Weeds, ed. M. Liebman, C. L. Mohler and C. P. Staver, pp. 40-98. Cambridge University Press: New York.

Mohler, C. L. and M. B. Callaway. 1995. Effects of tillage and mulch on weed seed production and seed banks in sweet corn. Journal of Applied Ecology. 32:627-639.

Mt. Pleasant, J. and K. J. Schlather. 1994. Incidence of weed seeds in cow (*Bos* sp.) manure and its importance as a weed source for cropland. Weed Technology 8:304-310.

Mulligan, G. A. and J. N. Findlay. 1970. Reproductive systems and colonization in Canadian weeds. Canadian Journal of Botany 48:859-860.

Mulligan, G. A. and B. E. Junkins. 1976. The biology of Canadian weeds. 17. *Cyperus esculentus* L. Canadian Journal of Plant Science 56:339-350.

Povilitis, B. 1956. Dormancy studies with seeds of various weed species. Proceedings of the International Seed Testing Association 21:88-111.

Qasem, J. R. 1992. Nutrient accumulation by weeds and their associated vegetable crops. Journal of Horticultural Science 67:189-195.

Roberts, H. A. and S. K. Benjamin. 1979. The interaction of light, nitrate and alternating temperature on the germination of *Chenopodium album*, *Capsella bursa-pastoris* and *Poa annuua* before and after chilling. Seed Science and Technology 7:379-392.

Roberts, H. A., and P. M. Feast. 1972. Fate of seeds of some annual weeds in different depths of cultivated and undisturbed soil. Weed Research 12:316-324.

Roberts, H. A., and P. M. Lockett. 1975. Germination of buried and dry-stored seeds of *Stellaria media*. Weed Research 15:199-304.

Scopel, A. L., C. L. Ballaré, and S. R. Radosevich. Photostimulation of seed germination during soil tillage. New Phytologist 126:145-152.

Seibert, A. C., and R. B. Pierce. 1993. Growth analysis of weed and crop species with reference to seed weight. Weed Science 41:52-56.

Teasdale, J. R. and C. L. Mohler. 1993. Light transmittance, soil temperature, and soil moisture under residue of hairy vetch and rye. Agronomy Journal 85:673:680.

Totterdell, S. and E. H. Roberts. 1980. Characteristics of alternating temperatures which stimulate loss of dormancy in seeds of *Rumex abtusifolius* L. and *Rumex crispus* L. Plant, Cell and Environment 3:3-12.

Vengris, J., M. Drake, W. G. Colby, and J. Bart. 1953. Chemical composition of weeds and accompanying crop plants. Agronomy Journal 45:213-218.

Vengris, J., S. Dunn, and M. Stacewicz-Sapuncakis. 1972. Life history studies as related to weed control in the Northeast. 7 — Common purslane. Research Bulletin 598, Agricultural Experiment Station, The University of Massachusetts, Amherst, MA.

Vincint, E. M. and E. H. Roberts. 1977. The interaction of light, nitrate and alternating temperature in promoting the germination of dormant seeds of common weed species. Seed Science and Technology 5:659-670.

Wesson, G. and P. F. Wareing. 1969. The induction of light sensitivity in weed seeds by burial. Journal of Experimental Botany 20:414-425.

Wiegand, K. M. and A. J. Eames. 1925. The Flora of the Cayuga Lake Basin, New York: Vascular Plants. Cornell Agricultural Experiment Station Memoir 92, 491 p.

Weed Management on Organic Vegetable Farms

Vern Grubinger
Vegetable and Berry Specialist
University of Vermont Extension
157 Old Guilford Rd. #4
Brattleboro VT 05301-3669
(802) 257-7967
VERNON.GRUBINGER@UVM.EDU

Many organic vegetable growers consider weeds to be their primary pest problem. Integrating a variety of weed control techniques is the best way to achieve effective organic weed control.

Weed management techniques are aimed at preventing weeds before they appear, or at suppressing weeds once they are present.

Weed prevention techniques include:

- Rotation of crops, fields and tillage tools
- Composting animal manures to kill weed seeds
- Cleaning farm implements between use in different fields
- Controlling weeds in hedgerows, alleys, ditches, etc. before they set seed
- Growing allelopathic cover crops
- Mulching with plastics or organic residues
- Applying pre-emergent organic herbicide (corn gluten meal)

Weed suppression techniques include:

- Growing smother crops, intercrops and/or aggressive cash crops
- Hand-hoeing and hand-pulling
- Mechanical cultivation
- Flame-weeding
- Applying post-emergent organic herbicide (soaps, acetic acid, etc.)

Weed prevention is essential to organic weed management. Otherwise the need for cultivation can be excessive, eating into time and profits, and potentially damaging soil structure. Hand weeding is obviously costly and must be kept to a minimum. Weed prevention practices should begin in the years prior to planting a crop, with cover crops in a well-designed rotation. In the cropping year, clean fallowing and stale seedbeds may prepare for crop planting. Then, weed-crop competition can be managed through various combinations of cultivation, mulching, intercropping, mowing, and concentrating resources near the crop.

Cultural practices

Crop rotation

Crop rotation subjects weeds to an ever-changing habitat, reducing the opportunity for certain species to proliferate. Rotation strategies for weed control include row versus sod crops, frequently versus rarely cultivated crops, deep versus shallow tillage crops, early- versus late-season crops, and fallow versus cash-cropped periods.

Smother cropping

Smother cropping is cover cropping with competitive species in an attempt to starve weeds of light, nutrients, moisture and space. Smothering can weaken perennial weeds by depleting their carbohydrate reserves, and can lessen annual weed pressure by slowing growth and reducing seed production. Fast-growing, high-biomass species make good smother crops because they can get a jump on, and over, weeds.

Warm-season cover crops such as buckwheat, Japanese millet and sorghum-Sudangrass are good summer smother crops in hot conditions, but they should not be planted until soils are thoroughly warm. Cool season crops like oats, field pea, and ryegrass are candidates for smother cropping in the early spring and fall. High seeding rates, adequate moisture and fertility, and good soil-seed contact by drilling or otherwise covering seed are important to establishing a thick smother crop.

Stale seedbeds

Stale seedbeds takes advantage of the fact that most weeds have small seeds that germinate from the top inch or two of the soil, usually within a couple of weeks of preparing soil for planting. By letting these weeds germinate and then killing them without disturbing the soil and bringing up new weed seeds, subsequent weed pressure can be greatly reduced. In some cases, growers using stale seedbeds actually encourage weed germination with irrigation or row covers to overcome dry or cool conditions that slow weed growth.

Weeds can be killed with flaming, nonselective "organic" herbicides (potassium salts of fatty acids, acetic acid, etc.) or extremely shallow scraping, after which it is critical to minimize soil movement when planting or transplanting. Early-season stale seedbeds are often ineffective, as most broadleaf weeds germinate in warm soils. Many growers create a stale seedbed only in the crop row using a hand-held flamer, while cultivating between the rows. This works well with crops that are slow to establish, like carrots and onions.

Composting animal manure

Composting animal manure helps reduce the number of weed seeds added to the soil. In composting where temperatures reach approximately 140 degrees F many weed seeds can be killed. Maintaining the proper C:N ratio, moisture and aeration, and turning piles inside-out several times is important to ensure that most or all of the compost does indeed get hot. Turning also keeps weeds that sprout on the pile surface from going to seed.

Mulching

Mulching the soil provides a physical barrier to weed growth. Organic residues such as straw, leaves, etc. can suppress weeds for many weeks if put on thickly, but they keep soil temperatures cooler which may slow the growth of warm season crops. A thin layer of organic residues can be worse then none at all, since weed prevention will be poor but cultivation may be hampered.

Black plastic mulch completely blocks light from weeds and is a very effective weed suppressor. Clear plastic mulches warm the soil to a greater extent than black plastic, but allow light to penetrate thereby encouraging weed growth. Selective wavelength mulches, such as IRT, behave in between black and clear plastic, allowing limited weed growth. If weed pressure is high and canopy growth is slow then there may be a lot of weeds under clear or IRT plastic. However, under conditions of strong sunlight, solarization may kill weeds that grow under clear plastic if it is left undisturbed for several weeks prior to making planting holes in it. Paper mulches have been used with limited success since they tend to deteriorate during the season. Throwing soil up on the edges as they decompose has helped keep paper mulches in place for some growers. Organic growers need to avoid paper mulches treated with prohibited materials.

The edges of plastic or paper mulch pose a special challenge because weeds often grow well there but the mulch is easily ripped by close cultivation. To avoid hand-weeding, some growers have developed innovative cultivation tools to deal with this unique zone. These tools usually undercut then replace the mulch, or cultivate extremely close it. Both approaches require straight runs of mulch with uniformly buried edges. The planting hole may require hand weeding with slow-growing crops. Bulb planters, propane torches and other devices have been used to create small, uniform holes for planting into.

Interseeding

Interseeding is a form of inter-cropping that can add to soil organic matter, reduce soil erosion, improve field trafficability and also suppress weeds. To avoid competition with the cash crop it is advisable to interseed moderately competitive cover crops like low-growing clovers and/or ryegrasses into relatively vigorous cash crops like corn, potatoes or squash; to leave a bare planting strip for the cash crop that is kept free of intercrops as well as weeds; to sow the cover crop after the cash crop is well-established, usually at last cultivation; and to provide irrigation.

Mowing

Mowing (or weed-whacking) vegetation between the rows of a cash crop can control weeds, and or certain intercrops. It also enhances the environment for harvesting and pick-your-own sales. In most cases, between-row mowing is only practical on a small scale, or where rows are wide enough to accommodate tractor-pulled mowers. Side-discharge mowers damage crops by blowing debris on them.

Placement of resources

Placement of resources can be used to favor crops over weeds. By banding and sidedressing fertilizer, and in some cases by using drip irrigation, weeds can be denied nutrients or water needed for good growth. A word of caution is that many plants send roots laterally to obtain resources, so locating water and fertilizer only in the row may be more useful in limiting between-row weed pressure only if the rows are far apart.

Crop establishment

Crop establishment techniques that encourage the rapid early growth of vegetables and discourage rapid early growth of weeds can minimize weed control costs. Transplants give crops an obvious jump over weeds compared to direct seeding. Carefully placed starter fertilizer feeds crops not weeds.

Cultivation

Cultivation equipment for weed control varies in aggressiveness and is usually suited to killing weeds either before or after the crop emerges. Tools designed for use after a crop emerges provide either *between-row* weed control or *in-row* weed control, or in some cases, both. Cultivation implements are designed to dislodge, cut and/or bury plants. Matching the tool to the weeds, crops and soil conditions is key. Juggling the uncertainties of weather and other management demands on the farm is the challenge to using a cultivation tool at the right time.

Pre-emergence cultivation

Pre-emergence cultivation often involves shallow tillage of the soil with rotovators, various harrows or field cultivators. If performed repeatedly, this approach is called a "clean fallow" that can occur before or in-between plantings. The objective is to kill annual weeds, reduce the soil weed seed bank and remove perennial weed growth. While rather harsh on soil structure and organic matter, this technique can be justified if used in combination with a good cover crop rotation and/or addition of soil amendments to maintain soil structure.

Disk harrows

Disk harrows are often used for clean fallowing, but they may not be the best choice with a perennial weed problem like quackgrass, since rhizomes tend to be chopped up and spread them throughout a field. **Field cultivators** are used to create a seedbed and incorporate residues and soil amendments, as well as for weed control. Equipped with rows of S-tines and sweeps or shovel with lifting action, they can be used to dig up and lift quackgrass rhizomes to the surface of the soil where they will dry out and die in hot dry weather. A

variety of field cultivators are on the market, they vary in tine shape, flexibility, action, and spacing, as well as options like rollers, cultipackers, crop shields, leveling bars, and gauge wheels.

Blind cultivation

Blind cultivation relies on tools that work the entire surface of the soil 'over the top' of a recently seeded or recently emerged crop. The technique combines in-row and between-row cultivation, often to control weeds that have germinated but not yet emerged, the so-called 'white-thread' stage of growth. This disturbs and dries out small, vulnerable weeds before they start to size up alongside the crop. Such fast, shallow cultivation works best on weeds that have been up for week or less. Large-seeded crops sown deeply and young vigorous crops are able to tolerate such cultivation, while very small annual weeds cannot.

Flex-tine weeders

Flex-tine weeders can be used for blind cultivation on a number of vegetable crops. The weight of these units may be borne by the numerous thin metal tines that wiggle and dislodge weeds, or by gauge wheels attached to the frame. Gauge wheels help control tine depth and avoid gouging soil on uneven fields. With some units, the 3-point hitch can be used to adjust downward pressure on the tines. Tine weeders width ranges from narrow, bed-covering sizes to very wide units useful in large fields. Lely and Einbock are common brands.

Rotary hoe

A more aggressive blind cultivator is the rotary hoe. It has many thin spider wheels each with 16 or 18 tips, or spoons, which dislodge very small weeds. The spiders move independently and bear the weight of the unit, although gauge wheels are available. Rotary hoes come in widths of 6 feet and up. They are most often used for weed control in corn and beans and for breaking up the surface of soils prone to crusting. Rocks will jam in the spiders of a rotary hoe, keeping them from turning properly. Plastic mulch pieces in the field will also collect on spider wheels and require removal. Dull spoons reduce the effectiveness of rotary hoeing.

High clearance tractors

High clearance tractors facilitate post-emergence mechanical weed control since crops up to several feet tall can pass under the tractor, and tools can be "belly-mounted" in view of the operator, increasing the precision of cultivation. *Off-set* high clearance tractors are even better for cultivating because the driver's seat is off to the side of the tractor body, further enhancing vision of the row.

Cultivating tractors

Cultivating tractors are small, low to the ground, easy to guide and used only for precision cultivation of young or low-growing crops. The cultivation tools and the crop row(s) being cultivated are easily viewed by the operator. The Allis Chalmers "G" tractor, no longer made, is the classic of this type. Other brands, Hyspan, Saulkville, and Friday, are currently available.

Basket weeders

Basket weeders are metal cages that roll on top of and scuff the soil surface without moving soil sideways into the crop rows. This action makes them ideal for crops like lettuce that have to be kept free of soil and are not suited to hilling. Buddingh basket weeders are custom built for two to eight row beds. Angled baskets are available to work the sides of raised beds. Basket widths range from 2 to 14 inches depending on the space between rows. For wider widths, and for inner row widths that change as crops grow, overlapping baskets are available that "telescope" or expand in and out to adjust for the width.

Commonly used at speeds of 4 to 8 mph, straight rows and an experienced operator are helpful to avoid crop damage. The front row of baskets turn at ground speed and a chain drives the rear row of baskets a little bit faster; these kick up soil, and dislodge weeds that survive the first baskets. This tool is almost always belly-mounted to assist with close cultivation. The baskets handle some small stones but work best in fine soils free of clods and residues.

Finger weeders

Finger weeders cultivate around the stems of crop plants that are sturdy enough to handle some contact. Rubber-coated metal fingers provide some in-row

weeding. These are connected to a lower set of metal fingers work deeper in the ground and drive the unit at ground speed. These units can be used at just a few miles per hour since they are in such close proximity to the plants. They require belly-mounting, and are ideal for a G-type tractor. Wet clayey soils can stick to fingers and require frequent removal.

Brush-hoe weeders

Brush-hoe weeders are European tools for close cultivation in narrow rows, not very common here, and expensive. Shields protect plants from bristle wheels that rotate independently between the rows, "sweeping" weeds out of the soil. An operator sits behind the rotating wheels and steers the unit to assure precision.

Sweeps, shovels, and knives

Sweeps, shovels, and knives attach to the shanks (vertical pieces of metal that attach to the toolbar). Depending on their shape and orientation, these tools move soil in different ways as they are pulled between crop rows. People are not consistent in how they name these tools, so there can be some confusion. The shanks can be clamped to different places on the toolbar(s) to achieve an arrangement that provides the desired in-row coverage and extent of soil movement. Toolbars can be rear-mounted, belly-mounted (underneath a high-clearance tractor), or with special attachments, front-mounted.

Sweeps are wing-shaped, come in various sizes and angles, and are used to dig up larger weeds between crop rows while throwing soil into the row. Big sweeps, or duckfeet, are used to cultivate wheel tracks. Half-sweeps have a wing on just one side, so the wingless-side can cut closer to the crop rows or plastic edges. Shovels are narrower than sweeps, throw less soil, and sometimes have 2 points that are reversible. Knives are like angled shovels that are used to cut more horizontally and closer to a crop.

Wiggle-hoes

Wiggle-hoes have shanks with half sweeps attached that can be hand-steered around plants in a row by an operator seated on the back of the tractor-pulled unit. Close cultivation is possible, but extra labor is required for the operator. Slow tractor speed and wide crop spacing must be used to allow shanks to be moved in and out of the row. The **Reigi weeder** has PTO-driven rotating hubs with stiff tines that can be steered in and out of the row by an operator seated behind the tractor.

Row-crop cultivators

Row-crop cultivators consist of toolbars on a tractor-pulled frame with various shanks and cultivation implements attached so as to leave space for the crop rows to pass. These are much like field cultivators except for the spacing of the shanks and the absence of implements that completely cover the soil such as rolling baskets. Shields may be mounted on either side of the crop rows to protect them from soil and rock movement during cultivation.

Spyders, spring-hoes, and torsion weeders

Spyders, spring-hoes, and torsion weeders (made by Bezzerides) are used alone or in combination for close between-row cultivation. The spyder wheel has staggered curved teeth and is ground-driven on a ball-bearing hub. A pair of 12-inch spyders can be angled at 45 degrees toward or away from the row to either pull soil away or throw it back. Aggressive and rapid cultivation of a variety of row crops is possible, even on stony soils. Torsion weeders are square stock metal bars that can be mounted to follow the spyders, leveling the soil and flexing around the plants to clean up spots missed by the spyders. Spring hoes are flat blades 16 inches long that are a bit more aggressive than the torsion weeders, oscillating just below the soil surface.

Rolling cultivators

Rolling cultivators consist of gangs of heavy slicer tines that aggressively dig up weeds and pulverize soil between rows. Individual gang width ranges from 10 to 16 inches depending on number of slicer tines, and units are available for one to 12 rows. Gangs can be angled to hill up or throw soil into the row. Used with fertilizer attachments, sidedressing is possible while cultivating. Rocks may jam in tines, and action may be unduly aggressive for sandy soils.

Hilling disks

Hilling disks are used to aggressively throw soil into the rows of crops such as potatoes, leeks, sweet corn and other crops that tolerate or benefit from being bur-

ied. Properly timed, this results in excellent in-row weed control.

Flame weeding

Flame weeding is the killing of weeds with intense, directed heat, usually with a propane burner. Flame weeding is used primarily to control small weeds in a stale seedbed (without disturbing the soil). Because weeds tend to emerge in 'flushes' stimulated by tillage, the initial emergence of weeds represents a major portion of the weed pressure in a given field, provided subsequent tillage that brings new seeds to the surface is delayed or avoided. Prior to flaming, the soil is prepared for planting in the normal fashion, then weeds are allowed, even encouraged, to emerge, so they can be killed with flame. After planting the crop, but just before it emerges, another flaming may be applied to kill weeds that have emerged in the interim. With slow-to-germinate crops, this final flame weeding is most critical to success.

Backpack or hand-held flamers are the simplest, least expensive and safest method of flame weeding. A small canister is carried by hand or in a backpack, while a single burner at the end of a wand is aimed at the area to be flamed. The burner size, walking speed, and flame adjustment determine how much heat is applied to an area. This technique is popular for small plantings of crops that will later be close-cultivated between the rows but will not tolerate soil being thrown into the row. For example: carrot, lettuce, radish, spinach, herbs, etc.

Tractor-mounted flame weeders have been custom-built by growers to flame multiple rows or wide beds. The components include a tank (or several), valves, gas lines, regulators, pilot lights, and emergency shut-off. Gas may flow directly to individual burners, or it may be distributed through a manifold first. Burners are specific for propane in the gas or the liquid phase and are available with different BTU ratings. Liquid burners can avoid 'ice up' of gas lines. Burners may be arranged in a row to flame the entire width of a bed, including wheel, or they may be aimed at or between the rows. They may be fixed to the unit, or adjustable. Having individual burner shut-off valves and angle adjustments provides flexibility in how a flame weeder can be used.

Tractor speed when flaming is just a few mph. The larger the weeds or the heavier the dew, the slower tractor speed needs to be. Flaming is not intended to burn the weeds, but to provide a short exposure to intense heat which 'blanches' the weeds, and they collapse and die within minutes or hours. Exceptions to this are grasses, with below-ground growing points, and some succulent weeds like purslane, which can take the heat. These weeds require hotter temperatures and/or subsequent cultivation to control.

The propane containers used on tractor-mounted flamers must be 'motor fuel' tanks, which are rather expensive, but intended for mobile use, unlike stationary propane canisters. The design of the system and the selection of valves and controls should be done in consultation with a propane professional. All tractor mounts, canister straps, and lines should be carefully examined before using the flamer. Besides the potential for explosion, concerns include: fires started in dry grass or hedgerows, liability insurance and regulations.

Conclusion

Effective organic weed control on vegetable farms is possible through the use of cultural practices, cultivation and flaming. Organic weed control practices can be economically viable when utilized as part of a whole-farm management system that includes rigorous use of cover crops, crop rotation, and sanitation.

References

Altieri, M. and M. Leibman, 1988. *Weed-Crop Ecology: Principles in Weed Management.* Breton Publishers, Boca Raton FL

Colquhoun, J. and R. Bellinder. 1997. *New Cultivation Tools for Mechanical Weed Control in Vegetables.* IPM Fact Sheet, Cornell Cooperative Extension, Ithaca NY

Bowman, G. (ed.) 1997. *Steel in the Field: A Farmer's Guide to Weed Management Tools.* Northeast SARE Program, UVM, Burlington VT

Grubinger, V.P. and M.J. Else. 1996. *Vegetable Farmers and their Weed Control Equipment* (video) Center for Sustainable Agriculture, UVM, Burlington VT

Some sources of cultivation equipment

Bartschi-Fobro LLC
P.O. Box 651
Grand Haven, MI 49417
(616) 847-0300

Bezzerides Bros., Inc
P.O. Box 211
Orosi, CA 93647
(559) 528-3011

BDi Machinery Sales Co.
430 E. Main St.
Macunie, PA 18062
(800) 808-0454

Buddingh Weeder Co.
7015 Hammond Ave.
Dutton, MI 49316
(616) 698-8613

Chauncey Farm
119 Bridle Rd.
Antrim, NH 03440
(603) 588-2857

HWE Agricultural Technology (Einbock)
B.P. 1515
Embrun, ON K0A 1W0
Canada
(613) 443-3386

Market Farm Implement
257 Fawn Hollow Rd.
Friedens, PA 15541
(814) 443-1931

Lely Corp.
P.O. Box 1060
Wilson, NC 27894
(252) 291-7050

Univerco (Reigi weeder)
713 Route 219
Napierville, Quebec J0J 1L0
Canada
(800) 663-8423
(450) 245-7152

Unverferth Manufacturing
P.O. Box 357
Kalida, OH 45853
(800) 322-6301

Wasco Hardfacing Co.
P.O. Box 2476
Fresno, CA 93745
(559) 485-5860

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How to Get 99% Weed Control without Chemicals

Brian Caldwell
Farm Education Coordinator
Northeast Organic Farming Association of New York

In order to grow a vegetable crop to its full potential, weed control needs to be good, really good!

How good?

Often, dozens or hundreds of weed seeds per square foot of vegetable field will sprout, ready to out-compete your crop. Even if 90% of those seedlings are killed, that can leave several survivors per square foot--more than enough to hurt yields. **99% or more of emerging weeds must be prevented from competing with the crop.** This translates to less than one weed per square foot (note: we're not talking about a "99% clean" field--there still might be thousands of weeds per acre, just not enough to hurt yields). Some growers do this routinely, without herbicides and with minimal hand weeding.

In order to consistently get this 99+% control, four strategies must be combined:

1. Preplant weed control
2. Weed control between rows
3. Weed control within rows
4. Reducing weed reproduction

Skipping one of these strategies will result in too many weeds and a yield loss or the need for expensive hand labor to get rid of them.

Preplant weed control

Preplant weed control starts with the right tools. The strategies described here can be done with hand tools and walking tractors, but for operations of over an acre, tractor-mounted equipment is worthwhile. Investing in good used equipment will quickly pay off in reduced labor and better results. Use compatible, effective equipment to prepare the soil and seed and cultivate the crop. Seedbeds must be level. Rows must be straight and exactly the right distance apart for the cultivator. Belly-mounted seeders and cultivators are best.

Plan crops, cover crops, and tillage to stifle weed outbreaks each year. If a long season heat-loving crop or cover crop is grown one year, follow it with an early or late cool weather crop. Vary tillage times and crop types (long or short season, warm or cool weather crops) from year to year, in addition to not repeating related crops in a field. Deep tillage at different times during the season will strongly suppress perennial weeds like quackgrass, Canada thistle, and yellow nutsedge. If you have these weeds, plan to rotovate or plow twice a season (followed by your crop or cover

crop) until they are gone. After a few years, discing or field cultivating may be all the primary tillage you need.

Stale seedbed techniques can knock out your first 50-75% or more of the weeds. The best non-chemical approach for this is to prepare a fine, firmed seedbed 2 or more weeks in advance. When it's time to plant, go over the seedbed using flaming or a shallow cultivation with a basket weeder to kill the emerged weeds. Plant your crop right away, with no further soil disturbance. Many fewer annual weeds will emerge to compete with the crop. This method works better for crops that are planted during warm weather (June or later), so that weeds have had a chance to germinate.

Weed control between the rows

Weed control between the rows is relatively easy. Pictures of some common types of cultivators can be found in *Steel in the Field,* edited by Greg Bowman, the best reference on mechanical weed control. If you want to control weeds without chemicals, you need this book. You can order it at 802-656-0471 for $18.

Growers on stone-free soils tend to prefer basket weeders, which allow cultivation very close to the row and do an excellent job if weeds are less than 1 inch tall. For stonier soils or somewhat larger weeds, gangs of overlapping sweeps are also effective, but they throw more soil and must be set further from the row. "Spyder" toothed disks can be mounted next to the row to get closer. Without throwing any toward the row, they shear soil away, which is then thrown back by the following sweeps.

Cultivate early on a sunny day for best results. If you don't have an ideal cultivator, go over the rows twice (i.e. in both directions), to do a more complete job on those weeds.

If possible, cultivating a couple days after a good rain is an effective strategy for reducing weeds and holding moisture. The loosened surface soil may form a "dust mulch," which will hold moisture beneath, but which will not be a good seedbed for new weeds.

While cultivators kill existing weed sprouts, new seeds are stirred up and will sprout after a rain. That's why several cultivations are needed. I often hear growers say, "It's a mess now, but it was clean as a whistle 3 weeks ago." They should have cultivated at least once more, even though the weeds were barely visible.

If weed pressure has been reduced 75% by stale seedbed, and between row cultivation gets 80% of what's left, then we have 5% of the original weed pressure left-mostly right in the rows next to the crop. We're at 95% weed control, close to our 99% goal.

Weed control within rows

Weed control within the row is very tricky. For one thing, research done by Dr. Chuck Mohler of Cornell and myself showed that annual weeds may come **up 2-3 times more thickly within the row.** Why? Because they do best on a well-firmed seedbed, just like your crops. (Similarly, be sure not to leave packed soil caused by your tractor tires. Mount sweeps behind the rear tractor tires.) That in-row location is precisely where weeds are hardest to kill and where they most reduce your yield.

"Broadcast" cultivation with a flexible tine ("tine-tooth" or "finger") weeder or a rotary hoe solves part of the problem for large-seeded crops that can be planted deeply like corn, beans, peas, potatoes or onion sets. The implements are pulled at high speed "blindly" right over the crop rows, scratching out the newly-sprouting weeds while going right over deeper crop seeds or better-rooted crop seedlings. This is usually done 4-5 days after the crop is planted, then a week later, and perhaps once more. The crop shoots get a bit beat up by the process, and a few are pulled out of the ground, but yield is reduced only slightly or not at all. Most of the weeds within the rows are killed, so the broadcast cultivation is quite worthwhile. But it must be done when the weeds are in the "white thread" stage—just before emergence—to be effective.

After the crop is too big to broadcast cultivate, the between-row cultivators are used. For the last one or two between-row cultivations, soil can usually be purposely thrown at the base of the crop ("hilling"), smothering small weeds coming up in the row.

If we can kill 80% or more of the in-row weeds with

broadcast cultivation and hilling, our 5% of the original weed pressure has been reduced to 1% or less. **We have reached our 99% goal.**

There are variations in this strategy for some crops. Potatoes, for instance, are deeply hilled. If this is done twice, good weed control is usually attained. Transplanted crops like brassicas cannot be blind cultivated, but they quickly grow to the point where they can take some hilling. The trickiest crops are root crops like carrots, parsnips, beets, direct-seeded onions, or herbs like dill, cilantro, etc. They usually require some hand weeding. Turnips and daikon are often seeded after mid summer when weeds pressure is not so strong, so hand weeding is light. A special trick can be done with carrots and parsnips, which are slow to germinate. Just before the crop comes up, but after the main flush of weeds has germinated, the rows can be flamed. Weed control is excellent when this is done right. If a small pane of glass is placed over part of a carrot row, the crop seeds under it will come up a day or two ahead of the uncovered rows-so the grower is alerted when it's time to flame.

Reducing weed reproduction

What we are trying to accomplish here is to limit year-to-year weed pressure by reducing the soil weed seedbank. This is a long term process. *The key practice here is to till under the crop as soon as harvest is finished.* This reduces new weed seed production, and also helps with disease and insect control. Seed a cover crop at the same time.

Some growers are able to send someone through the field late in the season to hand pull large maturing weeds and get them out of the field--not a bad job if weed control has been excellent.

Cover crops can also be used in other ways to compete against weeds. At the final cultivation, they can be "undersown" into the cash crop. The crop should be far enough along that the cover crop will not compete heavily against it once it gets going. Slower establishing cover crops like red or sweet clover are better choices than oats or ryegrass for this purpose. In dry years, even late- interseeded cover crops will compete against the cash crop, unless the field is irrigated. On the other hand, undersown strips can reduce mud and protect the soil during a wet harvest.

In addition to killing flushes of weeds before seeding with the stale seedbed technique, the same idea can be applied after early-maturing crops. Till the crop in, wait for a flush of weeds, kill them, then plant your cover crop. You've gotten rid of another batch of weed seedlings.

Finally, avoid importing millions of weed seeds by not spreading manure from grain-fed animals. Compost such manure before use.

Mulching

Mulching controls weeds both in and between the rows. All transplanted crops and garlic are candidates for mulching.

Garlic can be mulched immediately after planting with organic materials like weed-free straw, hay, leaves, or wood chips, if the soil is well drained. Annual weeds are suppressed and these materials provide organic matter and long-term nutrients to the soil. Mulching with organic materials works well for other crops too, as long as they grow well in cool soil and the field is free of perennial weeds. There is a labor cost in applying these mulches, but I'm convinced that growers can figure out reasonable ways to apply them if they want to. For instance, much time is saved by laying the mulch down before the crop is transplanted (or before it comes up, as in the case of garlic). High-residue no-till transplanters are being developed that may work through organic mulch.

The other major mulching material is black or colored plastic. Weeds along the edge of the plastic can be a headache. Covering the bare soil between the plastic with weed-free organic materials is a good solution. Moisture retention, soilborne disease reduction, and a dry picking lane are bonuses. Otherwise, rows can be set far enough apart so that a narrow tractor with a section of springtooth harrow or other cultivation setup can be pulled through every two weeks or so. Hoeing or flaming will have to be done along the plastic edges. Edge weeds that go to seed late in the season can be a real drawback to the use of plastic

mulch. If you use colored plastic mulches, make sure they are able to fully shade out weeds. Some work well only with herbicides.

How much does this cost?

A rough estimate would be $30-40 per equipment pass per acre (including amortized, pro-rated equipment costs for tractor plus cultivator and flamer setups, fuel, labor, etc., used on at least 10 acres per year). For large operations, this cost could perhaps be cut in half. Hand weeding costs are likely to be at least $400/acre (50+ hrs @ $8/hr). Organic mulching materials could run on the order of $500/acre (clean straw—5 tons/A @ $100/ton), plus considerable labor for spreading. Plastic mulch materials are perhaps $200/acre or more, depending on row spacing and type of plastic.

Varying intensities of weed control are needed for different crops, and much depends on crop mix and the scale of the operation. A typical sweet corn crop might require two blind passes with a flexible tine weeder, then two between-row cultivations with sweeps and hilling discs (roughly $60-160/acre, depending on farm size). Carrots, which are worth a lot more per acre, might get stale seedbed prep, a delayed flaming just before emergence, three cultivations, and a hand weeding ($600/acre or higher).

