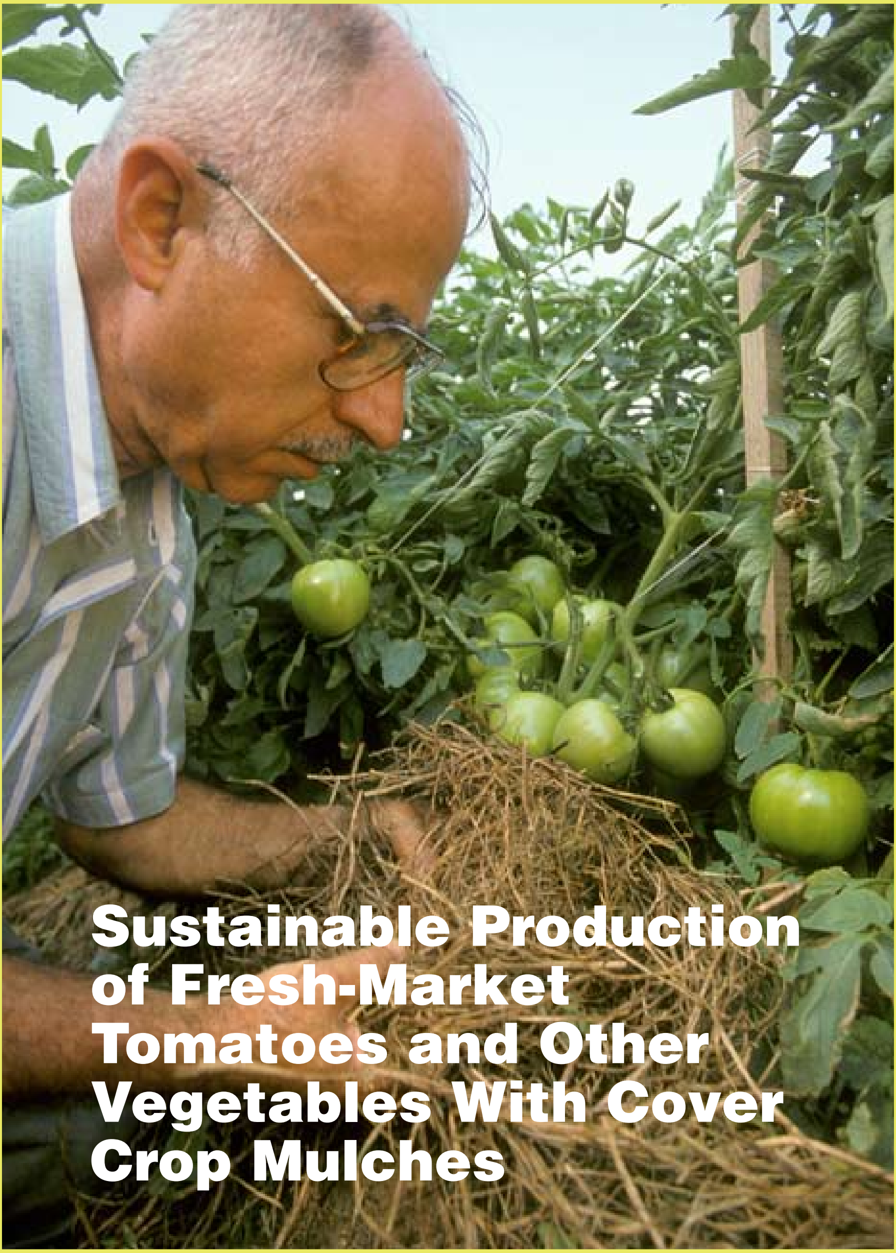

Sustainable Production of Fresh-Market Tomatoes and Other Vegetables With Cover Crop Mulches

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Research supporting these findings was conducted at the USDA–ARS Beltsville Agricultural Research Center in Beltsville, Maryland; at the University of Florida Tropical Research and Education Center, Homestead, Florida; and with growers on private farms as a contribution to the Sustainable Agriculture Program.

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Note: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S. Environmental Protection Agency, consult your local county agriculture agent or State extension specialist to be sure the intended use is still registered.

Use only pesticides that bear the EPA registration number and carry appropriate directions.

Cover photo. Hairy vetch mulch provides a thick residue that releases nutrients and suppresses growth of weeds.

October 2007

This document supersedes "Sustainable Production of Fresh-Market Tomatoes and Other Summer Vegetables With Organic Mulches," Farmers' Bulletin No. 2279.

