisms community towards bacterial rather than fungal and increase microbial stress. Black plastic is also a substantial annual cost to the farmer at $250-$300 per acre for the material and about $20 per acre for disposal.

With increases in cost of production and climate change, vegetable growers are looking into profitable and sustainable systems that increase soil health, reduce carbon foot print and increase their profits. The Northeast Sustainable Agriculture Research and Education (NE SARE) Program provided Rodale Institute with funding in 2010 to launch a three-year vegetable trial focusing on cover crop alternatives to petroleum-derived disposable black plastic mulch.

While researchers have made great headway in developing and demonstrating the efficacy of cover crop mulch systems, most of the systems that have been developed rely to some degree on synthetic herbicides to supplement the weed control provided by the cover crops. For this reason, researchers at Rodale Institute have been working to develop a cover crop mulch system in which herbicides are not necessary for weed suppression, furthering the work of making cover crop mulch a viable option for organic as well as conventional vegetable producers.

The goal of the study was to measure the impacts of these different mulch systems on soil quality and fertility, weed control, yields and waste production, and profitability for small to mid-size vegetable operations. The vegetable trials at Rodale Institute compared cover crop nitrogen, potential carbon contribution, weed suppression, yields and soil health between rolled and mowed vetch and rye cover crops as well as commonly used black plastic. At the four collaborating farms in Pennsylvania and New Jersey, each farmer tested one cover crop system with the standard system.

The cover crop systems provided serviceable weed control, added more biomass to the soil, contributed nutrients, and increased soil moisture and percent total soil carbon. Although marketable yields were lower, on average, some of the cover crop systems achieved higher profits across the three years. The cover crop mulch systems eliminated 91.5 lb of plastic waste per acre.

Challenges related to extreme weather conditions and late blight meant results were more variable than anticipated, but all of the partner farmers continue to use what they've learned from the project to reduce their reliance on black plastic. Benefits partner farmers experienced include discovering a method for more effective cover crop kill, substantial cost savings and new ways to use cover crops between rows for ecosystem benefits. One partner has already cut his black plastic use in half and hopes to expand even further.

BACKGROUND

Weed control is one of the primary challenges that farmers have faced around the world and through the ages. Before the introduction of herbicides into agriculture in the 1940s, cultivation, hand weeding, and, in some parts of the world, controlled flooding were the primary techniques used to suppress weed growth. The use of herbicides grew in popularity very quickly, and by the 1970s it was the dominant mode of weed control used by farmers in the United States.

These days, most conventional farmers deal with weeds using a combination of cultivation and herbicide. While these techniques are very effective at keeping weed populations low, they have many detrimental side-effects on the health of the soil, the environment, and people. Soil disturbance and applications of herbicides damage the ecology of the soil, reducing its ability to absorb and retain water, store and cycle nutrients, and maintain good soil structure. As a result, erosion and leaching of nutrients are more likely to occur, removing valuable material from the field and damaging the water systems into which these materials flow. In addition to its effects on soil biology, plowing is fuel intensive and creates a hardpan, which can impede the growth of roots and the flow of water. Some herbicides also have the potential to do harm to the environment and to human health when they enter streams, rivers, and lakes as runoff or when they get into the groundwater as leachate.

In the 1950s, black plastic mulch was introduced to the market as another tool to help with weed suppression. Black plastic mulch, often referred to simply as "black plastic," is a thin sheet of petroleum-based plastic that farmers lay over the surface of their rows, usually installing a drip line under the plastic for irrigation. Plants are transplanted through holes in the plastic by hand or with machinery. At the end of the growing season, the material is removed from the field and disposed of.

Black plastic very effectively prevents plants from growing in the areas it covers. Compared to growing vegetables in bare soil, using black plastic greatly reduces the need for other forms of weed control, be it herbicide application, cultivation, or labor-intensive hand weeding. Another perk of using black plastic is that it warms the soil, in some cases allowing for earlier planting. For these reasons, black plastic has grown in popularity over the last 50 years.

The Importance of Healthy Soil Biota

Healthy soil contains a diverse set of microorganisms that provide many benefits to crops and to the farmer. These bacteria, protozoa, nematodes, fungi, and microarthropods decompose plant residues, improve soil aggregation and porosity, cycle nutrients from the soil organic matter and minerals into plant available forms, and can even protect plants against pathogens. As a result, plants growing in fields with healthy soil biota will be more resistant to disease and will do better in times of stress, such as during drought or extreme heat. The fields themselves will be more able to absorb and retain moisture, and will be less likely to erode.

However, black plastic has its downsides. While it is allowed within organic agriculture, it is inherently unsustainable as it is a petroleum-based product and difficult to recycle. Every acre of land farmed using black plastic produces 100-120 lb of waste that typically goes to landfills.[1,2,3,4] What's more, when black plastic is used, 50-70% of a field is transformed into an impervious surface, increasing the volume of runoff by 40% and erosion by 80%.[5] And when herbicides and pesticides are used on fields covered in black plastic, the concentration of these chemicals in the fields' runoff increases, making environmental and human health impacts even more of a concern.[6] Finally, the increase in soil temperatures during hot summer days under black plastic mulch has been found to shift the soil organisms community towards bacterial rather than fungal and increase microbial stress.[7,8] Black plastic is also a substantial annual cost to the farmer at $250-$300 per acre for the material and about $20 per acre for disposal.

For these reasons, researchers have been exploring cover crop mulch systems as an alternative to black plastic mulch. Several cover crop-based vegetable production systems have been developed and discussed in scientific literature, including the use of flail mowers, roller-crimpers, or undercutters to terminate the cover crop and transform it into mulch.

Whereas black plastic damages soil quality, cover crop mulches improve it by adding organic matter to the soil and increasing soil microbial life.[9] Researchers have found that leaving cover crop residue on the soil surface resulted in crops with "increased disease tolerance…high vigor, higher marketable yield, and delayed senescence."[10] These systems are also less expensive and faster to execute than black plastic, and they require no cost or labor for the removal and disposal of material at the end of the season.

While researchers have made great headway in developing and demonstrating the efficacy of cover crop mulch systems, most of the systems that have been developed rely to some degree on synthetic herbicides to supplement the weed control provided by the cover crops. For this reason, researchers at Rodale Institute have been working to develop a cover crop mulch system in which herbicides are not necessary for weed suppression, furthering the work of making cover crop mulch a viable option for organic as well as conventional vegetable producers.

The Work of John Teasdale and Aref Abdul-Baki

John Teasdale and Aref Abdul-Baki, both plant physiologists with the U.S. Department of Agriculture, began exploring cover crop mluch as an alternative to black plastic in the 1980s. They developed a mowed hairy vetch mulch system for tomatoes, in which the vetch is flail-mowed just prior to tomato planting and one or two applications of herbicide are used to control re-growth of the vetch and other weeds that emerge throughout the season. Through their research, they found that tomatoes grown in this system generally produced better yields, had less foliar disease, and required fewer commercial fertilizers than those grown in black plastic. In addition, the vetch mulch system produced profits that were two-thirds greater than profits in the black plastic system. Not only did Teasdale and Abdul-Baki establish that cover crop mulch systems can be a viable alternative to black plastic mulch, they demonstrated that these systems are beneficial to the soil, the plants, and the environment.[11]

ORGANIC NO-TILL AND THE ROLLER-CRIMPER

WHAT IS ORGANIC NO-TILL?

Tillage is often used for pre-plant soil preparation, as a means of managing weeds, and as a method of incorporating fertilizers, crop residue, and soil amendments. Tillage is harmful to soils because it stimulates the breakdown of soil organic matter, sometimes at a very rapid rate. It can also physically damage the soil structure, breaking down soil aggregates and structural elements like infiltration channels. Tillage often inverts the soil, causing disturbance to soil life. Organic no-till addresses a criticism often aimed at organic agriculture—that it uses too much tillage and cultivation, which disturb the soil. Vegetable farmers especially may till the soil several times a year as they plant multiple crops and use cultivation to manage annual weeds.