A crucial management issue that goes along with mechanical weed control is the need for getting the **job done on time.** If you do it with the right equipment, at the right time, it's easy. Otherwise, you may be in for a tough time, or a lot of healthy weeds!

Mulching for Weed Control and Organic Matter

Transcript of a presentation by:

Paul Arnold
Pleasant Valley Farm
Argyle, New York

We bought this land back in 1988 and put up the houses and the barns that you see. I started in my father's back yard for a couple of years just because I grew up in suburbia and I decided I wanted to farm and then went to play around in his back yard for a few years then bought this place in '88. Bought land and then put up the house and all the barns you see and planted the orchard and just got things up and running. I would do a little work in the wintertime and then farmed in the summer. Met my wife Sandy right after I bought the land, she knew she was going to marry a farmer and I wanted to make sure that she really liked farming before I married her. Since then we have had two kids, they are 10 and 7 and they help quite a bit on the farm. Kim and Robert. When we started out I had my father to help me and my step-mom and they helped me quite a bit. About three years ago my father passed on, but we have been able to keep the farm going because it was a threesome for a long time. It worked really well and that is how we got the buildings up and houses up and everything else kind of going on this farm.

What we do is raise about six acres of vegetables now, we probably have about ten acres that are available to us and so some are kept in cover crop and rotation. We sell at area farmers markets, four of them. So for us a typical week starting from May 1 to November is market on Monday afternoon so we are picking Monday morning, market in the afternoon. Tuesday to do field work, Wednesday is pick in the morning and market in the afternoon. Thursday is fieldwork, Friday is pick all day and Saturday is two markets. So that's kind of a typical week for us. We try not to work Sunday. Usually in the early spring we will be pushing to do everything. Like I say, to get things planted and get things cultivated at the same time. It gets kind of pushing in June and May.

We grow about 35 different crops, small amounts of each one, constant planting right through from early February so we have crops from May 1st on. Usually spinach and lettuce the first week in May, and rhubarb and asparagus. We grow a small amount of perennials. A lot of our mix of vegetables is to have a consistent amount through the whole year and that is how we kind of control our income is to always have something coming on because we all know it is a good year and bad year for something. With the just two days a week that we all have to do field work we have really had to be efficient at our cultivation and be efficient at trying to prevent weeds. This is why we got into mulching. In Washington County we are a dairy county primarily but right around me there are not really any dairy farms. To haul manure or bring in stuff like that was difficult in the early years so we looked to what we had and one thing we did have around us a lot was hay fields that were being unused. That became our source of building our soils. What we actually bought on this farm was a corn field. Probably continuous corn for 30 years. So we had a couple of years of cover

crops and we started right in after getting some equipment putting on hay mulch trying to build up organic matter because it was only a little over 2%. This is where we kind of started.

We have a slope here going down. From here to the house is north and so we are kind of on a northeast slope with good northwest protection of trees and this makes this ground very early. We have other fields and a 120 acre farm next door that we rent. We have plenty of hay fields and ability to rotate. On top of growing vegetables we have about an acre of fruit and one thing we set out to do to make sure is we always had fruit on the table so we had a lot of different small fruits and apples on top of that. Not too much of anything. We hardly grow an acre of anything.

One of my goals of getting into farming, and I was pretty naive when I got into it, was the fact that I did not know that farmers did not make a living at farming. I got told that quite a bit when I first got started and I told them this is what I am going to do and I am going to make a living at farming. I am going to make a living at farming because I wanted that lifestyle of staying home and raising food for my family and selling. Even though I was told by pretty much everybody and I hate to say the Extension Service that it wouldn't work but I don't think they have the models at that time like they have now to show that it does work. This is going on 15-16 years ago. So we set out to do it and so far with the goals that I have it has worked very well. We have been able to make a living at farming for 10 years. We have never worked outside the farm and have been able to reach our goals of making this a good income. With being able to be so diversified and having an unlimited water supply, a good irrigation system and good markets were we are we have been able to have a consistent income and not really have any of this roller coaster up and down. That has been good for us.

This is shot from across the valley because we are on the edge of the valley. The apple trees are grown where they are because there is quite a slope. We have made conscious decisions as to where to plant stuff and because we are up off the valley floor we really stay away from the frost. What we have for soils is up on top we have rocky silt looms and down below the lower fields are sometimes a little heavier clay. It makes rotation sometimes tough because you can't always put it where you should rotate but you put it in the best place you can. You don't want to put spring and fall crops in the lower areas.

Here is a shot from the house showing all the diversity we have – little bits of a lot of different things. We kind of break it up into knowing what crops are going to be there all year and what crops are going to be coming and going really quick like lettuce and some of the ones that are there all year like tomatoes and peppers.

This is going back toward the house. This is our main field where we started and as we grew we did more and more acreage. We kind of started right from the beginning trying to put down mulch and we tried different things. You can see right here we have zucchini and cucumbers and we tried sawdust from a horse farm and found that it really tied up nitrogen bad. After a year, when this broke down it made the best soil on the farm but meanwhile there was a lot of starvation for nitrogen. It held things down pretty well. There were a few escapees there but it made life a lot easier putting down mulch because there was just that much less area that I had to cultivate.

Just a little diversity of a lot of different crops that we are growing, lettuce. This is where we are putting down mulch and after the mulch is turned under from the year before trying to grow lettuce through the summer. Looking for high organic matter for these real high demand crops especially when it gets to be 90 degrees you are really happy it has a lot of organic matter down. When we were putting a lot of mulch down we were doing a lot of it for fertility. We have gone on to now without a lot of extra hands, like my father, around we have gone into doing compost because it is a lot faster. We are constantly evolving and if I come here another three years from now I might be doing something totally different again. I think that is one thing you always do is you are always evolving and changing and finding better ways and using the best use of your time and equipment that you have. Compost came around because we finally got a front-end loader and we just had to buy a manure spreader and also it became available around our area to get compost. Back when I first started we did not have a choice there wasn't anything else to get. There was no compost except for along long distance away. This is how we are holding our organic matter now.

Let's talk a little bit about cultivation that we use. Because we are really tight spacing just because something is older and not a new product – this still worked very well for the first few years on the farm. Somebody gave it to me and I put it to use and it did very well. It is like anything else, I talked about even with tractor cultivation, you can't buy one cultivator and expect it to do everything so this works well as long as you are using it in combinations with other things. If you just use this those few escapees are going to get by and you are just going to have a problem with one weed. A lot of these older tools work really well. This is a typical wheel hoe and it worked well for us for crops that are straight up and down and with walk paths and wider areas where you can really go along quite quickly. A lot of different attachments you can get down at the bottom here. Wider ones. You can also get kind of a duckbill one.

When we first got going a lot of our crops that we were cultivating were on 12 inch centers. We were just packing stuff in. We did not have a lot of land. We were land limited and we needed to get things in close, close spacing and so cultivation with these smaller tools were the most efficient thing. You do not need to start out with tractors right off the bat. Starting out with these smaller tools like that push hoe I showed you, the wheel hoe and that little push cultivator were very effective up until five years ago for us and were a real time savings. I think you get to a certain size and time when all of a sudden priorities change a little and you find you can change and add some new tools, some tractor mounted stuff when you finally can evolve to own tractors that will do the job that you want it to do. We do not have a picture of it but we depend mostly on your Farmall 200s or Super-Cs that are a little bit bigger than a cub or a little A that they sometimes show. We found that we can do two rows at once and also with the Super-C you can get real wide spacing. We are doing four rows underneath our Super-C on 14 inch centers. That is very efficient to be doing four rows underneath the tractor than to be doing three because of the amount of rows you can get done within a time. As we have evolved we are still using push hoes, we are still using some tractor cultivation for crops that are just there for a short time like beets, carrots, lettuce, spinach and crops like that. What happens is we start getting into using mulching. Where we use mulching is mostly the crops that are going to be there all year – tomatoes, peppers, cucumbers. Areas like that. A lot of it is grass mulching. We are cutting the grass out in the fields and bringing it in and laying it down. It is kind of a whole farm approach. If you just looked a the economics of just putting down the grass mulch and just left it at that you would probably say it is a losing venture but the fact is if you look at the whole farm approach and you are trying to increase organic matter, trying to make the most of your soil on top of single and double cropping on close spacing, having that organic matter and rotating that around your farm in these mulched areas you can build organic matter. We have gone from I think it was like 2.1% when we first got there and all these years we have never really given that main field you have been seeing up there a rest and we have been able to increase it to at least 4.5% now. Five years of mulching and a little bit of compost the last few years. Mulching – you have to be able to look at that and say it is a good whole farm approach not just a matter of what it is doing for you at that moment. So we are using grass mulch and we are also using straw mulch. We are buying in straw from a neighboring farm and this is something really important and I know people have gotten themselves into trouble is that we work with the farmer and we ask him to cut the straw before it goes into pollen. He does that for us and we are paying a little extra for it but the reason is there is no seed in it. If you are getting straw and if you are going to buy it for mulching and they have already combined it there is plenty of seed in it. There is a lot they can only get out so much. You can get yourself a real weed problem. With using the straw mulching it is really important to either raise it yourself and cut it at the right time or hire somebody or get some farmer near by to do it for you.

We mulch asparagus, that's how we keep the weeds out of that. Its funny with asparagus you think that it's a high value crop and its not. It barely breaks, what we call a $10,000 an acre rule, something has to make at least $10,000 an acre although of course you know we barely grow an acre of anything. But the asparagus just barely makes it over that. It seems like a really high value crop, but its just a nice thing to have in May and June.

We mulch raspberries and blueberries. I don't have a picture of the blueberries but we mulch them both with wood chips. There are a lot of businesses that go along and they are chopping where the power lines are going through so we get all of our wood chips for free. And also if we have any shavings left over from the chickens they go on there. But we will go ahead and

cover this up with something that is going to stay there a long time. We do this once every few years just put down a lot of chips on this instead of putting hay down every year. These are the fall ones that we are going to turn under and we've got the drip irrigation on them. And to make them come in a little earlier we put the row covers over the top of them. And so we can get Heritage raspberries coming in, in August.

Some of the crops we are going to put out when we go out there are Swiss chard. We are using soil block lots of times on the bigger seeded stuff like this. Stuff like lettuce is usually going in as seedlings and these grow really well on that. This is Swiss chard again and parsley. This might have been that same year where we saw it when it was a little bigger. But that is what it looks like after finishing planting it in and then we just have to harvest. Everything is clean after that you don't have to whack any of the dirt off of the parsley or weed it. You just go out there and grab a clump without getting weeds with it. There is it when it gets bigger. It is easy to take care of that way. And you see there's some smaller cucumbers that are coming on and the late tomatoes coming on there. And the next year I might move this whole batch right to here and then do something with more mulch. I'll just keep working it down the field to constantly be doing more.

Also I like to mulch the garlic in the fall and then in the spring we add a lot more so that we don't have to weed it. So that we just go in planting it, mulching it, in the spring adding a little more mulch and then just harvesting it. I really don't really have to do anything else with it. Again, it is another crop we just keep moving around and then in July when it's all out of there we'll be turning that under and probably putting in a fall crop. That's going to be tremendous ground after a week or two of it breaking down. Any crop that you put in there is going to grow the best. We are planting late kale.

Brussels sprouts are going to sit there all year long. We are going to harvest them sometime in October or November. Those are my lower fields right there and, again, once I put down the mulch and I plant it, then I don't have to go back in again. It's all set. And it just kind of breaks down as you go along and it actually feeds a little bit of nitrogen down there and the soil is so much better for the next year for anything else you want to grow like beets that are heavy feeders.

Q: What kind of transplanter are you using?

A: I don't use a transplanter, I'm doing it all by hand.

Q: How do you make the holes?

A: What we have for prepping the soil is a five-foot rototiller on the back of the tractor. And I'm going along making the soil soft and I know where my rows are going to be so if I'm using that self unloading wagon I'm very careful not to go where I'm going to plant. I make one wheel track down the row where it's going to go and keep one out. Then I'll just wad it kind of in the middle and then from there just throw it to either side so it doesn't take but half a day or so to cover all that ground. So if the ground is really soft then I can easily just put my fingers right into it and make the hole.

Peppers sit there all year. Another great crop to put in. This is something that you have to watch for. I'm not going to just show you all of the best things that happen to us, I'm going to show you some of the worst so we can all learn here. When you have plastic over the top of straw or you put a row cover over top of the straw this stuff is shiny and when the sun gets on it, it really heats up. It can produce a tremendous amount of heat. Probably if I put a row cover over this and didn't have this it would be the same effect. It would burn all the plants right up. And if you put your hand in there you would probably burn your hand. It gets so hot. You can't just go out and put straw down, plant your zucchinis and your cucumbers through and throw a row cover over it. If the sun gets on it, it's going to burn everything up, underneath it. There is something with the shininess, it doesn't do it with the hay mulch but it will do it with the straw mulch. After we started noticing what was going on here, and it took us a little while to figure out what was going on, we thought we had a problem underneath, but it worked out and these are the peppers by late August. They filled in quite nicely. Again, we've got clean peppers, we just have to pick them, we don't have to wash them hardly. It's kind of nice, there are no weeds in there, nothing. Again you just send somebody out to pick all season long.

Here we are, I think this is annual bed strawberries going in. I believe, or it's the matted row system but we are covering up here. This has already been done before and we are adding more as we go. We've got full irrigation so that kind of helps. That kind of gives you what it looks like after throwing all of the mulch down.

Here we are planting winter squash, the rows. All I am doing is putting down a string and somebody is dropping a plant every 18 inches or so. Pretty simple, and as I said you end up with nice clean winter squash when you are done.

Some of the time what we have is these field houses that we do, you can see that I am putting it up in the fall. We've thrown down the mulch on it and I can have it ready for the next year for the peppers. We'll put this up and it will make sure that the ground stays unfrozen and we can start other things in here too or plant anything else I've thought about planting, tomatoes or something, early and again it's no weeding. The ground stays warmer. There it is all finished. We move these around the field also.

Putting down straw mulch or it's all hay mulch I believe here and were putting down the stakes for tomatoes. Another nice crop to mulch, we don't have to have any diseases that splash up onto the leaves, like early blight. That's another good thing to not have to worry about. Much more even with the irrigation. In other words it doesn't dry out and get wet and dry out and get wet. So you don't have a lot of cracking when you have some rain.

Q: So do you drip irrigate that?

A: No, we do overhead irrigation because right next to it could be lettuce growing right here and I can't stop the water from splashing onto the tomatoes. But that is why we don't have to worry so much about having diseases splash up because of the mulch being on top. It kind of eliminates that.

Q: Doesn't the mulch keep the ground too cool and slow the plants down?

A: Not during the summer. Most plants like it warm on top and they like their feet cool. So if their feet get hot they do not like that too much. The bad part of what you are running into with the straw, especially if you are talking about cucumbers and other things like that, is the fact that if there is a light frost out there, this will not allow that heat from the ground in the fall to keep your plants from frosting so much. These will frost earlier. So you have to be much more diligent with getting row covers on. Realize that if you've got mulch out there you are going to lose the plant faster. Because it doesn't allow that heat from the ground to come up and maybe save your plants when you are getting really close to 32.

We came across something really interesting this spring, we ended up in our area being one of the very few that had strawberries because of that late May frost. We went out and we were doing the annual bed strawberries and we were doing row covers on them, we were doing triple row covers on them. They started flowering the first week in April and flowered right through until the end of May. We went out one evening around 8:00 or so and it was 41 degrees on our thermometer and we have a digital one so it is pretty accurate and it was 41 and the row covers were starting to freeze together. So most farmers probably did not go out and do any row covering or frost irrigation that night till it got much lower but the damage was already long done if you waited much longer than we did. It was already starting to freeze so it is really interesting that when you are talking about mulch or having something high up in the air like that when you get that radiational cooling it's occurring much earlier than when you think. You can't wait for it to be 36 or 35 and start up that irrigation. Depending on the sky.

So they get a little bigger. We have found that now on our ground we cannot plant tomatoes up on these fields were we have been doing this mulch for years because now the ground is so rich that we have tomatoes that come up over the top and then come all of the way down. These are all indeterminate types and the ground has gotten too rich for that because we are doing all of this mulching. We have to put it on some really poor ground. So this has really helped the soil, but it has also changed a few things that we have done.

This is strawberries, this is the matted row system. We don't do matted row anymore but if people are still doing it I'll show you what we did with that. When we

plant the strawberries, we will put down the mulch first or put it down afterward because you can kind of drop it on between the plants. We'll put mulch down after planting the plants and then we don't have to weed this thing the whole rest of the season. The main question people usually ask is "Well, how do the runners get set down in the mulch? It seems like they are far off of the ground." Never had a problem. It is always too many runners that set and if a few don't then fine but this makes matters a whole lot easier than having to weed that whole year. And then in about the first week in November we just go ahead and go in and rototill the rows right down and get it down to where it is the width that you want. We'll have straw put on for the strawberries and then pull the straw off of the walk paths and then put the row cover on to finish it off until they are blooming. So we are adding more organic matter. This is another thing that even though we had matted row we moved it every year. It kind of confused the insects, we did not build up the insect population but we were also using it, again, as the whole farm approach. We knew this was a reason to keep adding more organic matter to our soil. Adding all this nice straw. And then they would look like this when they got up and going. Moving them every year we really didn't come up with any weeds. And putting down a lot of the straw kept everything clean and again we didn't have problems with dirty fruit or with weeds. So they came out kind of nice. We got away from this system because of the gray mold problem and because they took up space on the farm all year long and didn't really pay us back anything. When you are a small farm and you are trying to make use of all your space that seemed like kind of a waste to me. When you have one spot that is costing you money and not giving you back anything. So we went to the annual bed system. So we are preparing ground now in the fall, around the first week in September.

And this is that tractor again and you can just barely see it. I'm sorry for that. Its got two disks here and it is basically like hilling potatoes. I'm building a hill right here and that's where I'm going to plant the strawberries. It's making two hills at a time. Then we are going along and again it is the first week of September and the grass seeds are not out of the grass. They usually fall down during the season and some hold on a little later so the first week of September it is not clean out there. I can't just go out and get grass mulch and put it down the first week. I'm putting down straw mulch, just shaking it out. You can see the hills that I have made and this is where I am going to plant the annual strawberries through. I'm going to cover the whole area, someone is laying them out and I'm going through and just planting them as we are going along. So on each side of that hill we've got annual bed strawberries going in. We just plant about 3,000 plants there. Got some free help there. After planting them we put the row covers on them for the fall. They look like that come May first. They are flowering pretty good. Again no weeds, clean fruit, with the annual bed system they are all gone by the first of July. But again we turn this under and made a lot better soil. There is also no gray mold with this system. I've never encountered any gray mold and that makes it a lot easier. They also pick about three times faster because you can see them better.

It's a nice system. Everything is kind of open. There is not one touching another one. They all have got a ring of strawberries around each one. So the picking goes fast.

I also went ahead and we've got a lot of flowers around the house and I am mulching that so that we can enjoy the flowers without having to weed them.

Some of the benefits are that we had some investment in buying the equipment, but when we first started out from one year to the next the only thing that we did different was to put mulch down in the fall, turned it under in the spring and then started planting our crops through it. That first few years, when we started farming because the soil did so much better, we found we jumped $10,000 just the first year in gross income. So that more than paid for all of the equipment that we to buy and the time spent putting it on. So there was immediate payback on healthier crops. It really does so much better. It feeds the soil incredibly and some organisms that are there. It brings more of a balance to the soil and everything that happens with it. What also happened was, because this was a cornfield for years and years. I think that it was continuous corn for 30 years. The dairy farmer had a program of so many ton of 15-15-15 every year and never took soil tests. We had an enormous amount of potassium and phosphorus. We found that every year when we were building up that soil and getting more soil organisms in there and a lot more freeing up of a lot of the nutrients that are there, that our soil tests started going up and up and up tremendously. We're kind of off the charts for phosphorus and potassium because of what he put on more than 17 years ago. We have yet to use it up, prob-

ably it is going to be there a whole lifetime and we will never have to put down phosphorous or potassium.

As I said we are going into more compost now with soil management. Even then as we are using it I'm thinking about going back to more grass mulch because right now if I can control and hold my organic matter at 4-5% or where some of them are a little closer to 6% we can maybe go back to a little more grass mulching and do more with rotation of that rather than buying in compost, where you can bring in weed seeds, you can have problems with phosphorus levels. We are already in trouble with our phosphorus levels. Just one less thing that we have to do.

We don't use black plastic on our farm because we didn't want to deal with getting rid of it. There are some things like melons that do much better with black plastic. We choose still not to use it, we still put our melons down on the mulch. Our melons are the last melons to come in for the year. The rest of the farmers, they get them all early in late July and August. Ours come in September and that is fine with us because they are all out of them. It really isn't a big problem for us.

We don't do this winter time or fall. We don't throw mulch down on the fields anymore. We don't have the help and the time. But when you are first getting going that really helps the organic matter really quickly and helps your plant health. Now we can go though spinach and lettuce and grow it right through the summer because of our organic levels and the amount of nutrients it released.

Questions and answers

Any questions?

Q: How do you control the pH? Do you check that?

A: pH was 6.4 when we started and it is still 6.4. It has never changed in 16 years. Not at all.

Q: Are you harvesting the mulch when fresh?

A: Oh! As in green, yes. You are going out and you are chopping it, that is what this flail chopper is doing it is cutting standing grass. Whether it's the straw or grass and it will be green. You definitely don't want to go out there in the early morning when there is a lot of dew on there because it will just plug up the machine.

Q: Do you cut it and let it dry before you put it down?

A: No, not with the grass especially. If it's heavy in clover, maybe heavy in alfalfa I do go out and do some with alfalfa. That is not so bad when it gets a little older but if you try to do it there is so much nitrogen in there and there is so much water to it that it kind of turns sort of slimy and melts away real fast. It's gone within a month.

Q: Do you add any nutrients to your hay mulch fields?

A: This is always the thing with organic farmers; we are kind of robbing Peter to pay Paul. Whether or not I'm hauling in compost or doing the hay mulch is that we are always taking from something else and putting it on our most valuable fields. Right now we have gotten into, just this past year; we are going to start fertilizing the fields. We have taken soil tests and we are bringing in organic fertilizers and spreading it on to build the soils back up. We could see a definite drop over these years in the production of these fields because we don't have the ability to bring in manure and spread it on the fields. So we are going just the fertilizer route at this point. Just putting on a 5-3-4 on it. Our lowest amount is phosphorus and potassium on these fields. In the early years the important thing was to get the vegetables paying, start paying ourselves, and now that we have got some extra money, we are starting to go back to the hay fields and giving them their due. You have to maintain them or else they go downhill real quick over the years.

Q: Do you get 100% weed suppression with the mulch?

A: I wouldn't say that you are going to get like you have alluded to. You are never going to get a 100% weed suppression with it. For us it is probably 90%. So the little 10% for us that comes through, because it is either breaking down really fast or there is a spot that someone let a transplant go through, a weed came up through because there was exposed light. But it is so minuscule the fact that when you are going down

and harvesting something, you can just pull the weed as you go along as long as it hasn't gone to seed you can just kind of drop it. But for the most part 90% weed reduction is it. Basically with our weed population, I think you heard me say we don't allow weeds to go to seed. If I grow carrots, lets say, and I seed them and a week later I start to see them coming up through. Two weeks later you might see in a row 150 feet long or a bed of four 150 feet long you might be able to count 10 weeds in that area. What you mainly see, and I'll say any other type of weed but you will mainly see for use is purslane because that is what is left is weeds like that, those three weeds galinsoga, purslane and chickweed. If you don't have them, be diligent that if you see one to get rid of it on your farm or just make sure you are not buying it in. We started getting a little galinsoga and chickweed because we brought in somebody's compost and it was in the potting soil mix. Wherever we planted it that one year we've got little bits of it. We keep a bucket hanging around, so that when we see those two weeds, it doesn't matter what you are doing, you drop it, go get the bucket and you get rid of that one weed and put it in the bucket and then we just take it off of the farm. So we are trying to control the two weeds. Of course trying to control purslane is bad enough. It comes up and within a week or two or three weeks it can start to set seed. If it is big enough no matter how hot it is, if you go along with your push hoe and cut it off it will live long enough to produce seed and it does not need to go to flower. That's how we killed ourselves with the fact that, that one weed does not have to go to flower. It can produce, within its bud, viable seed. Only when it feels kind of comfortable and hanging out during the heat of the summer, will you see a yellow flower on it. But for the most part it will never flower and it produces it. We thought in the fall one year when we had a bunch of it, Oh, we are OK because it is not going to go to seed; and then we realized way too late that it doesn't need to flower. The adaptation of this weed is so tremendous.

Q: Do you have any problems with molds or insects under the mulch?

A: No. The only thing it can do when you say insects. What we had the first few years, because we had quite an imbalance on the farm of not having organic matter and then all of a sudden having a lot of organic matter free flowing around the place, is that you can start to have a problem with slugs. Because there is a lot of moisture, a lot of nice stuff that they can chew on, a nice habitat. It took a year or two after we really started with that, to start to get some control of the slugs. One was we used some ducks because if you put out grain and put out slugs, a dish of each, they will go for the slugs first. They love them. The other thing that happens is that there is a little black beetle. He is about 1/4 to 1/2 of an inch and you see him scurrying around your farm. That is a lot of their main diet. To eat slug eggs. So all of a sudden with one predator, and it wasn't like we were trying to go out and kill these slugs because there is nothing you can do about them if they are there, is that these black beetles became abundant. They just went along and brought the balance back in, but we suffered for a year or two of having quite a few slugs. Now nothing is really out of kilter at all with what we are doing.

With molds and stuff like that I don't think it makes any difference. When you are stepping and walking through it you are not seeing this puff of mold. I want to make sure that is said. Very little bit is mold. It is either in the breakdown period right close to the surface, or it is dry on the very top.

Q: How are you doing your direct seeded crops?

A: Well we are not using any mulch, of course, because that crop goes in and out. For us we are using an Earth-Way precision seeder, the plastic one. We have used the Planet Jr. and we have used the other type and they both have their strengths and weaknesses. When you are doing a lot of different things, a lot of crops that day, and you are putting four types of carrots and three types of beets and stuff like that, you will find that the Planet Jr. can get pretty cumbersome. With changing plates and changing shoes we found with the Earth Way, even though, it seems like such a crude piece of machinery it's so much faster. You can cut your seeding time down from 3 to 4 hours with a Planet Jr. down to 45 minutes with an Earth Way. So it really makes a difference. Just having to buy in some fertilizers, when you are thinking about how you are going to get your farm up and going and trying to keep your farm together, using just what you have on your farm for your own fertility. When you have hay available, and you can use it then you know you are not importing a lot of stuff that may hurt you eventually with weeds. Some day somebody is going to say something about compost, that it's got something in it. Using your own mulch and hay can really keep you out

of that one problem in your area. The longer you are in business the more these little things pop up.

Q: Have you ever tried using sawdust as a mulch?

A: We only used the sawdust mulch once. That was going to be it because it just took too long for it to break down in a situation where you are changing crops rapidly. In the end it really made nice soil. In the interim, within a year period, you couldn't grow anything in it because it was just too much nitrogen uptake by it. You can get by using a little soybean meal as a nitrogen source. That has 7% nitrogen. That works very nice if you need to put a little bit of nitrogen around the Swiss chard after it has been there a long time to add a little nitrogen. Or if you are turning under this mulch and you are going to plant. For us we would turn under mulch in the spring in the early years and then transplant lettuce right into it. It was a lot of gobs of mulch that hadn't broken down completely during the winter. By throwing down a little bit of soybean meal on it makes it so that there isn't that starvation of nitrogen for the lettuce plants while the mulch is breaking down the rest of the way.

I found the list here of what we do, about 15 crops that we mulch. Rhubarb, asparagus, Swiss chard, garlic, winter squash, cukes, melons, eggplant, tomatoes, Brussels sprouts, raspberries, blueberries, parsley, peppers and strawberries. We also mulch our basil that we keep all year long. It's much cleaner. That's the crops we are working with when we mulch.

Q: How deep are you tilling with your roto-tiller?

A: We are probably going down a good six inches with it. We do it in the spring or sometime during the year we try to get around with our neighbor's big 4-wheel drive tractor. We put chisel plows on it and if we have got ground that is open or in the early spring we will hit it with chisels to make sure that we don't end up with plow pans. You know the kind that you get with rototillers or really with a lot of different tillage you can end up with that. That's about the depth. Very few times we will use it just to go along the surface. But for us, we don't do any stale seed bedding because most of our weeds are very much under control and I guess it's an organizational factor. We always seem to be running behind so you are going out there and just tilling the soil and planting right off the bat. There's a few people out there that are more organized that can stale seedbed and get things ahead.

We may try a little bit of flaming this year. It was interesting just talking about the mulch and using flaming. Because we were thinking about the few escapees that get into asparagus and that is a big thing is the perennial type weeds. The fall annuals and perennials that will get in there. It seems they have a long taproot that can get down and below where other ones can't. We were just kicking that around. Maybe it will be a fire hazard.

Q: Can you talk a little bit about your crop analysis. How you set what is making you money and what's not.

A: For us, we keep just two kinds of records. We keep records to know how much we are making on a per acre basis on each crop so that we can judge whether or not we need to do something with that crop. Do we need to put it closer or not grow it or charge more or something else. We need to know if it is making us money because if we are trying to make enough money on six acres of land than as I have said you have to produce $10,000 to $20,000 an acre to really make any money with this. So we are doing our $10,000 an acre rule which probably should be at least $15,000 at this point. The records we are keeping tell how much space things are taking up. So if I'm putting in four rows of carrots every week for so many weeks I will know how much square footage that is taking up. We will add up the square footage and because we are keeping records on our yield, every time when we are getting ready for market things are getting weighed I can tell you how many pounds of carrots we produce in a year. Then from there we know how much we sell the pound for and we can figure out about how much carrots are making us on a per acre basis. Or how much they have made us on a square foot. Whatever way you want to figure it out it is called extrapolation. So we are keeping that record. That takes two records, yield records and how much space things are taking up. Then we keep records on how long it is taking us to harvest something and how long did it take us to harvest 400 pounds of carrots. We don't do that every day or every other day. It might take four crops or five crops that season and do a good analysis of those over several weeks. When it's good or when it's worse depending on how things are coming out of the ground. So you get a good average. We keep an average of that and that's how we make decisions on whether or not

we need to invest in a certain piece of equipment that will make harvesting faster or better. That also gives us an idea of how much these crops are worth and helps us all in pricing. Between how much it is costing us to harvest and how much it is worth to have that crop sit on that land are the only two things that we keep track of. We have no idea how much it costs us to raise a carrot. There doesn't seem to be any reason to know. As you know when you are doing 35 crops that would be an enormous record keeping. To know I push hoed down a row of carrots and then went on to do the beets and then went on … It's just too much record keeping. That's basically how we are making decisions on the farm as to what our pricing is going to be and what equipment we are going to buy and how to make things more efficient for our employees or what we are doing or how we are selling a crop. Whether we decide to drop a crop. So the last thing you want to do is drop crops because then you ruin your diversity. If lettuce does terrible next year it really won't show up on the radar screen. Something else will probably be doing terrific. So keeping a lot of crops out there makes the big difference.

Doing things that control your overhead is also important. Irrigation for us, we decided to go electric. Electric pumps, and valves. So we can irrigate at the drop of a hat. It takes ten minutes to irrigate. I just go in, throw some valves and throw on a switch and I'm irrigating. Irrigating for me cost $0.48 an hour. So I can irrigate all night for ten hours for $4.80. That's a lot less for most people than what it costs to run a tractor for an hour. So I have a tendency to irrigate more and when the crops really need it because it is easy to irrigate and also it doesn't cost me much. So if I want to do some frost irrigation on some raspberries, I only have to sell two half-pints of raspberries to pay for the whole night's irrigation in October. That's the record keeping that we keep. So we know whether or not what we are doing is worth while.

Q: Are you doing any cover cropping?

