The Wool Mulch System of Producing Strawberries

A Manual for Commercial Growers in Minnesota

BY

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ACKNOWLEDGEMENTS

This manual is the result of the work and collaboration of many individuals and organizations. Their contributions of time, expertise and resources made the research successful and this manual a valuable tool. The following individuals were instrumental in the latest phase of research.

DR. EMILY HOOVER is a professor and researcher in the Department of Horticultural Science at the University of Minnesota. Dr. Hoover spearheaded much of the research on wool mulch.

STEVE POPPE is the research plot coordinator at the University of Minnesota West Central Research and Outreach Center in Morris, MN. He conducted the field trials for this research.

RON BRANCH owns Berry Ridge Farm in Alexandria, MN. Ron provided land for field trials and participated in presentations of this research.

DAVID MACGREGOR and MARSHA ANKLAM own Fairhaven Farm in South Haven, MN. David and Marsha offered a portion of their land for field trials, and hosted a field day to educate growers about the wool mulch system.

While research on wool mulch spanned over ten years, the author's involvement began in June, 2007. This manual is not only the culmination of the research but serves as the final Integrating Project for the fulfillment of the author's degree of Master of Agriculture in Horticulture.

For editorial review and personal support of this project the author would like to thank Dirk Kramer, Nancy Meuse, Charles Tepe, Eric Tepe, Chris Meuse, Connie Scarborough, Maria Paz Moreno, Steve McKay, Adriana Telias and David Zlezak.

Finally, the author would like to thank Dr. Emily Hoover for providing the opportunity to work on this project. Additionally, her support and guidance were invaluable as the author pursued the degree of Master of Agriculture in Horticulture.

INTRODUCTION

This manual was developed after ten years of research on a new system of producing strawberries using a combination of wool mulch and a canola cover crop/mulch. The wool mulch – a locally produced, biodegradable and renewable product – is used in the strawberry rows, and functions as a weed deterrent while also regulating soil temperature, retaining moisture and suppressing many diseases. The canola is used before planting as a weed suppressing cover crop. Later, canola is used between the rows of strawberries where it continues its role as weed suppressant. Only two herbicide applications are used in the system, both on the canola, which is a reduction from conventional methods.

This system has proved extremely effective in significantly reducing pesticide use in strawberry fields. In addition, weed pressure is greatly reduced, equating to reduced labor and tilling. Yields are typically higher with larger and higher quality fruit that can be harvested one to two weeks earlier than in the traditional matted row system of strawberry production.

Figure 1. Wool mulch and strawberry plant.

These benefits combined, the wool mulch system is an extremely effective method for growers who are interested in reducing pesticide use on strawberries. Growers implementing this system will be part of an upward trend in which improved methodologies are utilized to reduce dependence on pesticides.

Figure 2. Ripe strawberries on wool mulch.

This manual contains an overview of the research on wool mulch conducted at the University of Minnesota between 1998 and 2008. Detailed instructions for implementing the system follow, including many photographs and graphics. A list of valuable resources is included at the end of the manual, where readers can access detailed information on the research, general production guidelines, integrated pest management practices, and suppliers.

BACKGROUND

COMMERCIAL STRAWBERRY PRODUCTION IN MINNESOTA

Minnesota strawberry growers have traditionally relied on the matted row system of production. In this system, strawberries are typically grown in three-year cycles. In the first growing year (establishment year), dormant strawberry transplants are planted in April or May. From time of planting through September, the plants must grow vigorously to send out runners which will root and produce daughter plants. Fruit yield is directly proportional to the number of well-established daughter plants. Weed control during this time is essential since weeds compete for light, water, and nutrients. If the strawberry plants do not have sufficient access to these elements, establishment is slower, runnering is less prolific, and lower yields will result. Weed control is costly and time consuming as it must be done by hand or with hand tools to prevent damaging the young strawberry plants.

Figure 3. Small strawberry plants among weeds.

Availability of herbicides approved for use on strawberries is diminishing due to stringent safety restrictions, while the costs of such compounds are increasing. Additionally, in recent years there has been a swift rise in consumer demand for more environmentally friendly, reduced-pesticide foods. Faced with these challenges, growers are seeking alternatives to this traditional method of producing strawberries.

GROWING INTEREST IN REDUCED-PESTICIDE FOODS

As research continues upon the significant health benefits of fruits and vegetables, consumers are responding with demands for more variety and quality. A USDA study found that fresh fruit consumption among Americans rose 19 percent between 1979 and 2005 (Wells and Buzby 2008). The same study indicated that while bananas, apples, and oranges lead fruit consumption in the U.S., fruits such as grapes, pears, and strawberries have gained in popularity owing in part to published health benefits.

The consumer trend toward more healthful eating seems to be closely followed by an interest in safer foods, environmentally sound food production, and a closer connection to food source (Kremen *et al.* 2001). This is made apparent by the growing number of farmers' markets, Community Supported Agriculture (CSA) cooperatives, and organic/natural food stores in the U.S (Hartnett 2006; Kremen *et al.* 2001). The number of farmers' markets alone increased 150 percent between 1994 and 2006, and

consumers shopping at these sources list freshness, high quality, and local production as high priorities (Kremen *et al.* 2001; USDA 2007a). In addition, consumers indicate concern regarding pesticide use on foods, and consequently are showing a greater demand for safer, reduced-pesticide, or pesticide-free produce (Henneberry 2000).

The majority of Minnesota strawberry growers market fresh fruit directly to consumers as 'Pick-Your-Own' (PYO) and pre-picked, or at farmers' markets. Consumers most interested in reduced-pesticide produce choose to purchase the majority of their fresh fruits and vegetables at these outlets. (Henneberry 2000; Hoover *et al.* 1990; MN Dept. of Agr. 2007).

These growing consumer demands are among the reasons many growers are searching for alternate methods of controlling insect pests, diseases, and weeds in their fields (Forcella 2003).

LOOKING FOR ALTERNATIVES

Research in fruit production has been focusing more and more on the goal of reducing dependence on chemicals for profitable yields (National Research Council 2001). With rising consumer awareness of the dangers of exposure to excessive pesticide residues, the fresh food industry must make efforts to meet the needs of today's concerned consumer in order to maintain profitability. This is not to say that any particular crop typically exceeds legal limits of residue. Rather, considering the number of crops that are treated with similar compounds, cumulative consumer exposure to those particular compounds can reach unsafe levels. In altering traditional methods to reduce pesticide use, growers have the opportunity to reduce overall consumer exposure – as well as exposure of laborers during application and harvest – while offering a high value crop that can be marketed as safer and environmentally sound.