Sustainable Production of Fresh-Market Tomatoes and Other Vegetables With Cover Crop Mulches

Aref A. Abdul-Baki and John R. Teasdale

The alternative production system described in this bulletin focuses on the winter annual legume hairy vetch (*Vicia villosa* L. Roth) both as a cover crop and as a mulch in a sustainable tomato production system. As a cover, vetch serves to fix nitrogen, recycle nutrients, reduce soil erosion and compaction, and add organic matter to the soil. When converted to a mulch, the residue reduces weed emergence, reduces water loss from the soil, acts as a slow-release fertilizer, and suppresses some pathogens and pests.

Research on this mode of production was originally confined to growing tomatoes in stands of hairy vetch. Within a few years, however, the underlying concept showed a great deal of promise. The concept can be easily modified to suit other crops and regional growing conditions. A surprising number of options have met with success. Some direct-seeded vegetables can be grown effectively, as can winter vegetables in subtropical climates. Other cover crops can be selected and even seeded in beneficial mixtures to suit local growing conditions.

This publication first describes the basics of the original system: how to establish a stand of hairy vetch, convert it into a mulch, and nurture young tomato plants in the mulch. Once you understand the process, consider modifying it to grow other vegetables, first on a small scale. Or try customizing the cover crop to suit your climate or soil condition. These possibilities are discussed in a later section, “Customizing the Basic System.” Other excellent sources of information on cover crops can be derived from Sustainable Agriculture Network (2007) and the University of California online cover crop database. (See References.)

Recommended Cover Crops

Winter annual cover crops are normally grown in areas where cold winter months preclude growing cash crops. Your choice of a winter annual cover crop species should take into consideration factors such as its winter-hardiness, efficiency in fixing nitrogen and producing biomass, and length of the growing season. Table

Table 1. Winter annual legumes tested in Maryland

Cover crop	Best variety	Vigor	Winter hardiness	Time of maximum growth	Typical nitrogen content (%)
Hairy vetch	—*	Excellent	Excellent	May	4.0
Bigflower vetch	Woodford	Excellent	Excellent	May	3.5
Common vetch	Vantage	Good	Fair	May	3.5
Crimson clover	Chief/Dixie	Good	Good	April	2.5
Subterranean clover	Mt. Barker	Variable	Fair	May	3.0
Arrowleaf clover	Yuchi	Good	Fair	June	3.0
Austrian winter pea	—*	Good	Fair	May	3.5
Berseem clover	Bigbee	Good	Poor	June	3.0

*— = no varieties.

1 lists properties of winter annual legumes tested in Maryland.

Of the winter annual legumes, hairy vetch is the most adaptable and produces consistently high amounts of nitrogen and biomass. Common vetch, subterranean clover, arrowleaf clover, Austrian winter pea, and berseem clover are not as winter hardy in Maryland as hairy vetch, big-flower vetch, or crimson clover. Bigflower vetch seed is difficult to obtain. Crimson clover provides excellent biomass for mulching and attracts beneficial insects but has a lower nitrogen content than hairy vetch. A cultivar of hairy vetch developed at Auburn University—AU Early Cover—develops and flowers about 2 weeks earlier than common hairy vetch but is less winter hardy and may not be suitable for areas north of southern Pennsylvania.

Summer annual cover crops are most useful in subtropical climates where hot temperatures

Table 2. **Nematode-resistant summer annual cover crops for tropical/subtropical climates**

Cover crop	Best variety	Vigor	Time of excellent growth	Seeding rate (lb/acre)	Typical nitrogen content (%)
Sunn hemp	Tropic Sun	Excellent	June-July	50	3.0
Velvetbean	Georgia Bush	Excellent	June-July	30	3.5
Cowpea	Iron Clay	Good	June-July	100	3.5
Sorghum-sudangrass	_____	Good	June-July	40	1.0

in the summer may be less favorable than winter temperatures for crop production. Table 2 lists species that have done well under south Florida and southern California conditions. One serious group of vegetable pests in these areas is phytoparasitic nematodes. Thus, cover crops resistant to nematodes are a priority in the development of environmentally friendly cropping systems for fragile ecosystems such as the Florida Everglades.

Establishing the Cover Crop

Prepare your seedbed in late summer but early enough to allow the cover crop to get established about 2 months before winter begins. (See suggested planting dates below.) Form permanent beds—4 feet wide (5 feet center to center) and 6 inches high and seed them with the winter annual cover crop.