A: What we are doing now for cover cropping is doing winter rye. We are re-seeding a lot of these crops; you saw how much stuff we have at the end of the season. So crops are growing all the way to the end. And with that, winter rye is something that we get on and that's about the only cover crop that we work a lot with. For the most part we do very little of anything else. What was very interesting last year in our meeting, you are going to hear a lot more about NEON over the years, North East Organic Network. We participated in that and it was interesting talking because we had a room full of sizes of growers. Some small, some big and what was interesting, we were all accomplished farmers, been in it for a long time and the small growers that were down in my scale, ten acres or less, were very intensive. A lot of them, cover crops, some of them didn't use any. Some of us were just in the winter rye mode because we were just using every bit of land intensively all of the time. So we are always having these guilt feelings that we should be using a lot more cover crops. We never seem to have time to put them in or the land that you can kind of put stuff on. What we came to realize is that the guys who were bigger, cover cropping was everything for them. They couldn't afford to buy compost or work things as intensively to make that soil rich. The were working more on the fact of half their land was in cover crops building organic matter to turn under for crops to come because that was the way they had to deal with it. So they were using cover crops more judiciously. Lots of different kinds, different spots they were sticking them in. So it basically took off the guilt feelings of us small farmers. The fact that none of us were doing it. I think its something not to get too worried about, cover cropping when you are really small because you are using that land really intensively. I am getting into this mulching and adding organic matter. That's what you are really trying to do—you are trying to protect the soil from erosion, trying to keep your nutrients there and trying to improve your soil while you are using it. I think mulching kind of covers that area for me. I don't have to feel quite so guilty about not having all of this nice perfect cover cropping that everyone really focuses on.

Q: Do you think mulching would work on a larger scale?

A: I think for a lot of crops anything is possible at whatever scale you want to have it at. It just depends on if you have a lot of soil that doesn't have a lot of organic matter and it is performing poorly you find ways to try and build that soil up and if you really build it with cover crops you are going to be in it for long term. If you are looking to get it into production next year then trying to find some straw mulch that's good and trying to add organic matter, it's going to make you money. For us all of a sudden jumping $10,000 from one year to the next was quite a jump.

On a larger scale you are just looking at that much more. There is the cost there but that mulch is there and the benefits are there for a few years. It isn't like the cost is all gone after one year. I think it can really make a difference.

Q: Is it ever a problem for the mulch to get moldy?

A: It's okay if it does get a little moldy. If you're putting grass mulch over the top of strawberries, some people will think, "Well, I've got grass mulch I'll throw it on top of strawberries for the winter." It's going to mat down, turn slimy and get moldy, that's the worse for it. But just covering the ground, getting a little moldy is okay. It's not really something that is going to hurt your crop at all.

Q: Are you talking about lawn clippings?

A: I'm talking about hay fields. This is something else you need to learn. If you are going to go out and do that. When does it have seed and when does it not? What we are doing is that we are cutting hay out in the fields right up to the point of the fact that it is going to pollen. Different varieties go to pollen at different times. Like this past year we had this farm nearby, we seeded it to reed canary grass which gets a lot more bulk matter out there and goes to seed much later. I got a bigger window of opportunity of getting it. You are looking for, obviously, the most mass out there. You are looking for hay fields that when you are going across them you are getting what you want out of it. Not, like you say with grass clippings where it's going to take you a long time. Because we're talking, I'd probably do more like a third of an acre or a half an acre of mulching. If you are putting all of the pieces together and added it up. With that movement around on the six acres, it is every few years that we are really getting a lot of mulch down on an area. We are using it in other ways too, just getting it down. What I've noticed for years, is after dealing with the grass mulch is that the soil is actually a lot more alive and a lot more activity than when you are just putting down compost. Compost is something that's already finished. The mulch needs to break down. That causes a lot of biological activity within the soil. It makes your soil much more alive at that point. This is kind of anecdotal, I realize, but it seemed like the plants grew much better that way as opposed to just putting down compost. Any mulch you are going to hold or add will also not bring down as much phosphorus or potassium as the compost and you will not have a problem with that. You are also looking at the other benefits of mulching. The fact that it is basically sheet composting because you are building your worm population. You are basically feeding your worms. By putting down all this mulch you are feeding your worms. Obviously that's going to make more biological activity and you are going to end up with a better soil.

It's also the weed management. If I'm planting a long term crop that's going to be there. Like tomatoes and cucumbers and zucchini and stuff. I'm not going to have to weed that the rest of the season. We are putting it down between six and seven inches sometimes more than that. Because as your soil gets more biologically active, we find that lots of times we can't even make it to the end of the season even at six or seven inches thick. Because there are more worms, more bacteria it's breaking down at a faster rate. Also it depends on what mulch you're using. If you are using alfalfa or clovers, it looks great but it can burn up fast. There is not a lot of substance to it like a thick stemmed grass would be. Like we use canary grass. That will stay around longer. Straw will stay around longer. You will have less problems at the end of the season with spots coming through and having some weeds.

You are obviously controlling the water that is there. Some of the downsides are, if it's really wet it will stay really wet in the spring. Sometimes it doesn't help with trying to get it broken down or trying to get it turned under at times. It stays sometimes too wet for the crops.

All right, As I have said we sell at the farmers' market. You can see all the different array of things that we are doing a lot of different crops, a lot of different opportunities to put mulch down. This is the last day in November. This is all the different crops that we have that we are selling in the week before Thanksgiving. We are zone four. We are not exactly the warmest spot but we have learned season extension on top of this. This is one of our best days because this is the Saturday before Thanksgiving. That is the biggest sale day of the year, the last day for us. Pretty amazing.

So there's compost. I'm getting it down. We bought the manure spreader. This one place, H & D, that we

got this from. They actually make spreaders that have different types of beaters on the back. One is made for compost, spreading it more evenly. So that is why we went with this style. We had to get a new one because if you bought old ones they are usually just death worn out by the time somebody traded it in. Cultivators. Wheel hoe. There I am push hoeing. This is the technique of going up and down these rows at a real close spacing. This is where we went to some use of the tractor, using the basket weeders that they were showing. I can go up and down this and this will take me probably 25 minutes or more to go up and down these rows and if I did it with the tractor it would take somewhere in the neighborhood of about four minutes to go up and down twice. Like we showed, going up one side and then going to the other.

This tractor is what we use for a lot of cultivation. It's got the mid-mount and we've got these regular cultivators on the front, on the mid. After these potatoes go in. This is a potato planter. On the back I'll carry a Leily tine weeder. That will be the first thing I go over it with after the potatoes are planted is the Leily tine weeder. I'll go over that at least twice. On the second time I might be cultivating at the same time I'm using the Leily tine weeder. That works. Then for finishing, I'm just using the cultivators. So I can put hillers on the front of these. We can do a lot of cultivation that way.

This is our equipment that is used for getting straw or hay off the fields. This is called a flail chopper. It was used by the dairy industry for a number of years and then, like anything else, they kind of moved on. So these things are a dime a dozen. I think we paid $400 for it. I don't know how many years ago, twelve, thirteen, fourteen years ago and I've probably only put $100 into it. It's basically, for every foot width this is it takes nine horsepower. So ours is six-foot so it takes fifty-four horsepower. This thing puts out fifty-three so when this is trying to take on too much it's slowing the tractor down and I know I'm not going to hurt this thing by putting an 80 horse power tractor on it and just kind of ram-rodding through. This is a real good stand of rye that we are putting in and that will really fill the wagon quickly.

This is how we did it in the early years, with just a wagon like that. This is how we built organic matter up really quickly in the first few years. So we could grow spinach or lettuce because we couldn't grow it even. It wouldn't produce on the soil with the organic matter that was there. In the fall we would just go along and just cover the whole ground. No cover cropping just put down on the ground. This was just adding tremendous amounts of organic matter and in the spring we would turn it under.

There we are going down. We are actually putting it in between a field house we are going to put up. This was quite a few years ago but now we've got a self-unloading wagon. I'm covering for winter squash, that is what I'm doing. I'm making an area for winter squash to go down so I don't have to weed it and it just makes for clean fruit and everything else that comes along with it. I'm just kind of going along, blobbing it out, very quick and then somebody is going along and just spreading them the last little bit. This is where we are putting in some late tomatoes here in this area. Putting it right next to Swiss chard and parsley. This was put in real early. This was put in the beginning of May. There is obviously no hay out there to get.

This is where we use some straw. There are times when I cannot get out there and get hay, like in the middle of summer if I need it. Or in the very early spring there isn't anything out there to chop. This is where we keep straw in the barn in bales that we have bought and we will put it down and then plant through it. You don't want to go ahead and plant this and then try to put the straw. It just doesn't work. You've got to put the straw down first and then plant right through it. This works very well. Now I don't have to weed this the rest of the year. It's much easier on the plants. It's cooler. All plants like to be warm on top with cool roots. The next year I'm going to have better ground than when I started. This is what the whole farm plan is. The fact of just trying to improve the ground along with doing some intensive planting along the way.

This is buying straw from somebody. Bringing it up. One thing we did try one year just to see if it would work is a bedding chopper that you can get from a dairy farm. They do it in the barn and it is for chopping their bedding. You throw a bale right down in there and it spreads it out. It nicely chops it down, because sometimes working with long pieces of straw is a little difficult. We just had somebody driving along with the tractor and bales of straw sitting on top and went ahead with somebody just throwing it out. By the time we got it all done it looked pretty good and we were able to plant through it. We've never tried

that again. This was a borrowed piece of equipment just to see if it worked. I think these things are quite a few thousand dollars. So we haven't gotten into the practice of doing it all the time. But it just gives you ideas if you had that thought, gee this is one way to get the bales out there and chopped up nice. It did put it out nice and even.

Q: Did the chopped straw control weeds better than the regular straw?

A: Didn't make any difference. They both control weeds it was just the fact that planting through it was a lot easier.

Q: Why wouldn't you use the chopped straw all the time?

A: It would be the cost of the machine and the time. I can't say I figured out how long it would have taken me to put it down by hand. You know just break the bales out and spread it as opposed to doing this. I really didn't make a cost comparison with that. I knew the machine was more than we really wanted to spend for that little bit that we do with it.

Q: What kind of transplanter did you use to plant through that.

A: We do all of our plantings by hand. We don't have any transplanter. Whether it's on bare ground or through that. We are just lining stuff out and putting it through. We don't own a transplanter. I'm basically the person who transplants.

This is a little section. We are on a steep slope and we basically wanted anything that was already on this steeper slope to be mulched or in grass. So that is why you see that the orchard is here. We started out, from somebody's garden they gave us rhubarb. So we started splitting it and splitting it and splitting it and after a few years we ended up with 72 rhubarb plants on a three by three grid here. So every spring or late fall we go in and put straw on it, mulch it. In 14 years that we have had it we have never weeded it once or done anything other than put straw on it, put row cover on it. We put row cover on it the first of April. Whenever the snow is gone, take it off first of May when we want it to start selling. This was just taken off you can see the dandelions are just flowering. So this is around the first of May and this is what it looks like. As you know I'm from zone four. So it's pretty rich ground there with having straw for all those years and with the row covers you can have full size rhubarb right off the bat. And again we just go in, we are harvesting it and when we are done harvesting it at the end of May it's done. We walk away. There is no weeding to be done. There's nothing. So it makes it kind of nice with rhubarb. When you say, "well when you mulch is it really worth it to do it?" You are sometimes picking crops that you can make a lot of money on. This little rhubarb patch is on 0.0186 of an acre. When you bring it right down to what it is. We sold about 774 lbs., this is back in 1999, with a total value of, I'm trying to think if we sold it for $1.50 a pound or whatever. If somebody has got a quick calculator. $1,161.00 came out of this little patch. If you work that out to what it is worth on an acre basis, because this is where a lot of our crops if they are worth doing, a lot of this mulch bed is extrapolating out, that if we had an acre's worth than this is how much it is worth. This is what we base all of our crops on is the fact that we know the yield because we are keeping records and we are also keeping track of how much we are planting all the time so that we can add up at the end of the year about how much square footage everything took. Then we know the yield and we know how much we sold it for. So you can kind of extrapolate out using that system. Some people do it on square footage. We just happen to do it on acreage basis because in the world of dairy farms and everybody else, they are doing it on a per acre basis. But this little thing is worth $62,000 an acre. This little rhubarb patch. If we are doing not too much work with it and we can spread that a few bales of straw on it. Ten or 15 bales of straw on it really thickly is well worth the money spent on it. That's where a lot of our crops are well over the $10,000 or $20,000 an acre and with that you can start to make a living at this. But this is how we keep the overhead down and be able to bring some money home. After finding this out it is well worth putting down a few bales of straw on it.

Bio-Extensive Approach to Market Gardening

Anne and Eric Nordell
Beech Grove Farm
Beech Grove, Pennsylvania

Part One: A Strategy for Weed-Free Onions

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Onions can be a real challenge in terms of weed control because of their slow growth and sparse canopy. Given that our original goals for the farm included remaining debt free, keeping the market garden a two-person-operation, and relying on the internal resources of the farm as much as possible, we needed a way-to reduce weed pressure in onions that relied more on management than off-farm inputs and that carefully distributed our labor over the course of the growing season. We also decided to lean heavily on the most available resource close at hand, namely the land.

It took us five years to develop the following system, which has kept in-the-row hand weeding of onions well below 15 hours an acre, regardless of the weather. The rewards for taking time to develop this system were twofold: we could now afford to grow staple, storage items, such as onions, carrots and potatoes; and we could devote more time during the busiest months in the market garden to high value perishables and specialty items for restaurant sales and farmers market.

We begin weed control for onions a full year in advance of planting. This "fallow year" usually includes two winter cover crops sandwiching a bare fallow midsummer. We have tailored this cover crop/fallow sequence to take advantage of the growing-conditions on our farm and the life cycle of the weeds we needed to control.

The cover crop/fallow sequence leads off with rye established after the previous cash crop in the rotation. If circumstances prevent us from planting rye in the fall, then we plant oats the following spring. We manage these small grain covers by clipping them repeatedly before they shoot to head. Mowing them at this time encourages them to tiller and regrow, creating the mulch effect you see in figure 1. This shot captures the second clipping of rye at the end of May 1992. Cut-and come-again cover crop management prevents spring weeds, such as the mustard family, from setting seed and makes incorporation of the cover crop easier a than letting the rye grow to its full height of four to-five feet.

We plow the first cover crop down after it has put on the bulk of its biomass but before summer weeds have had a chance to set seed. For rye, in our climate, that means after the third clipping at the end of June; for oats, after the second clipping in mid-July. Incorporating these carbonaceous residues during the biologically active summer months gives them plenty of time to break down without robbing nitrogen from the next spring's crop of onions. This may-seem farfetched, but we think the soil has less "need" to grow weeds when we use these high carbon cover crops and their aggressive root systems to repair the damage done to soil structure by the preceding cultivated crop.

More to the point, plowing deeply at this time of year targets perennial weeds at the weakest point in their life cycle. Likewise, harrowing the ground every two to three weeks during the following bare fallow period brings the roots and rhizomes of perennial weeds to the surface to dry in the sun while preventing annual weeds from getting established at a time of year when they are likely to grow quickly and run to seed. As a result of religiously fallowing our fields every other year this way, quackgrass no longer exists in the market garden and broadleaf weeds like pigweed and lamb's-quarter are rare visitors. In fact, in recent years we have been able to reduce the bare fallow period to as little as two to three weeks without sacrificing weed control.

However, the transition from very manageable to minimal weed pressure was only realized when we began composting the horse manure we use to fertilize the fields. The composting process kills most weed seeds in the manure and bedding, and the resulting stable soil amendment does not seem to stimulate weed growth in the fields like fresh manures or fast-acting fertilizers. Applying the compost during the fallow year gives it more time to break down before early planted cash crops, saves a step in spring, and enhances the root and top growth of the second soil improving cover crop in this fallow sequence leading up to onions.

The bare fallow ends the first or second week of August when we seed down the field to the second cover crop. This planting date takes advantage of the fact that most annual weeds which germinate now are likely to frost kill before setting seed here in the mountains of north-central Pennsylvania. Our preference of a cover crop before onions is Canadian field peas because they fix nitrogen, put on a lot of top growth in fall and tend die back over winter.

The big advantage of winterkilled cover crops is that they are so easy to incorporate first thing in spring, making timely planting of onions more dependable. Thanks to winterkilled field peas, we got the 1993 crop in the ground in plenty of time despite receiving two inches of rain every week that spring.

In terms of weed control, an easily incorporated cover crop allows us to restrict tillage to just the top two to three inches of the soil. For example, in figure 2, taken the last week of April 1993, you can see that discing the winterkilled field peas lightly is not as likely to

Figure 1
Clipping small grain covers repeatedly makes incorporation easier

Figure 2
Discing winter-killed field peas lightly in spring brings up fewer weed seeds

bring new weed seeds to the surface as plowing or rotovating deeply. Keeping the residues near the surface also helps with erosion and moisture control.

Figure 3 shows the 1993 onion crop the middle of June. We had yet to do any in-the-row hand weeding at this time even though the extremely wet conditions extended through May. We usually do plan on cultivating onions three or four times. But because we have been able to reduce weed pressure during the previous fallow year, we target cultivation more for moisture control than weed control. That means getting into the fields as soon as possible after a heavy rain to break the crust and create a mulch of loose soil around the plants to slow evaporation.

Figure 4 shows the onion crop three hot, rainless weeks later. We spent a total of six hours hand weeding this half-acre field by the time harvest was complete the middle of August. By hand weeding, we mean simply walking the field and pulling those few weeds that threaten to go to seed-not a rescue effort to save the crop. Nor is this an attempt to completely clean the field of weeds. Those weeds that manifest themselves later in July or August, such as blown-in dandelions, volunteer clover and a few smartweed, we plan on plowing out after harvest when preparing the field for seeding the winter cover crop and starting the fallow cycle over again.

Keep in mind that a single fallow year is not likely to work miracles. And that the types and timing of cover crops to get this kind of control will depend on your climate, soil and weeds. For example, we can well imagine that the bare fallow period between two winter cover crops might be excessively long in a warmer climate than ours, causing unnecessary damage to soil structure. By the same token, the life cycle and growth habits of winter weeds might require a very different cover crop/fallow sequence than the one we have described for controlling weeks like quackgrass, landcrest, pigweed and lamb's-quarter.

We learned this firsthand the past two years when we saw chickweed creeping into the field slated for onion production. Based on past experience with isolated patches of this intruder, we were afraid our usual sequence might proliferate rather than control chickweeds since it sets seed well ahead of the normal bare fallow period and is too low growing to control by mowing. So we plowed down the first cover crop prematurely before the chickweed had a chance to reseed. We planted a cover of quick-growing buckwheat the first of June to avoid an extended bare fallow period, and followed the buckwheat with the usual fall cover of winter killed field peas. Both years, this outwitted the chickweed.

Figure 3
Cultivating three or four times is done mainly for moisture control

Figure 4
A half-acre field of onions with only six hours of hand weeding

To be truthful, some of our time is tied up managing the cover crops and that needs to be figured into the labor equation. As we see it, the total hours devoted to cover crop management are a small fraction of the time spend hand-hoeing an otherwise weedy crop of onions. Besides, we find the fieldwork involved is a welcome balance to all the stoop labor that goes with market gardening. Of more practical importance, this in-

tegrated approach to weed management allows us to spread the weed control effort over the course of the growing season to suit our schedule rather than letting the weeds set the pace.

While many growers may feel they cannot afford to idle productive land for weed control alone, bear in mind that the cover crops in the fallow fields serve many purposes. We count on cover crops to help restore fertility, structure and moisture holding capacity after cultivated cash crops. And we depend on them to minimize erosion, interrupt the cycles of insects and disease and attract beneficials. The beauty of the fallow years is that it gives us the opportunity to use the cover crops to their fullest potential, in this way increasing biodiversity on the farm.

Part Two: A Whole Farm Overview

Reprinted from OEFFA News, *which is published bimonthly as part of the educational mission of the Ohio Ecological Food and Farm Association, a nonprofit organization for farmers, gardeners, and citizens interested in ecological agriculture and creating a sustainable alternative food system.*

"A Strategy for Weed-Free Onions" (part one) describes the cover crop sequence of rye/bare fallow/winter-killed peas we use in the fallow year before EARLY planted cash crops like onions, spring spinach, lettuce and snap peas. In the fallow year before LATE planted cash crops like tomatoes, squash, main crop potatoes, or fall greens, we employ a cover crop sequence of clover/bare fallow/rye and vetch. Alternating the cash crops between those planted EARLY and LATE sets in motion these two distinct cover crop sequences which help to keep weeds off balance and adds more diversity to the overall farm system.

The four-field photo (figure 5) shows how the cover crop sequences and cash crop rotation work together. For instance, in this shot taken around the fourth of July in 1991 you see:

1. A cover crop of yellow sweet clover in the fallow field to the left, fixing nitrogen and building soil structure for the next year's heavy feeding cash crops of...

2. LATE planted mixed vegetables, such as squash, celery, tomatoes, and corn.

3. To the right, winter hardy rye, seeded after the previous year's LATE planted cash crop, has been plowed down to begin the bare fallow period. We count on the summer fallow, in conjunction with the cover crops, to create weed-free conditions for the next year's crop of....

4. EARLY planted onions to the far right. To start the rotation over again, we seed the clover right into-or immediately after-these early cash crops so the clover is well established before winter.

By the time we plow down the sweet clover the next July, almost a full year later, the tap roots have tilled and fiberized the soil much deeper than plow depth or the root zone of most market garden crops. If we can use the cover crops to improve soil structure, then the weeds, which often come in to perform this important role, have less reason to grow.

The four-year rotation then repeats itself three times over the twelve-field market garden. We simply sub-

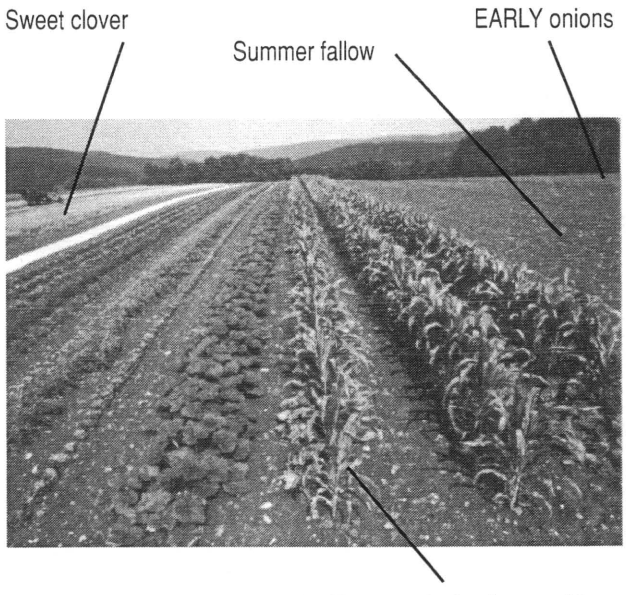

Figure 5
Four-field crop rotation

stitute different cash crops into the EARLY and LATE slots as shown in figure 6 (lower half). Even the depth of tillage can be rotated to the benefit of the crops and discouragement of the weeds.

Of course, the details of the rotation have changed over the years as we adapt to the changes in the climate, marketplace and insect pressure. The principle we keep in mind as we fine tune the system is simply to rotate the types and timing of cover crops in the fallow fields to create the best conditions and control for the cash crop to follow. In this way we have been able to maintain our original objective of substituting land for off-farm inputs and pain labor.

This land-extensive, or bio-extensive, approach to market gardening is much easier to visualize in the slide presentation we had videotaped at the 1996 Pennsylvania Association for Sustainable Agriculture Conference. The 52-minute video also includes segments on designing the market garden with work horses in mind, deer control, marketing, and animal-powered composting. Tapes are available for $10 (which includes postage) from Anne and Eric Nordell, RD 1, Box 205, Trout Run, PA 17771.

Rotating the half-acre strips between cash crops and fallow lands is the key to our two-prong weed-control strategy

Following half of the market garden each year allows us to utilize the bare fallow period midsummer to reduce the weed seed bank in the soil and to realize the full soil structuring potential of the cover crops so that weeds have less need to fill this important role.

Four-year rotation shown in figure 5 (page 99)

SPRING	rye and vetch	rye	lettuce peas spinach	clover	rye & vetch	rye	onions	clover	rye & vetch	oats	herbs berries flowers	clover & herbs
↓	potatoes		clover		celery kale squash		clover		fall coles spinach lettuce		clover & mulch	rye & vetch
		oats & peas		rye & vetch		oats & peas		rye & vetch		oats & peas		
FALL	rye				rye							
CROPS	cash crop	fallow	cash crop	fallow	cash crop	fallow	cash crop	fallow	cash crop	fallow	cash crop	fallow
BY TYPE	root		leaf		leaf & fruit		root		leaf		leaf & flower	
BY PLANT/ HARVEST	late		early		late		early		late		early	
TILLAGE	shallow		shallow		shallow		shallow		shallow		shallow	
		deep		deep		deep		deep		deep		deep

COMPOST

1. light application (5 tons/acre) in fallow year before root and early crops
2. light applications sheet composted with rye and vetch cover crop 6 weeks before late, heavy feeding crops
3. light application topdressed on leguminous cover crops

Figure 6
Rotation of cash crops, cover crops, tillage, and compost applications to enhance weed control, moisture preservation, and soil tilth.

A Few Long Furrows on Horsedrawn Tillage

Eric Nordell
Beech Grove Farm
Beech Grove, Pennsylvania

Photos by Anne Nordell
Beech Grove Farm
Beech Grove, Pennsylvania

Illustration by Edward H. Ochsner II

Skim plow
A well sodded cover crop is necessary to provide suction for such shallow plowing and to maintain soil structure and capillary action throughout the growing season.

Skim plow rye and vetch before late crops
Raw organic matter breaks down quickly near the soil surface into homegrown starter fertilizer for the heavy feeding cash crops to follow.

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When we settled in northern Pennsylvania 10 years ago, we tilled in the conventional manner of the area, plowing deep with the moldboard plow, repeatedly harrowing with the spring tooth or disc, then rolling with the cultipacker. The result was a deep, loose seedbed of finely pulverized soil. Under ideal conditions, crops seemed to thrive, but under less than ideal conditions this seedbed had a lot to be desired.

Our third year here the spring winds blew hot and dry, sucking moisture out of the loose topsoil to plow depth. Seeding carrots into six inches of dust was a disaster. Even under less severe conditions we noticed the silty soil on our exposed hilltop site dried to the depth it had been tilled in as little as a week or two without rain, then crusted after the first downpour.

Enough humidity remained in the topsoil to germinate large seeded field crops, like corn or oats, which could quickly put their roots down to moist ground beneath,

but small seeded root crops and succulent transplants really suffered. Without irrigation, we needed to find some way to hold precious moisture near the soil surface where shallow rooted market crops did most of their growing.

More typically, these mountain soils stayed wet and cool. Deep plowed cover crops and manures decomposed slowly, if at all. After a damp, cold spring, it was not unusual to dig up raw manure or pieces of still-green rye as late as the end of June. We kind of suspected these pickled animal and green manures may have contributed to incidences of uneven and unbalanced plant growth those first years. Discovering mushrooms sprouted above buried chunks of horse manure reinforced in our minds the idea that what happens below ground often expresses itself above ground as well.

Weed growth seemed to follow the same pattern. We found the clean look of deep plowed fields to be deceiving. Many perennial weeds just seemed to be transplanted by the plow – granted, upside down - only to raise their ugly heads a few weeks later. More to the point, we noticed a sort of delayed reaction with annual weeds. It almost appeared as if their seeds would not germinate until the soil life in the inverted sod had a chance to regroup and eat their fill of raw and rotting organic matter. Inconveniently, that meant weeds came on at the same time the crop did. Pre-plant cultivation for weed control was recreational at best. As if this delayed reaction was not perplexing enough, plowing brought up a whole new batch of weed seeds from down deep, so we never really knew what sort of weeds to expect.

A final concern was conventional tillage did not seem like a good match for our lightweight team. We may have set some speed-plowing records those first years with the Standardbreds, but soft and sassy after a long winter's rest it almost seemed like deep plowing was more than their minds, if not bodies, could bear. One solution was to work our way up to a somewhat heavier and steadier team of crossbreds. That change only avoided what we thought the Standardbred mares were trying to tell us: Does it really make sense to greet the soil first thing in the spring with the most disruptive and toughest tillage of the year?

When we saw our neighbors park their two bottom plow and hitch nine head to an offset disc you can be sure that we took notice! They claimed the cornstalks broke down faster when worked into the soil surface, reducing erosion and improving tilth. Well, we just had to put this idea to the test in the market garden. With some good humored help from friends near and far, we had some fun rigging up miniaturized versions of offset discs, chisel plows and field cultivators suitable for a lightweight team.

The machines may not have looked like much, but the results in the fields were impressive. Cover crops and manures decayed quickly when tilled into the soil surface close to the warmth of the sun and the air above. This sort of sheet composting led to more uniform and disease resistant crop growth. And the farm was now mushroom-free.

Since surface tillage did not disrupt the soil life like deep plowing, weed growth became more predictable. Instead of a delayed reaction, annuals germinated readily after surface tilling, making preplant cultivation a very effective technique. As for shallowly undercut perennials, they simply dried and died in the sun.

Additionally, the ground rarely dried deeper than the shallowly disturbed soil. In fact, the firm earth below maintained capillary action much better than plowed ground, drawing subsoil moisture to the surface where an inch or two mulch of loose topsoil slowed evaporation. Where it might take two or more inches of rain to thoroughly re-wet deep plowed ground often only a few tenths of an inch moistened surface tilled soil adequately for seeding or transplanting market crops. Cover crop residues decaying on the surface not only helped to hold moisture, but fiberized our silty soil so it did not wash or crust as badly after heavy rains.

Last but not least, the mares approved of this new technique. Spring tillage was now much easier for these soft and spirited horses. Follow-up passes with the harrow on relatively firm ground were much kinder on man and beast than walking in deep plowed ground. Indeed, surface tillage seemed like a much better way to condition the horses, both psychologically and physically, for the rest of the growing season.

Pleased with our new tools, we intended to use them all the time. We just barely scratched the surface of the farm before planting cash crops, before seeding down cover crops, and before the summer fallow. In

short, we surface tilled whenever and wherever we could.

In a few years time, some disadvantages to this single-minded approach began to become clear. To kill and incorporate well-established cover crops, like clover sod or August seeded rye, required repeated trips with our lightweight two-horse equipment. Sometimes it seemed that in an effort to improve the soil through surface tillage, instead, we were wearing it out. In a wet spring, successfully knocking back these covers was nearly impossible, at least to do so in a timely fashion before early planted cash crops. Likewise, weeds and cover crops during the fallow required many passes with the harrow, disc and field cultivator at a time of year when we were busy enough with the demands of cultivating, picking, packing and marketing vegetables and herbs. And all of that nice mulchy material on the surface protecting the soil during heavy rains often splashed into the cash crops themselves, making washing lettuce and spinach quite a chore.

Concentrating nutrients and organic matter near the surface with these new tools may not have been such a bad idea in wet years, but crops seemed to suffer doubly in drought conditions as their roots worked their way downward, leaving the dry nutrient zone in search for water. At the same time, that nutrient rich mulch at the surface encouraged weeds to germinate and take hold. Perhaps most surprising of all, after three years of surface tilling some fields became both excessively well drained and firm.

We were not willing to give up on surface tillage altogether, but these observations certainly made us think you can do too much of a good thing. That thought then led us to the idea that the benefits of rotating crops might apply to tillage as well. Why not rotate tillage techniques according to the needs of the crops, soil, and seasons of the year?

Practical considerations more or less showed us the way. First off, surface tillage in the spring had proved to be fool proof and effective after winter killed cover crops such as oats and Canadian field peas. Planted late summer, these spring annuals died back at the onset of winter making incorporation and seedbed preparation a snap with just a disc and a harrow before the earliest planted market crops, like spinach, onions and peas. As most of these cash crops were also harvested early in the season, a cover crop of clover could be established before winter.

Secondly, we had learned that vigorous, winter-hardy covers, such as a mix of rye and hairy vetch, required significantly more time to kill and decompose in the spring than winter-killed cover crops. It just made sense to use rye and vetch before later planted cash crops like tomatoes, celery and fall coles. Rye turned out to be the only cover crop tough enough to establish after these late harvested cash crops.

The trick to making this second crop sequence work was finding an appropriate and efficient way to incorporate a live cover crop in the spring. We did not want to return to deep plowing given the problems it caused with our soil and crops, but trying to work up a well-sodded cover crop of rye and vetch with our lightweight two horse chisel was a joke. So we tried a compromise approach and plowed as shallowly as we could set the old Leroy walking plow to run. With a little experience, we discovered we could turn a furrow just two to three inches deep. We called this "skim plowing" as the plow just peeled the sod right over, leaving the cover crop residues near the surface and the coarsest portion of the root mass intact below.

We were really pleased with the results. First of all, undercutting the cover crop so close to the surface was sure and sudden death for rye, vetch and volunteer weeds. Secondly, the horses walked along without a hint of hesitation or even breaking a sweat. Most importantly, skim plowed cover crops and manures decomposed quickly at this warm, aerobic and well-protected depth into homegrown starter fertilizer placed at just the right level for the heavy feeding cash crops to follow. Lastly, a pass or two with the spring tooth harrow brought up a good deal of skim plowed top growth and coarse root mass to the surface to help hold and fiberize the soil.