Consumer interest in- and demand for environmentally sound and safe fruit continues to rise (USDA 2007c). The University of Minnesota, along with other research institutions, is developing effective production methodologies that offer growers successful alternatives to traditional growing systems that rely heavily on pesticides. Growers implementing such improved systems based on this research are on the cutting edge of modern agriculture and are securing a premium price for their high quality, sustainably produced crops (Guerena and Born 2007).

A survey of strawberry growers conducted by the author at the 2008 Minnesota Fruit and Vegetable Growers Association annual meeting indicated that there is increased consumer interest in fruit grown with fewer pesticides, and that growers are beginning to feel greater pressure to decrease pesticide use. Eighty percent of growers are questioned at least occasionally each season by customers about pesticide use. Seventy-two percent declare that customers occasionally or often ask if their strawberries are grown organically. Sixty-three percent indicate feeling moderate

to extreme pressure from customers and media to reduce pesticide use.

Due to these pressures, growers are seeking alternatives to traditional methods of growing strawberries. Research conducted at the University of Minnesota between 1998 and 2008, funded in part by the U.S. Environmental Protection Agency, has resulted in a system – referred to herein as the wool mulch system – that significantly reduces the need for herbicides, and virtually eliminates the fungicides and insecticides used on strawberries.

WHY WOOL?

In 1998 the University of Minnesota began collaborating with the Minnesota Lamb and Wool Producers Association (MLWPA) and the Agricultural Utilization Research Institute (AURI) to develop a use for large amounts of short-fiber wool produced in the state. This low value wool is

Figure 4. Sheep typical of those grown in Minnesota.

the byproduct of the carding process, in which raw wool is cleaned and separated before spinning. Similarly, short-fiber wool is also discarded after the napping process of blanket-making at Minnesota woolen mills. At the time the research began, the MLWPA was looking for uses for this abundant by-product while the University was looking into various biological mulches to use in fruit production to help control weeds and reduce dependence on pesticides.

Early on in the research, the wool was trucked to a company in Texas where it was needle-punched into felt-like mats and sent back to Minnesota for use as mulch. The goal however was to make wool mulch a truly local product, and finally in 2004 the MLWPA contracted with an erosion control matting manufacturer in Floodwood, MN to create the wool mulch mats. Experiments were conducted with various methods and contents until a cost-effective blend of wool fibers and wood shavings was devised. The

Figure 5. Rolls of wool mulch.

wood shavings are waste products from Minnesota timber mills. The combination of wood shavings and wool fibers creates a lightweight and affordable product that is effective at suppressing weeds, retaining soil moisture, and stabilizing soil temperature. The MLWPA has trademarked this product under the name *Woolch™.*

Figure 6. Strawberry transplants growing through slits in wool mulch.

The immediate benefits of wool mulch are significant. Studies since 1998 using wool mulch with strawberries have indicated dramatically decreased weeds in the fields (Hoover 2000). Hand weeding in wool-mulched strawberry rows is very minimal.

Variability in soil temperature is greatly reduced beneath the covering of wool mulch, keeping the root zone warm when temperatures dip, and insulating the soil from drastic temperature fluctuations. Furthermore, due to the density of the wool mulch and its nature of adhering to the soil, it helps the soil to retain moisture much longer than if not mulched.

In addition to these characteristics, wool mulch offers other valuable benefits crucial to strawberry production. Because wool mulch adheres tightly to the soil and the plants grow through small slits or root directly through it (daughter plants produced from runners root easily through wool mulch), it creates an effective barrier between the plants and many soil borne diseases. This barrier also prevents fruit from making contact with the soil that can harbor fungal spores leading to fruit molds and rots. The layer of wool mulch between the berries and the soil creates a cleaner, drier, virtually disease-free surface on which the berries can grow.

Figure 7. Strawberries on wool mulch.

Eventually, the wool begins to decompose. The degrading wool adds nitrogen and organic matter to the soil, becoming more of a natural fertilizer than a weed-deterrent. When it is time to plow the strawberry plants under and rotate to another crop, the wool mulch can be tilled into the soil with the plant remains where it will continue to decompose and add nutrients. Thus, the lifecycle of wool mulch is completed and the process can begin again on a new plot with fresh wool mulch.

Research on Strawberries Grown with Wool-Canola Mulch

Research into a biological weed control option for strawberry growers was conducted at the University of Minnesota primarily by Dr. Emily Hoover and Steve Poppe. This research began in 1998, and was completed in October, 2008. The study developed a strawberry production system using a combination of felted wool fabric mulch and a canola *(Brassica napus*) cover crop/mulch.

The wool mulch is laid over double rows of strawberry transplants at planting time in early-August (a shift from the May planting in the matted row method) and the plants grow through slits in the mulch. The

Figure 8. Newly installed wool mulch with strawberry transplants growing through.

wool permits water and nutrients to pass through from above, and allows the rooting of daughter plants. However, the wool prevents weed seeds from germinating and rooting, and smothers any weeds growing beneath. The wool typically begins to decompose after the first harvest year, at which point the strawberry plants are well established and are not as susceptible to competition from weeds.

The practice of late planting in this system – as compared to the April/May planting in the matted row system – is beneficial for a few reasons. First, by August most weeds have dispersed their seeds and weed seed germination is reduced. Second, hand weeding labor that would have been spent during the summer months is eliminated. Finally, the plants take advantage of the late season warmth to become established without competition from spring weeds. They send out fewer runners and concentrate on denser crowns, which produce larger clusters of fruit the following season – often a week earlier than traditionally grown strawberries. The few runners which are sent out root easily through the wool mulch and help create dense stands of very robust and productive plants.

Canola is used in this system as both a cover crop and mulch. This species was chosen due to its allelopathic (ability to inhibit growth of other plants) qualities in regards to competitive weeds. When used as a cover crop in spring canola inhibits weeds with its fast growth and dense cover. By early summer, the canola is treated with one application of glyphosate (Roundup™) and is left to decompose on the soil surface. The decomposing canola releases glucosinolates, compounds which inhibit weed seed germination for up to eight weeks (Hoover 2000). Before strawberry transplanting in early-August, the cover crop is tilled into the soil to increase fertility and organic matter.

Figure 9. Canola cover crop.