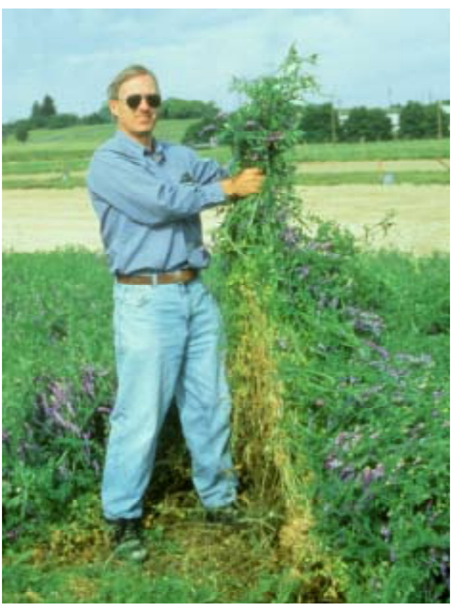


Figure 1. Hairy vetch makes an excellent cover crop because of its broad adaptability, fast growth, high efficiency in fixing nitrogen, and production of high-quality biomass for mulch.

Hairy vetch should be seeded at 25 to 40 pounds per acre. Inoculation of seeds with the proper rhizobium immediately before seeding is necessary only if vetch has not been previously seeded in the field. In a firm seedbed, place the seed just below the soil surface using a forage or grass seeder. Hairy vetch emerges within 1 week. The seedlings grow 5 to 6 inches high and establish a mat over the ground before winter. During subfreezing temperatures, plants can be expected to turn gray to purple, but they will resume growth early in the spring. When it's time to transplant your tomatoes to the field, the vetch plants should already be 4 to 5 feet in length (figure 1); however, because of their creeping growth habit, they will remain prostrate and form a thick stand about 2 feet high.

Between October and May, a vetch cover crop produces 3,000 to 5,000 pounds of dry matter per acre that contains about 120 to 200 pounds of nitrogen per acre (table 3). Vetch also accumulates an appreciable amount of phosphorus, potassium, and micronutrients.

Hairy vetch biomass can be predicted by the accumulation of growing degree days (GDD) between planting and plant termination in the

Table 3. Typical biomass and nutrient content of cover crop mixtures at Beltsville, Maryland

Cover crop	Biomass	Nutrient		
		Nitrogen	Phosphorus	Potassium
			(lb/acre)	
Hairy vetch	4,036	125	18	132
Hairy vetch + rye	6,054	138	18	170
Hairy vetch + rye + crimson clover	7,366	148	19	166

spring (Teasdale et al. 2004). GDD is determined by adding together the difference between the average temperature and 39 ºF for each day between planting and vetch termination. (Negative numbers resulting from temperatures below 39 ºF are discounted.) Research has shown that hairy vetch will produce about 265 pounds of dry biomass per acre for every 100 GDD accumulated. Given the average daily temperatures for any location, the optimum planting date can be determined for producing a desired amount of biomass by a desired date. For example, hairy vetch would require 1,509 GDD to produce 4,000 pound per acre of dry biomass; this would require planting on September 28 at Beltsville, Maryland, to achieve this target biomass by the 90-percent frost-free date of May 6 (table 4). Research also shows that early planting is necessary to achieve a high level of hairy vetch ground cover before winter to protect against soil erosion. For example, over 1,100

Table 4. **Date that hairy vetch should be planted to accumulate 4,000 pounds of dry biomass per acre on the 90-percent frost-free date, assuming 30-year average temperatures and adequate moisture and soil conditions**

Location	90% frost-free date	Projected planting date
Binghamton, NY	May 15	August 24
Peoria, IL	May 2	September 8
Beltsville, MD	May 6	September 28
Nashville, TN	April 19	October 13
Raleigh, NC	April 17	October 18

GDD are required in the fall to achieve greater than 50-percent soil cover before winter. If hairy vetch is planted 2 or 3 weeks later than optimum, low levels of soil coverage will be achieved before winter, and adequate biomass levels may only be achieved in the spring by waiting to terminate vetch at full bloom, which is usually well beyond the 90-percent frost-free date.

Converting the Cover Crop Into an Organic Mulch

The cover crop produces most of its growth during the month before tomatoes are transplanted, so it should be allowed to grow until immediately before transplanting. When it's time to convert the cover crop into a mulch, there are three options.

Figure 2. **A high-speed flail mower converts the cover crop to a mulch without disturbing the soil.**

1. *Chemical kill* with a contact herbicide.