Conventional farmers are able to reduce or eliminate tillage in their fields by using herbicides to control weeds and special no-till equipment for planting. As herbicide is not an option in organic productions, many organic farmers rely heavily on tillage to control weeds and are often accused of over tilling the soil. New techniques and tools that have been developed in the last two decades, such as the roller-crimper, allow organic farmers to begin to reduce tillage within production systems.

Organic no-till rests on three fundamental principles: (1) soil biology powers the system, (2) cover crops are a source of fertility and weed management, and (3) tillage is limited and best described as rotational tillage. In goals and ideology, organic no-till is very similar to other kinds of organic farming. These include soil building with organic matter and soil biology; managing weeds, insects, and diseases through diverse and non-chemical means; and achieving general plant health through soil health and good management practices. However, organic no-till uses different methods to achieve those goals. Much more emphasis is placed on cover cropping, which replaces tillage and cultivation as a means of building soil health and managing weeds.

THE ROLLER-CRIMPER

The roller-crimper is a specialized tool designed by Rodale Institute that allows a farmer to terminate a living cover crop and convert it into a mulch layer. It works by rolling the cover crop plants in one direction, crushing them, and crimping their stems. When done properly, the plants are killed and left as a dense mat of residue covering the surface of the soil and suppressing weed growth.

Since the system is based on biology and mechanics, it is scale neutral: suitable for use on either small or large farms. The roller-crimper can be pulled behind a tractor, a horse, or even pushed by hand depending on the scale of the operation. It can be mounted on the front or back of a tractor. When mounted on the front, it frees up the rear of the tractor for a no-till drill or transplanter to plant directly into the rolled cover crop. In this way, the cover crop can be terminated and the cash crop planted in just one pass.

While other tools such as flail mowers and undercutters have the capacity to convert cover crops into mulch, the roller-crimper has some advantages over them. It requires less fuel and creates a more consistent groundcover. While flail mowers and undercutters can result in patchy coverage of the soil, the roller-crimper allows a farmer to create an intact mat that covers the ground thoroughly.

A front-mounted roller-crimper terminates a rye/vetch cover crop, creating a solid mat of plant residue that will serve as mulch.

MANAGEMENT CONSIDERATIONS FOR ROLLED COVER CROPS

The timing of rolling is important in order to achieve 100% termination and prevent the cover crop from re-growing. The correct time to roll for most crops is when the plant is in anthesis, or producing pollen. During this phase of the plant's life cycle, it is much more vulnerable and can be effectively killed by the roller-crimper. For hairy vetch, at least 75% of the plants should be in bloom, while 100% bloom is ideal. In eastern Pennsylvania, the proper time for termination of both winter rye and hairy vetch typically falls in late May or early June.

To achieve adequate weed control, there must be enough cover crop biomass by the time the plants reach anthesis. The cover crop should be planted at a high seeding rate and produce approximately 3 to 4 tons per acre of dry matter. For this reason, cover crops that yield a high amount of biomass work best for the no-till system. In addition, it's important to select cover crops with a carbon-to-nitrogen ratio higher than 20:1. The higher the ratio, the more carbon and the more slowly the crop will break down. This will provide consistent weed management through the season.

After harvest, the remaining cover crop residues can be disked under and the next round of cover crops can be planted for the following season. Thus, the crop year begins in the fall with planning for the following year. For this reason, organic no-till requires considerable long-term planning.

Rodale Institute's Jeff Moyer uses a front-mounted roller-crimper and a rear-mounted no-till seeder to simultaneously terminate the winter rye and hairy vetch cover crop and direct seed soybeans.

RODALE INSTITUTE'S ORGANIC MULCH TRIAL

Rodale Institute received a grant from the Northeast Sustainable Agriculture Research and Education (NE SARE) Program in 2009 to compare rolled and mowed cover crop mulches with standard black plastic mulch for production of tomatoes and other vegetables.

The goal of the study was to measure the impacts of these different mulch systems on:

1) soil quality and fertility
2) weed control
3) yields and waste production
4) profitability for small to mid-size vegetable operations

The expectations were that the cover crop mulches would improve soil quality and fertility, demonstrate weed control and yields similar to the black plastic, produce little or no waste product, and be a more profitable technique for vegetable production.

Plots were established in fall of 2009, 2010, and 2011 in certified organic fields at Rodale Institute to compare these nine different mulching systems. All test plots were plowed, disked, and packed, and cover crops were drilled in each plot in September. The cover crop varieties used were "Aroostook" cereal rye and "Purple Bounty" hairy vetch. Vetch was planted at a rate of 35 lb/acre, rye at a rate of 168 lb/acre, and rye/vetch at a rate of 95 lb/acre (70 lb rye, 25 lb vetch).

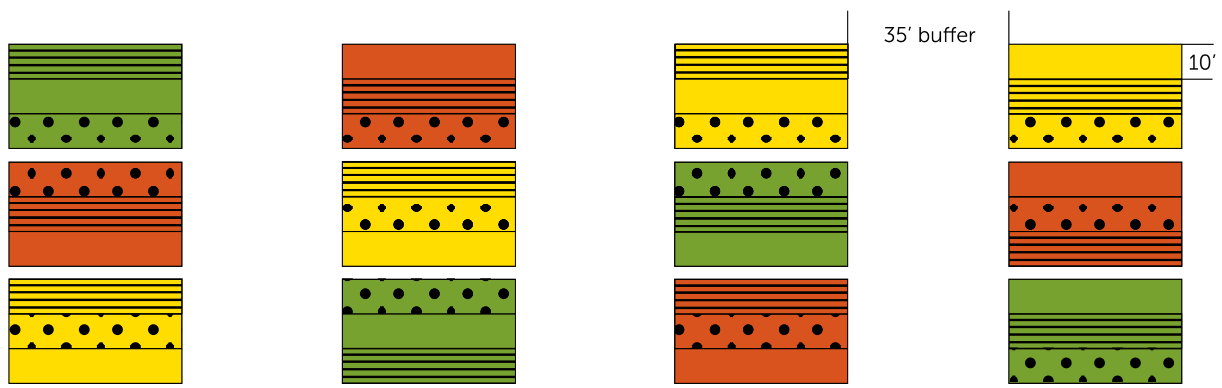
After allowing the cover crop to overwinter and regrow in the early spring, researchers terminated the cover crop in each plot according to the treatment types. In the black plastic treatments, the cover crop was tilled in early May, a month prior to planting. The plastic mulch and drip line were laid down a few weeks after plowing. In the other two treatments, the cover crop was either mowed with a flail mower or rolled with a roller-crimper in late May or early June when at

The Layout

The plot layout of the trials done at Rodale Institute is depicted here. Each treatment was replicated four times. The colors and patterns shown below correspond with the charts in the upcoming pages. There were a total of nine treatments in this trial, each a combination of one of the following cover crops and termination methods:

Cover crop treatments
- vetch
- rye
- rye & vetch

Termination methods
- black plastic
- rolled
- mowed



Tomatoes were planted 18 inches apart, with one row per plot. The plants were staked and twined, as is typical in tomato production.

least 50% of the plants had reached anthesis (were producing pollen). This was typically about a week prior to planting.

To ensure that all treatments had the same level of nitrogen input, a nutrient analysis was performed on the cover crops and supplemental fertilization was applied. Tomatoes were planted in mid-June and were staked and twined as is the standard practice in commercial tomato production. Drip line was added to the mulch treatments and all treatments were irrigated as needed. Harvest started in the beginning of August and continued until mid-October, generally occurring once or twice a week. Throughout the season, researchers collected data on soil moisture, soil conditions (moisture, temperature, and percent carbon and nitrogen), weed biomass, and tomato yields (total and marketable).

In addition to the on-site research at Rodale Institute, four collaborating farmers from Pennsylvania and New Jersey trialed different mulch methods on their farms in 2011 and 2012. With the help of these farmers, researchers were able to test these mulch systems in different locations and with different crops; tomatoes, peppers, watermelon, butternut squash, cabbage, and summer squash were grown by the collaborating farmers. The results of these off-site trials can be found in the case study section of this booklet.