Canola is later used as a weed suppressing mulch between rows of strawberry plants. It is sown concurrently with strawberry transplanting and treated with glyphosate after 30 days, offering the same weed inhibiting benefits as mentioned earlier. Used in conjunction with the wool mulch, weeds are virtually eliminated from the plot. In addition to weed control, the wool mulch system has proven extremely effective

Killing Canola Without Glyphosate

Several methods to eliminate the Canola were tested by Forcella and Poppe (1998) including mowing and undercutting. However, with these techniques the plant tissue left on the soil did not release the compounds that are so effective at preventing weed seed germination. In addition, while these methods did reduce growth of the canola they did not kill the plants outright and the plants continued to grow and eventually self-seeded. Thus the canola became a persistent weed, and its large stems and roots were difficult to remove.

Flaming is another possible method that has not yet been trialed. In this method, a propane torch would be directed onto the canola just long enough to singe the tissues. This method could prove to be as effective as glyphosate in killing the plant and encouraging the release of the weed suppressing compounds.

Contact herbicides such as citric acid- or vinegar based compounds might be effective at killing canola and promoting its release of glucosinolates, similar to when treated with glyphosate. These methods were not trialed in this research.

Figure 10. Methods of killing canola without glyphosate.

for disease suppression, soil moisture regulation, temperature moderation, enhanced growth and higher yields (Forcella *et al.* 2003). Use of this system eliminates the four herbicide applications conventionally used in the establishment year as well as the typical fungicide applications.

Figure 11. Canola growing between rows of strawberries.

Several articles and reports are listed in the Resources section of the Appendix, which offer detailed background information on various stages of research on the wool mulch system of strawberry production.

Can the Wool Mulch System Be Made Organic?

The wool mulch system of growing strawberries is not an organic system at this point because of the use of glyphosate to kill the canola. Yet, the system significantly reduces pesticides used on the strawberry plants themselves. Therefore, impact to the environment is lessened, and residues on berries are eliminated. There is the potential of making this system organic if an effective method of killing the canola can be identified. Research done thus far has found that treating the canola with glyphosate is the most effective way of ceasing growth while promoting its weed suppressing capabilities.

Whereas the wool mulch system effectively reduces competition from weeds and prevents many fungal diseases on strawberry plants, there may be the need for chemical control of tarnished plant bug (TPB). However, employing Integrated Pest Management (IPM) tactics such as scouting and monitoring might limit the need for insecticides. A grower could conduct targeted sprays only when necessary, to keep the pest below the economic threshold. Researchers are investigating a vacuum system to suck TPB off the plants and eliminate the need for spraying. If this proves to be effective, the wool mulch system could become truly organic.

Figure 12. Various levels of TPB damage. Notice seediness at tips of berries. Photo credit MN Dept. of Ag.

Some strawberry growers are already producing organically, and the use of wool mulch in their established system may simply help reduce hand weeding, which could cut labor costs significantly.

Although the wool mulch system is not currently deemed organic, it does subscribe to the concept of sustainability. The term 'sustainable', when used to describe an agricultural system, can be puzzling and easily misconstrued. The USDA offers a definition to help clarify the concept of sustainable agriculture, which can be found in Figure 13. The wool mulch system subscribes to these goals by

1) reducing pesticide inputs into biological cycles
2) utilizing a value-added product (wool mulch) to support local industry
3) providing growers with high yields of a high value crop
4) reducing the exposure of growers and consumers to harmful pesticide residues, thus enhancing quality of life.

A growing system such as this, which relies on improved methodologies and techniques rather than chemical input, can result in a safer, healthier, more productive, profitable, environmentally benign, therefore truly sustainable farming operation.

USDA Definition of Sustainable Agriculture (USDA 2007)

The word "sustain," from the Latin sustinere (sus-, from below and tenere, to hold), to keep in existence or maintain, implies long-term support or permanence. As it pertains to agriculture, sustainable describes farming systems that are "capable of maintaining their productivity and usefulness to society indefinitely. Such systems... must be resource-conserving, socially supportive, commercially competitive, and environmentally sound." [John Ikerd, as quoted by Richard Duesterhaus in "Sustainability's Promise," *Journal of Soil and Water Conservation* (Jan.-Feb. 1990) 45(1): p.4. NAL Call # 56.8 J822]

"Sustainable agriculture" was addressed by Congress in the 1990 "Farm Bill" [Food, Agriculture, Conservation, and Trade Act of 1990 (FACTA), Public Law 101-624, Title XVI, Subtitle A, Section 1603 (Government Printing Office, Washington, DC, 1990) NAL Call # KF1692.A31 1990]. Under that law, "the term sustainable agriculture means an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

- satisfy human food and fiber needs;
- enhance environmental quality and the natural resource base upon which the agricultural economy depends;
- make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls;
- sustain the economic viability of farm operations; and
- enhance the quality of life for farmers and society as a whole.

Figure 13. USDA definition of sustainable agriculture.

INSTRUCTIONS FOR IMPLEMENTING THE WOOL MULCH SYSTEM OF STRAWBERRY PRODUCTION

The following section provides detailed step-by-step instructions for implementing the wool-canola mulch system. These instructions, which begin with the establishment year and conclude with the end of the first harvest year, can be applied to any size operation, from very small to several acres.

The calendar on the next page gives a visual representation of when the various practices occur throughout the season – early in the month, mid-month, or late in the month. If you are viewing this guide online, you can click on a practice or on a month to go directly to that section in the instructions.

PRACTICE	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	APR	MAY	JUN
Add essential nutrients according to soil test	Early										
Till to incorporate nutrients	Late										
Plant canola cover crop		Mid									
Apply glyphosate to canola, leave on surface			Mid								
Till to incorporate canola, create semi-raised beds				Late							
Plant dormant strawberry transplants in double ribbon row					Early						
Apply wool mulch in rows at time of planting					Early						
Sow canola between rows at time of planting					Early						
Apply glyphosate to canola between rows, leave on surface						Early					
Apply floating row cover to enhance fall growth						Mid					
Remove floating row cover, apply straw mulch								Mid			
Remove straw mulch, reapply floating row cover									Early		
Remove floating row cover at 10% bloom										Mid	
Monitor for tarnished plant bug										Continuous	
Harvest begins											**10-Jun**

Figure 14. Calendar of practices in the wool mulch system of strawberry production.