2. *Mechanical kill* with a mower. A high-speed flail mower, which cuts the plants 2 to 3 inches above the bed surface, is recommended to produce a uniform residue cover that controls soil erosion and inhibits weed emergence (figure 2). A high-speed mower is essential; a lower speed mower, such as a sickle bar, tangles in the vetch vines, especially when the biomass is high. It's important to perform this operation when the cover crop is flowering; otherwise, the cover crop will continue growing. Mowing is also best performed in the afternoon after morning dew has dried.

Other innovative equipment, such as rollers and choppers, has been evaluated for mechanically killing cover crops. These approaches can have the benefits of faster operations than mowing but are also prone to inadequate kill and can leave unmanageable residue that interferes with planting operations. New equipment designs are currently being developed to solve these problems. (See The New Farm No-Till + Page listed in References.) For small areas, such as a home garden, you can manually cut the vetch plants or pull them out by the roots and spread them to cover the bed before planting.

3. *Plowing* the hairy vetch vines into the bed with a rototiller or a similar piece of equipment to form green manure. This alternative offers rapid decomposition of the vetch and nitrogen release. This method may be preferable in areas with too little summer rainfall to adequately break down a surface mulch, but then you lose the benefits of

Figure 3. Transplanting tomatoes into hairy vetch mulch using no-till transplanters.

a surface mulch—erosion control, soil moisture retention, improved water infiltration, improved soil structure, and weed suppression.

Transplanting the Tomato Crop

For large fields, commercial transplanters of varying sizes and capacities are available that are designed to operate in thick organic mulches (figure 3). They can be equipped with coulters that cut and loosen a narrow band in the bed with minimal interruption to the mulch layer. Note that the coulter axles can tangle in the vetch vines if not set properly. Transplanters can also be equipped with spades to open a hole, deliver a dose of liquid fertilizer, set the plant at the right depth, and press the soil firmly around it. It's important to set the root ball of each transplant firmly in the underlying soil, not in the mulch layer. Recommended spacing between plants within the row is 16 to 24 inches, depending on plant vigor and variety.

A hand planter (also called a tree planter) can be used for manual planting. Insert the planter into the soil to a depth of 4 or 5 inches and move it back and forth once to open a wedge-shaped hole 4 inches deep by 2 inches wide. Insert the transplant into the hole, press the soil around it, and reposition the mulch around the plant.

Whether transplanting manually or mechanically, avoid walking on the beds; this helps prevent soil compaction and maintain mulch uniformity. Disruption of the mulch during any operation will promote weed growth and moisture loss.

Managing the Tomato Crop

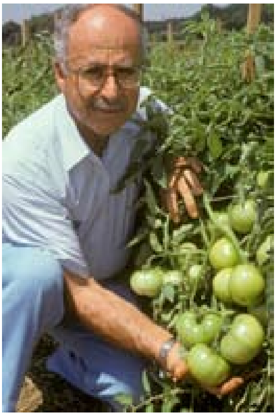


Figure 4.
Tomato plants grown in hairy vetch mulch are vigorous, healthy, and high yielders.

Crop management should focus mainly on practices that result in a high yield of a high-quality, uniform product—that is, providing optimum amounts of water and nutrients and controlling weeds and pests throughout the growing season (figure 4).

Water management is critical for producing high-quality tomatoes. Short dry spells may delay maturity, reduce yield, and lower quality. Excessive water, especially in soils with poor drainage, reduces plant growth and increases incidence of disease.

Trickle irrigation is particularly effective when used with mulches. It conserves water by applying small amounts directly to the plant root zone, and you can use the system to apply fertilizer as often as needed. It has the added advantage of reducing weed growth in areas of the field that remain dry.

A trickle system must be installed immediately after planting so the transplanted plants do not face moisture stress conditions. Install the trickle irrigation lines on top of the vetch mulch and 3 to 4 inches from the tomato row, with the emission pores toward the ground. They should be fixed in place with U-shaped wires.

The frequency of irrigation depends on soil type, temperature, plant size, and quantity of water applied at each irrigation. Generally, small quantities of water applied more often are preferable to large quantities applied less often. Excessive watering tends to wash nutrients downward to depths below the root zone and reduce efficiency of fertilizer use. It's advisable to flush the trickle system monthly with chlorinated water to keep the emission pores from clogging.