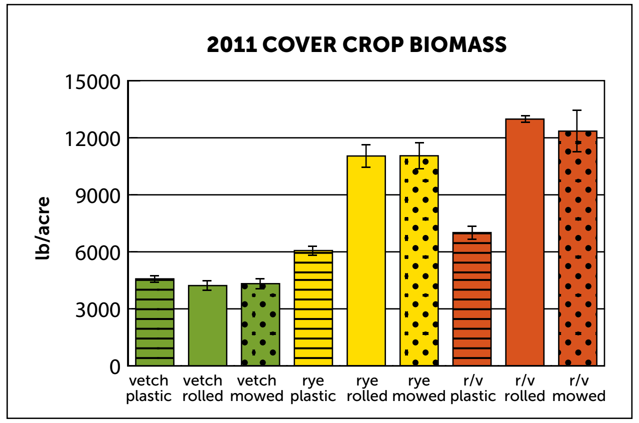
Trial plots at Rodale Institute, 2010. The plot on the left is black plastic with rye/vetch, and the plot on the right is a mowed rye/vetch.

RESULTS

COVER CROP INPUTS

Cover crop biomass

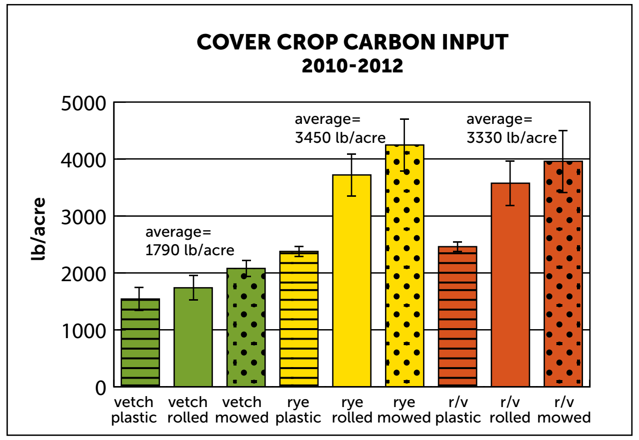
Cover crops in this treatment were terminated earlier than the cover crops in the other two treatments to allow time for the cultivation of the black plastic plots. As a result, the cover crops in the black plastic treatments had less time to grow and thus had a lower biomass at the time they were tilled in. This was not observed in the vetch-only cover crop. In addition, the cover crops that contained rye had higher biomass than the vetch-only cover crop.



This chart shows the cover crop biomass in all treatments in 2011, measured just before cover crop termination. (Error bars represent standard errors.)

Cover crop carbon input

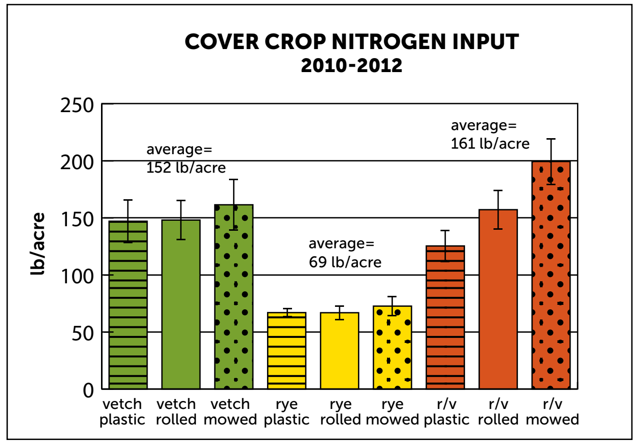
As a result of being terminated earlier and therefore having less biomass, the contributions of carbon from cover crops in the black plastic treatments were less than in the organic mulch treatments. This effect was observed less in the vetch-only treatments, as vetch undergoes its rapid growth period in the early spring before the black plastic plots were tilled. However, in the plots that included rye, the rolled and mowed treatments had contributions of carbon that were 60.2% higher, on average, than the plastic treatments. There were differences in carbon contribution even between the three different cover crops. While the vetch-only cover crop averaged 1,790 lb of carbon per acre, the rye and rye/vetch cover crops averaged roughly twice as much: 3,450 and 3,330 lb/acre, respectively.



This chart shows the average carbon input from cover crops in each of the nine treatments. The values here are the averages from 2010, 2011, and 2012.

Cover crop nitrogen input

Across three years, cover crop nitrogen input was lowest in the rye-alone treatment. The addition of vetch to rye enhanced nitrogen input by twofold.



This chart shows the average nitrogen input from cover crops in each of the nine treatments. The values here are the averages from 2010, 2011, and 2012.

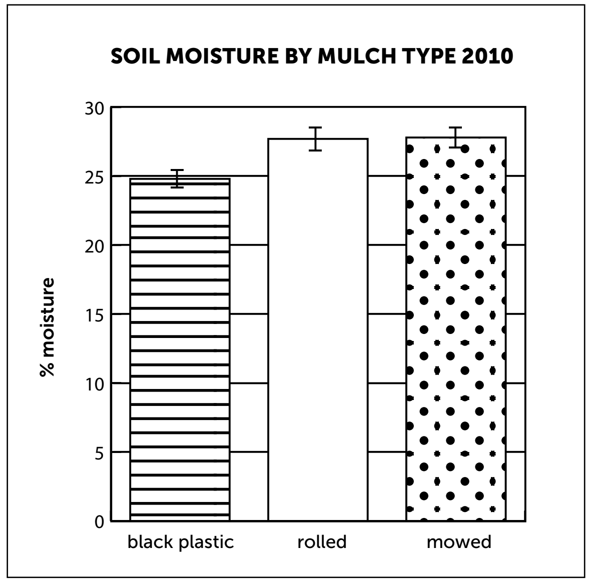
EFFECTS ON SOIL QUALITY

Researchers measured soil moisture and temperature in all treatments throughout each growing season. The percentage of carbon and nitrogen in the soil was measured in each treatment before and after each season.

Soil Moisture

Soil moisture was lower in the black plastic treatment as compared to the mowed and rolled treatments. As the black plastic plots were receiving most of their water via drip-line irrigation, this difference could be easily rectified by increasing the amount or frequency of irrigation in the black plastic plots.

When averaged across the 2011 season, areas covered with black plastic had 25% soil moisture, while the mowed and rolled areas both had 28% moisture. Averages from 2012 were 20% for black plastic, 23% for mowed treatments, and 22% for rolled.



This chart demonstrates the trend observed across the soil moisture data: beds covered with black plastic mulch generally had lower moisture than the mowed and rolled beds. While this pattern was observed on many of the sampling dates, it was not always the case.

Soil Temperature

Differences in soil temperature between black plastic and cover crop mulch plots were greater early on and were fairly minimal by end of the season. In June and July, plots covered in black plastic had higher soil temperatures than the mowed and rolled plots. Such differences were very slight at the end of the season (September, October). The maximum soil temperatures in the black plastic treatments averaged 5.8 °F higher than the rolled and mowed treatments in June, 4.0 °F in July, 2.0 °F in September, and 0.5 °F in October. Minimum soil temperatures in June and July 2012 were higher in the black plastic treatment by roughly 2 °F. There was no difference in soil temperatures based on cover crop types. Cover crop mulch kept soil temperature moderate and reduced fluctuations over time, which is favorable for tomato production.

SOIL TEMPERATURES

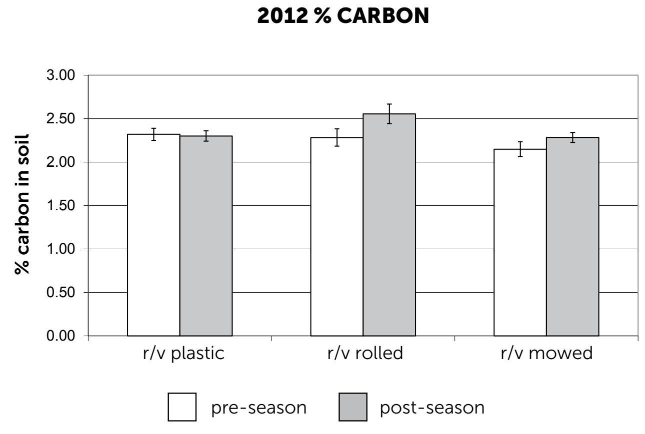
	June	July	Aug.	Sept.	Oct.
	2012 High Temps				
black plastic	79.2	81.3	75.9	69.7	69.9
rolled	73.0	77.2	75.0	67.7	69.4
mowed	73.9	77.3	75.5	67.8	69.4
	2012 Low Temps				
black plastic	68.7	72.8	69.8	63.7	65.7
rolled	66.1	70.5	69.2	63.0	65.2
mowed	66.6	71.0	69.7	63.4	65.4

This table summarizes the monthly high and low soil temperatures in the three different termination treatments from June to October, 2012.