Wow, were we both surprised and encouraged to read this past year of two others advocating skim plowing under certain circumstances. We were just naive enough to think we were the only ones to stumble on this technique and crazy enough to actually pursue it. In the Fall 1992 *Small Farmer's Journal,* British horse farmer Jeff Peterson writes:

> "...What I really like about the moldboard, pulled by horses, is one can bring it down to a fine art and make it a very tidy job, after enough

practice. It is possible to plow very shallow, 3" (7.5 cm) or maybe even less. When I plough I like the organic matter as near to the surface as possible and tidily turned over..."

And from Michael Jost's Field Advisory File in the Summer 1992 *Biodynamics* come these comments on improving the sandy soils on Greg and Marley Niewendorp's Belgian-powered farm:

"...A remark about tilling the soil and good stewardship: There is an advantage of shallow turning (e.g. 2") of thin layers of soil. Better in two steps than in one. Timing: 2-3 weeks apart, then sow. Plow should not move layers that are not enlivened. The old fashioned horse plow has the advantage that it can indeed be adjusted in such a way that it removes only very thin slices of soil..."

Whether or not skim plowing holds up to the test of time, we think it is exciting and important that farmers are putting old tools to new purposes, adapting low horsepower implements to the needs of the land, and proving that new and expensive equipment is not necessary for conscientious soil management.

Here are a few things we learned the hard way about skim plowing: It is essential to work with a well-sodded cover crop for at least two reasons. First off, without deep tillage we are relying on the undisturbed and extensive root system beneath the skim plowed layer to maintain soil structure and capillary action throughout the growing season. In fact, the results seemed much better than after deep plowing. Secondly, a strong sod is absolutely necessary to create suction for such shallow plowing. Likewise, a good share and landside are even more important for skim plowing than conventional deep plowing.

We would not recommend this unorthodox form of plowing for rocky, compacted or unimproved land. Or for beginner teamsters. With the plow planted so lightly in the soil, it seems to have a little more life of its own and may require, at least at first, faster reflexes. To be sure, we are using Leroy in a way for which he was never intended.

Thanks to skim plowing, we now had two reliable crop sequences based on two types of tillage:

1. Surface tilled oats and peas → early cash crops → clover

2. Skim plowed rye and vetch → late cash crops → rye

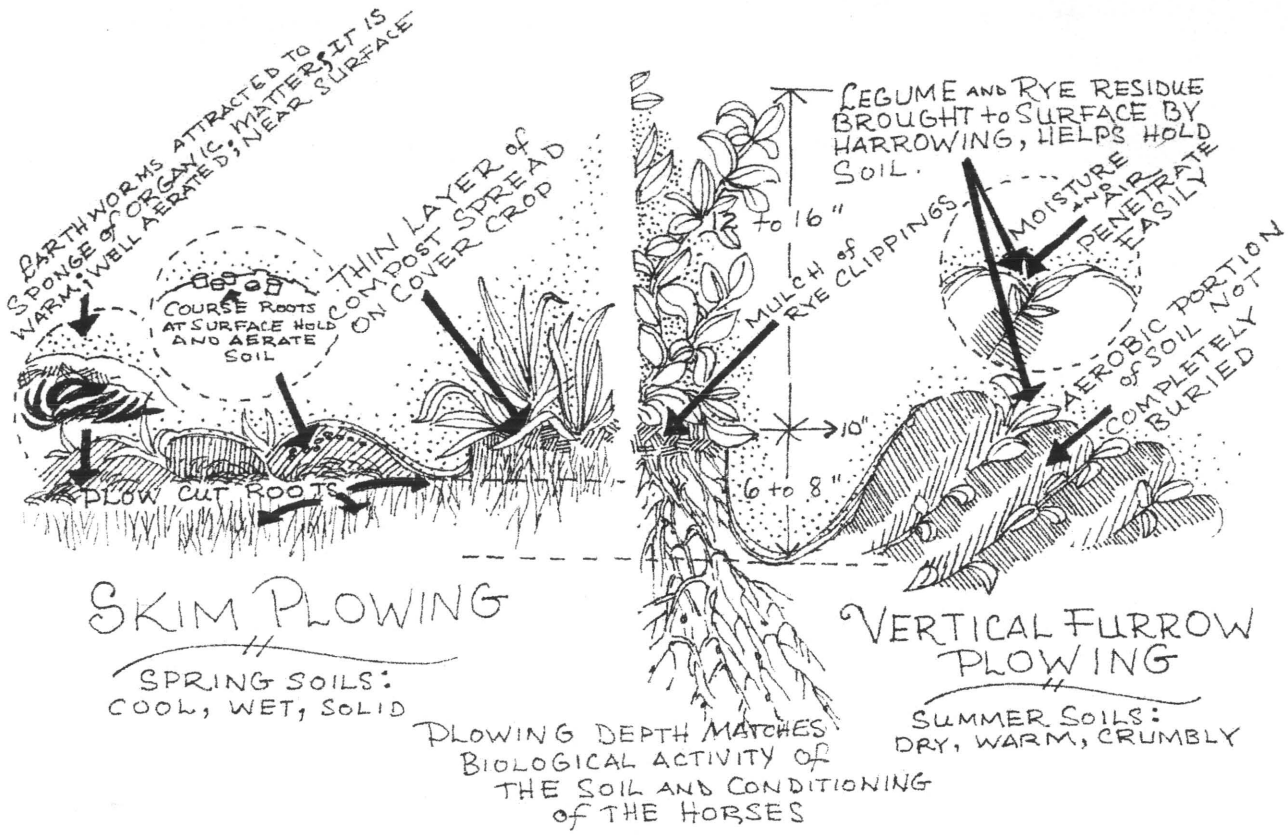
It did not take us long to realize that we could piece these two crop sequences together by way of the summer fallow into the full blown crop rotation illustrated in the chart (see figure 6, page 100). We were amazed to see how a simple notion like rotating tillage techniques had brought so much more diversity and complexity to the whole farm.

One question remained. How to incorporate full term cover crops before the summer fallow? Chiselling, discing and field cultivating had proved too time-consuming with tools suited for a team. Skim plowing could be difficult if the ground turned hard and dry. And such shallow tillage did not solve the problem of how to deepen the topsoil to create a larger zone of moisture and fertility for shallow rooted market crops to draw on in times of drought. It finally dawned on us that this might be the appropriate place to plow deeply.

We can usually count on these mountain soils to warm up and dry out by the summer solstice. Deep plowing at this time would not be as likely to pickle organic matter, cause compaction or fail to kill perennial weeds as turning wet, cold soil in the spring. Also, there would be plenty of time during the summer fallow to set back a new crop of plowed up annual weeds.

If we were going to plow deeply, we decided we should plow as conscientiously as we could. So we plowed the way Raymond Smoker showed us. Raymond not only taught us how to work horses, but also taught us the love of working horses, a gift for which we will be forever grateful.

Raymond warned that this method of plowing might not win many ribbons at a plowing contest, but that it *was* the way the walking plow was intended to be used. He simply removed the jointer from the plow and set the clevis to cut a fairly narrow (10-12") and deep (6-8") furrow, laying the furrow slice on its side rather than flipping it all the way over. Plowed in this fashion, manures, cover crop residues and the aerobic portion of the soil were not completely buried, but distributed vertically in the good earth. Raymond also pointed out that furrows laid on edge allowed mois-



Skim plowing (left) and vertical furrow plowing (right)
Plowing depth matches biological activity of the soil and conditioning of the horses.

ture, warmth and air to penetrate the soil easily for quick and proper decomposition of raw organic matter. And he recommended setting the teeth of the harrow deeper with each pass, bringing crop residues to the surface to speed decomposition and slow erosion.

Although Raymond likes nothing better than walking barefoot behind the horses, he made it clear that this style of plowing was not limited to the walking plow. It was possible with sulky plows, gang plows and tractor plows, just so long as the moldboards were not too wide. For example, a trailer plow with four 12" bottoms would work just fine, but a three bottom plow with 16" shares, although turning the same amount of land, would not lay the furrow on edge unless the plows were set excessively deep. Choice of ground speed and moldboard design would also influence the roll of the furrow.

We found vertical furrow plowing to be an ideal way to start the summer fallow because it combined the best features of conventional moldboard and chisel plowing. Like conventional moldboard plowing, the walking plow adjusted in this manner provided quick and effective weed control while mixing stratified layers of organic matter, minerals and acidity. Like chiselling, vertical furrow plowing loosened the ground deeply without burying all the organic matter and the live portion of the soil. At any rate, it seemed the crops grew better in the following year.

Those Standardbred mares were right! Depth of tillage ought to reflect the natural procession of the seasons, from surface tillage in the spring to deep plowing in the summer months. Although plowing in the heat of the summer can be hard work for horses, the team, already toughened by a few months of fieldwork, took it in stride. The soil also seemed ready, with the earthworms and other soil life now active throughout the whole plow layer, and the cover crop roots so much thicker and deeper than in the spring. Looking from the plow handles, it appeared that the conditioning of

the soil followed closely the conditioning of the horses.

For more information on the summer fallow, hog composted manure and our neighbors' offset disc, please see:

- "The Summer Fallow," Summer, 1991, *Small Farmer's Journal*
- "Work Hogs and Horse Manure," Spring, 1991, *Small Farmer's Journal*
- "Alternative Horsedrawn Tillage," Spring, 1987, *Small Farmer's Journal*

Vertical furrow plow, cover crop of clover in fallow year before late crops

Insect and Disease Management

Impacts of Soil Quality on Disease and Insect Resistance in Plants

Anusuya Rangarajan
Dept. of Horticulture
Cornell University
Ithaca, NY

Organic farmers have long claimed that, on their farms, insect and disease pressure is less than on conventional farms. They believe their emphasis on good soil management and soil quality results in improved plant health and resistance to infection or infestation. Soil quality includes those biological, chemical and physical traits that enhance the ability of a soil to support healthy plant growth (among other things). While there is little conclusive scientific data about the relationship between soil quality and pest suppression, there are several plant and soil interactions may contribute to these phenomena.

Different soil biological, chemical and physical traits have been associated with disease suppression. Many researchers have tried to identify biological indicators for soil health and disease suppression (van Bruggen and Semenov, 2000). However, many of these measurements are sensitive to the environment or short-term management effects, minimizing their usefulness. Other researchers have found that soil physical and chemical characteristics can also influence disease levels, including organic matter quality and quantity, pH, calcium, iron, micronutrients, compaction, soil texture, structure, parent material and the predominate clay type, and soil moisture (Hoper and Alabouvette, 1996). The relative importance of any trait varied by the specific disease, and no generalizations could be made for all diseases. In many cases, trying to manipulate these traits within a soil is impossible (e.g. clay type). These findings suggest that trying to predict a suppressive soil is nearly impossible, and that focusing on any one trait does not appreciate the complexity of the interactions between soils, microorganisms and plants.

We know that plants can respond to their environment and adapt to some stressful conditions, such as moisture stress or low light levels. Recently, research has found that some of these plant responses are quite instantaneous and suggest that plants are much more active in adapting and responding to the environment than previously believed. Some of these rapid responses affect crop susceptibility to pests. These responses are induced by cues from the environment and some of these cues are based upon root interactions with soils and soil microorganisms. To understand how soils affect crop susceptibility to pests, we must consider some these different plant responses and evaluate how they may be optimized to reduce plant losses (Figure 1, page 114). This discussion will:

a. review some of the strategies of pest resistance in plants,

b. soil and rhizosphere effects on this plant resistance, and

c. suggest some strategies to maintain or enhance pest suppression in vegetable systems.

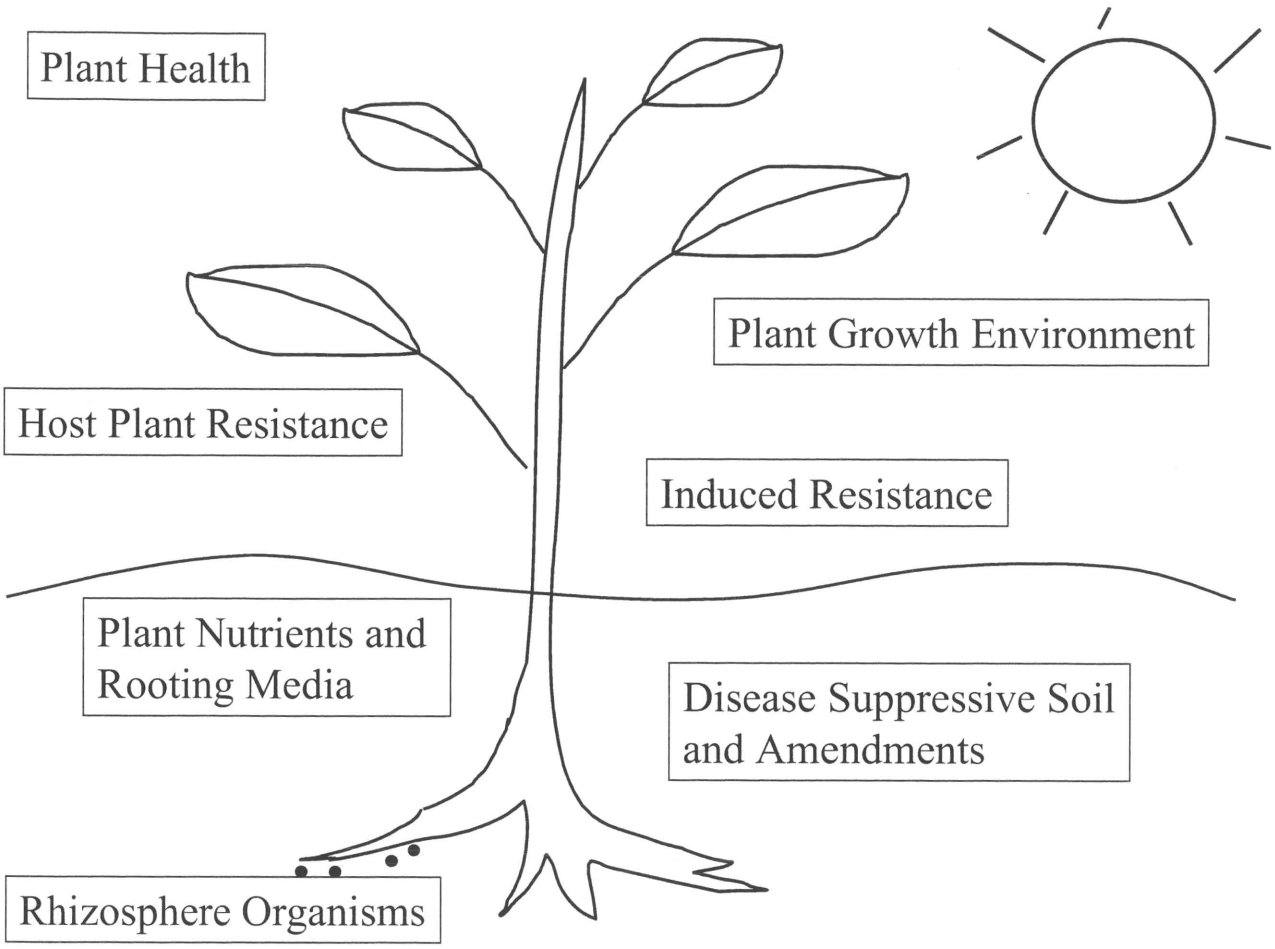


Figure 1
Factors affecting plant resistance in insect and disease pests.

Plant resistance to pests

Plants may escape damage by pests by associating with other species, developing in times with reduced pest pressure, having some tolerance to the herbivore or confronting the pest with physical or chemical challenges. These physical and chemical challenges to pests include host plant resistance and systemic or induced resistance. Both of these modes of resistance can be affected by plant growth and soil conditions.

Host Plant Resistance

Host Plant Resistance occurs from the expression of plant genes that result in physical or chemical attributes that interfere with the ability of an herbivore (insect, disease or animal) to utilize a plant compared to a plant not expressing those genes. Common examples of host plant resistance can be found in vegetable varieties that have disease resistance, e.g. tomatoes with resistance to verticillium, fusarium and nematodes. These physical or chemical attributes make the plant less appealing or even toxic to pests. Some physical traits that confer host plant resistance include hairiness of leaves (trichomes) or toughness (lignification) of plant parts (e.g. stem solidness in wheat). Hairiness of leaves can reduce ability of sucking insects to land and feed on leaves, and lignification can restrict insect boring into stems or restrict fungal spread into plant tissue. Chemical factors include secondary plant compounds or phytochemicals, such as alkaloids, glucosinolates, terpenoids or polyphenols. These chemicals are the primary mode of host plant resistance and often have very specific effects on pests.

In some cases, these phytochemicals associated with host plant resistance are always present in the plant. In other cases, they are affected by factors, such as plant age, previous plant injury, planting arrangement and crop competition, light levels, ultraviolet radiation, and soil nutrients. Fully expanded, maximally photosynthesizing leaves have the highest carbon, nitrogen and water, and are likely best for herbivores. When leaves age and develop toughness, they often are less nutritious to pests. Previous plant injury by one plant-feeding insect (herbivore) can lead to resistance to other herbivores. Infection by a plant pathogen can change suitability of a host to other pathogens or herbivores for better or worse. Planting arrangement and density can increase or decrease plant stress and subsequent susceptibility by affecting plant health and vigor.

An example of host plant resistance in vegetables is the effect of cucurbitacin in cucurbit leaves on the feeding by cucumber beetle and two-spotted mite. This compound is a powerful feeding stimulant for cucumber beetle but confers resistance to mites. The level of cucurbitacin varies among species and even cultivars of cucurbits. Cucumbers that lack cucurbitacin are resistant to the beetles but susceptible to mites.

Another example is the production of glycoalkaloids in potatoes. These compounds confer resistance of leaves to the Colorado potato beetle. These glycoalkaloids in tubers, however, can be toxic to humans. A beetle-resistant cultivar "Lenape" was pulled from the market due to the high levels of glycoalkaloids in the tubers.

Induced Plant Resistance

Induced plant resistance is an enhanced defense capacity developed in a plant after being stimulated (Kuc, 2001). In some ways, this could be described as priming or vaccinating plants—after receiving a "shot" (inducing agent) in a single part of the plant, the whole plant becomes more resistant to future attack. Induced resistance does not, however, require application of antibiotics.

This induced resistance is different than host plant resistance in that the effects tend to be non-specific for the target pest. Induced resistance has been described for pathogens in 30 species and for herbivores in 100 species. For diseases, induced resistance is most effective at suppressing fungi, followed by bacteria and then viruses. For example, anthracnose inoculation of cucumbers provides systemic protection against the same and other fungi, some viruses, wilt fungi and bacteria, but not spider mites or beet armyworm. In cotton: spider mites on cotyledons protect against mites, caterpillars, thrips, whiteflies, true bugs and vascular wilt fungi, but not bacterial blight. However, induced resistance will not protect against very aggressive pathogens such as Sclerotina white mold, late blight or some post-harvest rots.

For induced resistance, the plant first must be stimulated or challenged (given the "shot"). The challenge may be via an organism (e.g. insect, fungi or bacteria that are pathogenic or nonpathogenic) or a specific chemical (Figure 2, page 116). Induced resistance has been elicited by several different organisms, including pathogens, insects, plant-growth-promoting rhizobacteria (see below), composts and compost extracts. Several chemicals shown to induce resistance include salicylic acid, potassium phosphate, bicarbonate, oxalic acid (spinach or rhubarb extracts), some new chemicals such as Actigard, Bion (salicylic acid mimic), Milsana (giant knotweed extract) or Messenger, and some plant hormones (cytokinin and abscisic acid). Thus, the inducer or elicitor is important for what it does, not what the structure is. The modes of action of these different inducing agents are being actively explored by researchers. Interestingly, application of larger amounts of an inducing agent will not give greater resistance, and the response can vary by cultivars of plants.

Some time must pass after applying an inducing agent before resistance can be observed. The amount of time varies by the species as well as the pathogen. In addition, the inducing agent often needs to be reapplied to keep up the resistance. For example, some of the chemical inducers must be applied every two weeks to maintain the resistance levels (e.g. Messenger). Induced resistance can cause reductions in yield in some cases, but losses to the pest need to be balanced with yield depression.

The potential for induced resistance in agricultural settings seems obvious, but is difficult to document consistent effects. Treatment of crops with inducing agents has shown improved resistance to pests in some cases, but not all. New information on soil microorganisms indicates that even root infections can induce resistance in plant tops.

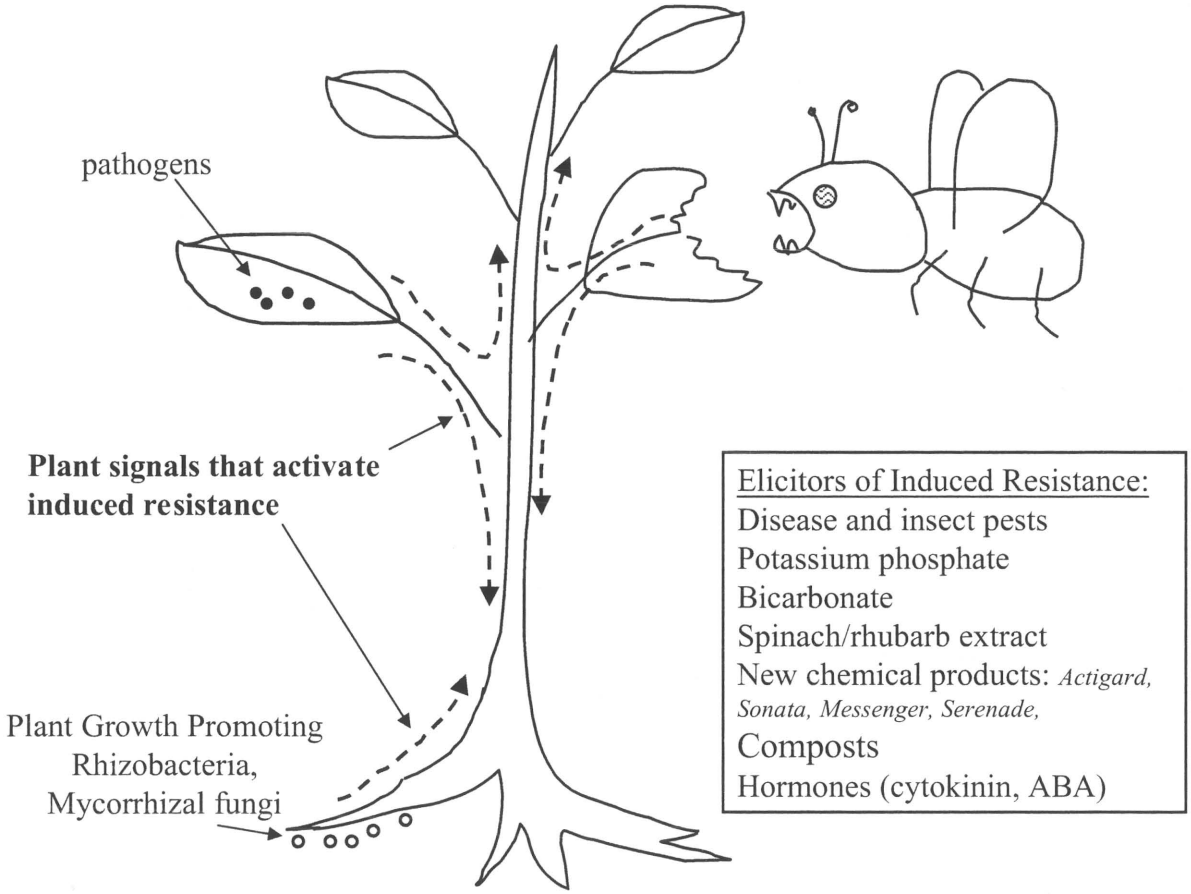


Figure 2
Induced resistance requires that the plant be challenged by a pest or by some other compound (elicitor).
Once challenged, the crop quickly sends signals to other parts of the plant that cause the plant to enhance resistance, in case of future attacks. The nature of this plant signal will vary by the crop. In some crops, up to two weeks are required after the initial challenge for induced resistance to have an effect.

Soil organisms and amendments that affect plant resistance

Plant growth promoting rhizobacteria (PGPR)

The rhizosphere is the 2-5 mm region immediately around plant roots, into which plants pump large amounts of carbon as exudates. Free-living rhizosphere organisms survive on plant root exudates and can affect plant growth rate and defend against plant diseases (Whipps 2001). Some of the organisms living in this nutrient rich zone are plant growth promoting rhizobacteria (PGPR) and plant growth promoting fungi (PGPF). PGPR stimulate plant growth and performance under stress in several ways. Some suppress growth of pathogens through a) direct competition for resources or nutrients like iron; b) by predation; or c) by producing antibiotic or antifungal compounds. Fluorescent pseudomonads species are some of the most effective bacteria for suppressing soil borne diseases. Other organisms supply nutrients such as phosphorous or nitrogen, or produce or metabolize plant hormones, affecting crop growth. The types of PGPR often vary

by plant species and sometimes even variety, making inoculation of plants for crop protection challenging. The amount of organisms needed to affect crop growth is unknown.

Sixteen different commonly occurring soil bacteria have been found to induce plant resistance. A link between PGPRs and induced resistance has been reported for anthracnose of cucumber, fusarium wilt on carnation and halo blight on beans (Ramamoorthy et al 2001). Mixtures of these PGPRs have been more effective at inducing resistance than application of just one PGPR. These bacteria are applied as seed treatments or drenches to transplants. One interesting interaction has been found between a PGPR and cucurbitacin content of cucumbers. Seed inoculation followed by drenching with a Bacillus species led to reduced cucurbitacin content in both bitter (high concentration of cucurbitacin) as well as non-bitter cultivars. This consequently reduced feeding by cucumber beetles and reduced transmission of bacterial wilt (Zehnder et al 2001). Thus, a rhizobacteria, growing around the roots affected the expression of a host plant gene, and that in turn affected both insect and disease incidence in the crop. We are only beginning to understand these complex interactions between soil PGPR and the crop's composition and disease resistance.

Compost and disease suppression

Manure and compost amendments are typically applied to soil to recycle nutrients and build soil organic matter. Composts have also been shown to suppress soil borne diseases and induce resistance in crops (Hoitink and Grebus, 1994). In a study with cucumbers grown in either compost-amended or no-compost media, those grown in compost showed a higher level of induced resistance (after being challenged) than those not grown in a compost media (Zhang et al 1998). This indicates that multiple organisms may affect plant resistance (soil organisms as well as above-ground challengers) without causing disease (Figure 2). Microorganisms in compost may also control diseases by competing with the pathogen for food, by producing compounds that kill the pathogen, or by attacking the pathogen directly. Several researchers have explored this type of disease suppression in compost-based media used for ornamentals and food crops. The ability of compost to suppress diseases has been associated with the composting conditions (food stocks, management), can change with maturity, and can be enhanced through inoculation with some specific suppressive fungi, such as Trichoderma or Bacillus spp. Not all composts suppress diseases, and some composts may actually increase disease levels. Those high in salts have been shown to increase levels of Pythium, and those not sufficiently cured, especially if they have high nitrogen content, may increase disease.

To maximize benefits of compost in potting media, select well-cured (6 to 12 months) composts. Mix and pot the media before planting, and water to leach any salts out of the media that may inhibit germination and growth. In fields, if the maturity of the product is unknown, apply the compost well in advance of the crop to allow for stabilization of the compost (and reduce nitrogen tie-up) and leaching of any salts.

Strategies to optimize pest suppression through soil management

Organic matter additions to soil become part of a complex food web of soil organisms. Regular additions of fresh organic matter (active soil organic matter) will increase microbial activity as it is decomposed by different groups of organisms. In turn, these microbes will affect soil disease suppressiveness, as well as soil physical and chemical characteristics and nutrient availability. Older, more stable organic matter (passive organic matter) is that humus fraction in the soil that contributes to cation exchange capacity and aggregate stability—factors that enhance plant growth.

Since soil organic matter is dynamic, the effect of any particular amendment on soil quality will change over time. Trying to predict the response of various soil microbial functional groups with the addition of any specific amendment is incredibly complex. Compost, while disease suppressive, should be considered only one part of a systems approach to disease management. A good approach is to use repeated (not just single) applications of different types of organic amendments. These amendments will feed different microbes as they are decomposed and increase soil microbial diversity and activity. Evaluate your soil amendments to provide a diversity of food choices to the "soil micro-herd" (Figure 3, page 118). An analogy to the human nutrition food guide pyramid could be applied here. Avoid

reliance on any one type of soil amendment, e.g. only rye as a cover crop, to enhance soil health.

Organic agriculture requires use of organic matter amendments to improve soil quality and provide nutrients to growing crops. In one study, field corn was grown (in the greenhouse) in soils collected from organic and conventional farms. European corn borers laid more eggs on plants grown in the conventional soils. The researchers concluded that the overall soil management approach was more important than any specific soil amendments or nutrient levels to predict the insect behavior (Phelan et al, 1995). Other researchers have found that in organically managed systems, there is greater diversity in soil biota, higher microbial activity which could contribute to greater competition, antagonism and predation of disease organisms, higher populations of fluorescent pseudomonads and actinomycetes (important biocontrol organisms), and generally a lower incidence of soilborne diseases (van Bruggen, 1995).

There are several components that growers must keep in mind to make full use of the benefits of healthy soil on crop health and pest suppression. First, always strive to optimize plant growth conditions, including mini-

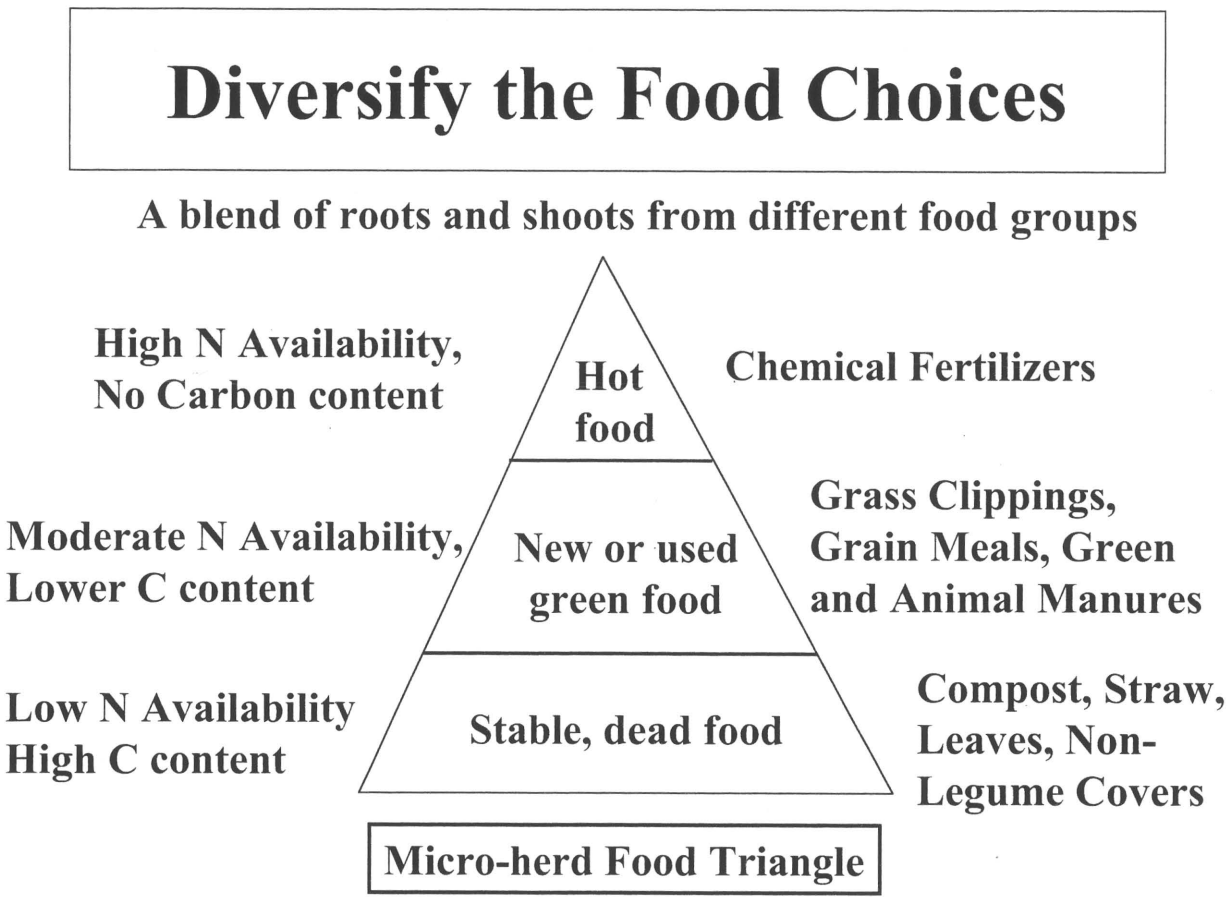


Figure 3
Soil organic matter amendments have different rates of decomposition in soil
Each phase of degradation will support different functional groups of soil organisms. The analogy of the food pyramid is helpful to remember to provide different types of soil amendments to encourage a diverse and active population of soil organisms. Prioritize carbon additions to soil, with nitrogen additions (as green or animal manures) that are more moderate, and aim to minimize chemical fertilizers.

mizing crop stress and competition, and using the best cultural practices for your region. Second, always try to select resistant varieties. Third, provide a diversity of organic matter residues to your soils. These residues, as they are degraded, will enhance microbial diversity and abundance. Some of these microbes will reduce soil pathogens as well as induce resistance in plants, making the plants more able to defend against future pest attacks.