Application of fertilizers through the trickle system is

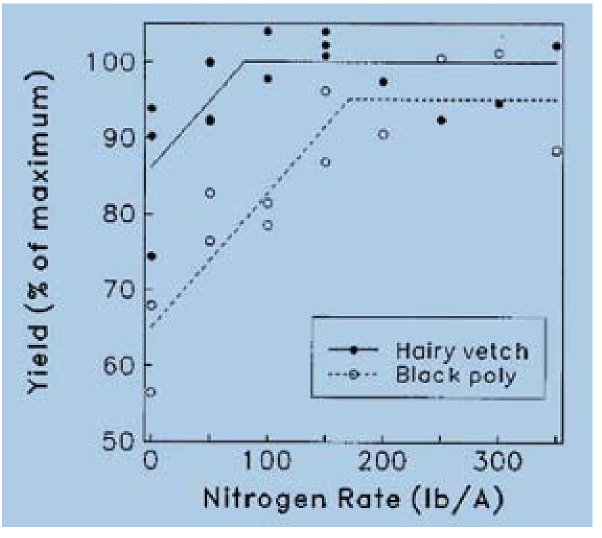


Figure 5.

Nitrogen requirements of fresh-market tomatoes, variety Sunbeam, grown in black polyethylene and hairy vetch mulches.

most efficient, delivering only small amounts at a time. Best results are achieved when fertilizer is applied at least four times per season. When tomatoes are grown in a vetch mulch, the need for commercial fertilizers in general, and for nitrogen in particular, lessens (Abdul-Baki et al. 1997). As a rule, tomatoes grown in a hairy vetch mulch produce about 85 percent of maximum yields without any addition of commercial nitrogen fertilizer (figure 5). Adding about one-half the recommended nitrogen rate results in maximum yields. Note, however, that excessive nitrogen can lead to higher losses into the environment. Other nutrients, such as phosphorus and potassium, should be added at the time of bed preparation according to soil test results.

Drip irrigation, which delivers water in a very local area of the bed, may not provide sufficient moisture during hot, dry weather in midsummer. This is the period that tomatoes are setting fruit and growing rapidly to support fruit development. Inadequate moisture throughout the bed would preclude tomato roots from taking up the water as well as precluding decomposition and release of nutrients from vetch residue. We recommend overhead irrigation with the hairy vetch system during midseason periods of prolonged dry weather to optimize the benefits of this system.

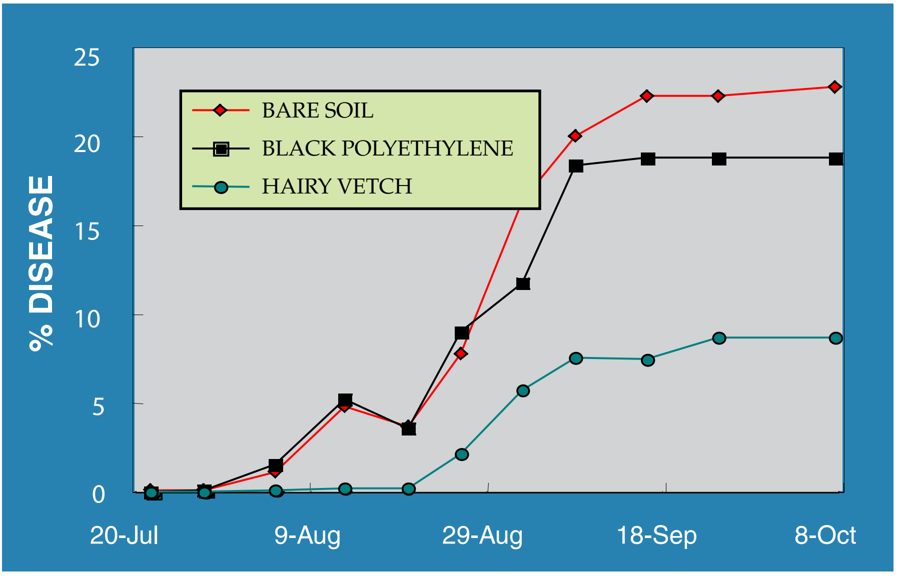
Staking and tying up the plants is highly recommended for fresh-market tomatoes. Though staking doesn’t increase yield, it does facilitate management and improve fruit quality.

Figure 6. **Staking raises the fruit off the ground, exposes the plant to light, and facilitates field operations.**

Within 2 weeks of planting, place stake between every other plant and support the plants with twine woven from stake to stake. Usually, three rows of twine are needed to support full-grown plants (figure 6).