Soil Nutrients: % Carbon and Nitrogen

There were not observable changes in the percent of carbon and nitrogen in the soil onsite at Rodale Institute. However, within the rye/vetch cover crop in 2012, the percentage of carbon did increase in the course of the season in both the rolled and mowed treatments. The increase in the rolled rye/vetch was twofold the increase in the mowed rye/vetch treatment.

In the trials at collaborating farms, one out of four farms experienced a small increase in the percentage of carbon in the soil within the black plastic treatment (0.22%), while another experienced an increase of 0.31% in the rolled rye/vetch.



This chart shows the percent of carbon in the soils at the Rodale Institute test site pre- and post-season in 2012. Only the rye/vetch treatments are shown here, as there were no significant changes in the percent of carbon in either of vetch or rye singly.

WEED CONTROL

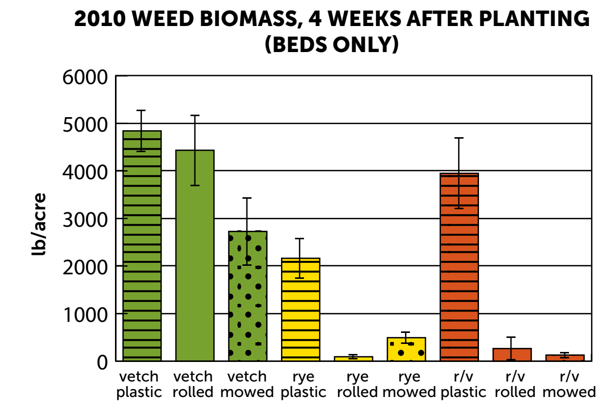
Weed biomass was measured four weeks after planting the tomatoes. In 2010 and 2012, the areas sampled for weed biomass included the beds as well as the paths in between. In 2011, weed biomass measurements were taken only from within the beds themselves. This resulted in lower weed biomass values in 2011 across all treatments, especially the black plastic.

In 2010, the cover crop mulch treatments in the rye and the rye/vetch systems had very little weed pressure. In the rye/vetch treatment, weed pressure in the rolled and mowed systems averaged only 5% of that in the black plastic rye/vetch treatments. The rolled and mowed rye averaged 13% of the weed pressure in the black plastic rye. Across the cover crop types, vetch was the least effective at suppressing weed growth.

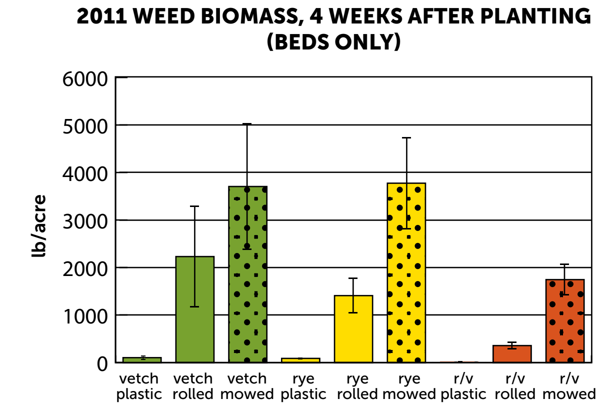
When measuring weed biomass within the beds only, as was done in 2011, the black plastic treatment had very low weed biomass. In the rye/vetch and the rye systems, the rolled plots had lower weed biomass than the mowed plots.

In 2012, within each cover crop type, the rolled and mowed treatments had higher weed biomass than the black plastic treatments—by roughly twofold in the vetch and rye cover crop systems and by roughly threefold in the rye/vetch system.

Over the three years, there was variation in the weed biomass in all treatments, though the black plastic systems were more consistent than the rolled and mowed. While black plastic more effectively suppressed weeds in 2011 and 2012, the rolled and mowed systems outperformed the black plastic in 2010. Rolling was generally more effective at suppressing weeds than mowing. In all years, the rye/vetch cover crop systems either matched or outperformed the vetch and rye systems.



This chart shows the weed biomass in 2010, measured four weeks after planting, in all treatments. These values represent weeds growing within the beds only (paths excluded).



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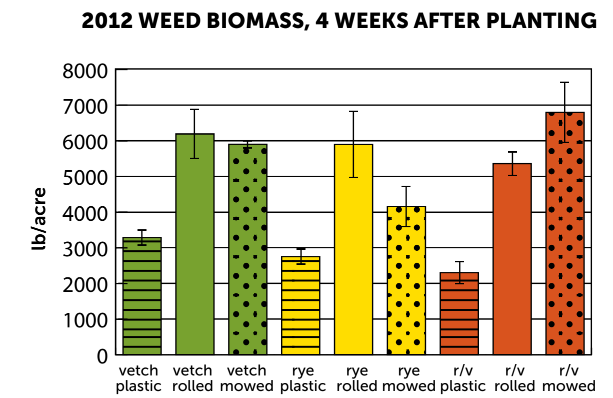


This chart shows the weed biomass in 2012, measured four weeks after planting, in all treatments. These values represent weeds growing within the beds and paths.

YIELDS

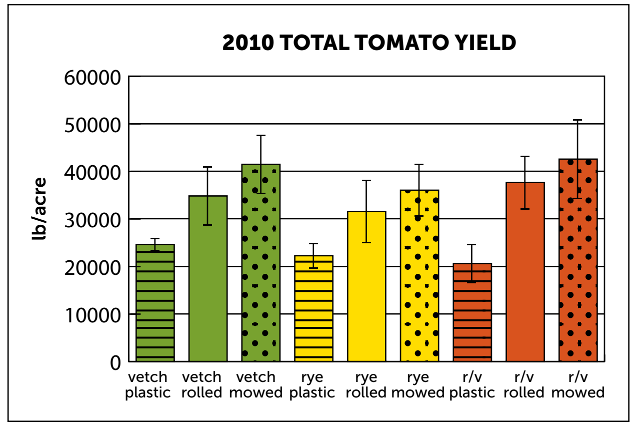
Tomatoes were harvested once or twice a week as needed. Total yield was measured in all years and marketable yield was measured in 2011 and 2012. In 2012, late blight dramatically reduced the tomato harvest, affecting total and marketable yields in all treatments.

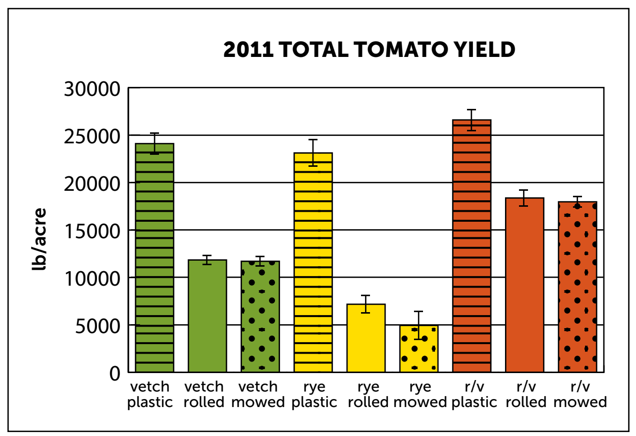
Total Yields

In 2010, the total yield in both the rolled and mowed cover crop treatments was higher than the total yield in the black plastic treatment. Cover crop type did not cause any significant differences in tomato yield.