ESTABLISHMENT YEAR

PLANNING AND PREPARATION

Site selection is an important first step in planning a strawberry planting. Strawberries require full sun, so the site should not be near trees or structures that might shade the planting. The site should be level and not in an area lower than surrounding land. Cold air sinks into low areas and can increase potential of frost damage. Soil should be well-drained and have medium to high percent sand. Lighter soils have better drainage, warm earlier, and harbor fewer diseases than heavy clay or silt soils.

The site should not have had strawberries planted on it the previous year, because the soil can contain inoculum that will be transferred to the new planting. Similarly, strawberries should not follow solanaceous crops (tomatoes, potatoes, etc.) or brambles (raspberries and blackberries) because these can harbor Verticillium wilt, which will also affect strawberries. Rather, it is ideal to plant strawberries on a site that has had a weed-suppressing cover crop or other crop the previous one or two years. In addition to eliminating diseases and controlling weeds, this type of rotation can add valuable nutrients to the soil.

When establishing a new strawberry planting, irrigation is an important consideration. Drip irrigation is superior to overhead irrigation for many crops, especially strawberries grown with wool mulch (Fig. 15). "Advantages of using drip irrigation include better control of foliar diseases and more efficient water and fertilizer use. Water savings with drip irrigation can amount to as much as 50 percent compared with an overhead sprinkler system" (Hoover *et al.* 2007).

Figure 15. Connecting drip irrigation lines.

Overhead sprinklers used for frost protection are unnecessary because the plants are protected by floating row covers during the fall and spring when danger of frost is greatest.

Perennial weeds – most importantly, quackgrass – must be eliminated from the site where strawberries will be planted. In trials of the wool-canola mulch system, quackgrass was able to grow up through the wool mulch (Fig. 16).

Figure16. Quackgrass growing through wool mulch.

More information on weed management and general production guidelines for strawberries can be found in the Resources section at the end of this publication.

Late April

The site should be tilled to incorporate any cover crop, plant residue, or compost and to loosen the soil for sowing canola, as shown in Figure 17.

Figure 17. Tilling prior to sowing canola.

Mid-May

Sow canola (*Brassicus napus*) seed at a rate of 18 lbs. per acre (double the standard rate) and rake in. The variety 'Dwarf Essex' is recommended for its small size and for its high concentration of glucosinolates – compounds which inhibit weed seed germination (Eberlein, Morra, Guttieri, Brown and Brown 1998). While the size of the canola is unimportant in the cover crop phase, the small size of 'Dwarf Essex' is essential when canola is later used between rows of strawberries.

Figure 18. 'Dwarf Essex' canola cover crop.

Larger varieties of canola, when used between the rows, shade the strawberry plants and topple on them when treated with glyphosate. The fresh glyphosate on the treated canola plants subsequently damages the strawberry plants. For this reason and for the high concentrations of weed suppressing glucosinolates, 'Dwarf Essex' is recommended for both applications.

Canola grows rapidly, and when seeded at such a high rate creates a dense stand which helps to suppress early spring weeds. The canola should be left to grow for four weeks until mid June.

Mid-June

Four weeks after the canola is sown, it should be sprayed with glyphosate and left on the soil surface (Fig. 19). The dying plant tissues release glucosinolates for approximately 8 weeks. If incorporated into the soil, the canola is not effective against weeds.

Figure 19. Canola has been treated with glyphosate and left on the soil surface.

The glyphosate in this case is not being used directly on weeds but rather on the canola which will release compounds that inhibit weeds through most of the summer. Figure 20 offers information about glyphosate, its effects on plants, movement in the soil and degradation.

Glyphosate Facts

- Glyphosate is a non-selective, systemic herbicide that is effective on most annual and perennial plants.
- It is a contact herbicide. The chemical is absorbed by the plant leaves and subsequently inhibits synthesis of various proteins necessary for growth.
- It is adsorbed to the soil (attaches to soil particles) which prevents leaching.
- Once attached to soil particles, glyphosate has no herbicidal effect on plants.
- Glyphosate is degraded by microbial metabolism.
- Degradation rate depends on soil texture and microbial community.
- Half life of glyphosate in the soil averages two months.
- Glyphosate is relatively non-toxic to birds and mammals and moderately toxic to aquatic species. However, it is unlikely to leach into aquatic environments. (Tu, Hurd, Robison & Randall 2001)

Figure 20. Facts about glyphosate.

LATE JULY

By late July preparation for planting should begin. The canola can be tilled into the soil as a green manure to increase nutrients and organic matter. At the same time, semi-raised beds should be created to prepare the plot for planting the dormant strawberry transplants in early August (Fig. 21).

Figure 21. Creating raised beds.

The raised beds should measure 24-inches wide by approximately 6-inches high with 24-inch aisles between rows (Fig. 22). Planting on raised beds improves drainage, exposes the plants to greater amounts of sunlight, allows the soil to warm up more quickly in the spring, and keeps the strawberry plants distinctly separated from the canola which will be planted between the rows. The raised beds also create a good foundation for the wool mulch which will be laid over the beds and secured with soil along the edges.

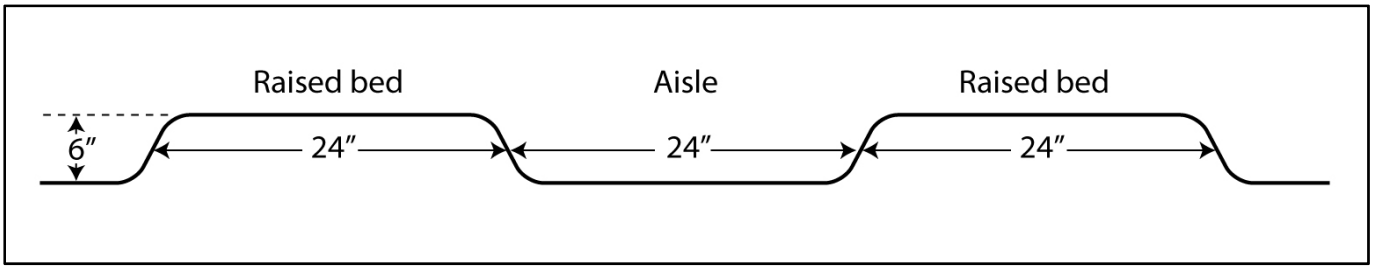

Figure 22. Width and height of raised beds.