Weed control is essential for maximum yields and high quality. Generally, hairy vetch will not regrow if mowed at flowering time. The optimum time for transplanting tomatoes (when the vetch should be mowed) is often 2 to 3 weeks ahead of vetch flowering. This early mowing doesn't kill the vetch completely, and it soon regrows in a weedlike fashion overgrowing the tomato plants in 3 to 4 weeks. Don't worry. The postemergence herbicide treatment described next will solve the regrowth problem.

Figure 7. **Severity of foliar disease on tomatoes grown in beds with bare soil, black polyethylene, and hairy vetch.**



The vetch mulch suppresses weed emergence for the first month after mowing. As the vetch vines decompose, weed seedlings eventually emerge through the mulch and require control with postemergence herbicides. An application of 0.5 pound of active ingredient of metribuzin per acre will probably be needed about 3 to 4 weeks after transplanting to control the vetch regrowth and emerging weeds, whichever appears first. (Follow all applicable regulations and precautions.) It's important to make this application promptly, when the weed seedlings are first sighted, or the vetch regrowth will begin to threaten the tomato plants. An additional postemergence application of a registered grass herbicide may be necessary to control late-emerging grass weeds. Consult product labels for specific information.

In all likelihood, disease and insect control will require fungicides and insecticides. Research at Beltsville has shown that a cover crop mulch can reduce foliar diseases (figure 7) and certain insect pests (Mills et al. 2002). Recent research by Autar Mattoo, also a plant physiologist at the Sustainable Agricultural Systems Laboratory, and colleagues has shown that hairy vetch triggers a cascade of genes to be activated that enhance disease tolerance and delay senescence (Kumar et al. 2004). Use of an integrated pest management program in combination with cover crops may significantly reduce the number of applications required. As in any well-managed vegetable rotation, the use of proper rotations is essential for preventing the buildup of disease and pest

Table 5. Production costs and profits of fresh-market tomatoes grown in black polyethylene and hairy vetch mulches in Beltsville, Maryland, 1991–93

	Black polyethylene	Hairy vetch
	($/acre)	
Production cost	2,908	2,535
Harvest and marketing	8,141	10,290
Total cost	**11,049**	**12,825**
Gross return	17,006	22,691
Marginal profit	**5,957**	**9,866**

populations. Consult your local extension office for further information.

Production and Profitability

Tomato plants grown in hairy vetch mulch continue to produce 2 to 3 weeks longer than those grown conventionally in black polyethylene. This extension of the production season contributes to high yields and profitability. Table 5 shows a 3-year average of the production costs, gross returns, and marginal profits for each type of system (Kelly et al. 1996). The marginal profits of tomatoes grown in hairy vetch average over $3,900 more per acre than those grown in black polyethylene. This difference is partly due to higher yield and partly due to reduced production costs by eliminating the expensive polyethylene mulch and by reducing fertilizer and herbicide use.

Environmental Benefits and Liabilities

In addition to the production and economic benefits of using a hairy vetch cover crop that have been mentioned already (including provision of nitrogen and other nutrients, weed and disease suppression, and enhanced yield and profitability), this system provides many environmental benefits. Cathleen Hapeman, Pam Rice, and colleagues (Rice et al. 2001) showed that hairy vetch residue aids infiltration of rainfall and reduces twofold to fourfold the amount of rainwater that runs off fields compared with the black polyethylene system, where about two-thirds of the surface area is covered by an impervious surface. Reduced rainwater runoff reduces erosion of soil sediments,

Figure 8. **High levels of sediment in runoff from polyethylene-mulched fields (tubes on left) compared with low levels in runoff from vetch-mulched fields (tubes on right).**

nutrients, and pesticides from tomato fields by 75 to 95 percent (figure 8). And toxicity of runoff from hairy vetch fields to aquatic organisms is lower than runoff from fields with black polyethylene.

The presence of a living cover crop in beds that were already formed in the fall can facilitate timely field operations in the spring. The combination of improved soil structure and water infiltration, water uptake by the cover crop, and preformed beds can prevent soils from becoming too wet for spring planting operations. It is often easier to get into the field for mowing and planting operations without tillage in the vetch system than to till the soil and install polyethylene mulch before planting in the polyethylene-based system.