Total yields in 2011 were comparable to 2010 yields in the black plastic systems but greatly reduced in the organic mulch systems. Total yields were higher in the black plastic treatment, and cover crop type within the black plastic treatment did not cause a significant difference in yield. Within the organic mulch systems, using the rye/vetch cover crop increased yield by 2 and 2.5 fold as compared to the vetch systems and rye systems, respectively. The 2011 results showed that there was a synergistic effect on tomato yield when the rye and vetch are combined.

The 2012 total yields, while greatly reduced by late blight, showed patterns that were similar to those observed in 2011.





These charts show the total tomato yields in 2010 and 2011. Notice the variation between the two years: in 2010, the cover crop mulches outperformed the black plastic treatments, and in 2011 the pattern was reversed.

Marketable Yields

In 2011, marketable yields paralleled total yields with an average of 20% reduction in each treatment. The rolled and mowed rye/vetch treatments competed best with the black plastic treatments with an average marketable yield that was about 70% of the black plastic rye/vetch.

In 2012, only 23% of the total yield was marketable due to late blight. The rolled and mowed vetch treatments had the lowest marketable yields and there were no significant differences in marketable yield between all other treatments.

These data suggest that the effects of different mulch types on tomato yields can vary from year to year. A longer-term study would be necessary in order to better understand the factors involved in these annual variations in mulch performance.

WASTE PRODUCTION

All of the trialed systems produced some plastic waste because of the use of drip tape for irrigation in all treatments. However, the amount of plastic pulled out of the fields was increased by fourfold in the black plastic treatments with 91.46 lb of plastic mulch per acre in addition to the 30.5 lb of drip tape.

PROFITABILITY

Expenses

While there were some expenses that varied according to treatment (variable costs), others were the same for all treatments (fixed costs). Variable costs included the cost of cover crop seed, fertilizer, plastic mulch, passes with equipment, plastic disposal, and hand weeding. The fixed costs totaled $9,668.26 per acre and included the cost of drip tape, stakes, twine, tomato seed, growing media, pots, and labor for twining, harvesting, planting, and grading.

The most pronounced differences in the total cost of each system occurred according to cover crop type. The vetch cover crop systems were generally the lowest in annual expense, as they required no nitrogen fertilizer. The rye systems generally had the highest annual expense, as these systems required the most nitrogen fertilizer. While the black plastic treatments were generally more expensive to implement than the rolled and mowed systems (a difference of $135, on average), there was too much variation in the data for this to be significant.

Revenue

Tomato prices in these calculations are based on reports from several large east-coast organic wholesalers. The price used for each year is an average of tomato prices throughout the season. Annual revenue was calculated by multiplying each system's marketable yield by the year's organic tomato price. As marketable yield was not measured in the first year of the trial, a speculative 2010 marketable yield was calculated assuming a cull rate of 20% as was observed in 2011.

Each system's revenue is directly correlated to its marketable yield. As such, the revenues varied greatly between systems and from year to year. The highest revenue in each treatment was observed in 2010 and the lowest in 2012 due to the effect of late blight on yields.

Profit

The profitability of each system varied throughout the years. The most profitable year for all systems was 2010. The rolled and mowed systems were much more profitable than the black plastic, bringing in an average of $23,000 of profit per acre. The mowed systems were consistently the most profitable in 2010. Within the organic mulch systems, the vetch and rye/vetch treatments had a higher annual profit than the rye treatments.

In 2011, the black plastic treatments had yields that were similar to those in 2010 while the rolled and mowed systems had much lower profits. The black plastic treatments were the most profitable treatments in 2011. Of the organic mulches, the rye/vetch systems were the most profitable and rye the least, bringing a net loss for the season.

All systems experienced a net loss in 2012 due to late blight. There were no trends observed in the profits in this year.

Because there was such a great deal of variation in profit from year to year, it is helpful to take all three years into account when considering the profitability of each system. When averaged across 2010-2012, the highest profits were achieved in the rolled rye/vetch and mowed rye/vetch systems. (See chart on page 24.)

Annual Cost, Revenue, and Profit per Acre
2010-2012 Average

	VETCH			RYE			RYE/VETCH		
	Plastic	Rolled	Mowed	Plastic	Rolled	Mowed	Plastic	Rolled	Mowed
Fixed Cost	$9,668	$9,668	$9,668	$9,668	$9,668	$9,668	$9,668	$9,668	$9,668
Variable Cost	$582	$583	$518	$1,190	$1,008	$1,028	$887	$660	$710
Total Cost	$10,250	$10,251	$10,186	$10,858	$10,676	$10,696	$10,555	$10,328	$10,378
Price (P)	$1.84	$1.84	$1.84	$1.84	$1.84	$1.84	$1.84	$1.84	$1.84
Marketable Yield (MY, lb/acre)*	15,010	13,061	14753	14,080	11,312	11,633	14,008	16,312	17,239
Revenue (P x MY)	$27,618	$24,032	$27,145	$25,907	$20,814	$21,404	$25,775	$30,015	$31,719
Profit	**$17,368**	**$13,780**	**$16,959**	**$15,049**	**$10,138**	**$10,708**	**$15,220**	**$19,687**	**$21,341**

* as marketable yield was not measured in 2010, marketable yields for this year were calculated using a 20% cull rate, as was observed in 2011

More Cover Crop Mulch Research

While this study was underway at Rodale Institute, others were also looking deeper into both organic and conventional cover crop mulch systems. A sampling of these studies is listed below:

"Reduced-tillage organic corn production in a hairy vetch cover crop"[12]
Teasdale, J.R., S.B. Mirsky, J.T. Spargo, M.A. Cavigelli, and J.E. Maul 2012. Reduced-tillage organic corn production in a hairy vetch cover crop. Agronomy Journal 104:621-628

Teasdale et al. found that organic corn in roll-killed hairy vetch yielded as much or more than corn in disk-killed hairy vetch when the weed seed bank is low.

"Fall- and spring-sown cover crop mulches affect yield, fruit cleanliness, and fusarium fruit rot development in pumpkin"[13]
Wyenandt, C.A., R.M. Riedel, L.H. Rhodes, M.A. Bennett, and S.G.P. Nameth. 2011. HortTechnology 21:343-354

Pumpkins grown in spring-terminated cover crop mulches produced number and weights comparable to or slightly higher than bare soil. What's more, the pumpkins in these plots were less susceptible to FFR (*Fusarium solani* f. sp. *Cucurbitae* race 1).

"A mechanistic approach to weed management in a cover crop mulched system"[14]
Wells, M.S. 2013. (Doctoral dissertation). Retrieved from http://www.lib.ncsu.edu/resolver/1840.16/9082

One of the many findings of this study was that within corn and soybean production, rolled rye with a biomass of about 9,000 lb/acre provided excellent weed control.

RESULTS WRAP-UP

Cover crop biomass: The earlier termination associated with the black plastic mulch resulted in lower cover crop biomass in these plots compared to the rolled and mowed plots. The rye and rye/vetch cover crops had roughly double the biomass of the vetch cover crop.

Nutrient inputs from cover crops: Rye/vetch was the superior cover crop in terms of nutrient input. It provided the highest amount of nitrogen per acre and very close to the highest amount of carbon per acre. While termination methods did not have a large impact on nitrogen input to the soil, carbon input was higher in the rolled and mowed treatments.

Soil moisture: The black plastic treatments generally had lower moisture than the organic mulch treatments.

Soil temperature: The maximum soil temperatures in the black plastic treatments averaged 5.8 °F higher than the rolled and mowed treatments in June, 4.0 °F in July, 2.0 °F in September, and 0.5 °F in October. Minimum soil temperatures in 2012 were higher in the black plastic treatment in June and July by roughly 2 °F. There was no difference in soil temperatures based on cover crop types.

Soil nutrient content: There was a small increase in the percentage of carbon in the soil in the rolled rye/vetch treatment. In all other treatments, there were no significant changes in the percentage of carbon and nitrogen in the soil.

Weed suppression: Over the three years, there was variation in the weed biomass in all treatments, though the black plastic systems were more consistent than the rolled and mowed. While black plastic more effectively suppressed weeds in 2011 and 2012, the rolled and mowed systems outperformed the black plastic in 2010. Rolling was generally more effective at suppressing weeds than mowing. In all years, the rye/vetch cover crop systems either matched or outperformed the vetch and rye systems.