PLANTING

Note: In the University of Minnesota trials of the wool mulch system, the dormant transplants were planted first and the wool mulch laid over the top. Openings were then cut for the plants to grow through. The trial plots were 1080 square feet, small enough to make this method effective with the help of several student workers. This method will be described here, and is recommended for relatively small plots. Figure 24 offers a suggestion for laying the wool first and planting into it

Planting in the wool mulch system takes place in August, which is a shift from the May planting of traditional matted-row strawberries. Growers benefit by having the early months of the season free for the many other demands on the farm. When growing traditional matted row strawberries, the summer months are spent controlling weeds. In the wool mulch system, at the time of planting in August, the wool is installed and canola seeded between the rows. These provide effective control against late season weeds.

EARLY AUGUST

The majority of labor is concentrated near the first of August for the establishment of strawberries grown with wool mulch. Installing drip irrigation, planting, laying the wool and sowing canola all must happen within a relatively short timeframe in order to establish the plot, maintain weed control and take advantage of late-season warmth.

Install the drip irrigation system first since the irrigation lines will run under the wool (Fig. 23). Lay drip lines along the center of the raised beds. Transplants will be planted along both sides of the drip line.

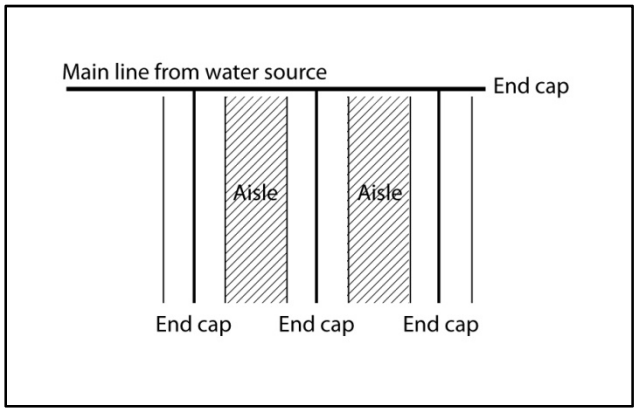

Figure23. Diagram of drip irrigation layout.

More information on laying drip irrigation, as well as supplier information can be found in the Resources section at the end of this publication.

Wool First – Plants Second

Because trial plots were small, researchers were able to perform many tasks by hand. Laying the wool over the transplants and cutting slits by hand may be far too time-consuming for the commercial grower. It is possible that the wool could be installed using a roller and the transplants punched through, similar to laying and planting through plastic mulch. Growers are encouraged to experiment with various methods to find the most efficient technique to fit within their systems.

Figure 24. Possible method of installing the wool mulch system.

PLANTING STEP 1

Plant dormant strawberry transplants on the raised beds in staggered double ribbon rows. Transplants should be set so the soil is just covering the roots but not covering the crown (Fig. 25). Space the plants 12 inches apart in rows spaced 12 inches apart (Fig. 26). Dense planting encourages crown development instead of runner development, which will bring about earlier and more abundant flowering and fruiting the following season. Transplants should be watered immediately.

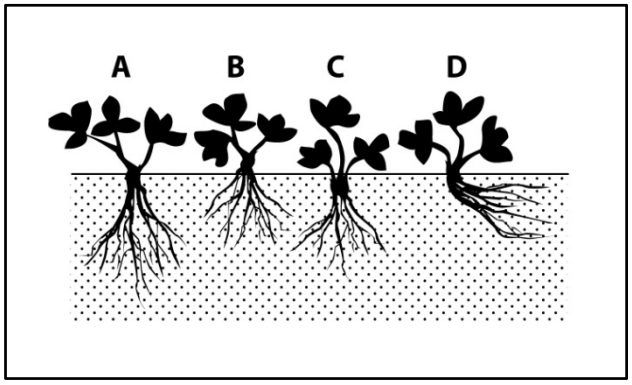

Figure 25. A. Proper planting depth; B. Incorrect: crown too shallow; C. Incorrect: crown too deep; D. Incorrect: roots spread laterally.

PLANTING STEP 2

The wool mulch is applied next `over the raised beds (Fig. 27). The wool mulch is manufactured and distributed in rolls measuring 5 feet wide by 80 feet long. For this system, it should be cut in half so the strips are 2.5 feet wide by 80 feet long. This is wide enough to cover the raised bed and wrap down the edges to provide weed protection on the entire surface of the bed.

After the transplants are watered, unroll the wool over the top of the plants, centered on the raised bed. Working along the row using a knife or pair of scissors, locate the plants and cut a slit in the wool (3- to 4-inches long) and ease the plant through the slit. The slit should close gently around the plant but not cover or restrict it (Figs. 29 & 29). This will prevent weeds from establishing in the opening while allowing the plants the space they need to grow through the wool. Once all the plants are coaxed through the slits in the wool, the edges of the wool along the sides of the raised beds should be secured with soil.

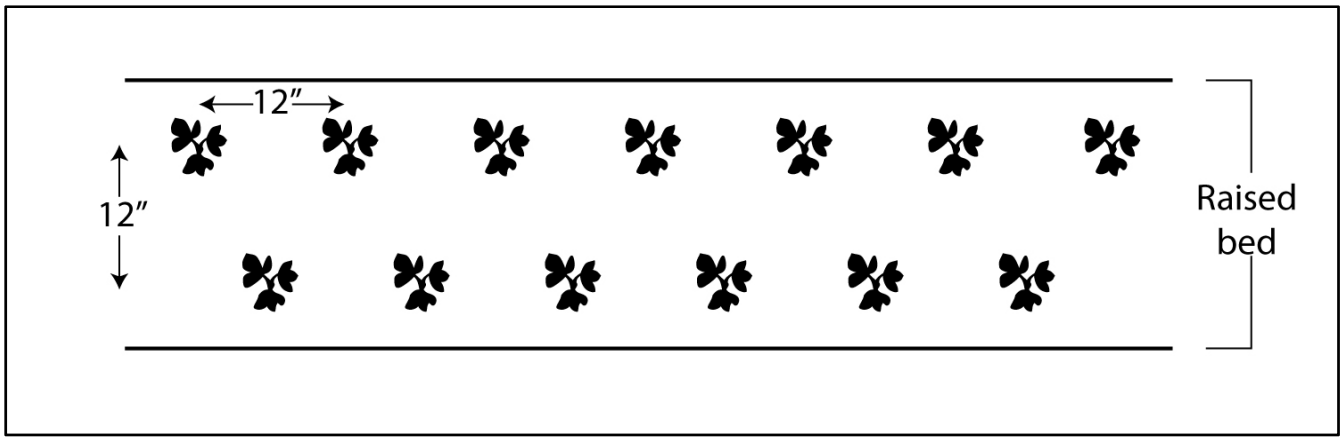

Figure 26. Plant spacing on raised bed.