Literature Cited

Hoitink, H.A.J and M.E. Grebus. 1994. Status of biological control of plant disease with composts. Compost Science and Utilization. 2(2):6-12.

H. Hoper and C. Alabouvette. 1996. Importance of physical and chemical soil properties in the suppression of soils to plant diseases. European Journal of Soil Biology. 32(1):41-58.

Kuc, J. 2001. Concepts and direction of induced systemic resistance in plants and its application. European Journal of Plant Pathology. 107:7-12.

Ramamoorthy, V., R. Viswanathan, T. Raguchander, V. Prakasam, R. Samiyappan. 2001. Induction of systemic resistance byplant growth promoting rhizobacteria in crop plants against pests and diseases. Crop Protection. 20:1-11.

Van Bruggen, A.H.C. 1995. Plant disease severity in high-input compared to reduced input and organic farming systems. Plant Disease. 79(10):976-984.

Van Bruggen, A.H.C and A.M. Semenov. 2000. In search of biological indicators for soil health and disease suppression. Applied Soil Ecology. 15:13-24.

Whipps, J. M. 2001. Microbial interactions and biocontrol in the rhizosphere. Journal of Experimental Botany. 52: 487-511.

Zehnder, G.W., J.F. Murphy, E.J. Sikora, and J. W. Kloepper. 2001. Application of rhizobacteria for induced resistance. European Journal of Plant Pathology. 107:39-50.

Zhang, W., D.Y Han, W.A Dick, K.R. Davis, H.A.J. Hoitink. 1998. Compost and compost water extract-induced systemic acquired resistance in cucumber and Arabidopsis. Phytopathology. 88(5) p. 450-455.

Zhang,-W.; Dick,-W.A.; Hoitink,-H.A.J. 1996. Compost-induced systemic acquired resistance in cucumber to Pythium root rot and anthracnose. Phytopathology. 86 (10):1066-1070.

Disease Management Strategies: Cultural Practices

Helene R. Dillard

Professor • Department of Plant Pathology
New York State Agricultural Experiment Station • Geneva, New York

Director • Cornell Cooperative Extension

Purchase seed or transplants that are certified disease free.

Select resistant or tolerant varieties.

Consider using hot water seed treatment to reduce contamination. Unfortunately, this treatment can reduce germination and vigor in some varieties, and may not eradicate disease from heavily infested lots. It is not a 100% guarantee that the seed will be disease free.

Direct seed when possible. Spread is slower in direct seeded systems. This is basically due to the ability of pathogens to spread among dense plantings found in transplant production areas.

Scout greenhouses and seedbeds on a weekly basis. Look for spots, wilts, or other symptoms characteristic of disease or disorder.

Select sites for seedbeds and crops where rotation has been practiced.

Select sites for disease-prone crops that have good air flow and good soil structure that promotes drainage.

Raise transplant beds above the surrounding area or trench the periphery to provide for drainage of excess rainfall. Flooding of the seedbed area can result in widespread infection.

Plant several smaller transplant beds rather than fewer large transplant beds. With smaller transplant beds, individual seed lots from different sources can be isolated from each other. Then, if one seed lot has an undesirable disease, you can destroy plants in that lot in order to prevent spread to the remainder of your plants.

Keep varieties separated in the greenhouse and in seedbeds. Pathogens and especially bacteria are rapidly spread in water; close spacing in seedbeds and in the greenhouse is ideal for rapid disease development. Keeping the varieties separate will help you identify problematic varieties.

Destroy volunteer plants and weeds growing in and near the transplant bed and production fields. These plants may harbor pathogens. Symptoms on weed species may or may not be present.

Destroy all remaining plants in a seedbed as soon as transplanting operations are completed. Transplants should only be handled when the foliage is dry.

Do not dip or water transplants in crates or boxes—this will very effectively spread pathogens.

Some bacterial diseases are highly contagious. For example, if black rot is detected in a seedbed consider all plants at the location to be contaminated. Do not attempt to separate healthy from diseased plants. Many

plants will be contaminated, but will not be showing symptoms until the environmental conditions are favorable for symptom development.

Do not plant transplants showing disease symptoms. These plants will continue to be problematic throughout the growing season.

Insects should be controlled because insect feeding injury provides wounds that are a large target of opportunity for infection.

Only new crates should be used for shipping transplants. Reusable plastic or wooden plant containers brought to the field should be cleaned and disinfested before returning them to the seedbed area for reuse.

Clean all transplanting equipment before and after each use.

A well-balanced nutrient program will suppress disease development. For example, studies have shown that excess nitrogen causes lush vegetative growth and can make crucifers more susceptible to black rot. Results from a recent study showed that boron applied alone or with nitrogen reduced the disease severity of black rot in cabbage.

Avoid using overhead irrigation, but if necessary irrigate during the time of day when the plants will dry quickly.

Contaminated equipment, people, animals, overhead irrigation, and wind-driven rain will spread pathogens. Always work in diseased fields last and restrict activities in fields until later in the day when plants are completely dry to reduce the potential spread of the disease.

Tools used for pruning, staking, and tying should be disinfested frequently, and especially when used on different varieties. Wounding plants during these operations should be avoided, as wounds provide a site for entry of pathogens.

Planting on raised beds allows excess water to drain from around plant foliage and roots. Removal of excessive moisture is a deterrent to disease development.

Mulching has been shown to provide a physical barrier between susceptible plant tissue and overwintering inoculum of pathogens. When disease pressure is not severe, mulching can provide as good control as conventional chemicals.

Achieve good weed and insect control. Weeds may harbor pathogens, rob the soil of valuable nutrients, and encourage moisture retention in the canopy that is favorable for disease development. Insects may serve as vectors for pathogens and/or their feeding injury may provide a site of entry for pathogens.

Plant residues should be incorporated after harvest to encourage breakdown of diseased tissues.

Cover crops and compost should incorporated into soil. Both have been shown to build overall soil health and promote buildup of beneficial microorganisms.

Various natural teas have been shown to provide disease suppression in specific pathogen systems. In general, compost teas hold the most promise for promoting, plant health and suppressing buildup of pathogens. Excellent information was recently published by the Organic Farming Research Foundation in the Winter 2001 number 9 information bulletin. Compost teas are very complex and require precise handling to produce efficacious teas.

Cull piles with infested debris should not be dumped on fields scheduled to grow the same crop the following year. Research conducted in the Netherlands has shown that fresh infested cull piles are a significant source of pathogenic bacteria that resulted in the development of a black rot epidemic.

Rotation to a non host crop is always recommended.

Helpful Disease Management References

Sustainable Vegetable Production From Start-Up to Market. Vernon P. Grubinger. NRAES-104, ISBN 0 935817 45 X

Plant Disease Control; towards environmentally acceptable methods. Richard N. Strange. Chapman and Hall, 1993, ISBN 0 442 31666 6

Alternative Agriculture. National Research Council. National Academy Press, Washington, DC 1989, ISBN 0 309 03987 8

The Real Dirt. Edited by Miranda Smith and members of NOFA. 1994, NESARE

Plant Diseases: their biology and social impact. Gail L. Schumann. 1991 APS Press, ISBN 0 89054 116 7

Compost Tea Manual. Karl Rubenberger, 1999. Available from Organic Farming Research Foundation

Web site for info on soil health, etc. Soil Food Web Incorporated. Dr. Elaine Ingham. HTTP://WWW.SOILFOODWEB.COM/SFI_HTML/EZINE/INDEX.HTML

Biocontrol Products, Manufacturer, Active Ingredient

- Mycostop, Kemira Agro Oy, *Streptomyces griseoviridis* strain K61
- RootShield and PlantShield, Bioworks, *Trichoderma harzianum* Rifai strain KRL-AG2
- Aspire, Ecogen, *Candida oleophiia* isolate 1-182
- Serenade (QRD 137), AgraQuest, *Bacillus subtilis* QST 713 strain
- SoilGard 12G, Thermo Trilogy, *Gliocladium virens* GL-21
- AQ10, Ecogen, *Ampelomyces quisqualis*
- Contans, Encore Technologies, *Coniothyrium minitans*

Products from organic origins, Manufacturer, Active Ingredient

- Elexa, Safe Science, chitosan
- Trilogy, Thermo Trilogy, clarified hydrophobic extract of neem oil
- Milsana (a.k.a. BAS 114 UBF and KHHUBF-99-001), KHH BioSci, *Reynoutria sachalinensis* (giant knotweed) extract

Cultural Practices for Disease Management

Curtis Petzoldt
Vegetable IPM Coordinator
Integrated Pest Management Program
New York State Agricultural Experiment Station
Geneva, New York

Resources for Disease and Pest Management

Northeast IPM Web site: HTTP://NORTHEASTIPM.ORG/

New York Resources

HTTP://WWW.NYSIPM.CORNELL.EDU/

1. A Growers' Guide to Cabbage Pest Management in New York
2. Snap Bean Pest Management: A guide to regular field monitoring in New York (manual and video)
3. Integrated Pest Management for Onions (manual and video)
4. Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production

   HTTP://WWW.NYSAES.CORNELL.EDU/RECOMMENDS/
5. Fresh Market Sweet Corn Scouting Procedures

   HTTP://WWW.NYSIPM.CORNELL.EDU/SCOUTING/SCOUTPROC/FMSC99.HTML
6. Processing Sweet Corn Scouting Procedures

   HTTP://WWW.NYSIPM.CORNELL.EDU/SCOUTING/SCOUTPROC/PRSWCORN99.HTML
7. Cucurbit Scouting Procedures

   HTTP://WWW.NYSIPM.CORNELL.EDU/SCOUTING/SCOUTPROC/CUKE00.HTML
8. Tomato Scouting Procedures

   HTTP://WWW.NYSIPM.CORNELL.EDU/SCOUTING/SCOUTPROC/TOM00.HTML
9. IPM Elements

   HTTP://WWW.NYSIPM.CORNELL.EDU/ELEMENTS/INDEX.HTML
10. Hoffmann, M and A. Frodsham, 1993. Natural Enemies of Vegetable Insect Pests. CCE
11. Biological Control: A Guide to Natural Enemies in North America

    HTTP://WWW.NYSAES.CORNELL.EDU/ENT/BIOCONTROL/INDEX.HTML

New York Contacts

C. Petzoldt

A. Seaman

J. Mishanec

Massachusetts Resources

HTTP://WWW.UMASS.EDU/UMEXT/PROGRAMS/AGRO/IPM/

1. General vegetable page with many links

   HTTP://WWW.UMASSVEGETABLE.ORG/

2. Specific crop page with scouting procedures for many crops including: Crucifers, Cucurbits, Herbs, Hydroponics, Legumes, Lettuce and Greens, Peppers, Potatoes, Specialty Crops, Root Crops, Sweet Corn, Tomatoes

   HTTP://WWW.UMASSVEGETABLE.ORG/SOIL_CROP_PEST_MGT/SPECIFIC_CROPS.HTML

Massachusetts Contact

Ruth V. Hazzard
Phone: (413) 545-3696
E-mail: RHAZZARD@UMEXT.UMASS.EDU

Maine Resources

HTTP://WWW.UMEXT.MAINE.EDU/TOPICS/PEST.HTM

1. Potato IPM page

   HTTP://PMO.UMEXT.MAINE.EDU/POTATOES/POTATO.HTM

2. Broccoli IPM page

   HTTP://PMO.UMEXT.MAINE.EDU/BROCCOLI/BROCCOLI.HTM

3. Sweet Corn IPM page

   HTTP://PMO.UMEXT.MAINE.EDU/SWETCORN/CORN.HTM

Maine Contact

Jim Dill
Phone: (207) 581-3880
E-mail: JDILL@UMCE.UMEXT.MAINE.EDU

New Jersey Resources

HTTP://PESTMANAGEMENT.RUTGERS.EDU/

1. Web page has link set up for scouting procedure location but they are not currently present

2. Web page includes IPM Elements for several vegetable crops

   HTTP://PESTMANAGEMENT.RUTGERS.EDU/

New Jersey Contact

Joe Ingerson-Mahar
Phone: (732) 932-9802
E-mail: MATLAR@AESOP.RUTGERS.EDU

Connecticut Resources

HTTP://WWW.HORT.UCONN.EDU/IPM/IPMPROG.HTM

1. Vegetable IPM information and fact sheets for peppers, tomatoes, beans, cole crops; corn, cucurbits, lettuce, potatoes, eggplant and squash

   HTTP://WWW.HORT.UCONN.EDU/IPM/IPMVEG.HTM

Connecticut Contact

T. Jude Boucher
Phone: (860) 875-3331
E-mail: TBOUCHER@CANR.CAG.UCONN.EDU

Delaware Resources

HTTP://WWW.UDEL.EDU/IPM/

1. Sampling Guidelines and action thresholds for Cabbage, muskmelons, potatoes, sweet corn, watermelons

   HTTP://WWW.UDEL.EDU/IPM/THRESH_INDEX.HTML

2. Insect trap catches and disease forecasts plus other reference publications

HTTP://WWW.UDEL.EDU/IPM/

Delaware Contact

Joanne Whalen
Phone: (302) 831-1303
E-mail: JWHALEN@UDEL.EDU

Rhode Island Resources

HTTP://NORTHEASTIPM.ORG/STATES/RI/INDEX.HTML

IPM page does not currently contain much specific vegetable scouting information.

Rhode Island Contact

Richard A. Casagrande
Phone: (401) 8742924
E-mail: CASA@URIACC.URI.EDU

Vermont Resources

HTTP://NORTHEASTIPM.ORG/STATES/RI/INDEX.HTML

IPM page does not currently contain much specific vegetable scouting information.

HTTP://PSS.UVM.EDU/IPM/SMALL.HTM

Vermont Contact

Ann Hazelrigg
Phone: (802) 656-0493
E-mail: ANN.HAZELRIGG@UVM.EDU

West Virginia Resources

HTTP://WWW.WVU.EDU/~AGEXTEN/IPM/

IPM page does not currently contain much specific vegetable scouting information.

West Virginia Contact

Rakesh S. Chandran.
Phone: (304) 293-6131 Ext. 4225

Maryland Resources

HTTP://WWW.AGNR.UMD.EDU/USERS/NRSL/ENTM/

IPM page does not currently contain much specific vegetable information.

Maryland Contact

Sandra Sardanelli
Phone: (301) 405-7877
E-mail: ss11@UMAIL.UMD.EDU

New Hampshire Resources

HTTP://CEINFO.UNH.EDU/AGRICULTURE/DOCUMENTS/AGIPM.HTM

IPM page does not currently contain much specific vegetable information.

New Hampshire Contact

Dr. Alan T. Eaton
Phone: (603) 862-1734
E-mail: ALAN.EATON@UNH.EDU

Pennsylvania Resources

HTTP://PAIPM.CAS.PSU.EDU/

IPM page does not currently contain much specific vegetable scouting information.

HTTP://PAIPM.CAS.PSU.EDU/CGUIDES.HTML

Pennsylvania Contact

Dr. Ed Rajotte
Phone: (814) 863-4641
E-mail: EGRAJOTTE@PSU.EDU

Regional/U.S. References

Peppers

Boucher, T. Jude and Richard Ashley. 2000 Northeast Pepper IPM Manual. University of Connecticut, Communications and Information Technology, 1376 Storrs Rd., U-4035 Storrs, CT 06269-4035. $19.95

Potatoes

Western Regional IPM Project. 1986. Integrated Pet Management for Potatoes in the Western US. University of California Publication 3316.

Hollingsworth, Craig S, David Ferro, and William Coli. 1986. Potato Production in the Northeast: A Guide to Integrated Pest Management. Massachusetts Cooperative Extension Publication C-178.

Rowe, Randall C. 1993. Potato Health Management. APS Press. 3340 Pilot Knob Road, St. Paul, Minnesota. 55121.

Hooker, W.J. 1981. Compendium of Potato Diseases. APS Press. 3340 Pilot Knob Road, St. Paul, Minnesota. 55121.

Cucurbits

Motes, Jim and Gerrit Cuperus. 199?. Cucurbit Production and Pest Management. Oklahoma Cooperative Extension Service Circular E-853.

Bernhardt, Elizabeth, Jeff Dodson, John Watterson. 1988. Cucurbit Diseases: A practical Guide for Seedsmen, Growers, and Agricultural Advisors. PetoSeed.

Zitter, Thomas, Donald Hopkins, and Claude Thomas. 1996. Compendium of Cucurbit Diseases. APS Press. 3340 Pilot Knob Road, St. Paul, Minnesota. 55121.

Onions

Schwartz, Howard F. and S. Krishna Mohan. 1995. APS Press. 3340 Pilot Knob Road, St. Paul, Minnesota. 55121.

Crucifers

University of California IPM program. 1985. Integrated Pest Management for Cole Crops and Lettuce. UC Publication 3307.

Schooley, Jan. 1995. Integrated Pest Management for Crucifers in Ontario: A Handbook for Growers, Scouts and Consultants. OMAFRA

Cucuzza, James, J. Dodson, B. Gabor, J. Jiang, J. Kao, D. Randleas, V. Stravato, and J. Watterson. 199?. Crucifer Diseases: A Practical Guide for Seedsmen, Growers, and Agricultural Advisors. PetoSeed.

Sweet Corn

Adams, Roger and Jennifer Clark. 1995. Northeast Sweet Corn Production and Integrated Pest Management Manual. University of Connecticut Cooperative Extension.

Shurtleff, Malcolm. 1980. Compendium of Corn Diseases. APS Press. 3340 Pilot Knob Road, St. Paul, Minnesota. 55121.

Blair, B.D. et al. 198?. Corn Pest Management for the Midwest. North Central Regional Publication No. 98.

Tomatoes

University of California IPM Program. 1985. Integrated Pest Management for Tomatoes. UC Publication 3274.

Jones, J.B., John Paul Jones, R.E. Stall, T.A. Zitter. 1991. Compendium of Tomato Diseases. APS Press. 3340 Pilot Knob Road, St. Paul, Minnesota. 55121.

Pernezny, K et al. 1995. Florida Tomato Scouting Guide. University of Florida Publication SP-22

IPM, Organic, and Sustainable Agriculture

Appropriate Technology Transfer for Rural Areas

HTTP://WWW.ATTRA.ORG/

Table 1
Cultural Practices for Controlling Plant Diseases

Practice	Conditions Affected	Disease Prevented
Use resistant varieties Manage vectors of diseases	Slows or stops disease development	Many diseases
Staking, pruning Wide-row spacing	Increase air movement and leaf drying	Many foliar diseases
Timely irrigation Use drip instead of sprinkler irrigation	Minimize leaf wetness period Slows or stops disease development	Many foliar diseases
Rogue or destroy infected plants	Slows or stops disease development	Many diseases
Windbreaks	Limit spread of airborne spores	Many foliar diseases
Plastic or straw mulches Do not work in fields with wet foliage	Prevent soil splashing onto foliage, fruit Reduce spread of inoculum	Many foliar diseases
Raised beds Chisel plow or subsoiling	Improve water drainage	Many root and crown rots
Careful cultivation	Promote healthy root growth	Many root and crown rots
Floating row covers Reflective mulches	Reduce aphid (vector) feeding	Many viruses
Use disease free seed or transplants Physically separate plantings	Reduce source of inoculum	Many diseases
Good weed control-on farm	Reduce source of inoculum	Many viruses
Gentle harvest methods	Avoid cuts, bruises	Postharvest diseases
Rapid cooling at harvest Store at cool temperatures	Slow microbial activity	Postharvest diseases
Optimize NPK fertility	Reduce stress, avoid rank growth	Diseases in general
Rotate crops Incorporate crop residues Remove infected crop debris	Reduce inoculum buildup	Diseases in general
Wash equipment frequently	Reduce spread of inoculum	Diseases in general

C. Petzoldt adapted from H. Dillard

Identifying and Encouraging Beneficial Insects

Michael P. Hoffmann
NYS IPM Program and Department of Entomology
Cornell University
Ithaca, NY 14853

Insect and mite pests plague vegetable farmers, causing damage to almost all crops. Many tactics are available to manage insect pests and the integrated pest management (IPM) strategy encompasses them all. Integrated pest management is fundamentally the same as organic pest management except in organic systems there may exist more long-term stability or balance in the overall system for a number of reasons including a more diversified farming system. The two approaches also differ when it comes to the use of pesticides. If pesticides are used in organic farming the options are limited to a relatively few "natural" products. In contrast, the conventional farmer has a multitude of synthetic and natural compounds to use. Like organic pest management, IPM is ecologically based and promotes pest control tactics such as pest-resistant plants, and cultural, mechanical, physical and biological control methods. Regardless, all farmers want to produce safe food with minimal risks to health and the environment.

One pest management tactic that is common to all vegetable farms and is generally free is biological control. All insect pests have natural enemies. These organisms may be predators, parasitoids or disease-causing pathogens. The use of these organisms to manage pests is known as biological control. The emphasis here is on the biological control of insects, though biological control is also very important for the control of weeds and plant diseases.

Predators

Predators such as lady beetles and lacewings, are mainly free-living species that consume a large number of prey during their lifetime. They include many beetle, bug, fly, mite, and spider species. Both adults and immatures are relatively mobile and search for prey. In some species such as lady beetles, both the larvae and the adults feed upon prey. In others, such as syrphid flies or lacewings, only the larvae consume insect prey. The adults may obtain nourishment by feeding on nectar or pollen. Examples of some common predators include:

Lady beetles

Adult lady beetles are small, round to oval, and dome-shaped and live for a few months to over a year. Lady beetle larvae are dark and alligator-like with three pairs of prominent legs. Both adults and larvae are predacious. Lady beetles overwinter as adults, often in aggregations along hedgerows, beneath leaf litter, under rocks and bark, and in other protected places including buildings. In spring, the adults disperse in search of prey and suitable egg laying sites.

Female lady beetles may lay from 200 to more than 1,000 eggs over a one to three month period, commencing in spring or early summer. Eggs are usually

deposited near prey such as aphids, often in small clusters in protected sites on leaves and stems. The more common species typically have one to two generations per year.

Most lady beetles found in vegetable crops and gardens are aphid predators. Some species prefer certain aphid species while others will attack several species on a variety of crops. If aphids are scarce, lady beetle adults and larvae may feed on the eggs of moths and beetles, and mites, thrips, and other small insects, as well as pollen and nectar. They may also be cannibalistic. Because of their ability to survive on other prey when aphids are in short supply, lady beetles are particularly valuable natural enemies.

Lady beetles are voracious feeders and may be numerous where prey are plentiful. Lady beetles need to eat many aphids per day so that they can lay eggs. The convergent lady beetle may eat its weight in aphids every day as a larva and consume as many as 50 aphids per day as an adult. Sevenspotted lady beetle adults may consume several hundred aphids per day and each larva eats 200 to 300 aphids as it grows.

Green lacewings

The common green lacewing is native to much of North America. Adults feed only on nectar and aphid honeydew, but their larvae are active predators. Adult green lacewings are pale to bright green, about ~1/2 to 3/4" long, with long antennae. Large, transparent wings are held upright over a fragile body. Some species have prominent, golden eyes. Adults are active fliers, particularly during the evening and night. Through spring and summer, the female lays several hundred small eggs, each at the end of a long silk stalk, sometimes in clusters, on leaves or twigs in the vicinity of aphids. The larvae are pinkish brown and cream, and alligator-like with well-developed legs and large, prominent pincer jaws, used to suck the juices from prey. They are very mobile and grow through three instars, in about two to three weeks.

Reported prey include several species of aphids; thrips; mites; whiteflies; eggs of leafhoppers, moths, including diamondback moth, cabbage looper, and corn earworm, Colorado potato beetle, asparagus beetle, and, possibly, leafminers; small caterpillars and beetle larvae, including small larvae of Colorado potato beetle. Lacewing larvae are generalist beneficials but are best known as aphid predators. The larvae are sometimes called aphid lions. Various reports suggest that developing lacewing larvae eat from 100 to 600 aphids. Larvae and adults may be common in sweet corn and field crops through summer.

Hover or syrphid flies

Adult hover flies resemble bees or wasps and are usually seen on or near flowers. The male flies have a distinctive hovering and darting habit. Hover flies range in size from quite small to a little larger and narrower than houseflies. The female hover fly lays single elongated eggs near or among aphid infestations. Females may lay several hundred eggs through mid-summer; the larvae hatch after two to three days. The small, cylindrical, legless maggots vary in color from cream to green to brown, depending on the species and prey consumed. They develop a "slug-like" form, up to ~1/2" long, tapered towards the head. The larvae can move around leaves and through the canopy in search of prey. The period from egg to adult ranges from two to six weeks, depending on the temperature, species, and availability of aphids. If aphids are plentiful, there may be five to seven generations per year.

Hover flies larvae feed on aphids, small caterpillars, and, possibly, thrips. Hover fly larvae have been recorded as predators of the larvae of European corn borer and corn earworm. In vegetable crops hover fly larvae may be most apparent from mid-summer to fall. This may be after the initial aphid infestation has established, depending on the crop, species, and region. Hover fly larvae are voracious aphid predators. A single larva may consume up to 400 aphids during development, depending on species of hover fly and aphid.

Bats

These natural predators are often overlooked as possible biological control agents. One reason is the difficulty in proving that they actually reduce pest infestations. However piecing together the existing information and knowing that they consume large numbers of insects strongly implies that they do provide farmers some benefit. Another point to bear in mind is that bats feed at night in contrast to most beneficial insects, which seek prey during the day. Thus bats complement the benefits derived from insect natural enemies. The reason not much is known about the potential ben-

efit derived from bats and birds is that they prey mostly on highly mobile adult insects and the impact on this stage has been exceedingly difficult to study.

The bats common to central New York include the little brown bat (*Myotis lucifugus*), big brown bats (*Eptesicus fuscus*), hoary bats (*Lasiurus cinereus*) and red bats (*Lasiurus borealis*). Little brown bats can eat up to 1200 mosquito sized insects in an hour. Big brown bats consume insects at a rate of 500 per hour. Bats are free to farmers and there are no environmental side effects associated with their use.

Parasitoids

Parasitoids are species which have an immature stage that develops on or within a single insect host, ultimately killing the host. The adult parasitoid lays her eggs on, within, or near the host. The immature parasitoids, which hatch from the eggs, are entirely dependent on their host for nourishment. They feed (internally or externally) on the host, developing to maturity and eventually leaving the host as adults or to complete development. Adult parasitoids may be predatory or they may seek other food sources. Many species of wasps and some flies are beneficial parasitoids. Examples include:

Aphid parasitoids

Aphidiid wasps attack only aphids. Adults are very small (~1/8") and dark, with long antennae. Typically, females lay up to several hundred eggs. One larva develops within each aphid. The larva either emerges to spin a cocoon under the dead aphid or pupates within the tanned and mummified aphid body. The adult wasp emerges after cutting a circular hole in its cocoon. Adults live from one to three weeks, and there can be many generations per year. Some species overwinter within the mummified aphid host.

The most conspicuous sign of aphidiid activity is the presence of aphid "mummies." The mummies may occur within an aphid colony or be found singly on leaves or stems. *Praon* species spin their cocoon beneath the aphid body to encase the developing parasitoid pupa. Most aphid species will be parasitized to some extent if aphidiid wasps are present. Different wasp species may parasitize different aphid species.

Egg parasitoids

Trichogramma species are egg parasitoids with a very wide host range, especially among the moths. Several species have been mass reared for use in biological control programs. The adult wasps are minute, mostly 1/50" long. The female wasp lays one or more eggs in an egg of the host insect, and one or several parasitoids may develop. *Trichogramma* species pupate within the host egg. Adult wasps emerge seven to 10 days after the egg is deposited. Warm temperatures favor development and many generations may be produced each season. *Trichogramma* overwinter in the host egg, emerging as adults the following spring. Eggs usually turn black as the parasitoids develop inside. A small hole in the black host egg indicates that the wasps have emerged. Reported hosts include eggs of caterpillar (worm) pests such as European corn borer, corn earworm, imported cabbageworm, diamondback moth, cabbage looper, and tomato and tobacco hornworm. *Trichogramma* are particularly good natural enemies of caterpillars because they parasitize and kill the pest in the egg stage, before the crop is damaged.

Worldwide, no other group of parasitoids has been used as extensively as the *Trichogramma* for direct control of pests, and considerable effort has gone into the mass rearing and release technology. Experimental or commercial biological control programs with *Trichogramma* have been undertaken or are available for control of pests of corn, cotton, cabbage, pea, avocado, tomato, forests, soybean, rice, and citrus. The successful use of commercially reared *Trichogramma* requires that the correct species be used, that it be of high quality, and that the parasitoid be released at the appropriate rate and when the host eggs are present. Users should follow directions very carefully and examine the release units before, and several days after, placing them in the field to see if the material is viable and to determine if the *Trichogramma* actually emerged (exit holes should be present in each egg). To determine if the releases are providing some control, pest eggs can be collected at the release site and observed for parasitism. Note, however, that naturally occurring (not released) *Trichogramma* may also be present.

Tachinid flies

Adult tachinid flies are often gray, reddish, or yellowish-brown, heavily bristled (or fuzzy), and about 3/8 to 1/2" long. Some tachinid flies resemble large, bris-

tly house flies. Females may place their small eggs directly on their host. Some species inject living larvae directly into the host; others lay eggs or larvae on a leaf surface where they can be eaten by the host, or at the entrance of a host cavity or feeding tunnel from where the larvae seek the host.

The larvae or maggots are grayish or greenish-white; they may have thick bodies with tiny spines or even plates. Usually only one larva survives per host. The larvae of many tachinid species bore out of the host to pupate, often in the soil. The time spent as larvae or pupae can be days or months, depending on the species. Tachinids overwinter as larvae or pupae within the host body. There may be one or several generations each season. Tachinid adults searching for hosts may walk rapidly over leaf or soil surfaces, moving in hops and small flights around their target. Caterpillars and beetle larvae become extremely agitated in their efforts to fend off attack by a fly and will attempt to remove the eggs from their body. Reported Tachinid hosts include larvae of European corn borer, corn earworm, imported cabbageworm, cabbage looper, potato stem borer, stalk borer, cutworms, armyworms, Mexican bean beetle, and Colorado potato beetle; stink bug and squash bug nymphs and adults; and adult tarnished plant bugs and cucumber beetles.

Immature insects parasitized by tachinids and other parasitoid flies invariably die. Parasitized adults may continue to lay eggs before succumbing but parasitized hosts are generally less able to survive environmental stresses and consequently their lifespan is shorter than unparasitized individuals. Some adult tachinids also feed on pest insects. Tachinid populations can increase very quickly and their high fecundity and relatively short life cycle give them a competitive edge over many of their hosts.

Pathogens

Pathogens are disease-causing organisms including bacteria, fungi, viruses and nematodes. They kill or debilitate their host and are relatively specific to certain insect groups. Their effectiveness can be dependent on environmental conditions such as humidity and frequently they are most effective when the susceptible insect species occurs at high densities (crowded conditions). Under the correct environmental conditions, certain diseases can decimate insect populations.

Bacteria

Over 90 species of naturally occurring, insect-specific (entomopathogenic) bacteria have been isolated from insects, plants, and the soil, but only a few have been studied intensively. Much attention has been given to *Bacillus thuringiensis* (Bt), a species that has been developed as a microbial insecticide. *Bacillus thuringiensis* occurs naturally in the soil and on plants. Different varieties of this bacterium produce a crystal protein that is toxic to specific groups of insects. Bt has been available in North America as a commercial microbial insecticide since the 1960s and is sold under various trade names. These products have an excellent safety record and can be used on crops until close to the day of harvest. Bt can be applied using conventional spray equipment but, because the bacteria must be eaten to be effective, good spray coverage is essential.