Total and marketable yield: The effect of mulch type on tomato yield varied from year to year. While the cover crop mulch systems brought higher yields than the black plastic system in 2010, the reverse occurred in 2011 and 2012. Within the cover crop mulch systems (vetch, rye, rye/vetch), the rolled and mowed rye/vetch treatments yielded the most.

Waste production: The use of black plastic mulch increased the amount of plastic waste fourfold. The cover crop mulch treatments produced 28 lb plastic waste per acre from drip lines. The black plastic treatments produced 122 lb/acre of plastic waste in the form of drip lines and plastic mulch.

Profitability: The annual profits for the organic mulch systems were much more variable than the profits in the black plastic systems. However, when averaged across 2010-2012, the highest profits were achieved in the rolled rye/vetch and mowed rye/vetch systems.

COLLABORATING FARMER CASE STUDIES

In addition to the trials done at Rodale Institute, four collaborating farmers in Pennsylvania and New Jersey trialed cover crop mulching on their own farms in 2011 and 2012. Each one compared the rolled rye/vetch system from Rodale's trial to their standard method of weed suppression. One farmer who grew on raised beds used a newly designed raised-bed roller on his experimental treatment plots. The test crops used in their field studies included tomatoes, winter and summer squash, peppers, and cabbage.

In 2011, the collaborating farmers were not permitted to weed their rolled cover crop treatment in order to make it possible for the researchers to accurately assess the weed suppression provided by the cover crop mulch. In 2012, the farmers were allowed to weed the rolled plots following a weed suppression assessment that was performed four weeks after the tomato planting. For this reason, yields in the rolled rye/vetch treatments were generally better in 2012 than they were in 2011. In both years, the farmers were allowed to use whatever weed control techniques they usually employ in their own management systems.

Case Study #1: The Community Supported Garden at Genesis Farm

When the Community Supported Garden at Genesis Farm started, it was one of the first CSAs in the United States. The farmers, from left to right: Smadar English, Mike Baki, and Judy Vonhandorf. Photo credit: Genesis Farm

Farm at a Glance
Location: Blairstown, NJ
Farmer: Mike Baki
Years farming: 22 years
Total acreage: 75 acres
Tillable acres: 50 acres
Soil type: Nassau-Manlius complex
Crops: Diversified vegetable production, fruit, hay
Livestock: Laying hens
Marketing: 300-member CSA

In the test plots at Genesis Farm, Mike Baki trialed Rodale's rolled rye/vetch system side-by-side with his standard black plastic system. His standard system uses biodegradable plastic within the rows and straw mulch in between rows. Hand weeding was performed in the standard treatment when needed. In 2011, Mike grew summer squash, tomatoes, and watermelon, and in 2012 he substituted peppers for watermelon.

In 2011, the rolled rye/vetch plots had higher weed pressure than the black plastic plots. This seems to have affected yield in all crops but to varying degrees. The watermelon and summer squash both yielded about twice as much in Mike's standard black plastic treatments as compared to the rolled rye/vetch. However, the tomatoes were more similar between the two systems, with the rolled rye/vetch plots producing about 75% of what the black plastic plots produced.

In 2012, when the farmers were permitted to weed after four weeks, there was no significant difference in weed pressure between the two treatments. The pepper and summer squash yields were again significantly lower in the rolled rye/vetch. The tomato yields were virtually the same in both systems: 15,942 lb/acre in the rolled rye/vetch and 16,465 lb/acre in the black plastic treatment.

The rolled rye/vetch treatment cost the farm $202.50 for 300 ft, less than half of the $506.80 cost of the black plastic treatment. If the 2012 tomato yields were achieved consistently, the above treatment costs would translate into substantial savings. Mike is continuing to experiment with the rolled rye/vetch system and hopes to find an effective way to put it to work at Genesis Farm.

The test field at Genesis Farm: the rolled rye/vetch treatment is on the left, black plastic on the right. The path in between the two treatments has been mulched with straw, which is part of Mike Baki's standard weed management system.

Case Study #2: Swallow Hill Farm


Douglas Randolph plants rye and crimson clover cover crop at Swallow Hill Farm in Cochranville, PA.

Farm at a Glance
Location: Cochranville, PA
Farmer: Douglas and Elizabeth Randolph
Years farming: 20 years
Total acreage: 50 acres
Tillable acres: 30 acres
Soil type: Glenelg silt loam
Crops: Peppers, tomatoes, brassicas, pumpkins, squash, hay, long-rye straw, blueberries, rhubarb, asparagus
Livestock: none
Marketing: Farm stand and wholesale to garden centers and restaurants

When Douglas and Elizabeth Randolph joined this study, cover crop mulching was already part of their regular farming routine. The system they had developed used a combination of rye after alfalfa hay, or rye and crimson clover, which they terminated using a cultipacker followed by an application of glyphosate to kill surviving cover crop.

The Randolphs compared Rodale's rolled rye/vetch system to a variation of their own technique: rye and crimson clover, rolled instead of cultipacked, with occasional applications of post-emergence herbicide. They planted butternut squash as their test crop with a no-till seeder. In both 2011 and 2012, the squash yield was greater by 27% in the rye and crimson clover system. It should be noted that while crimson clover forms very solid stands for the Randolphs in southern Pennsylvania (hardiness zone 6b), it may not be a viable option for farmers farther north as cold winters will kill the clover. Nevertheless, the Randolphs have demonstrated that crimson clover is a viable alternative to hairy vetch in rolled cover crop systems, providing it is grown in an appropriate climate.

Douglas and Elizabeth observed similar weed suppression between the two different cover crop combinations. Compared to their former method of cover crop termination using the cultipacker, the roller-crimper provided a more effective crimping of stems, reducing the chances of cover crop regrowth. As a result, there was much less of a need for post-emergence herbicide when using the roller-crimper.

Since participating in this study, the Randolphs have switched to using a roller-crimper instead of a cultipacker to terminate their rye or rye and crimson clover cover crop, reducing the use of herbicide on their farm by 40-50%.


Butternut squash growing in rolled rye and crimson clover on the Randolphs' farm

Case Study #3: Meadow View Farm


James Weaver of Meadow View Farm uses a raised-bed roller-crimper to terminate his rye/vetch cover crop.

Farm at a Glance
Location: Bowers, PA
Farmer: James and Alma Weaver, and sons
Years farming: 38 years
Total acreage: 78 acres
Tillable acres: 70 acres
Soil type: Clarksburg silt loam
Crops: Heirloom peppers and tomatoes, winter squash, pumpkins, sweet corn, field corn, soybeans, wheat
Livestock: Sheep and laying hens
Marketing: Farm stand, wholesale, Annual Chile Pepper Festival

James Weaver has been farming the same piece of land for 38 years. He is known locally and beyond for the many heirloom varieties he cultivates as well as the new tomato and ghost pepper varieties he's bred.

When Rodale approached James about participating in this study, he was putting roughly 15 acres of his produce production in black plastic every year. He trialed his standard black plastic management alongside Rodale's rolled rye/vetch. James's standard system uses black plastic mulch in combination with hand weeding, vinegar sprays (which cause the tops of plants to die back), and occasional pesticide applications on tougher perennial weeds. James grew two varieties of tomatoes in the test plots in 2011 and tomatoes and cabbage in 2012.

James reports that in the first year they used the rolled rye/vetch they had poor tomato yields for both varieties in that system. He attributes this to the fact that, due to the design of the study, he was not allowed to weed the rolled plots. In the second year of the trial, when weeding was permitted after four weeks, James's tomatoes yielded 15,650 lb/acre in the rolled treatment and 20,645 lb/acre in the black plastic treatment. Although the black plastic plots produced 32% more total yield, James reports that the quality of the tomatoes in the rolled rye/vetch was much better due to a good deal of splitting in the black plastic tomatoes. As a result, the actual marketable yields and profit from each treatment were very similar.