Figure 27. Rolling wool mulch over strawberry transplants.

Figure 28. Cutting slits in wool to allow strawberry transplants to grow through.

Figure 29. Strawberry transplant growing through 4-inch slit in wool mulch.

Using a spade, move some soil from the aisles over the edges of the wool (Fig. 30). This will prevent wind from blowing the wool off the beds. Upon installation, the wool will be very lightweight. However, once it is saturated by rain or by irrigation it will become flattened, dense, and hold firmly against the soil.

Figure 30. Securing edges of wool mulch with soil.

PLANTING STEP 3

After the transplants are planted and the wool mulch installed, the aisles must be planted with canola. Spread canola seed in the aisles at the same rate as before (Fig. 31). Rake it in taking care not to tear the edges of the wool. When the canola germinates, a few stray seedlings might be found growing through the slits in the wool mulch. Pluck seedlings out while they're small to prevent them from crowding the strawberry plants.

Figure 31. Sowing canola seed between the rows of strawberry transplants.

Early September

Four weeks after the canola is planted in the aisles, it should be treated with glyphosate as before and left on the surface of the soil (Fig. 32). The glucosinolates released from the dying canola tissues will

Figure 32. Killed canola in aisle next to strawberry row. Canola is left on soil surface to prevent late season weeds.

again act as a pre-emergent herbicide for any late season weed seeds. It is critical to prevent glyphosate from reaching the strawberry plants on the raised beds. In research trials, a hand-held sprayer was used to apply glyphosate while shields were held to protect strawberry plants. Directed herbicide sprayers, wick-, or wipe-type applicators would be effective in directing glyphosate onto the canola without reaching the strawberry plants.

Mid-September

Because the plants were planted in August, they will require extra time to become established before the onset of winter. One of the features of the wool mulch system is the extended growing season made possible through the use of floating row

Figure 33. Floating row cover being installed over strawberry plot.

covers. A floating row cover is a lightweight fabric sheet made from spun-bonded polyester or polypropylene. As the name implies, the material is so light that it literally 'floats' over the growing plants. The cover allows light and water to penetrate and holds heat near the soil surface. Floating row covers can last several years if properly handled to prevent tears.

When installing the floating row cover over the plot, secure the edges with sandbags or lumber (Figs. 33 & 34). It is important to secure the edges firmly because the row cover could be blown out of place by the wind.

Figure 34. Floating row cover installed. Edges are secured with lumber and sandbags.

The plants continue to grow through mid-November when the floating row cover will be removed and replaced with a straw cover for winter protection.

Mid-November

In mid-November, remove the floating row cover from the plot. The plants will have grown since the row cover was placed in mid-September. By this time however the risk of frost is approaching and the plants need extra protection against winter injury.

Using clean, seed-free straw, cover the entire plot to a depth of approximately six inches, as shown in Figure 35. Because the plants are on raised beds, the straw must be hilled up in these areas to ensure a sufficiently thick cover (Fig. 36). Winter injury is one of the most common problems in strawberry production, and can greatly reduce harvests the following year.

Figure 36. Straw mulch on strawberry rows.

Winter

Now that the plot is covered with straw, the strawberries can rest for winter. Check the straw cover from time to time and replenish it as necessary to maintain proper thickness.

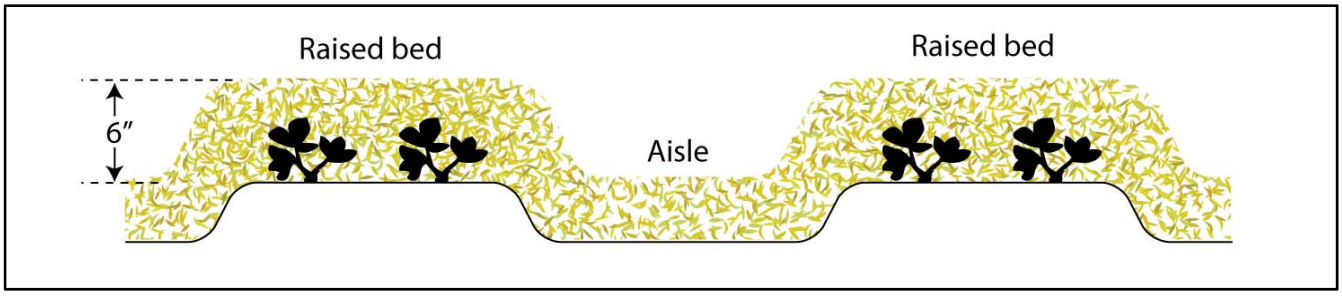

Figure 35. Recommended depth of straw mulch over strawberry plants.

HARVEST YEAR

Note: Weather patterns vary greatly in Minnesota. In 2008, the year this guide was published, Minnesota experienced an extended cold spring and many activities described here (including harvest) were delayed two to three weeks. The dates for each activity listed here are approximate and depend greatly on the weather. The instructions here are based on a 'typical' year.

EARLY APRIL

Around the first of April the danger of a hard frost is usually past. At this time, rake the straw from the raised beds into the aisles to uncover the plants (Fig. 37). Place the floating row cover over the plot once again and secure as before. The cover holds heat near the plants. This, along with the faster-warming soil in the raised beds, initiates early season growth of the plants.

Figure 37. Raking straw off strawberry rows into aisles.

MID-MAY

Remove the row cover at ten-percent bloom to allow insect access to the plants for pollination. Ten-percent bloom is generally reached between May 15 and May 20. Timing is critical considering that early removal of the row cover could mean cold injury or reduced growth, and late removal may result in un-pollinated flowers. Start checking for flowers in early May. The variable weather patterns during May could cause this schedule to shift either way by a week or two.

Figure 38. Strawberry blossoms on a wool mulch row.

Within a week after removing the row cover, a single insecticide application could be made for tarnished plant bug control if necessary. It is important to make this application before any fruit is formed to prevent chemical contact with the berries.

Early June

On approximately the tenth of June, a sufficient number of berries will have ripened to begin harvesting (Fig. 39). Again, this is dependent upon the weather. A few days of high temperatures will hasten ripening, so plots must be monitored carefully.

Figure 39. Strawberries on wool mulch ready for harvest.