One limitation to the hairy vetch system compared with the black polyethylene system is that it may result in more nitrogen losses. Though a hairy vetch cover crop accumulates high levels of nitrogen in its tissues and reduces nitrogen fertilizer needs, research suggests that not all of this nitrogen can be used by the crop (Rosecrance et al. 2000). Nitrates released from decomposing vetch residue are not efficiently taken up by the crop and can be leached from the root zone. Also, substantial amounts of nitrogen can be lost to the atmosphere by the process of denitrification. Black polyethylene may prevent rainfall from leaching nitrogen and may block release of volatile substances to the atmosphere. One approach to reducing potential nitrogen

Figure 9. **A six-row, no-tillage seeder planting snap beans.**

losses is to use a mixture of hairy vetch and rye. (See below.)

Customizing the Basic System

Other Crops

Large-seeded summer vegetables, such as sweet corn, snap beans, and pumpkins, are well suited for planting directly through mulch residues with a no-tillage seeder (figure 9). For direct-seeded vegetables, the cover crop should be planted onto a flat seedbed rather than raised beds. Management of the cover crop before planting the vegetable crop includes a choice of either killing with a herbicide or killing with a mower or other mechanical equipment as described for tomatoes. When registered postemergence herbicides are available, delay application of the herbicide and use it only as needed. A hairy vetch cover crop will supply most of the nitrogen requirement for these crops, so commercial nitrogen needs to be applied only by sidedressing when needed. Cover crop residue can also keep crops, such as pumpkins or snap beans, cleaner than production on bare soil.

Hairy vetch and other winter annual cover crops are most effective when used with summer vegetables. Early spring vegetables don't work as well in this system. Not only does the mulch delay the soil from warming in the spring, but there is not enough cover crop vegetation to form a mulch by the time spring vegetables need to be planted. Fall vegetables are equally

unsuited because, by that time of year, vetch has long since died and the remains have almost completely decomposed.

Without tillage, small-seeded vegetables are difficult to establish by direct seeding through cover crop residue. Transplanting is a better alternative. Lack of effective herbicides for controlling mulch regrowth or escaped weeds limits use of this system with many vegetables, particularly peppers. In these cases, cover crop combinations may be the best way to reduce the need for herbicides. (See below.)

Cover Crop Mixtures

An ideal cover crop varies from region to region, from farm to farm, and even from site to site within a farm. Selection may hinge on the primary purpose for the cover crop, such as controlling erosion, capturing nitrogen in the fall, releasing nitrogen to the next crop, improving the soil structure, and suppressing weeds.

For a crop with high nitrogen requirements, such as tomatoes or sweet corn, a cover crop such as hairy vetch or crimson clover, whose residues decompose and release nutrients within 1 month, is most suitable. However, full-season vegetable crops also require a cover crop whose residues decompose slowly and suppress weeds over a longer period. If erosion is the main concern, a fast-growing cover crop, such as rye, that rapidly forms an aboveground cover and an extensive root system is most effective in stopping soil erosion and capturing remaining nutrients.

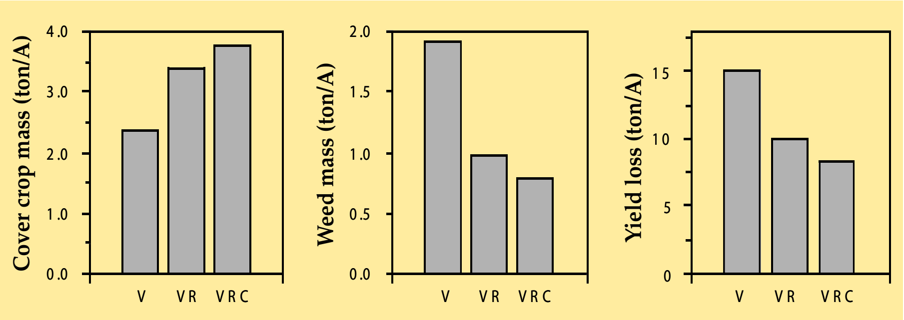
Figure 10.

A combination of hairy vetch, crimson clover, and rye provides a thicker stand, which prevents soil erosion.

To combine benefits, such as erosion control, nitrogen fixation, and slow decomposition, consider combining two or more cover crops into one stand. Combinations that work well in the mid-Atlantic States are hairy vetch plus rye or hairy vetch plus crimson clover plus rye (figure 10). Rye's early growth makes it effective in protecting the soil from erosion and in intercepting leftover nutrients from the previous vegetable crop. The hairy vetch and crimson clover components of the mixture offer the advantage of fixing nitrogen. It's worth repeating that mulch from the succulent vetch plant decomposes rapidly and releases nutrients, whereas mulch from rye decomposes slowly and provides weed suppression over a longer period of the growing season.