James says it was a bad year for the cabbages in both treatments, though the black plastic plots had higher yields by about 65%.

Since he participated in Rodale's cover crop mulch trial, James has replaced the black plastic mulch in his pumpkin and squash fields with rolled rye, cutting his overall use of black plastic nearly in half. He would like to transition more of his production to a rolled cover crop mulch system. Unfortunately, he doesn't have space in his field to plant the next year's cover crop on time; when it's time to plant the rye and vetch in September, he still has most of his crops in the ground. Nevertheless, he's hopeful that he can find a way to make it work. "Especially as I get older," James says, "I would be happy to not have to deal with plastic removal and disposal."

Case Study #4: Quiet Creek Farm

For the last eight years, John and Aimee Good have been farming organically on land they lease from Rodale Institute. Photo credit: Quiet Creek Farm

Farm at a Glance
Location: Kutztown, PA
Farmer: John and Aimee Good
Years farming: 12 years
Total acreage: 8 acres
Tillable acres: 8 acres
Soil type: Clarksburg silt loam
Crops: Diversified vegetable farm
Livestock: none
Marketing: CSA farm shares, wholesale

John and Aimee Good farm on land they rent from Rodale Institute. They trialed Rodale's rolled rye/vetch alongside their own organic weed management approach, which involves tillage and cultivation without black plastic. They used butternut squash as their test crop and did not perform any weeding in either of the years.

Weed pressure in John and Aimee's test plots varied between 2011 and 2012. In the first year, weed biomass was higher in the rolled rye/vetch treatments by about fourfold. In 2012, however, the Goods' standard bare-soil treatment had twice as much weed pressure as the rolled rye/vetch. The average yields of the two systems ended up being very similar. The rolled rye/vetch brought 13,503 lb/acre, while John and Aimee's standard management brought 14,249 lb/acre, a difference of about 5%.

John is experimenting with the rolled rye/vetch system and is hoping to find ways to make it work on their farm. The fact that they do so many types of vegetables makes this somewhat of a daunting challenge. It can be tricky to work around the timing of all of the different crops, and direct seeding into cover crop mulch would be difficult for vegetables with very small seed.

The Goods continue to use black plastic in roughly one acre of their vegetable production. However, since their participation in this study, John and Aimee have started to incorporate cover crops into the system. They now plant rye grass and clover in the paths between black plastic rows, adding organic matter to their soil and reducing the erosion that would otherwise occur due to the increased runoff from the plastic. In addition, John reports that this technique creates a much more pleasant space to work in between the rows, especially when the ground is wet. They manage the in-path cover crop with a high-wheel trimmer (picture a weed whacker on wheels).

IMPLEMENTING AN ORGANIC NO-TILL SYSTEM

GETTING STARTED

Here are some suggestions about how to get started—without planting a single seed. The following ideas will help you become a successful organic no-till farmer while managing the risks of adjusting to a new system.

Reading and learning
Find out as much as you can about which cover crops do well in your area. This might include talking to other organic and no-till farmers, taking advantage of resources available at your local extension office, and consulting reference guides.

Source local seed
Locally adapted cover crop seed will give you an edge, providing a crop that's already adapted to your area. It will be less likely to winter kill and may perform better on your farm. Since it may take some time to track down a local source, you should begin early. This is especially true for organic seed since quantities may be limited.

Test plot
Perhaps the biggest source of risk with organic no-till comes from transitioning to a new management system and a completely new technology. During the first couple of years, the learning curve may be fairly steep. It's a good idea to start with a small, experimental area or test plot on your farm.

Assess your farm
Look at your soil types, the crops you intend to plant, the equipment and resources you have, and the time you have to explore new planting systems. Like any changes on your farm, knowledge is power, and understanding how new cover crop management tools will fit into your operation will be critical to your success.

NO-TILL CAVEATS

Organic no-till can work in a variety of situations, but here are a few things to keep in mind.

Nitrogen tie-up
Organic no-till changes the way nitrogen cycles in the system. During the decomposition process, nitrogen can become temporarily less accessible to plants. This is especially true if you are working with very dry soil conditions—there could be a nitrogen tie-up early in the season if your cover is a cereal grain. There may also be nitrogen tie-up if you choose to till in mature cover crops, particularly cereal grains. There are a few things you can do to minimize these negative impacts: use legumes as the cover crop or part of a cover crop mix, only plant leguminous cash crops into grass cover crops (ie: soybeans into rye), or add supplemental nitrogen in an organic form.

Water use
Water needs for some cover crops can be heavy, especially for rye. If you farm in an arid location or if you depend on spring runoff and rain for your crop establishment, the cover crop may compete with your cash crop by taking up much of the available water, leaving less-than-adequate supplies for subsequent crops. The good news is that over time, no-till can help considerably with water conservation by improving the general health of your soils and by building the soil organic matter content.

Insufficient biomass
A poor stand of cover crops doesn't work well for the organic no-till system. If establishment is inadequate for any reason, the farmer must realistically assess the cover crop. Then he or she must either decide to continue as planned, choose to perform a tillage operation, or spray herbicide for weed control.

Rolling too early
Another common mistake is rolling too early, resulting in a poor kill with the roller-crimper. It can be very tempting to roll the cover crop before it is mature, especially when your neighbors have already planted and you're waiting for your cover crop. Cover crops that do not completely die can provide competition for the cash crop, robbing it of nutrients and moisture.

Problems with planting cash crops
Some experimentation may be needed to make sure your planter is working correctly. Common difficulties include: the planter does not cut through the cover crop, the planter does not provide good seed to soil contact, or the planter's depth wheels ride up, making it difficult to get the seed well placed in the furrow.

Delayed planting
Because you'll have to wait while cover crops mature in the spring to kill them effectively, you may have to delay planting your cash crop beyond your normal calendar date. You may want to source earlier maturing cover crop varieties or varieties that are better suited to your particular location. If you live in a northern climate, your planting window in the spring may be very tight. Summer cover cropping may be a better option for northern farmers depending on where they live. Consider the specific traits you need for your operation. Then search for varieties that express these traits.

Cooler soils
Cover crops can shade the soil, resulting in cooler soils in the spring. Crops that like hot temperatures, such as tomatoes, eggplant, and peppers, may get a slow start. However, soils will also be more even and moderate in temperature year-round, which can be an advantage. Once rolled and crimped, cover crops can maintain cooler, moister soil conditions protecting crops during hot dry periods later in the season.

Organic no-till corn in rolled hairy vetch at Rodale Institute

RESOURCES

This section contains sources of cover crop seed, equipment, and information regarding no-till organic production. Please note this list is a small sampling of the companies and contacts that sell these materials or are involved in this type of work. This is by no means a complete list, nor a preferred one. For more resources on no-till and organic mulch systems, contact one of your local extension agents. To read more about organic no-till and the roller-crimper, visit rodaleinstitute.org/our-work/organic-no-till/ or pick up a copy of Jeff Moyer's book, *Organic No-Till Farming*, published by ACRES USA and available at Rodale Institute's online store.