Post-Harvest

Once harvest is complete, there are several options with the wool mulch strawberry plot. In research trials, wool mulch plots were treated as annual systems. However, commercial growers typically keep a strawberry plot active for at least three years. This is certainly possible with the wool mulch system.

By the end of the first harvest season, the wool might be fairly decomposed or might remain fully intact. The plot could be renovated and prepared for another harvest the following year. Narrowing the rows by tilling or disking might not be necessary after the first harvest year because the plants will not have produced runners as profusely as in the matted row system. Crowns will be dense, but runnering and spreading minimal.

It is extremely important to remember that tilling the aisles could result in the wool mulch pulling and snagging if it is not yet sufficiently decomposed. Before tilling, begin by determining the degradation of the wool. At the end of a row, free up a small section of the edge of the wool from under the soil and tear a section off. If it tears very easily or comes apart in clumps, the wool should till under successfully. If the wool is difficult to pull apart, it is still effective as mulch and should be kept in place to take advantage of its weed and disease suppression, moisture retention, and temperature moderation qualities.

If mowing the strawberry plants, ensure the mower blade is set high enough so as not to disturb the wool. If set too low, the

result could be damaged plants or equipment.

The following season, the wool that remains will continue to offer benefits of weed suppression, moderation of soil temperature and soil moisture retention at some level until it is completely degraded.

The plot will eventually evolve into a traditional matted row planting, and can be treated as such from this point on. The wool has served its primary purpose of controlling weeds during the establishment- and first harvest years. Hereafter the wool will decompose, adding valuable nutrients to the soil.

The wool mulch system is a new development and presents opportunities for grower experimentation. As with any new method, some amount of fine-tuning might be required to make the wool mulch system excel within a grower's established practices.

Figure 40. Wool mulch strawberry plants near the end of the first harvest season.

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Online Resources

General Information

Minnesota Department of Agriculture	http://www.mda.state.mn.us/
University of Minnesota	
Department of Horticultural Science	http://horticulture.cfans.umn.edu/
Extension Service	http://www.extension.umn.edu/
Commercial Fruit	http://fruit.cfans.umn.edu/
Minnesota Fruit and Vegetable Growers Assn.	http://www.mfvga.org/
North American Strawberry Growers Assn.	http://www.nasga.org/
Minnesota Lamb and Wool Producers Assn.	http://www.mlwp.org/
Woolch Supplier	http://www.mlwp.org/woolch.htm
Cornell University Berries	http://www.fruit.cornell.edu/berry.html

Production Guidelines and Pest Management

Many sites offer information on suppliers

Commercial Strawberry Production in Minnesota	http://fruit.cfans.umn.edu/strawbs/commercialproduction.htm
Integrated Pest Management Manual for Minnesota Strawberry Fields, 2nd Edition 2007	http://www.mda.state.mn.us/plants/pestmanagement/berrymanual.htm
Midwest Small Fruit Pest Management Handbook	http://ohioline.osu.edu/b861/pdf/ch02_51-54.pdf
Minnesota High Tunnel Production Manual for Commercial Growers – includes drip irrigation information and suppliers	http://www.extension.umn.edu/distribution/horticulture/M1218.html
National Sustainable Agriculture Information Service – production and pest management information, suppliers	http://attra.ncat.org/

LINKS TO ARTICLES ON WOOL-CANOLA MULCH RESEARCH

Ag Innovation News: 2004, Vol. 13, No. 4	http://www.auri.org/news/ainoct04/04mulch.htm
Ag Innovation News: 2006, Vol. 15, No. 2	http://www.auri.org/news/ainapr06/berry_blankets.htm
Renewing the Countryside	http://renewingthecountryside.org/index.php?option=&mode=region&task=view&category=3&Itemid=43&limit=1&limitstart=4
Renewing the Countryside 2002 – Pine Tree Orchards	http://renewingthecountryside.org/component/option,com_smartpages/task,view/category,10/id,148/Itemid,43/
MN Dept of Agriculture Greenbook 2000	http://www.mda.state.mn.us/news/publications/protecting/sustainable/greenbook2000/fruitshoover.pdf
MFVGA Wool-Canola Fact Sheet	http://fruit.cfans.umn.edu/strawbsite/Wool-canola%20factsheet%20MFVGA%20.pdf
Weed Technology: 2003, Vol. 17, Issue 4	http://fruit.cfans.umn.edu/strawbsite/bioonweedtech2003v17.pdf

APPENDIX

This section provides information regarding material and labor comparisons, cost distributions and yield data. These figures are based on data taken from field trials during 2007-2008 and do not include overhead expenditures. Cost comparisons do not include labor. Trial plots measured 1,080 square feet, roughly 1/40 of an acre. Material costs and labor data from the trials were used to calculate estimates per acre.

Table 1. Comparison of establishment year costs per acre for matted row system and wool-canola mulch system.

Item	Matted Row Acre	Wool Mulch Acre
Tractor Use – fuel, lube, maintenance	$ 6,029.00	$ 3,922.00
Pesticides – herbicides, insecticides, fungicides	$ 259.00	$ 10.00
Cost of Transplants – Matted Row-10,648 plants; Wool Mulch: 21,295 plants	$ 936.00	$ 2,289.00
Wool Mulch – 32,670 sq. feet	$ 0	$ 4,900.00
Floating Row Covers	$ 0	$ 1,851.00
Sand Bags – to hold down floating row covers	$ 0	$ 338.00
Straw – winter protection for both systems	$ 3,121.00	$ 3,121.00
Drip Irrigation System – materials	$ 5,586.00	$ 5,586.00
TOTAL	**$ 15,931.00**	**$ 22,017.00**

Table 2. Breakdown of costs of establishment year and first harvest year indicating reduction in cash layout after establishment of system.

Item	Establishment Year	First Harvest Year
Tractor Use	$ 3,922.00	$ 1,961.00
Pesticides - glyphosate for canola	$ 10.00	$ 10.00
Cost of Transplants	$ 2,289.00	$ 0
Wool Mulch – 32,670 sq. feet	$ 4,900.00	$ 0
Floating Row Covers	$ 1,851.00	$ 0
Sand Bags	$ 338.00	$ 0
Straw	$ 3,121.00	$ 3,121.00
Drip Irrigation System	$ 5,586.00	$ 0
TOTAL	**$ 22,017.00**	**$5,092.00**

Table 3. Cost distribution of establishment year per acre.