Fungi

Some insect species, including many pests, are particularly susceptible to infection by naturally occurring, insect-pathogenic fungi. These fungi are very specific to insects, often to particular species, and do not infect animals or plants. Fungal growth is favored by moist conditions but fungi also have resistant stages that maintain infection potential under dry conditions. Fungi can spread quickly through an insect population and cause its collapse. Because fungi penetrate the insect body, they can infect sucking insects such as aphids and whiteflies that are not susceptible to bacteria and viruses.

Fungi invade insects by penetrating their cuticle or "skin." Once inside the insect, the fungus rapidly multiplies throughout the body. Death is caused by tissue destruction and occasionally by toxins produced by the fungus. The fungus frequently emerges from the insect's body to produce spores that, when spread by wind, rain, or contact with other insects, can spread infection. Infected insects stop feeding and become lethargic. They may die relatively rapidly, sometimes in an upright position still attached to a leaf or stem, perhaps in an elevated location or concentrated near crop borders. Infected root maggot flies may be clustered on shoot tips, tall grasses, or other prominent features.

Most insect pests of vegetables are susceptible to fungal pathogens. Some fungi, such as the *Entomophthora* and related species, are fairly specific with regard to the groups of insects affected; others, such as *Beauveria*, have a wider host range.

Insect-pathogenic fungi usually need moisture to enable infection, and natural epizootics are most common during wet or humid conditions. The effectiveness of these fungi against pest insects depends on having the correct fungal species and strain with the susceptible insect life stage, at the appropriate humidity, soil texture (to reach ground-dwelling pest species), and temperature. The fungal spores, which can be carried by wind or water, must contact the pest insect to cause infection. Naturally occurring fungal epizootics may decimate aphid, root maggot fly, caterpillar, leafhopper, and thrips populations. Some examples include:

- *Entomophthora muscae* infects flies. Susceptible pest species include the adults of the onion maggot, cabbage maggot, and seedcorn maggot. The fungus multiplies within the body of the adult fly which becomes enlarged; yellowish bands of fungal spores stripe the abdomen.

- *Beauveria bassiana* is an insect-pathogenic fungus found naturally on some plants and in the soil. Epizootics are favored by warm, humid weather. It is known as the white muscardine fungus because infected insect larvae eventually turn white or gray. Susceptible insects include the larvae of European corn borer, Colorado potato beetle, and Mexican bean beetle. Unfortunately, natural enemies, such as some lady beetles, can be susceptible to some fungi.

Viruses

Insect-specific viruses can be highly effective natural controls of several caterpillar pests of vegetable crops. Different strains of naturally occurring nuclear polyhedrosis virus (NPV) and granulosis virus are present at low levels in many insect populations. Epizootics can occasionally devastate populations of some pests, especially when insect numbers are high.

Insect viruses need to be eaten by an insect to cause infection, but may also spread from insect to insect during mating or egg laying. In some cases, for example while searching for suitable hosts for egg laying, beneficial insects such as parasitoids may physically spread a virus through the pest population. Insect viruses pose no threat to humans or wildlife. Viruses can overwinter in the environment or in overwintering insects to re-establish infection in subsequent seasons. The successful commercialization of insect-pathogenic viruses has been limited.

Viruses invade an insect's body via the gut. They replicate in many tissues and can disrupt components of an insect's physiology, interfering with feeding, egg laying, and movement. Different viruses cause different symptoms. NPV-infected larvae may initially turn white and granular or very dark. Some may climb to the top of the crop canopy, stop feeding, become limp, and hang from the upper leaves or stems, hence the common name "caterpillar wilt" or "tree top" disease. Victims of a granulosis virus may turn milky white and stop feeding. In both cases, the body contents of the dead larvae are liquefied and the cuticle ruptures easily to release infectious viral particles. Death from a virus infection usually occurs within three to eight days.

Naturally occurring viruses may affect many caterpillar pests of vegetables. Isolates of NPV have been successfully tested in field trials against corn earworm, imported cabbageworm, cabbage looper, armyworms, and European corn borer. Preparations of granulosis virus have been isolated from several caterpillar species, including imported cabbageworm, cabbage looper, armyworm, and fall webworm.

Nematodes

These are not the plant-attacking species of nematode, but beneficial, insect-attacking nematodes (or very small roundworms). Many species of naturally occurring, beneficial nematodes live both in the soil and on plant material. The role of many of these species is not well known, but some nematode species have received attention as potential biological control agents. Several species can now be mass produced and some are available commercially.

The commercially available nematodes are species of *Steinernema* and *Heterorhabditis*. Mass reared nematodes are shipped live as a suspension within a specially formulated gel, as a slurry adhering to sponge material, or in clay. When water is added, the nema-

todes are released from their carrier. These nematodes are too small to see without a microscope and there may be millions of squirming little worms in each handful of soupy mixture.

Some nematodes actively seek suitable hosts, often attracted by the carbon dioxide emitted by their prey. Others wait for passing prey. They carry insect-pathogenic bacteria within their gut. Different nematode species carry different species of bacteria. Once the nematode penetrates its host, usually through any available opening, the bacteria multiply and kill the pest by septicemia. The nematodes feed on the bacteria and insect tissue, then mate, and reproduce. After one to two weeks, young nematodes emerge from the dead insect to seek out and colonize new hosts. Affected insects usually die within one or two days. Those killed by *Steinernema* species turn a brownish-yellow color from the bacterial infection. Insects killed by *Heterorhabditis* nematodes become red and gummy.

Many vegetable pests are susceptible to attack by nematodes but, for many, the potential of nematodes for field control has yet to be evaluated. Candidates for control include soil-dwelling larvae such as those of cucumber beetles, cutworms, and armyworms, carrot, sweet potato, and other root weevils, Japanese beetle, squash borers, root and seed maggots, and fall armyworm and corn earworm in corn.

Types of biological control

Conservation

The conservation of natural enemies is probably the most important and readily available biological control practice available. Natural enemies occur in all vegetable production systems, from the backyard garden to the commercial field, they are adapted to the local environment and to the target pest, and their conservation is generally simple and cost-effective. With relatively little effort the activity of these naturally occurring beneficials can be observed. Lacewings, lady beetles, syrphid fly larvae, and parasitized aphid mummies are almost always present in aphid colonies. Fungus-infected adult flies are often common following periods of high humidity. These natural controls are important and need to be conserved and considered when making pest management decisions. In many instances the importance of these naturally occurring beneficials has not been adequately studied. The best we can often do is to recognize that these factors are present and minimize negative impacts on them.

Classical biological control

In many instances the complex of natural enemies associated with an insect pest may be inadequate. This is especially evident when an insect pest is accidentally introduced into a new geographic area without its associated natural enemies. These introduced pests comprise about 40% of the insect pests in the U.S. Examples include the European corn borer, cereal leaf beetle, and Japanese beetle. To obtain the needed natural enemies we turn to classical biological control. Classical biological control is the practice of importing and releasing natural enemies to help control introduced pests, although it is also practiced against native insect pests. The first step in the process is to determine the origin of the introduced pest and then collect appropriate natural enemies (from that location or similar locations) associated with the pest or closely related species. The natural enemy is then passed through a rigorous quarantine process to ensure that no unwanted organisms are introduced. The natural enemy is then reared, ideally in large numbers, and released. Follow-up studies are conducted to determine if the natural enemy successfully establishes at the site of release and the long-term impact (benefit) of its presence.

There are many examples of successful classical biological control programs. Damage from the alfalfa weevil, a serious introduced pest of forage, was substantially reduced by the introduction of several natural enemies. There are many classical biological control programs underway across the U.S. and around the world.

Augmentation

The third type of biological control is augmentation, which involves the supplemental release of natural enemies. A relatively few natural enemies may be released at a critical time of the season (inoculative release), or literally millions may be released (inundative release). Additionally, the cropping system may be modified (habitat manipulation) to favor or augment the natural enemies. An example of inoculative release occurs in greenhouse production of tomatoes and cu-

cumbers. Periodic releases of the parasitic wasp, *Encarsia formosa*, are used to control greenhouse whitefly; the predacious mite, *Phytoseilius persimilis*, is used for control of the two-spotted spider mite.

Lady beetles, lacewings, or parasitic wasps such as *Trichogramma* are frequently released in large numbers. Recommended release rates for *Trichogramma* in vegetable or field crops ranges from 5,000 to 200,000 per acre per week depending on level of pest infestation. Research over the past several years has demonstrated the *Trichogramma ostriniae*, an egg parasitoid originally from China, is effective for suppression of European corn borer in sweet corn. Releases of 30,000 wasps per acre when corn is 18 inches tall and corn borer is active should result in suppression of the pest and damage. The released female wasps seek out and insert their eggs into eggs of European corn borer. Larvae hatch from the eggs and consume the contents of the corn borer egg, killing the developing borer larvae in the process. From these eggs emerge more moths and the process continues through the season. *T. ostriniae* does not survive winters in New York so it has to be released each year – fields need to be "inoculated" each season. This species is now available for purchase and release. Recent work has shown that *T. ostriniae* also holds potential against corn borer in peppers and potatoes.

Many commercial insectaries rear and market a variety of natural enemies including predaceous mites, lady beetles, lacewings, praying mantids, and several species of parasitoids. Success with such releases requires appropriate timing (the host must be present or the natural enemy will simply die or leave the area) and release of the correct number of natural enemies per unit area (release rate). In many cases, the most effective release rate has not been identified as it will vary depending on crop type and target host density. Success also requires a healthy and robust natural enemy.

Conserving and encouraging natural enemies

Natural enemies are present all systems and their conservation and enhancement should be encouraged. Manipulating the farm system to augment the effectiveness of a natural enemy is relatively straightforward. Most beneficial wasps, flies, and many of the predatory insects benefit from sources of nectar and the protection provided by refuges such as hedgerows, cover crops, and weedy borders. Mixed plantings and the provision of flowering borders can increase the diversity of habitats and provide shelter and alternative food sources. Examples of habitat manipulation include the planting of flowering plants (pollen and nectar sources) near crops to attract and maintain populations of natural enemies. For example, syrphid fly adults can be attracted to umbelliferous plants in bloom. Caution should be used with this tactic because some plants attractive to natural enemies may also be hosts for certain plant diseases, especially plant viruses that could be vectored by insect pests to the crop. Although the tactic appears to hold much promise there are only a few examples that have been adequately researched and developed.

Lady beetles. Some species, in particular *Coleomegilla maculata*, consume pollen as an important part of their adult diet. A source of nectar and pollen, or an artificial substitute, in the vicinity of the crop may attract adult beetles and may reduce dispersal of this and other lady beetle species. Lady beetle adults also benefit from high humidity and nearby shelter, for protection from adverse weather and to provide overwintering sites.

Early season populations of some lady beetles may develop on aphid-infested perennials or shrubs. Collection and redistribution of lady beetles is effective but time consuming. The beetles should be handled gently and placed in groups at the base of plants, rather than broadcast. Hibernating adults, congregating in protected spaces, should not be disturbed as they are vulnerable to attack by predators and parasitoids if uncovered.

Lastly, a healthy soil with ample organic matter is not only good for crops, but can profoundly influence the nematode community structure. A healthy soil can increase the total number of nematodes so that predaceous nematodes and nematode attacking fungi can flourish. Generally, a healthy soil tends to reduce plant-attacking nematodes.

Given the lack of our full understanding of natural enemies and their interactions with pests, the best we can often do is to learn what they look like or signs of their activity and then minimize disturbance of the system.

References and additional reading

Bat Conservation International. 2000. <HTTP://WWW.BATCON.ORG/>.

Cunningham, S. J. 1998. Great Garden Companions—A companion planting system for a beautiful chemical-free vegetable garden. Rodale Press: Emmaus.

Flint, M. L. and S. H. Dreistadt, 1998. Natural Enemies Handbook—the illustrated guide to biological pest control. Univ. Calif. Div. Agric. and Nat. Res. Publication 3386.

Weeden, C., A. M. Shelton, L. Yi and M. P. Hoffmann. Biological control: A guide to natural enemies in North America. World Wide Web Document. Cornell University <HTTP://WWW.NYSAES.CORNELL.EDU/ENT/BIOCONTROL/>

Credit, excerpted material

Some of the material contained in this proceedings was excerpted from the following publications.

Hoffmann, M. P. 1999. Biological control of insects: Past, present and future. pp. 9-12. *In* K. Stoner (ed.). Proceedings, Farmer/Scientist Conference on Alternatives to Insecticides in Managing Vegetable Insects Dec. 6-7, 1998, New Haven, CT. NRAES-138, Ithaca, NY.

Hoffmann, M. P. and A. C. Frodsham. 1993. Natural enemies of vegetable insect pests. Cooperative Extension, Cornell University. 64 pp.

Insect Management: Managing Beneficial Habitats, Using Organic Insecticides

Ruth Hazzard
Dept. of Entomology
University of Massachusetts Extension
Amherst, MA 01003
Phone: (413) 545-3696
Email: RHAZZARD@UMEXT.UMASS.EDU

What's different about insect management on organic farms?

Scale and diversity

While its not always the case, organic vegetable farms tend to be smaller in acreage and at least as, if not more, diversified than conventional farms. This has the benefit that there are smaller plantings of any given crop at any given time (no massive monocultures), but the disadvantage that it can be difficult to rotate as far as is needed to escape a given pest. Another benefit is that is spreads the risk. If you lose one crop in a given year, you have 70 others to sell. If you lose the early planting, there will be several more coming along.

Attitude

I find that organic farmers are willing to tolerate higher levels of damage as the crop grows, and sometimes in the final product. Sometimes this is based on a certain philosophical view of nature and farming (nature is basically benign; as a farmer I am working *with* nature, not trying to overcome it; there is abundance enough to provide for what I need and the bugs, too) or sometimes its just accepting and making the best of what you can't do anything about (the flea beetles are munching on my early brassicas, but I can't afford row cover and I'll just hope they tough it out and outgrow it; OR leafhoppers brought down my potatoes early, so I'll just harvest them now, put them in small bags, and charge extra for small potatoes). Another approach is, if one crop is too difficult to grow organically, I'll grow a different crop.

Market demands

While wholesale organic markets can be just as demanding (zero tolerance for damage) as conventional markets, many organic growers choose markets that have more tolerance for damage, and this provides some leeway. This includes farmers markets and CSA's. Holey brassica greens (from flea beetle damage) go over OK in a CSA box or at a farmers market, but they would not do so well in a pallet going to Bread and Circus. NO markets get excited about wormy corn. However, I know organic farmers who are succeeding very well in very demanding wholesale markets and I know organic CSA's and farm stands who only put out the very best quality.

More attention to rotation, soil building and cover crops

On most organic farms, there is more willingness to invest in long-term soil building and to take land out of active production for a year or more and put it into cover crops. There may be more thought given to ro-

tational planning (though I find that conventional farmers do a lot this planning, too).

More commitment and interest in long-term whole-system strategies

There are organic farms that have been able to reach the point where they don't spray any organic pesticides and they have high-quality crops all season long. This represents the outcome of years of watching, adjusting, fine tuning, combining a whole array of practices and choices to create a whole system that works. It also requires adjusting what you grow and when, as well as using a host of cultural practices to minimize pests.

Beneficial insects (predators and parasites) have more opportunity to build up

Beneficial insects (predators and parasites) have more opportunity to build up to higher population levels, and very likely have more impact on pest populations. These natural enemies include lady beetles, spiders, spined soldier bugs, insidious flower bugs, green lacewings, syrphid fly larvae, and a host of parasitic wasps. Often you don't know these are present until you knock them out. There are only a few broad-spectrum toxins that organic growers can use (rotenone, pyrethrin), and most use them very sparingly.

The most striking example I've seen of this is corn leaf aphids in sweet corn. Aphids colonize organic corn just as they do conventional corn, but in years of scouting both types of farms, I've never (really, not ever! as strange as it may seem) seen the huge buildup of aphids in tassels on organic farms that is fairly common in conventional sweet corn. The difference: conventional farms routinely use broad-spectrum insecticides at least once in most corn plantings, knocking out natural enemies. Another factor may be the type of fertilizer. High levels of nitrogen from soluble fertilizers tend to foster higher aphid populations. In peppers, we have documented that use of permethrin results in aphid outbreaks, compared to very low numbers where no broad-spectrum insecticides were used.

You can't just knock out the pest, so you get creative

There are a number of key pests for which there is no knockdown organic insecticide. This means that you *have* to find other means and you are willing to try more expensive, creative, and innovative strategies.

Costs are higher

This all adds up to the fact that it costs more to produce a bushel of a given organic produce than it does to produce a bushel of conventional produce.

Prices are higher (sometimes)

The price differential is especially noticeable at the wholesale level, especially when demand is high and supply is low in the organic channels. The value of a box of wholesale organic produce in mid-season is the envy of any conventional farmer. At the farmers market, consumers may or may not care enough to spend more at your stand than someone else's who is not organic. CSA growers get essentially retail prices, without as much of the cost of running a retail stand.

What insect pests are the biggest challenges?

Beetles

Beetles, especially the leaf-feeding beetles (Chrysomelids): Colorado potato beetle, flea beetles, cucumber beetles. The options for beetle control (rotenone, pyrethrin) are short-lived and not very effective. These beetles overwinter as adults in field borders, colonize the crop very fast, and cause immediate damage. Some (e.g. striped cucumber beetles) also vector diseases. Lack of control in one year or one generation can result in buildup of populations in the next generation or next year. In a small-scale farm, it is difficult to rotate far enough to escape them. However, the arrival of spinosad as a control option will make some of these easier.

Migratory pests

These arrive suddenly in large numbers, do not have many natural enemies, and can be difficult to control. These include corn earworm in corn, and potato leafhopper in beans, and potatoes.

Root maggots

Root maggots, such as cabbage root maggot fly, which attacks spring brassica crops. Efforts to find effective biocontrols have failed. Row covers, soil health, crop rotation, and plant timing are key strategies.

Thrips

Thrips attack onions and cole crops. Often not a pest, but can bring crops down at high numbers and if crops are otherwise stressed.

Tarnished plant bug

This pest has a huge host range and causes damage to fruit (e.g. strawberries) and leaves (e.g. basil, pepper)

Mexican bean beetle

What pests are easy to deal with?

Caterpillars, especially those on brassicas. *Bacillus thuringiensis* (Bt) products work very well. European corn borer in sweet corn also can be effectively controlled with Bt sprays. Spinosad will add another effective tool.

What strategies help organic growers successfully prevent losses to insects?

Soil health, good production practices

Healthier crops do sustain less damage or tolerate and outgrow damage more readily.

Using IPM tools

Prevent pests using cultural practices, monitor pest conditions in the field; spray at the critical time the pest reaches economic thresholds. An example: an organic pepper grower who uses pheromone traps to detect European corn borer flight, then when the threshold is reached, applies Bt every 4-5 days during the flight period. Another example is a sweet corn grower who uses the pheromone traps to detect corn earworm flight, and applies oil to fresh silks when the flight reaches damaging levels.

Timing of plantings

Timing of plantings can help avoid periods of high pest pressure.

Plant early

Sweet corn: plant by mid May to avoid corn earworm, which migrates into the region in late July or August.

Plant late

Potato: plant early or mid June to avoid Colorado potato beetle, which emerges from overwintering sites late May to mid June. If beetles find no food source, they migrate elsewhere in search of host crops. Use early varieties to ensure maturity before season's end.

Crucifers: plant after mid-May to avoid spring cabbage root maggot fly (first flight active from late April to mid May); plant after mid July to avoid the first generation of flea beetle.

Vine crops: set out transplants after the middle of June to avoid the worst of the striped cucumber beetle, and get past the most susceptible early stages (cotyledon to 3 leaves).

Floating row covers. There are several different weights of floating row covers (e.g., Reemay, Typar), spun-bonded polypropylene covers, which can be laid directly over the crop or supported by hoops. Air and water travel through the cloth, but insects cannot (assuming edges are sealed). This is an excellent pest control as well as providing some frost protection and added air and soil warmth for earlier yields. Widely used by organic growers for:

1. Cabbage root maggot fly on spring crucifers. Eggs are laid at the base of the stem by first-generation adults, which fly from late April to mid May. Maggots feed on roots and kill early cole crop seedlings. Row covers are a very effective control.

2. Flea beetles on greens (crucifers and others). Tiny black beetles cause shot-hole feeding. Can be used all summer on direct-seeded crops, or in spring or

fall on transplants. Too hot for transplants in mid-summer.

3. Leaf miner on spring spinach and chard. A fly which lays eggs on underside of leaves, maggots tunnel inside leaf.

4. Cucumber beetle on melons, summer squash, cukes, winter squash. Protects both from feeding damage and vectoring of bacterial wilt. Must be removed at flowering.

5. European corn borer on early corn. Speeds growth of early corn and protects from moths if left on into mid to late June, after first flight has peaked. Apply loosely to allow for corn growth.

Interplanting and bio-strip intercropping

Build into the farm plan plants which provide resources for natural enemies, including those in the Umbelliferrae and Compositae families, which attract parasitic wasps and predaceous flies and beetles because their flowers have short nectaries. These resources can also be provided in sod strips between beds, or in border areas. May be mowed at key times to encourage flowering, or produce mulch.

Mulch or cover crops

Using strips of unmowed rye between rows of potato or cucurbits can reduce colonization by beetles. Similarly, rye or straw mulch has been shown to reduce colonization of potato by Colorado potato beetles.

Organic pesticides: using the tools we have

Many organic growers do spray for insect pests, but the tool box is very limited. Active ingredients and specific formulated products have to be approved by the National Organic Program. Several new options have recently been developed and approved, or are expected in the next year or two.

Bacillus thuringiensis (Bt)

Derived from a naturally-occurring bacterial pathogen, Bt has been isolated and formulated for use as a foliar spray. A tried-and-true organic tool. Organic growers use *Bt kurstaki (Dipel DF, Javelin WG* or *Bt aizawi* (e.g. Xentari) products against caterpillars and *Bt tenebrionis* (e.g. Novodor, Beetle Beater) against Colorado potato beetle. These are only good against larval stages. Some products contain prohibited inerts (e.g. mineral oil in Dipel ES) or have been genetically manipulated (e.g. Raven, Mattch) so are not allowed. And transgenic Bt plants are prohibited (as are contaminated kernels that might have resulted from the pollen of your neighbor's Bt corn). The manufacturer of Dipel has produced a special formulation of Dipel ES for the organic market, and it is making its way through the approval process. This is an indication that the organic farming industry has grown to a significant size.

Insecticidal soaps

Insecticidal soaps are made from the soaps of fatty acids, and are used as contact insecticides to control soft-bodied pests such as aphids, thrips, whiteflies, leafhoppers, some immature caterpillars, and mites. Good coverage and repeated applications are important, but it does work. Non-persistent, low toxicity. (M-Pede, Safer's Soap, Concern).

Vegetable oil

Used against corn earworm in direct silk applications to sweet corn. Corn oil or soybean oil may be used. Acts by creating a suffocating barrier to larvae crawling down the silk channel. Most effective when mixed with a Bt product. Exempt from FIFRA and food tolerance requirements. A specially-designed oil applicator (Zealater) is available from Johnny's. For more info, see <HTTP://WWW.UMASSVEGETABLE.ORG/>.

Beauvaria bassiana

One of several naturally-occurring fungal pathogens of insects. Spores are applied directly to insects or to plant surfaces or other habitats (e.g. soil), where insects pick them up on their bodies. Under favorable conditions (warmth and high humidity), spores germinate and penetrate the cuticle, and produce toxins that kill the insect. Hyphae grow fill the insect's body, often producing fuzzy white growth that is visible on the outside. Most effective when used in high humidity environments. (Naturalis-O, Botanigard 22W, ES, Mycotrol) GH, field. Note that Botanigard ES can cause oedema in greenhouse tomatoes; use the 22W formulation on tomato.

Kaolin clay

Fine white clay which disturbs insects' visual and tactile cues on host plants; adheres to insects. Beetles, soft-bodied insects. Labeled for flea beetles on fruiting crops, and cucumber beetle on cucurbits, thrips on onions. (Surround WP). Wear a mask or respirator to protect from inhalation.

Spinosad

Derived from an actinomycete fungus that is pathogenic to insects. Spintor 2SC has been on the market for several years, but was not allowed for organic production. In 2003 there will be a newly labeled formulation (Entrust) that has NOP approval. It is effective against caterpillars, Colorado potato beetle (CPB), thrips and leafminers and is labeled for fruiting vegetables, potatoes, brassicas, and cucurbits. This will be a big boon for CPB control, because it works against adults.

Botanicals (extracted from plants)

Neem

Extracts from the tropical neem tree have been used for centuries in insect control. Neem oil acts upon immature insects an insect growth regulator, disrupting their molting process. It is also an antifeedant and oviposition deterrent. It works slowly and should be applied several times well before numbers reach damaging levels to get the best results. (Azadirect, Azatin, Neemix, Bioneem, Align; Trilogy 90, Neemazad, Triact; active ingredient is azadirachtin).

Rotenone

Broad activity against a wide range of insects, especially beetles. Hard on beneficials; highly toxic to fish; applicators should use protective gear.

Pyrethrin

From the flowers of certain species of *Chrysanthemum*. Broad activity as a nervous system toxin, against a wide range of insects. Hard on beneficials, but low mammalian toxicity. Often mixed with piperonyl butoxide (PBO) as a synergist, but this makes it prohibited. Pyganic Crop Protectant is currently the only approved pyrethrin product.

Hot pepper wax

Capsacin (the "hot" component in hot peppers) micro-encapsulated in a mixture of mineral oil and paraffin, which adheres to plant surfaces. Acts primarily as an insect repellent, but is also a toxin to insects and mites. Looked promising vs. flea beetle in brassica greens in a UMass trial in 2002. (Hot Pepper Wax Insect Repellent)

Garlic oil

(Envirepel, Garlic Barrier, Garlic Grow)

More on biological control

Conservation of natural enemies

As mentioned above, using selective insecticides that do not harm beneficials, and providing them with resources such as nectar and shelter, increase the level of biocontrol that is taking place. In certain instances, **augmentation**, or the release of mass-reared beneficials, can also help in suppressing pests. This tends to be more successful in greenhouses than in the field, but there are now several instances where releases in the field have been proven to suppress, if not completely control, key pests.

A useful directory for choosing a natural enemy supplier is *Suppliers of Beneficial Organisms in North America* available from the California Environmental Protection Agency, Dept. of Pesticide Regulation, Environmental Monitoring and Pest Management, 1020 N St., Rm. 161, Sacramento, Calif. 95814-5604. tel. 916-324-4100 (HTTP://WWW.CDPR.CA.GOV/DOCS/IPMINOV/BENSUPPL.HTM).

Two helpful sources for biological controls located here in the Northeast are:

The Green Spot, Ltd.
93 Priest Rd.
Nottingham, NH 03290-6204
(603) 942-8925

IPM Laboratories, Inc.
Locke, NY 13092-0300
(315) 497-2063

Examples of mass-reared biocontrol organisms for vegetable crops

1. *Beneficial nematodes*. Nematodes are very small roundworms. Some species are plant pathogens, but some attack soil-dwelling insects and two in particular (*Steinernema and Heterorhabditis*) have been mass-reared for commercial use. These seek out and penetrate their host insects, multiply within the host and kill it. Most likely to be effective against the soil-dwelling immature stages of susceptible hosts, such as root weevils, cutworms, white grubs (use *Heterorhabditis*), wireworms, and maggots. Require moist soil conditions to survive.

2. *Pediobius faveolatus* is a small parasitic wasp of the Eulophid family, which attacks larvae of the Mexican bean beetle. To purchase Pediobius, contact: ARBICO, (800) 827-2847 (AZ), (HTTP://WWW.ARBICO.COM/); The Beneficial Insect Company (NC), 336-973-8490 (HTTP://BUGFARM. COM/) ; Rincon Vitova (CA), 800-248-2847 (HTTP://WWW.RINCONVITOVA.COM/) or The Green Spot (NH), 603-943-8925 For more information, you can contact: Carol A. Holko, Maryland Department of Agriculture, Plant Protection and Weed Management Section, 410-841-5920 (HTTP://WWW.MDA.STATE.MD.US/PLANT/MEX.HTM)

3. Other species in this family include *Edovum putlerii*, also an egg parsitoid, which can be released to control Colorado potato beetle in eggplant (not effective in potato).

4. *Trichogramma spp.* These tiny wasps lay their eggs inside the eggs of insects, and wasp larvae develop inside, killing the egg. Several species are commercially available, but the most useful in gardens would be *T. pretiosum* for caterpillar eggs. Releases should be timed to coincide with egg-laying. Another species, *T. ostriniae*, is now available and is very effective against European corn borer. Ask supplier for instructions on release. Sources for *T. ostriniae*: Beneficial Insectaries, 800-477-3715, IPM Labs (see above).

Pest Management on Applefield Farm

Transcript of a presentation by:

Steve Mong
Applefield Farm
Stow, Massachusetts

This kind of meeting is great. When I first started out there was no research, people, anything about how to grow a crop organically. There was nothing. There was no information, no interest, and in the last 10 to 15 years it is amazing how much good research is going on for our benefit. A lot of it's for ground water protection and other issues but it is benefiting us organic people tremendously. Most of us farmers won't change unless the research is there to show us that things actually work. Any of you that have been farming for a while know that it's always an ongoing research project. The years are never the same. You've got different growing conditions, different crops, different bug pressures. Things that work one year don't work at all the next. So it's not an exact science, which is what is part of the fun of farming.

We started out 20 some odd years ago, self-serve with a bench. Then the next year another bench and the next year another bench then put some people, started hiring full time and a steady progression over fifteen years adding up to where we are presently doing around 20 to 25 acres of field crops and around a half acre of greenhouse. We've been trying everything over the years. We don't have a single system on the farm that works, we have a bunch of systems and we keep trying new things and we keep going to meetings and learning more. We've done a bunch, we try a bunch and for the most part it is working out pretty well. We are a direct retail. We have a farm stand. 90-95% of our crop that we grow goes to our farm stand so that makes the market different than a lot of other people. We can talk to our customers. They can ask us questions.

Insect and disease control is what I am supposed to be talking about. I think in organic farming that is almost one of the easier subjects. To some extent there are not that many things we can do. I would guess that I spend less on 25 acres of property, where we are grossing $100,000 or something like that in vegetables, we spend less than $200 a year on average on chemicals. Most of insect and disease control revolves around your cultural practices. Whether it's planting a little bit later, going to transplants instead of seed. All of those things that they talked about earlier today. The cultural practices are probably the number one resource that we have to take care of the insects and disease.

Tremendous amount of beneficials out there. Once you start looking you realize that, yeah, there are aphids on those plants but don't spray them because you've got four different kinds of beneficials out there taking care of it. Give it some time. In 20 years I think I had to spray a pepper crop once. Because the aphid population was just too high and I didn't think it could balance out. It was probably there from in the greenhouse. I've gotten better. They don't go out in the field with aphids already on them. I don't know if that is what it was but in 20 years I've only had to spray pepper plants

once for aphids. Tomato plants the same way. I think one year the balance was out of whack. The hornworm was just too big. We sprayed them once. Many times I have thought about spraying. I didn't want to affect the natural population. I lost a few leaves but then sure enough the natural beneficial comes in and takes care of the problem.

A couple of other notes. I do a lot of beneficial stuff. Our greenhouse, we have almost up to a half acre of greenhouse now, its getting to be one of the bigger parts of the operation. I rely tremendously on brought in beneficials. In that enclosed environment they work extremely well for almost all of the insect pests that you might have. I've been doing the Trichogramma for years, ostriniae now and the pretiosum before that. I think that there is a lot of new research coming out and the rearing processes for some of these beneficials is getting better so the price is coming down. It is becoming more of a viable option on some of these crops.

I'm going to rely a lot on individual questions. The disease and insect control is so dependent on what is going on in your own farms. I'm happy to tell you what I do. A couple of the major crops I'll talk on briefly is something like tomatoes. For us and for anybody probably it's one of the number one value crops we grow. Insects to me are not a problem on tomatoes; I have never had, like I said once I had hornworm. Disease is an issue and what we've worked out is we plant three distinct crops of tomatoes. An early planting, the main season planting and I'll put in a late planting of tomatoes so that they are just starting to bear for the first of September which I consider the hardest time to keep tomatoes coming in. So they are young, they haven't even produced yet, they are coming in at the end of the season.

We will work hard not to pick one crop of tomatoes and another crop in the same day. I don't want to spread disease from one to another. Keep them separated, stay out of them. Disease management. When the plants are wet don't go in there. And you can really significantly extend your tomato-growing season without anything. I have to say I have in the last couple of years used a new product called Oxidate. Sometimes known as Zerotol. With this mist blower have been able to go through and have a surprisingly good late season crop of tomatoes. The cleanest I've ever seen.