Cover Crop Seed

Adams-Briscoe Seed Co.
Jackson, Georgia
Phone: (770) 775-7826
E-mail: abseed@juno.com
Website: www.abseed.com

Albert Lea Seed House
Albert Lea, Minnesota
Phone: (800) 352-5247
E-mail: seedhouse@alseed.com
Website: www.alseed.com

The American Organic Seed Co.
Warren, Illinois
Phone: (866) 471-9465
E-mail: art@american-organic.com
Website: www.american-organic.com

Fedco Seeds
Waterville, Maine
Phone: (207) 873-7333
Website: www.fedcoseeds.com

High Mowing Organic Seeds
Wolcott, Vermont
Phone: (802) 472-6174
E-mail: Meredith@highmowingseeds.com
Website: www.highmowingseeds.com

Peaceful Valley Farm and Garden Supply
Grass Valley, California
Phone: (888) 784-1722
E-mail: helpdesk@groworganic.com
Website: www.groworganic.com

Welter Seed & Honey Co.
Onslow, Iowa
Phone: (800) 728-8450
E-mail: info@welterseed.com
Website: www.welterseed.com

Manufacturers & Equipment Dealers

Buckeye Tractor Co. (front hitches)
Columbus Grove, Ohio
Phone: (800) 526-6791
E-mail: buctraco@bright.net
Website: www.buctraco.com

I&J Manufacturing (cover crop rollers)
Gap, Pennsylvania
Phone: (717) 442-9451
Website: www.croproller.com

Pequea Planter (residue slicers)
Gap, Pennsylvania
Phone: (717) 442-4406

Yetter Manufacturing Company (residue managers)
Colchester, Illinois
Phone: (800) 447-5777
E-mail: info@yetterco.com
Website: www.yetterco.com

No-Till Contacts

Seth Dabney
USDA-NRS National Sedimentation Laboratory
Oxford, Mississippi
Phone: (662) 232-2975
E-mail: sdabney@ars.usda.gov

Kathleen Delate
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Iowa State University
Ames, Iowa
Phone: (515) 294-7069
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Kearney Agricultural Center
University of California
Parlier, California
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E-mail: Mitchell@uckac.edu

Ron Morse
Dept. of Horticulture
VA Polytechnic Institute & State University
Blacksburg, Virginia
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Department of Agronomy
University of Wisconsin
Madison, Wisconsin
Phone: (608) 890-1503
E-mail: emsilva@wisc.edu

Steve Zwinger
NSDU Carrington Research Extension Center
Carrington, North Dakota
Phone: (701) 652-2055
E-mail: szwinger@ndsuext.nodak.edu

No-Till Websites

American Journal of Alternative Agriculture
eap.mcgill.ca/MagRack/AJAA/ajaa_ind.htm
A great resource for organic no-till articles.

ATTRA
attra.ncat.org
ATTRA, the National Sustainable Agriculture Information Service, is managed by the National Center for Appropriate Technology (NCAT) and provides information and other technical assistance to farmers and others involved in sustainable agriculture in the US.

National Organic Program
www.ams.usda.gov/AMSv1.0/nop
The National Organic Program is the federal regulatory framework that governs organic food production.

No-Till Farmer
www.no-tillfarmer.com
Homepage for a newsletter on no-till farming; has information on the national no-till conference.

USDA-SARE
www.sare.org
Research projects and publications on a range of topics, including no-till.

GLOSSARY

Anthesis
The flowering period of a plant, beginning with the opening of the flower buds

Biomass
The total mass of organisms in a given area

Black Plastic Mulch
A thin sheet of polyethylene plastic that is laid on agricultural fields to inhibit weed growth. Introduced to agriculture in the 1950s.

Community Supported Agriculture (CSA)
In basic terms, CSA consists of a community of individuals who pledge support to a farm operation so that the farmland becomes, either legally or spiritually, the community's farm, with the growers and consumers providing mutual support and sharing the risks and benefits of food production. Typically, members or "share-holders" of the farm or garden pledge in advance to cover the anticipated costs of the farm operation and farmer's salary. In return, they receive shares in the farm's bounty throughout the growing season, as well as satisfaction gained from reconnecting to the land and participating directly in food production. Members also share in the risks of farming, including poor harvests due to unfavorable weather or pests. By direct sales to community members, who have provided the farmer with working capital in advance, growers receive better prices for their crops, gain some financial security, and are relieved of much of the burden of marketing.

Conservation Tillage
Tillage systems that leave residue cover on the soil surface, substantially reducing the effects of soil erosion from wind and water. These practices minimize nutrient loss, decrease water storage capacity, crop damage, and farmability. The soil is left undisturbed from harvest to planting except for nutrient amendment. Weed control is accomplished primarily with herbicides, limited cultivation, and with cover crops. Some specific types of conservation tillage are Minimum Tillage, Zone Tillage, No-till, Ridge-till, Mulch-till, Reduced-till, Strip-till, Rotational Tillage, and Crop Residue Management.

Cover Crop
Any crop grown for the purpose of weed control, controlling erosion, amending soil fertility, and building organic matter. Cover crops are usually tilled under in an immature growth stage.

Cover Crop Mulch
Use of cover crops as soil coverage to suppress weed growth, moderate soil temperature, or conserve soil moisture (NOP definition).

Crop Residue
The plant parts remaining in a field after the harvest of a crop, which include stalks, stems, leaves, roots, and weeds (NOP definition)

Crop Rotation
The practice of alternating the annual crops grown on a specific field in a planned pattern or sequence in successive crop years so that crops of the same species or family are not grown repeatedly without interruption on the same field. Perennial cropping systems employ means such as alley cropping, intercropping, and hedgerows to introduce biological diversity in lieu of crop rotation (NOP definition).

Cultipacker
A cultipacker is a piece of agricultural equipment that crushes dirt clods, removes air pockets, and presses down small stones. Generally used to establish a smooth, firm seed bed.

Cultivation
Digging up or cutting the soil to prepare a seed bed; control weeds; aerate the soil; or work organic matter, crop residues, or fertilizers into the soil (NOP definition)

Erosion
The process by which soil and rock are removed from the Earth's surface by exogenetic processes such as wind or water flow, and then transported and deposited in other locations. Tillage and bare soil are the primary contributors to agricultural erosion.

Flail Mower
A PTO-driven tractor implement that is able to deal with heavier plant matter than a regular lawn mower could handle.

Hardpan
A hardened impervious layer, typically of clay, occurring in or below the soil and impairing drainage and plant growth.

Marketable Yield
The portion of total yield that is saleable.
Marketable Yield = Total Yield - Culls

Mulch
Any nonsynthetic material, such as wood chips, leaves, or straw, or any synthetic material included on the National List for such use, such as newspaper or plastic that serves to suppress weed growth, moderate soil temperature, or conserve soil moisture (NOP definition).

National Organic Program (NOP)
The program authorized by the Act for the purpose of implementing its provisions (NOP definition).

Nonsynthetic (natural)
A substance that is derived from mineral, plant, or animal matter and does not undergo a synthetic process as defined in section 6502(21) of the Act (7 U.S.C. 6502(21)). For the purposes of this part, nonsynthetic is used as a synonym for natural as the term is used in the Act (NOP definition).

No-Till
A system of planting crops without the major soil disturbance created by a tillage implement.

Organic
A labeling term that refers to an agricultural product produced in accordance with the Act and the regulations in this part (NOP definition).

Organic Production
A production system that is managed in accordance with the Act and regulations in this part to respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity (NOP definition).

Roller-crimper
A specialized piece of agricultural equipment designed by Rodale Institute; it is used to terminate a living cover crop and convert it into a mulch layer. Ranges in scale from just a few feet up to 30 feet in width.

Runoff
Water that flows off of a field due to saturation of the soil or the presence of impervious surfaces. It is a large contributor to soil erosion in agricultural fields, and the nutrients, chemicals, and particles within runoff create environmental problems when they enter water systems.

Senescence
The final stage in the life cycle of a plant, leading to the death of part or all of the plant.

Soil Aggregates
The building blocks formed when soil minerals and organic matter are bound together. Soil organisms are largely responsible for soil aggregation.

Soil Biota
The organisms, such as bacteria, fungi, protozoa, nematodes, arthropods, worms, and insects, that live in soil.

Soil Organic Matter (SOM)
Soil organic matter is the organic matter component of soil, consisting of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by soil organisms. SOM has numerous positive effects on soil physical and chemical properties and is a critical component of soil quality.

Synthetic
A substance that is formulated or manufactured by a chemical process or by a process that chemically changes a substance extracted from naturally occurring plant, animal, or mineral sources, except that such term shall not apply to substances created by naturally occurring biological processes (NOP definition).

Tillage
The mechanical manipulation of soil, usually to prepare seed bed, incorporate crop residues and soil amendments, and general soil loosening. Inversion tillage involves inverting soil layers, as when plowing with a moldboard plow. Non-inversion tillage does not mix soil layers, as well as when disking or harrowing.

Total Yield
The full amount of the desired crop that is produced.

Undercutter
A tool designed to cut plants 2" below the soil surface, used to manage weeds and kill cover crops, leaving them on the surface of the soil as mulch.

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