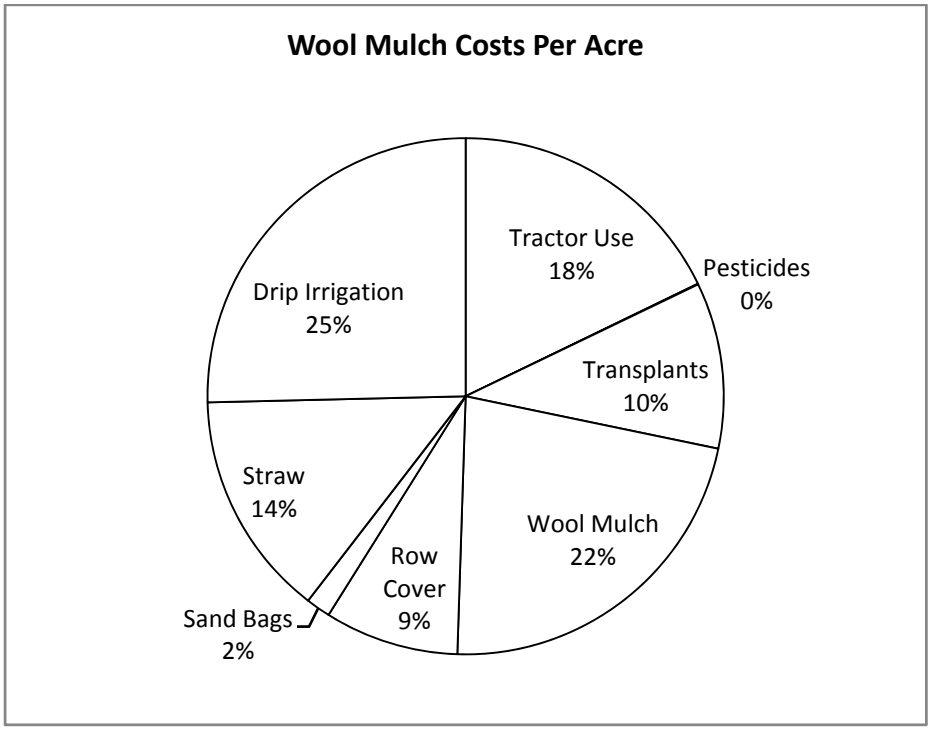
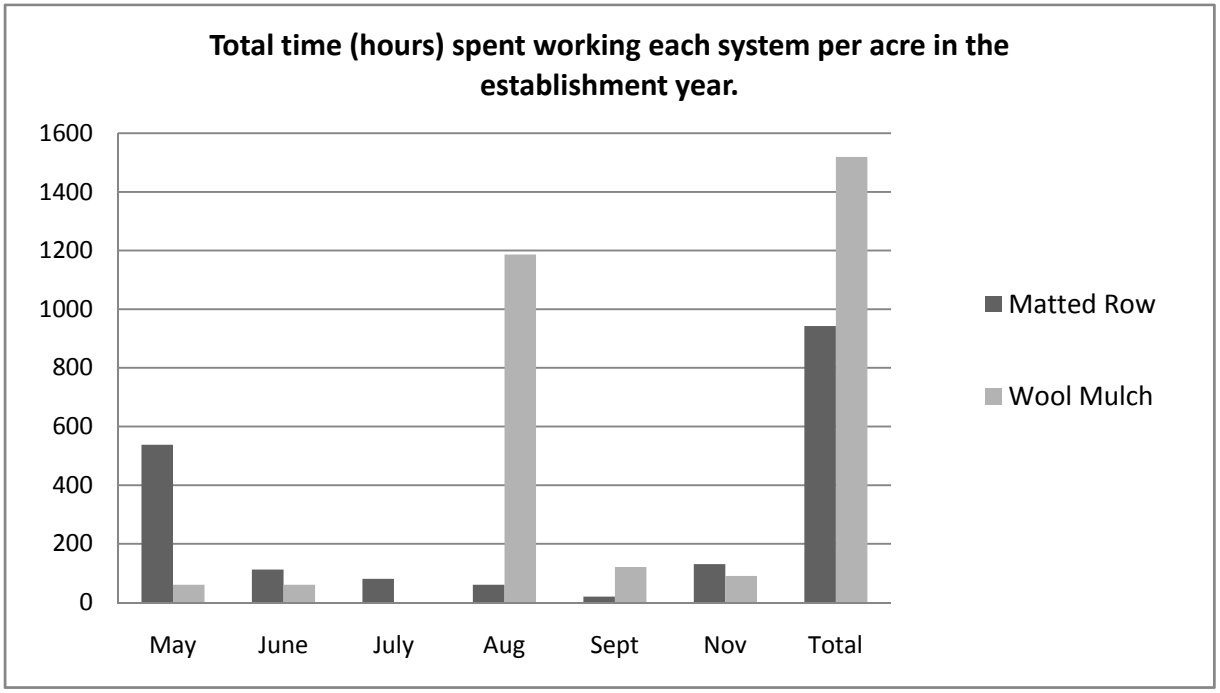


Table 4. Earnings from various yields at various price points. Average matted row yield is 10,000 pounds/acre. Average wool mulch yield is 15,000 pounds/acre. At $2.00/pound, establishment year investment would be returned in the first harvest year for the wool mulch system.

Pounds/A	$2.00/pound	$2.25/pound	$2.50/pound	$2.75/pound	$3.00/pound
8000	$16,000	$18,000	$20,000	$22,000	$24,000
9000	$18,000	$20,250	$22,500	$24,750	$27,000
10000	$20,000	$22,500	$25,000	$27,500	$30,000
11000	$22,000	$24,750	$27,500	$30,250	$33,000
12000	$24,000	$27,000	$30,000	$33,000	$36,000
13000	$26,000	$29,250	$32,500	$35,750	$39,000
14000	$28,000	$31,500	$35,000	$38,500	$42,000
15000	$30,000	$33,750	$37,500	$41,250	$45,000
16000	$32,000	$36,000	$40,000	$44,000	$48,000
17000	$34,000	$38,250	$42,500	$46,750	$51,000
18000	$36,000	$40,500	$45,000	$49,500	$54,000

Table 5. Comparison of labor between matted row and wool-canola mulch systems. *Note: Weeding labor on some matted-row research plots was significantly higher than displayed here. Weeding labor is highly dependent upon weed management practices. Similarly, August labor for the wool mulch system would typically be lower. At research plots, many laborers were tracking time though not always actively laboring.*



YIELD DATA

To be added when data becomes available.