Corn, Ruth mentioned. I've worked with Ruth Hazzard for almost 10 years on that corn earworm project. Built my own applicators for a while. People used oil cans and little bits. It doesn't have to be high tech. I started out the first year I actually tried it I had my acres of corn and I just did, I think, four rows. Two down and two back, and I tried to time it so that I could pick that on the weekend.

Because we have regular customers where we are picking and they learned about the worm and they didn't like it when it showed up. But we left a knife on the table they could leave the worm with us. It was okay but your sales do go down. But weekends it was a whole other crowd there is enough tourist activity and new people driving by and boy the customer comes in and your whole farm stand is judged by that one ear of corn. It's so disturbing to have them just "Ugh" and just run out of the door and you will never see them again. I saved this corn and I only picked it for the weekends. It only lasted that one weekend but I saw a remarkable difference in the numbers of ears. It wasn't 100% but it probably went from 40% clean to 60% or 75% clean. I'm not a researcher but if you don't hear too many squeals it is better. And so Ruth started this program, so we have been doing this for quite a while.

This past year we had such a drought where I am that I had a choice to water the corn or do the oiling and I watered the corn and the customers dealt with it. But the year prior to that I oiled almost all of the late season corn. It doesn't come in in the early season, it's the last month or so. It's not that daunting of a project and the corn was pretty darn good. I'm disappointed because I did put the ostriniae out there because I was thinking okay now I've got the corn borer protection and I just never followed up with the earworm protection. So those are the two main crops, corn, and I don't have aphids on the corn there are just tremendous beneficials out there. You have to be careful picking your corn to not squeeze the immature ladybug larvae that are running all over it.

Two other of the major pests that Ruth just mentioned. Leafhoppers, what a pain. And striped cucumber beetle primarily. But cucumber beetles there are so many even in the rotation all the pumpkins and squash and cucumbers and zucchini and gourds get mixed up around. But they are everywhere. Our answer for the striped cucumber beetle for the most part is we have gone back to all transplants so the plants are bigger when they go

in. Take off quicker. A lot of things we will plant a little bit later so the ground is warmer. They will grow quicker and it gets them out of that most susceptible stage. We did do the Surround two years ago in the transplant trays. That does make a difference. I don't like working with the Surround. I'm not sure if I will keep working with it. We were never a certified organic operation, being a direct retail we could talk. I followed MOFGA's rules, which is Maine organic farmers. Currently we are probably not going to go through the certification. I'm not sure how close we are going to follow. If we had to go around with a pump sprayer to spray a little bit with a rotenone pyrethrin is what we used to use. But again cultural practice and I think with some of this new trap cropping there are some improvements on that end.

Leafhopper that is one that to some extent we like the leafhopper coming in. That's our natural burn down. The plants decline so it hardens the potatoes off, so long as it doesn't come too early. There were a few times that I had to spray and that is one of the few times I used this machine here (backpack mist blower) and rotenone pyrethrin was allowed, this was probably three years ago. Last year we didn't really have much of a leafhopper problem. I don't know why. We were lucky. They do vary tremendously year to year. That is the problem with some of these pests. They all fire up one year and the next year they are not there. It's a tough one.

When I was spraying the pumpkin field. One of the advantages and I guess I'll briefly talk about the mist blower. This is a motorized backpack sprayer. I bought it primarily to use in the greenhouse. They run about $500. Some of these other sprayers people buy are $2,000-$3,000 and I don't have that big of an operation. I'm real surprised; we use that in the field a little bit. Primarily we rely on the pump sprayers and for the most part they do pretty good. The really nice thing about having a wind coming out is if you want to get material under, sometimes I have used it on the pumpkins and watermelons, real low rpm, walk around and you can just see that the plant is just blowing over. You are getting material all over it and I was real leery.

The project we had last year with the corn project where Ruth wanted everyone participating to spray two applications with BT for corn borer. I'm going "I don't have a sprayer. I can get over little corn but I can't drive the tractor over big corn. How am I going to spray acres of corn?" I sorted it out. I could spray with one tankful; I sprayed close to a half acre plus. Which is the concept of a sprayer like this. They call it low volume. Which means low volume water. You've got the same amount of material going on per acre. Instead of using 50 gallons of water or 25 gallons of water you are using two or three gallons of water. Very low water with a very high concentration in the tank but the application, as the droplets come out it drops into the air stream and it gets sheared off so it breaks whatever chemical you happen to be using into very small particles. To give a complete coating of whatever you are spraying.

It is really difficult to get used to the concept of using a tool like this because the concentrations are so high. I might put a quarter pound of BT in that two and a half gallons of water. It's a hard concept but for certain crops it makes a lot more sense than spending a few thousand dollars on a sprayer that you would use once or twice a year or every three or four years. It is just something to keep in mind. This is the least expensive thing I know for a mechanized sprayer that can do some acreage. People who have a small orchard application these things are great. If you are just doing ten or 15 trees. Peaches, apples, whatever. It's an interesting tool.

I can talk more about any of this stuff, so questions would be great at this point because I don't have much material.

Questions and answers

Q: How far does the mist go from the nozzle?

A: If there was a hanging basket hanging up in the corner I could spin it. Roughly a 200-mile per hour wind coming out. That's probably pushing it. If you were trying to do full sized apple trees you would have to walk into the tree and really work on it. It's got some distance and that's why I like it in the greenhouse. It's why I bought it in particular, because I can walk down the greenhouse and get what I need and then actually see the hanging baskets doing this. I've got coverage.

Q: Is there a concern with spray drift? Sometimes you only want to spray one crop.

A: True. Again you can adjust the airflow; you can adjust the droplet, so that when I spray I've got like two rows of tomatoes side by side on plastic. I'm concentrating my spray on the tomato plant. You've got very good control. If I was trying to grow an organic crop next to a non-organic crop I couldn't guarantee that there isn't going to be a little bit of a drift but there isn't much. So if you are worried about that you can walk down the other side of the plant. But pretty much if you need it to go the distance you can wait for it to get out there or you can adjust the droplet size, slow it down. They also have a diffuser; and different nozzles that you can put on to broaden or do different things with the exhaust. It's certainly no more of a problem, you have the same problem with the pump up sprayers if you've got two or three rows and if the wind is blowing there is some drift. Whenever you spray anything there is always a concern with drift. No more than, I don't think, any more than most things.

Q: How do you calibrate a mist sprayer?

A: That's what I say it's really a tough thing. The very best thing to do is fill it up with water, walk down whatever area you are going to be doing. Some of it is going to depend on, do you like to stroll, do you want to just take your time or are you willing to walk as fast as you can walk. It all depends on your pace to how long the water lasts. So if you know an area and go and spray that so you know OK that's a quarter acre. Now you know if you can only do half of that well then. You are only doing a quarter of it so it's all individual, it's going to depend.

Some people it takes some knowledge, because you can adjust the droplets going in there. So you can make flow fast so you see a bunch of material or you can make it flow so you almost don't see that there is anything coming out. So it's all in your comfort, but many people make the mistake of using this and to do a half acre they would fill up the tank eight times. It is just too much work. Once you get a little comfortable with it concentrate that spray material, but you have to gain the experience.

In the greenhouse I have gotten to the point where I know, because out in the fields they talk about so many pounds per acre. You know all of us small farmers we are doing a couple hundred of row feet, how much of an acre is that. In the greenhouse everything is done by amount of material per hundred gallons. Well I've finally figured out that in my greenhouse operation I treat that 2 1/5 gallons as if it was 25 gallons. That seems to work pretty good for me. I am treating the equivalent area that 100 gallons dilute would take care of. You have to gain some experience and it is not that easy and it is not that hard either.

Q: You're using Oxidate against tomato diseases?

A: Yeah OxiDate, ZeroTol. Are people familiar with it at all? Zero tolerance is what it first came out as and that was registered for greenhouse for cleanup so it wasn't registered specifically for vegetables. So they had to come out with the exact same formulation, but it's got the vegetable label and it is called OxiDate. It is a hydrogen peroxide type. There is some good proprietary stuff I don't know.

I use it a lot in the greenhouse. We do a lot of sub irrigation and to keep the water clean and to keep algae from forming, as a disinfectant it has been wonderful. But because of it being a disinfectant it does kill spores on contact. It has got no residual effect. You spray it, 10 minutes later it's gone. But as a disinfectant for some of the bacterial diseases, fungus and stuff I think it has a point.

But again, as a person I don't know if I have mentioned this but as a grower I have always hated to spray. If I can avoid spraying, I will do anything to avoid spraying. I read the label, just about six or seven years ago, I bought this stuff because we had smut, it was determined to be smut on our cosmos that we use as a real good cut-your-own flower. When you are cutting and you go cutting down the row and it looks a lot like powdery mildew but I identified it as smut. Anyway it was starting to take over a row and my wife said do something with it. I looked at this label and I said, "God, it says spray three days in a row and then spray once a week for the next two or three weeks." So that's a lot of spraying.

Part of the theory is there is now a sodium, a potassium bicarbonate. There are a number of products out there and ZeroTol is kind of in this same category. Part of the reason they said to spray three times is 90% coverage is not good enough for a lot of these diseases and even some of the insects. If you are doing apple trees and have mite problems. If you don't get 100% coating on the tree for mites or 100% coverage for some of these soft biologicals, the diseases multiply

so fast you almost might as well not bother. So you need 100% coverage. The way to get 100% coverage, since the stuff is basically harmless, they have you spray three times in a row. So that you hit it one day and now you have got 80% of the plant, and you hit it again and you get some more, you hit it again and you might get the rest. With the mist blower, I went through, and it's got the advantage that it does a better job. You hit the front side of the plant and it tends to draw back around. But I went back around the rows and hit from one direction, the next day I went and made sure that my application was going the opposite way. Dr. Wick, he didn't think that we would get rid of it.

That cleaned that crop up and let us get a harvest and near the end of the season I saw it starting to come back again, but by then it didn't matter so much. I don't think it is a Godsend. I don't think there has been much research done on it. But two years ago I tried it, I used one cup of OxiDate per tankful and with one tankful I could do about four 500-foot rows. So I just walked down pretty quick. Easy to fill up, easy to go spray it. Five or six days later do it again. I didn't do any trials. It's like all right it's late in the season, the dew is on the plants until 11:00 in the morning, the dew is back on at 4:00 in the afternoon. It is a tough time for tomatoes and we never got around to staking these particular tomatoes up. They are Mountain Fresh, which is a nice tomato, just coming into production. There is always foliage cramped down in. I've got to get something in there and I do not like using copper sulfate. I avoid it like the plague if I can. I use it very very little. It worked for me and I don't know if it is the answer but I had it, I liked the results. A lot of farming is like that. You guys must do the same thing, try things. Is that enough of an answer for OxiDate.

Q: How much does it cost?

A: Very expensive, I believe it is a hundred and something dollars for a 2 1/2 gallon jug. You don't need a whole lot on the rates. I use so much of it on the greenhouse operation I buy it by the 15 gallon drum which brings it down a little bit. It's just now being released, they just got a new product for sanitation, for a wash dip. If you wanted to dip your tomatoes, or dip things for helping to preserve instead of using chlorine or whatever, this is now registered and it is certified it will be an OMRI approved product. I think it is basically the same material.

Q: Does the mist blower work with Surround?

A: I used it. I also painted the car beside me and it took a while for that whitewash to come off. I have no idea what label rate I used. I called up the manufacturer, I go look, because the concept is not to be used a low volume. I more or less said "well I have got to make it thick, but I can't be too thick to go through the nozzle. I forget what rate I used, but I'm fairly impressed by how well it performed and the reason I did it with the mist blower is you just cannot get disturbance. You are only going to be painting the tops and sides of the leaves. What I would consider if you are doing it in flats, I don't know if anybody has tried this as a dip, whether or not you could make a solution and dip the flat in so that you have got the stuff soaked. That might even be a better way and not as messy either. We had two hay wagons full of flats and I just stood up and stood back and just painted the trailer and then we took them out to the field a couple of days later and planted them.

Q: What crop and pest were you using Surround on?

A: For striped cucumber beetle before we put them out in the field. That was something that Ruth had thought might work and I said "Hey I'm a farmer, we try anything."

Q: What do you do for powdery mildew control?

A: Nothing. Variety selection, rotation, but no I can't. The big crops that could be a problem with powdery mildew there is no way I am going to think about going and spray. I mean I possibly could, but I have not found it to be a serious enough issue to worry about it. Benign neglect works pretty good for most things. I just don't worry about it to a large extent. If I saw it on a high value crop I would use the OxiDate. I think it would work. I don't see those kinds of disease pressures enough. When I am thinking of powdery mildew, I am thinking of it primarily on the pumpkin leaves at the end of the season start getting white, and zucchinis and stuff like that. We don't lose enough fruit to worry about it too much from my experience.

Q: What are your favorite three tomato varieties?

A: Three? Oh, well it's not any individual. So I may grow four or five different types that I plant for an

early planting that I will pick for the farm as an early tomato. Early Cascade I use, and some of the cherry tomatoes. I have never liked Early Girl. But there is a new one this year I have done. Names I can't remember, but there is a new version of Early Girl out there that I think. No never done those. Everybody has their different areas.

Well Mountain Fresh I consider to be a late tomato, and when I first saw Mountain Fresh, this is getting off of the subject, but that is probably okay. Mountain Fresh scared me when I first saw the tomato because the plants were gorgeous, huge and healthy, the tomatoes looked good and I was worried that when I bit into it, it would be like some of these tomatoes – looks great but the skin is still in your mouth after you chew it up. It is a firm flesh, but I thought it was quite acceptable flavor and the customers don't seem to mind it so I am real impressed.

We grow almost all determinant varieties. I used to do trellising and I wish I had the time because some years the trellised tomatoes, some years the ones on the ground or on short stakes work better. It depends on the year and amount of rain or dryness. Ideally you do a little bit of all of these different things. We are primarily doing short stake. We have done the Best Boy, Bush Big Boy, it is a Burpee one that has been pretty good. So it is not the old fashioned Big Boy it is a dwarf version with more disease resistance. I gave up Mountain Pride for Mountain Fresh. A lot less disease issues, much healthier plant. Very similar tomato we just have had better luck with it.

The big secret or what I am trying to convey is not so much variety as being sure that whatever you choose to plant for early tomatoes you know that those early tomatoes do not last. Some of them do not taste good or the plants get tired, they get early blight. We do this with many crops, beans, zucchini. You succession plant. The thing is you do not want to succession plant side by side by side because that disease is just following you right along or the insects. The big thing is to isolate some of these earlier plantings from your main season plantings from your later plantings so that you have a chance. Whether it is insects you are trying to avoid or disease. To a large extent I think it is disease for tomatoes in particular. With good cultural practices you can avoid many, many of these problems.

Q: What kind of tomato diseases are you running into?

A: The primary disease that I am worried about is I think late blight. I have not identified it. Late in the season, I think everybody, especially if you are picking off plants that have been being harvested for a while. You are coming into cultural conditions where you just don't have much daylight. Late August and getting in to September the plants aren't even dry until 10:00 or 11:00 in the morning. The period of leaf wetness is just incredible. The temperature is up and the amount of disease that is blowing around in the field from your fields, your neighbor's fields or your earlier plantings is a problem.

Q: Are you thinking late blight or early blight?

A: Early blight is the more common tomato disease and then late blight is a really devastating tomato disease that comes in kind of sporadically. Some years we have it and some years we don't but that really common one that we get every year is early blight. Don't worry about that earliness or lateness part of the name.

It is a blight and it comes in late. I am sure Abby is right. I don't need to identify all these things exactly. I know it is a problem and I am trying to learn ways to deal with those individual problems.

Beneficials – we talked about these. Do many people buy or are many people working on beneficials? Using beneficials? Buying in Trichogrammas?

Q: When you bring beneficials into the greenhouse how long before you see results?

A: Part of the trick in the greenhouses and for preventative measure is you want to not wait. Thrips is probably the number one problem in the greenhouse. Last year was the first year that I went to 100% using a beneficial mite. I was real nervous because I hunted all season long and never saw any. I spent probably $1000 on these beneficial insects and never saw them. The only thing I know for sure is that it just could not be the first year in 15 years that the thrips just magically did not show up. I am pretty sure. That is the problem with the beneficials. Research people can get out there and put them in a cage and count how many holes are in the leaf and some of this stuff. We can't do

that. I looked at the research. It looked promising. I did it on a small scale a year before. I felt fairly comfortable and I continued scouting.

I have to say with the thrips I had to stop using my blue sticky cards in the greenhouse because I also released a little while later an aphid predator which is a wasp so they are highly mobile. I looked at my traps for the thrips and they were just loaded with my expensive beneficial wasps so I said I would just monitor by eye. I am extremely impressed in a greenhouse operation. I have cut my chemical use down to where I spray almost no pesticide. It is not an organic greenhouse operation, but I spent probably $4,000 on beneficials and only sprayed a very small amount of pesticide.

Q: Are you doing any greenhouse sanitation to manage pests?

A: Most of my greenhouse operation we set up a subirrigation, it is a plug floor so that the plants are growing on the ground on a concrete, basically a pad. And the water comes up from below and waters them so again it is a cultural thing. The leaves are never wet, the plants are never wet and that eliminates, I don't have to worry about shore flies and fungus gnats. The soil surface stays dry it is being pulled up from the bottom.

ZeroTol is in the tank mix so that it pretty much means that I do not have to worry about pathogens in the irrigation water and I may be even getting some beneficial effects because it does kill spores. Common sense in the green house, sanitation, keep it clean, air manipulation, keep the humidity at proper levels. That's part of common sense greenhouse management. Yes, we do all of those things, which does cut down the need for fungicides, the need for a lot of these things. But in our large commercial, we've got a half-acre of greenhouse so it is in a quarter of an acre range of greenhouse the scale is a little bit larger than you might have.

If I was growing just for the farm and just my own tomatoes and peppers and stuff I could manage it entirely organic, because diseases are not an issue with those. It is the flowering plants that you have got the petals falling and then Botrytis sets in and you can just lose a lot of value in a lot of crop. My vegetables and stuff are never sprayed with fungicides. If they are sprayed with a pesticide it is a biological, but for the last couple of years having the beneficial wasps take care of the aphids I have not had to spray them, I used to have terrible problems with the peppers and eggplant, aphids all over them. Even when you could use rotenone pyrethrin it is just like two days later they are covered in aphids again. Releasing these wasps, there is some aphid. It is not 100% clean but I don't need 100% clean. When this stuff goes out to the field, if you don't have a big population it gets cleaned up on its own. As long as it's kept in control that is good enough.

Q: Do you have European corn borer problems with your peppers?

A: No, I don't know if you heard Abby, she was wondering about European corn borer in my peppers. For about the last 10 or 15 years I have been releasing *Trichogramma pretiosium* as a what if. Everybody said they might work on European corn borer in the corn and it turned out with research they really do not do a damn thing. Historically, I always released them in the peppers too and I would have some maggot problems some years but whenever I released the *Trichogramma pretiosium* I didn't seem to have much borer in the peppers.

One year I listened to someone who said they really are not doing anything but I did not release any beneficials. We virtually did not have a pepper crop that year. Again I am a farmer, I don't know for sure what was going on but I went back to releasing and then last year I released *Trichogramma ostriniae* because they are a much more efficient predator for corn borer and I released by nature. I did a release in the peppers and my corn and I had very nice peppers. I'm going to let the researchers, which they are going to set up the trials and go look and count and that sort of thing. But I firmly believe, and they are not very expensive any more. They are about $15.00 an acre. You go set a couple things up, you do that a couple of times in the season, you are all done.

Q: Any problem with eggplant flea beetles?

A: Yes, once in a while and it is usually just the young plants when you first set them out. Oftentimes it is only, we will do most of our eggplants and peppers on black plastic. Then we have a pick your own field near the stand and it doesn't get taken care of as well so we

want to be able to easily till it under when it is done. So we will put some stuff in bare dirt. These plantings are different so it may be because of the separation, but on our farm it doesn't matter where you plant things that flea beetles like, they are there. But in that field, that year the ones that were in bare dirt, I had to spray them. They went into the ground and they got covered, I mean you just look at the plant and the whole poor little plant is black with flea beetles. They weren't going to make it. There was no problem with the ones on the plastic. I don't know why for sure.

For the most part what we have learned to do, and again we are not wholesalers, we have the bedding plant business, I don't feel that we need to be the first on the market with a crop. So we have started not struggling so much to get things in the ground early, and I think that makes a huge difference on whether the pest is there or whether the plant is a little bit bigger and it grows so much faster when it gets to the ground that it grows out of the susceptible stage that much quicker. It takes away a lot of the problems. It can make a huge difference to some other operation so that is why what works for me is not necessarily best.

I would consider some other things. Sometimes there are things we want to have early. We put them out there and they are under row cover. The bulk of the crop will go in a couple of weeks later somewhere else. We are doing that more and more, especially with the pumpkins and things. We used to do direct seed and some years that was great but if you get a wet cold spring and we lost an entire 5-6 acre crop of pumpkins and squash and whatever one year. The plants just sat there at the cotyledon stage for weeks. We must have sprayed seven times with rotenone pyrethrin walking those acres but it didn't matter. The plants weren't growing. The striped cucumber beetle was just there and feeding and the field was done. We have gone back, as much as we do not like dealing with plastic and stuff, we have backed off. We do transplants, let them get decent size and instead of putting them in late May, first week of June we are putting them in the second to third week in June. It has solved some of those problems for us.

Q: Where do you buy your beneficials?

A: I buy a lot from Koppert. I am sure there is a web site for them. There are a number of places. Working with U-Mass extension – they bought some of these beneficial mites from a number of different places and most of them are reared overseas and then shipped back here. Shipping is a big thing so find a company that produces and can ship them properly.

We buy a jar and they are supposed to have 100,000 mites in them. The researchers actually took a sample and counted them out and these things are microscopic. Koppert constantly had the highest count and the price is all competitive. I have had very good luck with them.

I did buy my *Trichogramma ostriniae* from IPM labs here in New York. Things like the Trichogramma I have a number of sources but Koppert's has been most reliable. They are a Dutch company I believe. They have a couple of outlets here in the U.S. and they are often at some of the trade shows and things. They are quite big. They are an excellent resource.

Mike Hoffmann mentioned this earlier, or maybe he didn't, that when you are using beneficials especially in the greenhouse, but also in the field you are really limited what you dare spray and not affect your beneficials. In the greenhouse your crop cycle may be only eight weeks. Something like Sevin which I know none of you guys use, I just happen to know this statistic. Sevin is still able to kill the beneficial eight weeks later or ten weeks later so it is not like you have time to spray material and then you can put your beneficial on. These materials, some persist for a long time.

Koppert's has, it is like Spinosad is supposedly listed as soft on some of the beneficials yet it is really scary because it has a really broad spectrum. How can it be soft on the good guys? Koppert anyway has a web page where they have done a lot of research to show depending on which beneficial you are using what materials might be okay so you can help with some of your choices.

Again, organic growers do not have many choices. Out in the field the biggest choice is whether to spray or not spray. As far as the value of the crop and in general, often times my wife and I will go out and see aphids just covering these plants but with closer inspection 60-70 percent of those aphids have mummified already and there are other beneficials crawling all over the place. Ignore it at that point, they are not doing any economical damage at that point. They are going to be under control next week. It seems to work.

[Editor's note: A list of suppliers of beneficial organisms can be found on the web: <HTTP://WWW.CDPR.CA.GOV/DOCS/IPMINOV/BENSUPPL.HTM>. The URL for the Koppert web site is: <HTTP://WWW. KOPPERT.COM/>.]

Q: Can you talk a little bit about your cutting garden? Tell how it enhances your stand and then how you sell the flowers to people.

A: When we very first started selling at farmers' markets, the first year we sold things I raised some apples and the lady at the stall next to us always brought flowers. It didn't matter if it was a rainy week or whatever. Some weeks we would sell our apples, some weeks we wouldn't. She always sold her flowers. My wife loves flowers. She said, "I am doing flowers."

Ever since we started a little garden a few bouquets of flowers have been part of what is for sale on our stand and then we have gone into this pick your own thing. Over the years we have found that pick-your-own vegetables is almost more trouble than it is worth. There are a few crops that I think are valuable, some of the greens, some of the herbs but a lot of the stuff is almost more confusion and more hassle than it is worth. We have always had a cut your own flower garden right out behind the farm. We work pretty hard to keep it looking nice.

It is a funny thing but the customers who are coming to cut your own flowers are just wonderful people it seems like. We will have wedding parties out there, we have mothers that come in to the shop whose daughters are out with some scissors cutting a small bouquet. What does therapy cost $40-$70 an hour and these people will just hang out there for an hour and cut five or six stems. They love it, they don't trash the place. Once in a while there are a few flower species we grow that are too valuable to sell with the rest of them so we hide some of that, but for the most part they are there and we have learned after listening to a lot of talks that cut-your-own flowers are a part of a lot of farm operations and how you sell them.

The way you sell them is you sell them by the pound like everything else. Develop a price. The customer comes in with their bouquet, they take them out of the pan and you do not have to sit there and count each one out. Put them on the scale, $7.00 a pound and out the door. Wrap them up and they're gone. We have been doing this for at least four or five years but I heard that this was the thing to do by other flower growers that have been doing it longer. I am surprised frankly that most people do not know about it.

It has been talked about at so many meetings that is really the way to sell the flowers and to a large extent, flowers are not like food. People do not have to buy flowers, they want to. They don't care what they pay. It really "pisses me off" we'll be a nickel higher than the place down the street and the customer will go there instead. The same guy will be in in the fall and spend $100 on a couple of pumpkins and cornstalks, Indian corn, whatever. It doesn't matter it is not food. Food is cheap. It is an ongoing battle and you guys are all organic trying to get the value added and that extra money but it is an issue that doesn't go away.

With the flowers you keep it simple, come up with something that you think is fair by the pound but really think about it. We will make an arranged bouquet that I think my wife sells for $12. It is a big bouquet, a little on the pricey side but it takes a bunch of time. It is not just a group of flowers; it's an arranged flower group. We also sell by the stem so they are sold retail. So she just takes some of her flowers, she knows her time and I think she has come with about $7-8 per pound as what we are currently charging for flowers.

All of you people that are doing pick your own. Flowers are not the same problem so I encourage, especially if you like flowers. It is always nice. They were talking about having nectar sources. Goldfinches love cosmos. You get a row of cosmos and there are goldfinch flying all over the place. Having flowers in your operation, you can think of it as a money source and as a food source for your beneficials. That is a good way to do it. Any more questions?

It is hard as a farmer and some of you hopefully will get asked to come to speak at some things. Get over it and get up here and do it.

Q: What kinds of flowers do you grow?

A: It is all the ones that grow easily – snap dragons, cosmos, marigolds, zinnias, asters. Asters are a little bit tough, but we grow a bunch. We do a bunch of dried flower stuff too – straw flowers, statice and we do larkspur but we grow that somewhere separate because it is so light and so valuable. Lisianthus is a flower that I love. It is a little bit difficult to grow, I

buy plugs and baby them. They go into a separate place because Lisianthus can sell for $1 or so a stem, just a single stem at wholesale. At $7 a pound you would not make enough money, but as a cut flower it can last for two weeks in a vase without changing the water. There is a lot of good resources I am sure on the web. There are cut flower associations. There is a lot out there. Some of it is what you like. Some of it is what fits into your operation. It is kind of unlimited.

Next year, there will be some talk on cut flowers at the New England Vegetable convention. It is a popular subject of a lot of us, especially the retail or direct retail type markets. Like I say, you bring some bouquets along with you to farmers' markets and watch those bouquets sell. If you ever do some cost equations on amount of money you make per acre for the same inputs, flowers will be way, way up there compared to some of the other crops that you grow and struggle with.

Q: Are your flowers organic?

A: No, they are not. Probably the only thing they are not is the potting soil. Whether or not you are getting some of the people who are starting to produce organic transplants for people. Whether you can get them to do some Lisianthus. It is a tricky one to germinate. This is part of the flower and part of the greenhouse operation. I order some Lisianthus trays in when I am buying the rest of my stuff. We do not start those ourselves. That is a new problem for you guys. They will have to stick to that for that government mandated … never mind – I won't go there!

Pest Management from a Farmer's Perspective

Transcript of a presentation by:

David Marchant
River Berry Farm
Fairfax, Vermont

My wife Jane Sorenson and I farm in northwestern Vermont. We bought the farm about 11 years ago. Before that I worked a little bit at U-Mass research farm and before that I spent a little time at Cornell so I got to know Abby and what not, so it is kind of fun to get back and see old faces. We have an old dairy farm, about 150 acres and we grow about 40 acres in vegetables and then some strawberries and then cover crops and straw. We are located right on the Lamoille River which drains into Lake Champlain. I am very close to New York State, I am probably only about 15 miles as the crow flies from Plattsburgh. We are in the Champlain Valley so while we are fairly far north our climate is pretty decent for vegetable production.

As I go on in terms of the pest stuff you notice I talk about being far north actually in terms of organic production I think we have a lot of advantages. Right now we have about three acres of pick-your-own strawberries. Those are not certified organic, they are IPM managed. We have got it down to approximately one spray for tarnished plant bug with a Malathion typically and anything else is certified organic. These are some of the crops we do, a lot of kale and collards. A lot of these are switching as market kind of influences our change. We do a lot of winter squash still. Our leaf lettuce is changing completely, we are doing very little. Cabbage and carrots are big and greenhouse and tunnel tomatoes are getting bigger for us.

Here is a picture of the farm. Again it is all river bottom land, sandy soils, not a stone on the farm and we have about a mile and a half of river frontage so irrigation is pretty easy. We looked for a long time. Everyone says we are lucky. But it is not all luck. It took us about three years to find a place suited for what we were looking for.

There is the river, Lamoille River, that is high spring, it will flood every once in while and we have had some problems with that, but water is usually not a problem for us to get. There is some of the bottomland you can see and it is all sandy hills up on the right and all bottomland and the river just kind of follows the whole farm. Apologies for some of the photographs, some of these are actually slides taken of pictures so they are not exposed just right. This will give you an idea of the place.

I will just start going through the crops that we do and kind of the pest problems that we have and what we do. We do a lot of bedding plants and that seems to be growing. Like a lot of you probably we are getting suburbanized and houses are being built all around us and we said well, I guess we just need to take advantage of it. So, we started to get into bedding plants and it keeps growing and becomes a bigger part of it. As the former speaker was saying, people will pay whatever for flowers and whatnot. We said we can't fight it, we might as well join it.

My wife runs this operation pretty much. All of our greenhouses are ground to ground greenhouses, fairly low tech. We kind of got into it cheap and as the years go by, when we put up houses now we do it a little bit better each time. When you are first getting started it is hard to put up a full range. In terms of pest control we make our own mix and this is a soil mixer that we bought out of Canada. It is a pot filler and soil mixer. We make our own compost and we use along with about 30% compost, peat and vermiculite mix. We simply put the pots here, there is a foot pedal that you step on and the mix is in here. It mixes a yard at a time. We do a lot of flats for our field production so it is a fabulous machine and it is really reasonably priced.

It is interesting, you look at a lot of the equipment and it is for big operations and there are some places in Canada that actually make smaller scaled equipment that really is suitable for operations like ours. Instead of $20,000 it is more like $7,000 or $8,000, so it became fairly cost effective.

We use T-22, it has been talked about a lot, in all our mix. It is hard to say, we were using compost in our mix, and maybe we are throwing money away but it just gives us a consistency in terms of damping off problems. Sometimes we have inexperienced people watering and we get overwatering happening and we seem to prevent a lot of soil problems by using the T-22, so we use it in everything and it seems to work very well for us. It is not cheap, but with the mixer it is easy to mix in so it is right there in the mix so as soon as you water then you start getting the effectiveness from it. This is some of the plug production we do. We vacuum seed, we do a lot of brassicas, a lot of kale, collards, cabbage, about 10-15 acres total of those crops and this is it where we are just setting up and germinating. We even use T-22 in all our field transplants mixes as well. This is when we first got started, before we even had decent benches. A real mixed hodgepodge of field transplants.

One thing I would point out is the old window fan and we now have HAF, but in terms of disease control I swear by HAF fans and air movement. Our next big crop besides bedding plants is tomatoes. For us tomatoes are greenhouse tomatoes and tunnel tomatoes. Some of our major pests that we have to deal with are different than field tomatoes. We are fairly far north so there are a lot of people that do produce field tomatoes but we are starting to pick about the third week of June and go right through until Thanksgiving and it really works out well for us. We just don't even deal with field tomatoes except for some paste tomatoes I put in for myself.