When planted in combination, hairy vetch and rye should be seeded at a similar rate. For example, if vetch is seeded at 40 pounds per acre, then rye should be seeded at a similar rate to keep it from dominating the mixture. Crimson clover should

Figure 11. **Cover crop biomass impact on weed biomass and tomato yield loss (difference between yield of weedy and weed-free treatments) when tomatoes were grown in a hairy vetch (V), hairy vetch plus rye (VR), or hairy vetch plus rye plus crimson clover (VRC) mulch. Average of 3 years of data.**



be seeded at 10 to 12 pounds per acre if added to the vetch-plus-rye mixture. Because of differences in seed size, making one pass for each type of seed provides better uniformity than mixing the seeds and planting them in one pass over the field. Properly seeded combinations yield more biomass and maintain high nutrient levels (table 3).

If weeds are a concern, using cover crop mixtures can improve weed suppression. Research has shown that a mixture of hairy vetch plus rye plus crimson clover produces a thicker, more persistent layer of mulch that suppresses weeds more efficiently than hairy vetch alone (figure 11) (Teasdale and Abdul-Baki 1998). Some weeds, however, particularly perennial or winter annual weeds, can still escape this mixture, requiring additional management. Clean up fields with difficult-to-control weeds before undertaking this system.

A Cover Cropping System for Tropical/ Subtropical Climates

Tropical/subtropical areas are highly productive per unit of land area because ample rainfall and warm temperatures allow growing crops and cover crops all year. Temperatures are often more favorable for growing vegetables in the winter than during the summer months. The high temperature and moisture that favor growth of crops and cover crops also encourage weeds. Likewise, because life cycles of insects, pathogens, and phytoparasitic nematodes, such as root-knot nematodes, depend on warm temperatures, those pests complete many life cycles per year hosting a large number of vegetable and weed species. This makes weed and pest control critical for production of economic crops in tropical/subtropical climates.

In collaboration with Waldemar Klassen and Herbert Bryan, of the University of Florida at Homestead, we developed a biologically based system for growing vegetables in winter in the Homestead area of south Florida (Abdul-Baki et al. 2005). The system is based on using nematode-resistant vegetable and cover crop cultivars in a cropping rotation and maintaining a weed-free field, especially of weed species that are hosts to root-knot nematodes. Nematode-resistant tomato cultivars, such as Sanibel, perform well under Florida conditions. There are many nematode-resistant summer cover crop species. The most promising species include sunn hemp, cowpeas, velvetbean, and sorghum sudangrass (table 2). The first three

Figure 12. **Vigorous growth of sunn hemp at Homestead, Florida.**

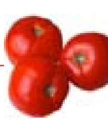
species are legumes that fix high levels of nitrogen. Sorghum sudangrass is commonly used to take up nitrogen left in the soil from the previous crop and to reduce nitrogen losses by leaching and runoff.

These summer cover crops are planted by late June and killed in early October. If managed well, particularly by irrigating in dry periods, they produce copious amounts of vegetative biomass (figure 12). One cutting can be made in midsummer; the residue is left in the field before the cover crop is killed in early October by mowing, and the residue is incorporated into the soil. Seeds of the legume species should be treated with rhizobium at seeding time. See table 2 for seeding rates.

Mowing these cover crops requires a high-speed flail mower because of their vigorous plant growth. Sunn hemp plants grow to a height of 10 feet and develop hard stems with high cellulose content. They should be mowed when the plants reach 5 to 6 feet and start to branch and flower. Velvetbeans form strong canes that are hard to chop except with a flail mower. The Georgia-dwarf cultivar doesn't have strong canes, so it's easy to manage.

Three years of testing these cover crops in the Homestead area, where the root-knot nematode population is low to moderate, revealed that the cover-cropping systems using sunn hemp, velvetbean, or cowpeas produced high net returns without use of methyl bromide. In fact, the sunn hemp system outyielded the methyl bromide system in 2 out of 3 years. The velvetbean and cowpea systems yielded slightly less than the sunn hemp system but were comparable to the methyl bromide system. Further testing of these cover crops on a large scale and in sandy soils that harbor higher nematode and pathogen populations is needed to establish whether these cover crops will be useful in wider geographical areas than the one where we conducted these tests.

Bear in mind that the performance of many potential cover crop species and combinations and killing methods have not been fully explored. We encourage growers to experiment on a small scale and report their results so they can be incorporated into future recommendations.



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