Our major pests are Botrytis, Fusarium, root problems because we are in houses that do not necessarily rotate out every year we can get some root disease problems. Whitefly as well. You can see some of the things that we do and I will show you some pictures of stuff that we do. For Botrytis, actually I picked up some tips when I was at this conference a couple of years ago and they talked about sanitation of the complete house that I hadn't thought about. We use OxiDate as well and I just got information from BioSafe who produces it and it is not NOP approved but they are reformulating it to get rid of the inerts and there will be a product this year that is available. We actually spray the entire house with OxiDate, the plastic, the metal, everything, just to get rid a lot of inoculum. It definitely seems to be making a big difference. That as well as proper ventilation. Root rot problems can be a big problem in greenhouse tomato production and we have gone to grafting. We graft all our own tomato plants now. It is a very simple system that we got out of Canada.

It is funny because we are a real anomaly, everyone milks cows and you are not a farmer unless you milk a cow in Vermont, but you go across about an hour north and there is about 20,000 acres of vegetable production just southwest of Montreal. So, there are a lot of resources for us. Some of the resources are the greenhouse tomato facilities and it is a very simple system of producing a root stock that is resistant to some of the diseases and a desired top and just using these little plastic clips and cutting them with a little razor blade. You've got a tray of tops, you've got a tray of root stock and you put one on top of the other and you can see a nice grafting right there. You just put the clip right over the graft and we put them in the hoods and that is the key right there, these high domes, it keeps the humidity high and we probably get 85-90% take. It is a very simple, quick way to do it. It works well. We do it for root disease problems, Fusarium. Some of the root stock of the greenhouse tomatoes the vigor is unbelievable, you get higher production, they are a lot more tolerant to a lot of the root disease problems and we find we get a lot longer life out of our tomato plants with the grafting.

Question: What rootstock do you use for your greenhouse tomatoes?

We have gone to Beaufort, we used Kyndia which you used to be able to get out of Johnny's and I have a catalog that is called Group Horticale le Doux, I have the seed catalog here out of Quebec and we have gone to Beaufort and they have another one coming out this year that we might try. It is just amazing, these things are like trees. It is unbelievable. So, we put everything in to a four inch pot.

Here is one of our greenhouse tomatoes, very small, simple houses, 25 ft. houses, 25 ft. x 150 ft. We run eight rows, you can get two rows per bed, but this is the way we try to get it really clean, spray the whole thing down. You can see we use these HAF. These are cheap HAF out of Grainger's. The plastic ones are about $45 instead of the typical $140 and if you look at the specs they are identical to the metal ones. When you start putting four or six in a house it saves you a lot of money. You can see we are getting ready to plant. We typically use T-22 in the soil, to just to give it a little extra protection. This is actually not our house, but this is how we do it, growing them on string. We have a lot more pathway than this. This is a little tight, but we just wanted to show you. I do not have a lot of great slides. I haven't taken a picture in about five years it seems like. We do trellis everything up on twine, as well. Everything is shipped out. We wholesale everything in to the Burlington area and we just have two stores that will pretty much take everything we can grow and we sell at one farmer's market and that is about it. The nice thing is we have a small stand with the pick-your-own strawberries and the farmer's market we can send all the B-product. We hardly throw anything out. Last year I don't think I threw out more than 100 pounds of tomatoes of overproduction, because we just couldn't keep up, so it is something that is worthwhile for us and pest-wise we have been able to deal with it.

The other thing I talked about is we introduce a lot, we do use *Encarsia* for whitefly and for aphid control we often use the *Hippodamia,* the lady bug that is pretty cheap to start with and also if we see a hot spot we may bring in lacewings, some of the more expensive predators a little bit, but we scout and we use yellow sticky cards within the houses to monitor for whitefly. We are doing that in the bedding plant houses, so it is kind of a progression. We start the bedding houses in February, we plant the tomato houses late March so we know if we are going to see any whitefly it will tend to show up first in the bedding plant houses, so we really keep a tight eye on that because they tend to move from one house to the next. The nice thing about being far north, I kind of pray for those –20 degree nights because the houses get to be –20 and a lot of things just don't like it that cold. The other thing that we do a lot of is we have a controlled temperature room, we keep it right around 50 degrees so if we get long, we can hold them, we are picking them at a breaker stage so we can hold them. It is a nice crop, you have a lot of control, and flavor wise people seem to love them. I know field tomatoes some people swear by, but we go this way.

The other thing we do is tunnel tomatoes: unheated greenhouses. I am sure a lot of people here use kind of walk in tunnels, no heat, roll up sides, cheap structures, throw a piece of plastic on it. We like to use Ultrasweet in these and we typically do basket weave trellis system. Something like that – four rows, drip tape and you walk away and come back once a week and string them and pick tomatoes. A very good way to go. We start in March with our greenhouse tomatoes and then we get this big production June or July. When they start to slow down these tunnels come in and we actually rip out an old bedding plant house and plant another crop in mid-July so we get a really nice fresh crop coming in September and October. The reason I do not grow tomatoes outside is because in the greenhouse we never have any early blight, we never have any Septoria, we never have any disease problems like this (slide). We don't have to grade through our tomatoes. We pick right into the boxes, number ones, number twos. Botrytis we do have to deal with. A little bit different pest complexes that you have to deal with in the houses and the tunnels, but you keep your leaves dry and I don't grow field tomatoes, that is basically what it amounts to.

Question: What is T22?

T-22 is a Trichoderma product that is produced here in Geneva through BioWorks. We get it through Griffin Greenhouse, but Seedway has it as well. It is a beneficial, soilborne fungus. It is actually a protectant in a lot of ways, competitive protectant, it will compete at infection sites, so in other words it can out compete Pythium or some of the damping off things and also I will talk about its use in strawberries a little bit.

Pick-your-own strawberries

Next crops – pick your own strawberries. They are not certified organic. I tried a number of years with different organic blocks in terms of the tarnished plant bug and I have still not come up with a successful way to control them. We have got it down to about one spray, but you can see here some of the pick-your-own strawberry fields. We don't do a lot, we can only really sell about three to four acres of pick your own. We have a lot of other people growing them around us. It is a good draw and it is part of our farm name so we have to grow them now, I guess.

We are starting to play with plug production and annual strawberry culture, plastic culture. I am sure a lot of you guys have heard about this. I am talking about strawberries, I know it is a vegetable workshop but I did look at my New York survey of vegetable crops and strawberries are listed in the vegetable section so I figured it counts. I know a lot of vegetable growers grow strawberries. We have been playing with this plastic culture. It is interesting.

Different pest problems. We get some different soft rots on the fruit where it is laying on the plastic. Anthracnose seems to be a little more of a problem. It is an interesting system, I think it doesn't work for pick-your-own because it is a very spread out type of ripening system that works great I think if you are trying to use it for planting for a retail operation, picking and resale. We have tried to send some pick-your-owners into the plastic culture and they kind of walked around. You get a berry here and a berry there and it produces over a very long period of time, but they were a little frustrated. It is kind of a fun way and it is a totally different way and you can get high production. They keep quoting these huge numbers down in New Jersey and as you go further north it seems to be less and less. I think it has promise and a lot of growers in Vermont are playing with it and we will see where it ends up.

You can see there we are using row covers. There is talk about row covers that Ruth talked about and we have gone to the plastic bags, sand filled bags and we really like it. For some reason it just does not blow up out of it like a shovel load of dirt. Even though it is not secured everywhere it just doesn't move and it is amazing how they work. So we will just go down with an apple bin full of bags and somebody just plunks, plunks, plunks as the tractor goes along. It is a really quick easy way to do it. We had it set up there for the annual culture strawberries. We do some trap monitoring for tarnished plant bug in strawberries. We use these white sticky traps just to get an idea when they are flying. It is hard to say. Some people say they don't work, but it is nice to be able to go to a spot and say, oh, they are there now, I better start trying to pay attention to them. As I said, we play with a lot of ideas.

Here we are releasing a predatory egg parasite of tarnished plant bug called a *Anaphes iola* and they use it out on the west coast for organic strawberry production. The problem is we are shooting in the dark. We use their release rate. It is fairly expensive and we just don't know if it is working. I would love it if someone could pick it up in the east and start working on it because with biocontrols it just takes a lot of research and a lot of time and it is so different out in California that it is hard to know if it is really working. We tried them a couple of years and I really did not get satisfactory control, so I stopped spending the money and said once somebody starts really researching it maybe we can go back to it. I think it has promise, but it is a parasitic wasp and it lays its egg inside the egg of the tarnished plant bug so it is a nice stage it is attacking it in. The nymph is what we get most of our problems from. It is hitting it before the pests can cause a lot of damage. That is why I think it has real good potential.

We do grow a lot of our own straw. There is a rye vetch crop and we just have it custom combined for us; it seems to be another way to avoid some weed pest problems. Not insect and disease pest problems, but by growing our own straw either if we combine it or sometimes grow it to seed head stage and cut it and bale it that way, so that we do not get seed production. Then you do not have any kind of volunteers at all.

Vegetable crops

Next on to some of the vegetable crops. Leaf and romaine lettuce. This is what we used to do and the wholesale prices have kind of been pretty dismal. We are doing less of this, but typically what we would do is start in late April and we would plant every week until about mid-August. Three rows per bed, 18 inches between rows, 15 inches between plants. It is fairly wide spacing. It certainly helps with disease problems.

Our major pest is Rhizoctonia bottom rot, it is always a problem for us. We rotate which seems to help. We are using raised beds now. This past year we had very little problems and we had real high raised beds. Who knows if it had anything to do with it. We tried using T-22, watering it in, seeing if it would be a protectant. In other words if you could get it growing down there it would out compete the Rhizoctonia and I don't know if it works or not, but we have tried it.

Other major pests – tarnished plant bug is a major pest in the summertime in lettuce so we try to hide. In other words we move it around some if the plantings and I often think that sometimes you just have to assume some large losses on one or two plantings. You don't know which one it is going to hit, but if you are trying to have a consistent market you just kind of figure that is going to happen. We tried not to do much romaine towards the mid-summer, late-summer and fall when they really like to hammer the ribs a lot.

Aphids can be a problem. We have had them flare up in the late summer and we have had luck with the neem product. That did seem to work. Downy mildew is also a real problem with romaine and we just stopped growing fall romaine. It seemed to be a better solution that trying to fight it all of the time. Tip burn is the other big problem and we try to irrigate regularly, try not to let the soils dry out and there is starting to be a lot better breeding work now in terms of tip burn tolerance. Some of the romaines now seem to be better and some of the green leafs. I just love growing red leaf, because all of the problems just seem to go away. It doesn't seem to have nearly the problems and so we tend to concentrate more on red leaf.

The other big problem is deer and we use portable electric fencing. One thing we have played with is lettuce produced in a tunnel. This is like the first of May and you can see green leaf and red leaf here. We were able to get $1,500 out of the tunnel on the real early lettuce and then we were still able to use it for tomatoes right after it. It is a nice way to get some extra usage out of your investment. Here we just had overhead sprinklers. So, we had very little labor. Here we are transplanting. We use a carousel planter a Lännan planter, it is a great transplanter. This might be onions, but we actually use it for everything and lettuce right now would be three rows. Everything is on three rows, 18 inch spacing. Our cultivators are set up for one spacing and we try to keep them that way. Here is a lettuce field you can see green and red leaf planted. Our raised beds are actually higher now. We have a better bed shaper.

Deer fencing

Here is some of the deer fencing. Here is a field you can see getting ready to be cut. We have a lot of problems with deer. You can see we have a lot of woods around us and they would love to come in. I went to a guy who specializes in fencing and we started with these tall white posts, New Zealand system and went with seven strands. It really did work. I put them out at an angle and we baited them with peanut butter on aluminum foil and now I am down to just two strands.

What I have discovered for our deer pressure and I know it is a lot different in parts of New York State were it is really heavy, but, I have dealt a lot with deer and what I have discovered is that if it is changing they won't get used to it and cause you problems. So, in other words we will come in and protect this crop and as soon as it is harvested we will move the fence. We spent a lot of money on a permanent fence around the whole field and it was a total waste of money because they got used to it and I didn't maintain it and they just plowed right through it. But, you put these things up and you are in and out. It seems to me visually they can see this, this white thing and they associate it, you know, they lick this once on a nice wet morning and they get a good shock and they just don't seem to tolerate it. In fact I can even turn the fence off and they don't even bother it. It seems to be the key. If you leave it up all season then they just ignore it and start plowing through it. For us, the key is to move it. So, this is what we are down to. Two strands and some peanut butter on aluminum foil.

Field packing

Here we are field packing. We field wash. The efficiency of this is marginal. I would say it is more efficient than taking it all back and washing it, but I think for us to be able to compete on a wholesale market to do lettuce you really have to pack directly into boxes and use hydrocoolers to beat the prices and we just decided it wasn't worth the investment. We grow it now for more local markets and every once in a while

if we get long we can ship it to our co-op. Here we are field washing. We are able to do a good job with field washing, get it cool and get it into our cooler so we can pick a field, keep it for a week and sell it out of our coolers for a week which is a big advantage for us. We try to concentrate a lot on post harvest cause I think it is a real important part and it makes life a lot easier and the quality of our vegetables a lot better.

Greens

Another big crop for us is greens. It is funny, I was talking to Ruth and all the things she talked about are all our problems. I will tell you what we do. All the same things.

What we have gone to is we grow collards, kale as soon as we can put them into the ground until we stop picking them around the end of November sometime. Again it is everything three rows per bed, 18 inches per row and 18 inches in the row. All this early spring stuff we plant it out and we put wide row covers over it right away. It is the first thing we do. For two reasons, one for cabbage root maggot and also for flea beetle. The cost of the cover is fairly expensive, but it certainly warrants it for us. Another thing that we have done sometimes is to just not even worry about weeding that crop and go in and cut that first crop and then have another planting behind it that we tend to maintain a little bit and we are able to not have to use a row cover quite so long so that we don't have to take it on and off so much. That was one thing we have had success with.

We have a lot of imported cabbage worm. I use Bts and I use a lot of Bt. That is pretty much what we do and I am really excited about this Spintor maybe we will be able to rotate it because I am starting to worry about resistance, especially with diamondback. Diamondback is another problem we have. Flea beetles are a problem, they used to be a major problem for us. I think since we started using the row covers and listening to what Ruth said I am starting to think that we are not getting the big population build up and I used to spray a lot rotenone and I don't spray it at all anymore. I know I am killing a lot of beneficial with it and I guess now I can't even use it with the new NOP standards. The flea beetles have come into more of a balance. For what everyone says I was always a little bit skeptical, but after being on the place ten years and managing the place I definitely see some of the pest cycles, the pressures reduce in general and more of a balance coming on. We avoid a lot of the early flea beetle. We do get some of that second flush that Ruth was talking about but it is never super severe. It has become much less of a problem for us. Club root is the other problem and we have it. We try to keep our equipment clean from field to field, but we do not do a great job of keeping all the mustards down. We are starting to look at using lime to try to get the pH up to avoid it because it is definitely a problem for us.

Cabbage

Cabbage. I am going to go through all the greens and then I will show you the pictures of how we grow them. We do a lot of cabbage. Everything is transplanted. We do not direct seed anything into our field in terms of brassicas. It gives us a head start in terms of weed control. It gets the plants out there growing before pests can be a major problem. We transplant every two to three weeks starting in early May and then we transplant storage cabbage end of June. Actually I have gone to planting cabbage until about August first just using with short season fresh market stuff to carry me through more on a weekly basis instead of trying to time different late season cabbages and having them all come on too early or too late. I have gone to something like a Columbia, like a 65-day cabbage, a nice fresh market cabbage, that we can just plant every two weeks and we get a nice consistent supply and then we will put in a fall storage cabbage that once we are done with that crop we can get into. Major pests—same thing. We do have Alternaria problems sometimes and we just rotate. I would say the number one disease thing we do on our farm is rotate. It is the first thing we can do. We would never consider planting brassica upon brassica.

Broccoli

Broccoli, we don't do a lot, a few acres of broccoli, we don't transplant it until about mid-July. We really only go for the fall crop mainly I don't want to deal with tarnished plant bug problems, all the brown beading that you get. It is probably one of our major insect pest that we can't deal with real well. We can deal with imported cabbage worm real well and then head rot we just got some nice Rise, Everest and Marathon, some of the nice really tight beaded domed head vari-

eties that seem to do really well against head rot. A little bit about how we prep some of the ground. This is a rye vetch cover crop. When I was talking to Ruth I think it might be part of our tarnished plant bug problem, too. I seems to build up a lot of tarnished plant bug. We use it everywhere on the farm for a nice plow down and a soil builder but you get into these systems and you start to realize it effects other things as well. Here we are transplanting collards again using our plug planter and my sister and her kids were up visiting. The nice thing about these transplanters is that very young people can use them and they love to do it. Some of our major pests you can see there imported cabbage worm, some of the damage. With collards and kale, Lacinato kale, especially, they love and you can't tolerate hardly any damage. You just can't ship it and because we are shipping a lot to the supermarkets in Boston and Philadelphia and DC we really can't tolerate much damage. We are on these spraying quite a bit, but that is what it can look like and if it's like that then it is too late. Cabbage root maggot you can see when it happens and that is when we really avoid it with the row covers and after that it doesn't seem to be a big problem for us. Club root, you I don't know if you guys have all seen club root, but his is what it looks like. It is not very pretty and it can really devastate a brassica planting pretty quickly. I think we are going to start concentrating more on liming and I have kind of just tried to keep pH on the farm general in the 6.5 range. I'm realizing now that I have to be a little bit further ahead in my rotation thinking and plan where I'm going to get brassicas and try to get the pH up.

I'm starting to do some dense planting type stuff for crown production instead of head stuff. But again you get into these tight situations and you get some other problems, that's another way of dealing with problems is getting a crop in and out quick so while you may be tight and you would certainly get a lot of head rot if you let these things mature, if you get in there and cut them out quick. It is a way to avoid those disease problems.

Head rot on broccoli (slide). I'm sure everyone has seen that.

Here we are, I'm not sure what we are harvesting here. Greens, I think collard greens but we use a harvest conveyer on all of our cabbage and we pack right into boxes as well as, we used to use it on greens. A lot of times now we just send pickers out with boxes and they pack right into the boxes. We use it on broccoli as well, but it is a nice way to facilitate harvesting and make it go a little bit quicker.

We ship a lot of our brassicas through our grower's co-op. We belong to a co-op called Deep Roots Organic Co-op. We have about 12 farm members and we ship under one name and we ship into supermarket chains: Whole Foods, Fresh Foods, Albert's, what used to be Northeast Co-ops which is now United Natural. It is a good way for us to sell quantity but what is happening is I think I am getting less now for my collards then I did ten years ago through the co-op. I am starting to rethink how much emphasis we put on our wholesale especially as we are able to grow some of the retail end of our operations. Even though – I think we are doing very well with our local wholesale situation. We have a lot of interest with organic product in Burlington. Having some of this kind of stuff really makes a big difference on your product. It really makes it stand out and looks nice and people seem to like it that way. Everything gets iced here – you can see ice on top of all the greens, they go into the coolers and then they get shipped out the next day. With this situation we can keep them in here for five to seven days and they would still be beautiful. Post harvest is a really good place to do a lot to make farm management easier. I like post-harvest it is one of my favorite parts. I think I can improve my yields more in post-harvest than I can in a lot of other places. It makes the flexibility of marketing a lot easier.

This is an old dairy barn, an old five stall barn we put coolers in. It is a pretty low-key operation, but it works. The problem is low head height but we deal with it and in hindsight it would be nice to put up a new building but it is all in place so we use it.

Cucurbits

Another big crop for us. Cucumbers, we do winter squash, anywhere between five and ten acres. It depends on the year. We do some melons, but a small amount. I sound like Steve because we have had some good years of direct seeding winter squash, like last year I said, "Oh, great, my buttercup did so great the year before I am going to do it again" – now I swear I am never going to direct seed any winter squash, we are just going to transplant. That is how we deal with

striped cucumber beetle. We just transplant in mid-June and it seems to make a huge difference. I am going to do it with our pumpkins now, too. It is just so easy and so quick with our transplanter to plant an acre. You get such an even stand. Weed control is so much better and with the striped cucumber beetle it is really a big advantage. I use a dust with 5% rotenone. I have a backpack duster and then that would work okay. I have gone to a coffee can or a sock because you can hit each spot. I think we might try doing some of the trap cropping and transplanting to see if we can get away with just the spot treatment.

Powdery mildew is a problem. We are starting to use some resistant varieties. I love Tay Belle it is a great acorn variety, Athena is a real good one, too. It makes a big difference with the melons. I would say powdery mildew is more of a problem with our melons and our winter squash by the time powdery mildew comes into our winter squash we have pretty much matured our crop. Climate wise we can not produce the secondary flush and get things to mature. Most of our fruits are mature by the time mildew really becomes a problem whereas the melons – it can seem to take them down relatively quickly. I have tried some of the potassium bicarbonate sprays. I am not sure how effective they are because I can't get coverage on the underside of the leaves, but again with the way Steve said, it is there, I know it is there, it probably reduces my yield some, but we just don't spend a lot of time managing it. Bacterial wilt is a problem. We row cover our melons and that seems to help a lot to get them far along before striped cucumber beetle comes in. They are on plastic as well. Post harvest is real important. We try to store our winter squash at 50-55, we also try to sell out by about mid-December. That way we are able to kind of reduce our losses in terms of post harvest.

We used to plant on plastic. I have gotten away from plastic on winter squash but here is a nice transplanted crop. They just grow so quick once you get them on transplants. It is that cotyledon stage when striped cucumber beetles can just wipe you out. So we just decided we are just going to transplant. It does take up some greenhouse space but you don't really need hardly any heat. We use the edges of the tunnels to do it and it works pretty well. You can see our melons on plastic. Again, they will be row covered. They are this big before we take the row covers off. Powdery mildew, again, it just doesn't seem to be a huge problem in terms of how we grow our cucurbits.

Sweet corn

We grow about seven to ten acres of sweet corn and we grow certified organic sweet corn so we can actually ship a fair bit. There is a fairly good market on the organic end because there is very little competition and the reason we can do is because corn earworm is really not a major problem with us. We will get it blown in every once in a while but we haven't gone to the Zealator applicator primarily because we are not getting the real big dollars for it and time wise with the amount of pressure we have I am not sure it is worth it. Corn borer we have gone to using the wasps that everyone has been talking about. This is our first year and it seemed to work quite well. We do spray with Bts and with the raccoons, another big problem, we use a portable electric fence, one strand. Another issue now is the fact you can't use any treated seed for organic production. We have now started to work with transplanting sweet corn for the early corn so we can get a decent stand. We can get very early sweet corn and we tend to just retail that. I would not wholesale any of that. It is a great way to grow sweet corn if you are haven't tried it. We put two seeds per plug in about a 150 cell tray every foot. It is amazing, the corn may only be this tall but you get actually gorgeous sweet corn. If you got a good market for it is a good way to go and get a good early stand.

Earworm is what we don't have a lot of problem with and I called Ruth actually this summer and said if it comes in is it around forever and then it vanished. It just wasn't there again, so I don't know whether not enough of it came up to be a problem. I hire a scout and that has been great. He is a friend who used to be an IPM coordinator in Michigan and so he has a small operation and we trade things and he comes and scouts my corn and my brassicas for me. He said it looked like we had a problem but it did not stay around for more than one planting. We scout for borer and spray for borer and we are able to keep it under pretty good control.

Smut – I hear it is a delicacy but have not tried it. This is a transplanted field of corn, a nice even stand that I took a picture of.

Corn varieties

One problem we have with a variety we love, Lancelot, it is extremely tender, it ships well, but you can get blow-down problems. This year we did have a real blow-down problem. This is an early blow-down. It was kind of a physical test problem for us. Variety selection is something to think about.

Sprayers

We use a boom sprayer. I do not use an air blast. Air blasts are good but sometimes you do not know where everything is going and I like to know everything is going right on my crop. We have gone to the pack-tank sprayer because it has a mechanical agitator. It has a shaft right through the middle of the tank and if you are using any kind of wettable powders it makes a huge difference in terms of keeping things mixed up. When we tried to use kaolin clay it seems to work well. I have also gone to being able to raise the booms and then I would put drops on this for sweet corn. It works out okay as long as the corn is not super huge. There is inside the tank. You can see the paddle. It turns all the time. It is always agitated. I have another sprayer that recirculates and agitates and it is not nearly as effective. If you are looking a buying something and you are going to be working with some of these materials that don't dissolve real well I really suggest these.

Potatoes

We grow a couple of acres of potatoes and what we do is try to get in and out quick. The years that they don't go down with leaf hopper we get bigger yields and we market them for a longer period of time. We have often green-sprouted potatoes on the greenhouses and put seed potato in, green-sprout them and then put them in the ground, right through the planter and they really come up quite strong. You have a big plant before CPB is even around. It is a good way to get a crop and avoid some of the problems.

I would say our biggest kind of use of pest control on potatoes is avoidance more than anything. We had some real trouble with hopper burn. I tried rotenone on it without much success. At this point I really don't use any fungicide, any copper on the potatoes at all. We just get them in early, try to get a lot of growth, get what we can out of them. Market them at a high price early on and then if we get a big yield we will carry them on through the fall. Our biggest problem is Rhizoctonia or scurf, the black dotting that you get. What we have tried to do with that is to rotate as much as we can out of other susceptible crops like lettuce. We found this year's potato crop was in where corn was and we had very little Rhizoctonia problem at all. I don't know if that has anything to do with following corn but it is something for us to maybe try again. That is probably our biggest problem in terms of selling potatoes is our Rhizoctonia problem.

Root crops

We do about three acres of carrots, couple acres of beets and we are still shipping carrots now. The biggest problem for us is Alternaria in the field. We have used copper every once in awhile. We try to use some resistant varieties and we can also get some storage problems with the cavity spot which I will show you as well. We direct seed everything with the Stan-hay seeders, pelleted seed so we get pretty good seed distribution. Typical bed preparation would be disking and then field cultivating but that gives you an idea of some of the carrot fields. Three row, fairly tight which is probably perpetuating some of my Alternaria problems but it just works out pretty well for us. Everything is on raised beds and it has been a really good crop. We have a very good market for it in the Burlington area. If I had to try to ship against California all the time it just wouldn't pay.

Here is the Rhizoctonia, which we get problems with in storage. What we have gone to now in our coolers is we actually mist completely. We do a lot of purple top turnips because we can machine harvest these. They are fairly efficient for us in terms of being lucrative. Beets, specialty beets, chioggia beets, gold beets, some of the things we can wholesale into supermarkets at a fairly decent price. They all store very easily. Our pest problems are very minor on these. I think it is a big reason we choose to grow what we do because we can manage the pests.

There is an old time carrot harvester that we use on beets, turnips and carrots. We store everything in bulk

bins and then we mist our rooms. We actually have misters in there to try to keep the humidity up. That has definitely helped a lot. I would like to go to plastic bins if I could afford them but that is going to be a few years down the road because I think we do probably have problems from year to year with some of the wood bins. They do store quite well in here. What we are packing out now is pretty nice product. We have a small packing house in the dairy barn. We have a barrel washer and we run a few people during the winter time a couple of days a week and we pack out cellos, then we put out a bulk product that gets shipped to local health food stores. We have a couple juice bars that take some of our products. People seem to love our carrots because they are very sweet. We harvest them late in the fall so they develop a lot of sugars and for some reason it is one crop that people just love what we grow.

With beets it's the same way and it's a very easy crop to wholesale. It is amazing how much demand there is for cut beets. That's it, I guess. Any questions?

Questions and answers

Q: When you store carrots is there any sawdust or anything surrounding them?

A: No, no, but they are in the bulk bins and they are in the coolers and we try to keep the coolers as close as we can to 32, 34. Right now they are in our barn. I don't even use the coolers, I can kind of keep the barn just at about the right temperature because it is half buried in the ground and then I mist to keep the humidity up.

Q: What kind of price do you need to make money from sweet corn?

A: We wholesale 4 dozen for about 48 counts for $15.00. So I probably see $12.00 by the time subtract my trucking and my commission and things. What I use a lot of my wholesale thing for, I will sell my local retail for $3.50 a dozen and then I can retail it for maybe $4.00 a dozen and then if I am long I can ship it down to Boston to the supermarket. So I kind of use it that way. The reason it makes money for us that way is because we have no labor into it except picking it. I plant it, I field cultivate it, we don't hoe it. We have spent a lot of time analyzing how much labor, we track all the labor we put into each crop. Our workers fill out a time sheet with the number of hours they work on each crop. Sweet corn is a really good ratio in terms of labor input to what we get out. From a per acre basis it is not real profitable, I can't really make more than about $1,500 an acre probably from it. From a labor cost standpoint it is really good.

Q: What does tarnished plant bug damage look like on lettuce?

A: It is right on the ribs and it pokes in it. Have you ever seen it where it gets really corky on the ribs? That's tarnished plant bug feeding.

Q: Is it the nymphs causing the damage?

A: No it is adults. They are in there, you just open it up and they are all in it.

Q: What does tarnished plant bug damage look like on broccoli?

A: It's the brown beads. Have you ever seen the dead beads? They will feed on the bead and the adults will feed on the bead and you get brown bead and it seems to be a bigger problem for us in the summer time. You know the first cutting in late August and early September we will see some and then it just goes away.

Q: How do you make the beds for your carrots? Is it a two step deal?

A: Do you mean two passes? Well what we do, you saw the disk and we use a light field cultivator and then we will go through with the bed shaper and our bed shaper usually has to go over it twice to get it perfectly smooth. Yeah, press pan type.

Q: What's your favorite early sweet corn variety?

A: I like Aladdin out of Stokes. I don't think I am going to be able to use any more because I can't get it untreated. But now that I am transplanting early corn, I can go into a little bit later varieties so that I don't have deal with really short ear ones. So I'm trying to think of some of the names. I use Mystique as my second one and then Lancelot quite a bit, also Trinity is a pretty decent type ear for an early one that if I transplant seems to do OK.

Q: Which of those varieties is the most vigorous grower?

A: Mystique is an awfully good grower I think. I am not an expert on corn varieties though. I'm kind of new at corn. I have only been growing it about four years. Now with the new NOP standards, in Vermont we could use treated seed so what I could get untreated late in the season I would use it, but now I've got to really source that out. Lancelot I really enjoy and Seedway does carry that, even though you do get some blow down problems. I have found that if I got some other varieties around it, it doesn't seem to blow as much. It is just so tender for so long the tenderness is throughout the plant so not only does the ear stay tender but the stalk is very tender, and that is why it tends to blow down.

Conclusion

Just a couple of resources. This is my bible for diseases and pests of vegetable crops. It is *Disease and Pests of Vegetable Crops* in Canada and it's got every picture that you would want. It covers greenhouse tomatoes and greenhouse cucumbers as well. The nice thing is I don't have to go turn the computer on and try to fire up a web site. It is just right here and it is all in one book. I can leave it out here if you want to look at it, it is available through the University of Vermont, Anne Hazlerig, Hills Building, Burlington, Vermont. It is just a really good compilation. Certainly, all of the stuff from Cornell is available but it is not all in one spot that I have been able to find. The other thing is the greenhouse tomato group, I have got the seed catalog here if you want to look at it or get an address.

Thanks for having me.

About NRAES

NRAES, the Natural Resource, Agriculture, and Engineering Service, is a not-for-profit program dedicated to assisting land grant university faculty and others in increasing the public availability of research- and experienced-based knowledge. NRAES is sponsored by fourteen land grant universities in the eastern United States (see map below). We receive administrative support from Cornell University, the host university.

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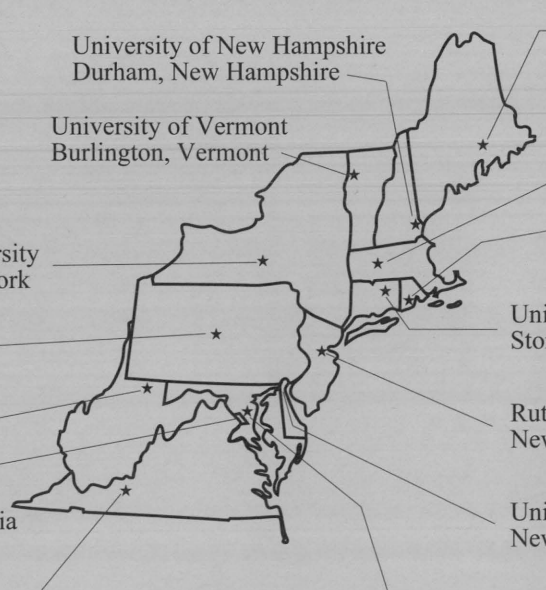
NRAES
Natural Resource, Agriculture, and Engineering Service
Cooperative Extension
PO Box 4557
Ithaca, New York 14852-4557
Phone: (607) 255-7654
Fax: (607) 254-8770
E-mail: NRAES@CORNELL.EDU
Web site: WWW.NRAES.ORG

Marty Sailus, NRAES Director
Jeffrey S. Popow, NRAES Managing Editor

NRAES Member Universities



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